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Improvement In Strength Behaviour of Dispersive Soil In Presence Of Additives

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Abstract. The present study focuses on improving the strength characteristics of dispersive soil using bagasse ash as an admixture**.** Dispersive soil is naturally considered to be an erodible type and possess lower stability in presence of moisture. It is well known that dispersive soil contains higher number of sodium ions, being the cause for dispersive nature. In the current study, an attempt has been made to evaluate the effectiveness of bagasse ash as a stabilizer to improve the strength properties of dispersive soil along with reduction in dispersivity. The soil used in the present study exhibited an intermediate dispersive state upon conduction of dispersivity tests viz., Crumb test, double hydrometer analysis and unconfined compressive strength test The strength tests were carried out at varying contents of admixtures for different curing periods. The addition of bagasse ash displayed reduction in dispersivity and increase in strength characteristics. With the 15% addition of bagasse ash by weight of soil, the dispersivity changed from intermediate to non-dispersive state and the strength of soil increased by about 2.5 folds after 60 days of curing period. This effect of significant reduction in dispersivity and increase in strength of soil may be attributed to the pozzolanic nature of bagasse ash and the same has been observed in Scanning electron microscope images.

Keywords: Unconfined compressive strength; dispersivity, Bagasse ash

1 Introduction

Dispersive Soil Characteristics plays an important role in Geotechnical Engineering where erosion is prominent. Prior clay was considered as non-dispersive as well as erosion resistant. Later on it has seen that dispersive soils are erodible in nature. This type of soil is commonly found in South Africa, United States, Brazil, Thailand, and India. Soil possessing high amount of sodium are generally unstable when amount of water content interacting with is high. Dispersive soils when used for construction in hydraulic structures such as roadway embankments, dams, canals or other structures can create severe problems if they are not well identified. Embankment dam constructed on dispersive soil results in piping failure due to deflocculating when water travels through a concentrated leakage channel. This type of soil has a tendency to get separate go in suspension even in still water. Dispersivity of soil is governed by clay mineralogy and chemical composition (Umesh et al. 2011). Clay fraction behaves like single grained particle while in suspension by means of water because there exist a minimum electrochemical attraction between the soil particles and it remains deflocculated. Repulsive forces are more than the attractive forces and particles moves in suspension under saturation condition (Umesha et al. 2009). Dispersive soil mass splits up into individual soil grains and easily dislodge and quickly within flow of water with little saline absorption. This result in contact erosion failure and leads to severe pavement deformation results in reduction in pavement performance and increase in maintenance and operation cost (Prem Kumar, Rajeev 2016).

Naturally, there are two types of dispersive soil they are clayey soil and silty soil. Dispersivity of the silty soil is due to less cohesion, resistance presented by the submerged mass of the residue is lesser than shear stress induce through a fluid flow (Umesha et al. 2009). Dispersivity in clayey soil is because of presence of exchangeable sodium ions in the soil (Umesha et al. 2009). When soils with high sodium content go in suspension with water, the clay fractions work as individual clay platelets; that is, the attraction between the clay particles is reduced to a minimum thus failing to closely bond with the other soil particles. When a sodic soil interacts with water of low salt concentration, water molecules are drawn in between the clay platelet which causes the swelling of soil particles and get separated from the aggregate. Water molecules enter in-between the clay platelets which causes these ions to hydrate which forces the clay particles to move away from each other The attractive force is reduced to a minimum making the clay to swell to such an extent that individual clay platelets are separated from the aggregate (Hardie 2009). In soils, if divalent ions example calcium or magnesium is absorbed instead of sodium, dispersivity in clayey soil would be reduced. This is because of non-sodic clay.

Next to Brazil, India being the second largest producer of sugarcane in the world, contributes about 15% of the total sugarcane production in the world, with an annual production of 240 Million tonnes (2017). Bagasse ash (BA), a by-product from the incineration of bagasse in sugar industries is another alternative material which has high potential to similarly replace lime, thereby making the lime stabilization process more economical. An estimated 10 million tonne of BA is collected for every 300 million tonnes of sugar produced. Moreover, BA when disposed without proper considerations may poses acute problems to human health and the environment – ranging to respiratory difficulties, and air and water contaminations respectively. It is for this reason; the sugar industries are exploring sustainable solutions and safe disposal procedures for BA. The pozzolanic activity of the BA due to the presence of reactive silica and traces of calcium oxide. The objectives of present study are (i) to study the basic properties of dispersive soil and to measure dispersivity of the soil(ii) To compare strength of the dispersive soil and soil treated with Bagasse ash and lime.

2 Materials

2.1 Dispersive soil (DS)

Dispersive soil was procured at a distance downward 1.5m under the existing earth altitude from Haveri district, Karnataka State. Manual methods were used for procurement of the soil. Dispersivity of the soil can be altered by process of drying. For this reason, soil sample was placed in an air tight bag in order to preserve their moisture content in natural state and carefully transported to the Laboratory. The Physical Properties of Dispersive soil and bagasse ash are presented in Table 1.

Table 1. Standard testing Procedure for various test and geotechnical properties of Dispersive soil and bagasse ash.

Property	Test procedure	DS	Bagasse ash
Specific gravity	IS 2720-3(Sec1): 1980	2.61	1.21
Sand – 4.75 to 0.075mm (%)	IS 2720-4: 1985	47.1	7.12
Silt – 0.075 to 0.002mm (%)	IS 2720-4: 1985	23.9	66.4
Clay – less than 0.002mm (%)	IS 2720-4: 1985	31.1	–
Liquid limit (%)	IS 2720-5:1985	31.0	65
Plastic limit (%)	IS 2720-5:1985	20.9	Non-plastic
Plasticity index (%)	IS 2720-5:1985	10.1	–
Shrinkage limit (%)	IS 2720-6:1972	16.7	–
Optimum moisture content (%)	Sridharan and Sivapullaiah (2005)	18.6	41
Maximum dry unit weight (kN/m^3)	Sridharan and Sivapullaiah (2005)	16.8	10.9
Unconfined Compressive Strength,kPa	IS 2720-10:1991	211	

3 Methodology

3.1 Test to measure dispersivity

Physical test

Emerson Crumb Test is a quantitative method used to test the Soil dispersivity. A crumb of soil sample is added to the breaker containing distilled water. A visual determination of dispersion grade is observed. Based on ASTM D 6572 recommendations, Soil is classified depending upon the formation of cloudier sized particles from crumb of soil. Double hydrometer test is the first method developed to estimate the nature of dispersion of soil. Particle size distribution is determined by dispersing the soil sample into the dispersing agent i.e. Sodium Hexa metaphospate in distilled water and similar soil sample is discrete in distilled water, except dispersing agent. Degree of Soil dispersal is classified based on ASTM D 4221.

Unconfined Compression Strength (UCS) test is an appropriate method to determine dispersivity of soil (Umesh et al 2011). UCS was determined as per the standard testing procedure. In addition, the tests were conducted on soil samples with the addition of 3%, 6%, 9%, dispersing agent (sodium hexa metaphosphate) and compare the dispersivity values obtained from UCS test with double hydrometer results. Also, UCS test are done by adding varying percentage of bagasse ash from 5% to 30% in intervals of 5% and 1 % cement for different percentage of dispersing agent.

Chemical test

Exchangeable sodium percentage (ESP) and Sodium absorption ratio (SAR) are conventionally used parameter for estimating dispersivity involve in measurement of sodium ion and classifying dispersive soil. Soil Cation exchange capacity (CEC) is measured, and then proportion of exchangeable sodium relative to summation of exchangeable cations is calculated to provide the ESP. Exchangeable sodium percentage is defined as concentration of sodium ions in the presences of soil with respect to the dispersive soil CEC. It is given by the equation,

$$ESP = \frac{[Na^{+}]}{CEC} \times 100 \tag{1}$$

Sodium absorption ratio gives an indication of amount of dissolve sodium (Na+) in pore water compared to amounts to amounts of dissolved calcium and magnesium. It is the amount of cationic charge offered by sodium ion to that by calcium and magnesium. SAR is defined as

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{2+}]+[Mg^{2+}]}{2}}} \times 100 \tag{2}$$

In the present investigation, Bagasse ash is used to convert Dispersive soil to non-dispersive soil. Bagasse ash is used in percentage by weight of the soil. The optimum percentage of Bagasse ash is added to dispersive soil has been determined based on the unconfined compressive strength. The optimization of bagasse ash in dispersive soil has been determined by adding 5%, 10%, 15%, 20% , 25% and 30% of bagasse ash to dispersive soil and it was found that 15% of bagasse ash of dispersive soil to be optimum. The soil samples of dispersive soil stabilized with 15% bagasse ash is treated with 1% cement percentage was prepared at a Maximum dry density(MDD) and optimum moisture content (OMC).

Unconfined compression strength test

UCS tests were carried out as per IS 2720- 10 (1991), for various combinations of Dispersive soil alone, soil treated with Bagasse ash and cement. All samples were prepared at its MDD and OMC. Prepared samples taken in sealed plastic bag and placed in the desiccators and maintained 100% humidity for prolonged curing periods in such a way that there is no moisture movement.
Strength of the soil sample can be established using UCS test when treated with Bagasse ash of different dosage from 5% to 30% in order to decide the Optimized dosage of bagasse ash to be added to dispersive soil by unconfined compression Strength test. On addition of 5% to 30% of bagasse ash to the dispersive soil, the strength increases up to 15% of bagasse ash, addition on immediate testing as well as with increased curing period results in decrease in deflocculation of clayey particle. Dispersive soil treated with bagasse ash beyond 15% of weight, strength of the stabilized soil decreases. Hence, 15% addition of bagasse ash was considered as the optimum amount to be added. Owing to the low calcium content in bagasse ash, Cement was added to suffice the calcium ions to enable reduction in dispersivity of the virgin soil. Hence, an optimum of 1% cement was added to the dispersive soil-bagasse ash mixture.

4 Results and Discussions

Laboratory tests have been carried out to establish type as well as characteristic property of dispersive soil chosen for stabilization. Outcome of dispersive soil treated with bagasse ash and cement was studied in order to study the Strength of dispersive soil.

4.1 Physical test results

Emerson crumb test

Crumb test is a qualitative test which is used to determine whether the soil is dispersive or non- dispersive. In this test two types of soil are used, One being locally available soil collected from RVCE campus, Bengaluru, Karnataka, India and other being dispersive soil which is taken from Haveri district, Karnataka, India Soil is placed in a beaker containing distilled water and colour of the distilled water is seen after one hour. The beaker with dispersive soil shows colloidal clouds can be easily recognizable at the bottom of the beaker. The result concludes that the nature of soil is dispersive. Fig 1 shows a variation between dispersive and non dispersive soil sample.

Fig. 1(a). Dispersive soil

Fig.1(b). Non-dispersive soil

Double hydrometer test

Double hydrometer test gives mathematical value of dispersivity of soil. It involves estimation of particle size distribution as per ASTM D4221. 6% is the optimum dosage of dispersing agent which is found from an UCS test. The degree of dispersion as 53.2% it falls in the range of High (above 40) which is observed from Fig.2, which depicts the result of Double Hydrometer.

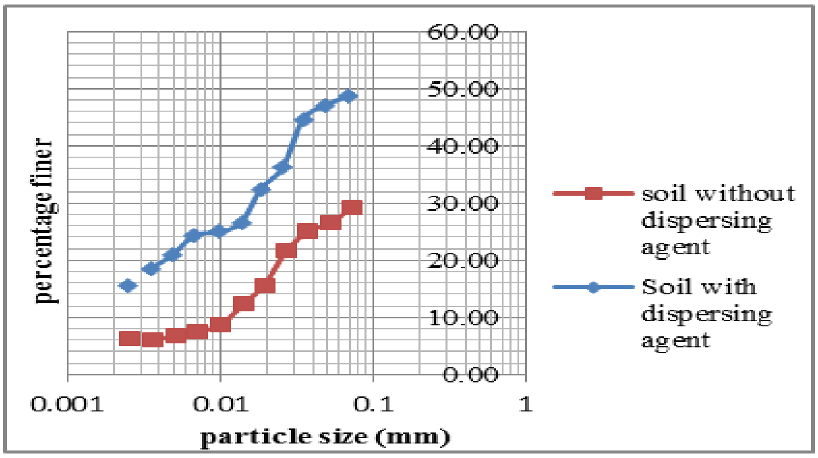

Fig.2. Particle size of dispersive soil with dispersing agent and without dispersing agent

Unconfined compression strength test (UCS)

UCS is a qualitative test used to describe dispersivity of soil, being the most accurate test to quantify the dispersive soil. Table 2 presents the UCS value for various percentage of dispersing agent i.e. sodium hexa metaphosphate with soil. The reason for decrease in strength can be attributed to addition of dispersing agent, which reduces the strength and after a particular dosage it gives almost a constant value. The result shows the optimum dosage of dispersing agent is 6%. Addition of dispersing agent increases the amount of negative charge in the soil and hence the repulsion. The increased repulsion in the soil forces the soil to maintain a dispersed structure. Addition of an optimum quantity of Sodium hexa metaphosphate makes the soil completely dispersive. Soil dispersion obtained by the test is 38.86%. It is also clear that Soil dispersivity of particles decreases by adding optimized dosage of 15% Bagasse ash and 1% cement which induces flocculation. Dispersivity of dispersing agent without cement and 15% Bagasse ash decreases to 28.50%. With the addition of dispersing agent and 15% Bagasse ash and 1% cement decreases to 22.72%.

Table 2. Variation of Unconfined Compression Strength of Dispersive Soil with Dispersing agent and additives

Dispersing agent (%)	Soil +Dispersing agent, kPa	Soil +Dispersing agent+ bagasse ash, kPa	Soil +Dispersing agent+ bagasse ash+ cement, kPa
0	211	293	280
3	185	254	236
6	153	224	198
9	151	212	195

Chemical test results

The Chemical tests were conducted on dispersive soil at College of Agricultural science, Mandya, Karnataka state. Table 3 presents the chemical composition of the dispersive soil used in the present study.

Table 3. Chemical composition of Dispersive soil

Particular	Obtained Values	Standard Values
pH	7.6	3 – 9
Cation Exchange Capacity	17.3meq/100g soil	<15 meq/100g soil = ND ≥15 meq/100g soil = D
Exchangeable Sodium Ions	22.9 meq/100g soil	<10 meq/100g soil = D ≥ 10meq/100g soil = ND
Sodium Absorption Ratio	11.5	>10 = D 6-10 = I <6 = ND

Where, ND – Non Dispersive, D – Dispersive, I – Intermediate

Effect of bagasse ash and cement on strength of dispersive soil

The unconfined compressive strength were conducted on dispersive soil with 15% bagasse ash and 1% cement are represented in Fig. 3. The results indicated that the addition of bagasse ash and cement improved the strength of the mixture, since it enhances the bonding between the soil particles. The increase in strength was due to the decrease in diffused double layer thickness as well as flocculation of clay particles, thus exhibiting the reduction in dispersivity of soil.

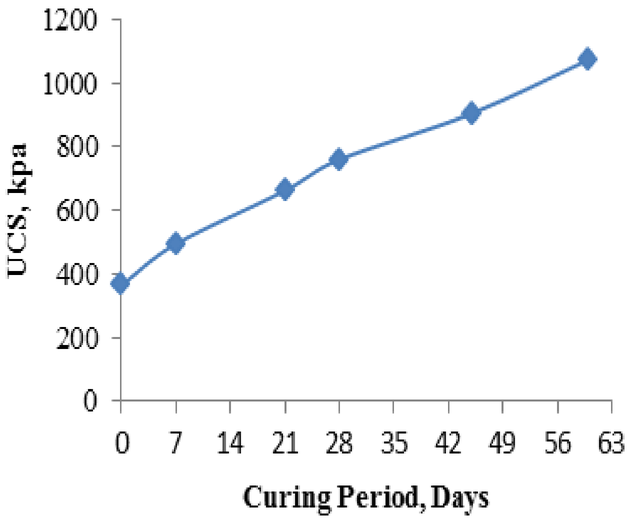

Fig. 3. Variation of UCS of Dispersive soil treated with 15% bagasse ash and 1% cement with curing.

Scanning Electron Microscope analysis (SEM)

SEM analysis is used to examine the behaviour of soil structure. The effect of bagasse ash and cement on the structure of dispersive soil is studied through SEM analysis. The structure of untreated dispersive soil and treated with bagasse ash and cement are presented in Fig. 4 and Fig.5 respectively

It can be observed from Fig. 4 of untreated dispersive soil, particles are distinctly separate indicating the absence of bonding between them. The effect of addition of bagasse ash and cement on the dispersive soil is found to be significant in Fig. 5. The SEM image indicates a flocculated structure type which may have occurred due to the diffusion of calcium cations resulting in reduction in double diffused layer and decrease in dispersivity of the soil particles.

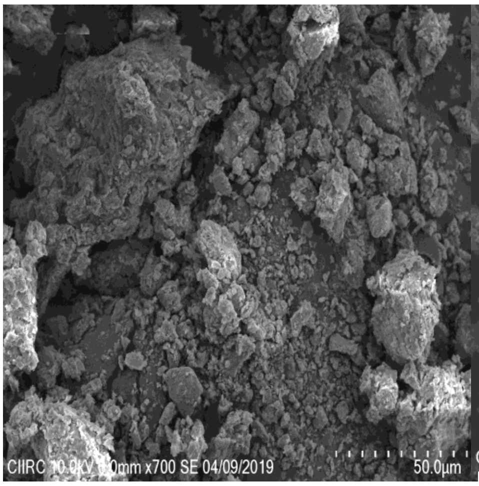

Fig.4. SEM images of Dispersive soil

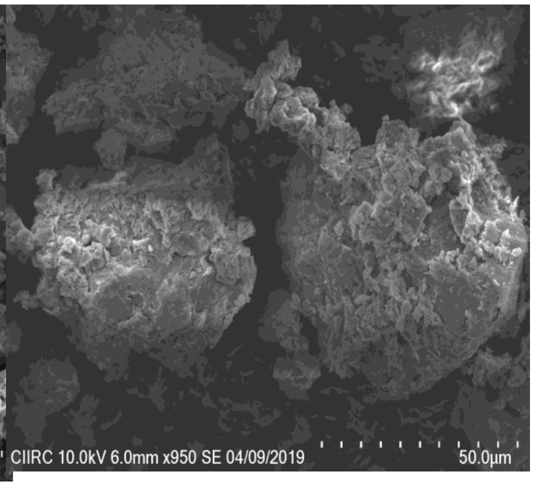

Fig.5. SEM images of dispersive soil treated with 15% bagasse ash and 1% Cement

5 Conclusions

Based on the experimental investigation carried out in the study and analysis of the results obtained, the following concluding remarks have been drawn:

1. The dispersivity of the soil was quantified by the physical tests and on the basis of UCS and the soil was a highly dispersive soil.

2. With addition of optimum amount of bagasse ash as 15% and 1% cement by weight to the dispersive soil, the UCS of soil increased and the dispersivity also reduces. This was justified by the SEM images attributed to the flocculation formation by the admixtures.

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