Strength Characteristics of Dispersive Soil by Using Industrial By-Products

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ABSTRACT: Soils of low salt concentration that dislodge easily and quickly, when comes in contact with water are called dispersive soils. These are unstable and disintegrate or erodible. These soils are present in many parts of the world such as India, United States, Australia, Greece, America, South Africa, Thailand, and others. They pose serious problems in stability of earthen structures, road fills, and other engineering structures. Even if there are simple methods to identify the dispersivity of the soils but it is more difficult to quantify the dispersivity. Visual classification such that Atterberg's limits and particle size distribution is not sufficient to differentiate between ordinary erosion resistant clays and dispersive clays. In the present work, the dispersive soil is identified by conducting double hydrometer test to find the percentage of dispersion. The CBR results are presented and unconfined compressive strength tests are carried out at different curing period such as 0, 7, 14, 28 days. After stabilization using cement clinker, the dispersive soil can be prevented from collapse, settlement, pipe failures and slope failures in earth dams, embankments and may become suitable for other engineering purposes.

INTRODUCTION

The dispersive soils are extensively found in various parts of the world such as India, Australia, United States, South Africa, Greece, Thailand and Latin America. These soils may constitute extensive distress if not taken care of effectively. One of the simple ways to prevent the problems encountered in dispersive soils is to replace them with suitable materials.

Many researchers have studied the fundamental aspects of the interaction between dispersive soil, aluminum sulfate, fly ash, cement, and lime to bind the soil clay particles and reduce the dispersivity. A.H. Vakili observed that adding pozzolan followed by curing reduces dispersivity potential of the samples. Hamza Gullu and Kenan Hazirbaba studied relatively new non-traditional stabilizer (synthetic fluid) in conjunction with fiber to improve the strength characteristics of a low-plastic fine-grain soil. Hamza Gullu and Ali Shahabaldeen Khudir observed the effect of freeze–thaw cycles on the unconfined compressive strength of fine-grained soil treated with steel fiber, jute fiber, and lime. In the present study, an attempt has been made to improve the strength by mixing the dispersive soil with clinker.

MATERIALS

In the present study, the sodium bentonite representing dispersive soil and cement clinker are used for the mixture material. Sodium bentonite used for this study was procured from Cuttack, Odisha, India, which contains montmorillonite and sodium as the predominant clay mineral. Cement clinker is made by heating clay and limestone in a rotary kiln at high temperature. It was procured from Rourkela, Odisha, India. The cement clinker used in the experiment is first crushed in crusher machine and then fined in a ball mill.

METHODOLOGY

The Sodium bentonite and cement clinker are oven dried. After that the geotechnical properties (**Table 1**) like grain size analysis, specific gravity, double hydrometer test, CBR test, compaction characteristics, and UCS test are performed to characterize the strength of dispersive soil. Following these XRD test is performed for sodium bentonite and cement clinker. Different proportion of cement clinker is mixed with bentonite to find the optimum strength.

RESULTS AND DISCUSSION

Dispersive Test

The double hydrometer test (ASTM D4221-99) is performed to identify the dispersiveness of soil. Primarily the particle size distribution of the soil is determined using the standard hydrometer test where the soil is dispersed in water with the chemical dispersing agent (Sodium hexametaphosphate). A parallel hydrometer test is then made on a soil specimen but without a chemical dispersing agent, the percent dispersion is the ratio of the dry mass of particles smaller than 0.005mm diameter of the second test to the first expressed as a percentage. The value of greater than 50 is highly dispersive. **FIG.1** shows that from double hydrometer test the percentage of sodium bentonite is found to be 90.66% and classified under highly dispersive soil. **Table 2** shows the results of double hydrometer test of bentonite with different % of cement clinker.

Grain Size Distribution

FIG. 2 shows that cement clinker used in the present study is found to be coarse grained and poorly graded.

XRD (X-ray diffraction)

The XRD pattern in **FIG. 3 (a)** shows that the bentonite used in the present work contains quartz, kaolinite, montmorillonite, and phillipsite & **FIG. 3 (b)** shows that cement clinker contains calcium silicate oxide barium strontium tellurite and strontium tungsten nitride.

Compaction Characteristics

Standard Proctor compaction tests are conducted on specimens of sodium bentonite, cement clinker and sodium bentonite with 5,10,15,20 and 25 percentage of cement clinker respectively (IS: 2720-7) (1980). The maximum dry density of sodium bentonite is found to be 13.98 kN/m^3 at an optimum moisture content of 28.6% as illustrated in **FIG. 4 (a)**. The maximum dry density of cement clinker is found to be 18.05 kN/m^3 at an optimum moisture content of 14.6% as illustrated in **FIG. 4 (b)**. Similarly, the compaction curve for bentonite-cement clinker mixture is presented in **FIG. 4 (c). Table 3** shows the OMC and MDD values of bentonite–cement clinker mixture.

CBR Test

CBR tests are conducted for both soaked and unsoaked condition on the samples as per IS Code IS: 2720-16 (1987). The soaked CBR test is performed on soil sample with a surcharge for 96 hours. Both soaked and unsoaked condition CBR value of bentonite-cement clinker mixture is presented in **FIG. 5**. It is found that with the addition of cement clinker of 15%, 20%, and 25%, CBR values are higher in soaked condition than the unsoaked condition.

UCS Test

Unconfined compressive strength tests are conducted on soil sample using IS Code IS: 2720- 10 (1991), to find the strength of Bentonite-cement clinker mixture. **FIG. 6** shows the results obtained from UCS test of sodium bentonite mixed with different percentages of 5%, 10%, 15%, 20% and

25% cement clinker at curing periods 0,7,14 and 28 days in normal room temperature. Results show that in addition of 25% cement clinker, the strength of bentonite-cement clinker mix gives higher strength as compared to other percentages of cement clinker.

CONCLUSIONS

Sodium bentonite is a highly dispersive soil and needs to be stabilized to avoid failure of structures resting on such type of soil. As observed from the double hydrometer test results, the addition of 25% cement clinker to bentonite reduces dispersion from 90.66% to 16.80% and thus the bentonite and cement clinker mixture become non-dispersive. In XRD test it was observed that bentonite mainly consists of montmorillonite, kaolinite, quartz, and phillipsite minerals. Philipsite minerals contain sodium, which is mainly responsible for dispersive nature of the soil. With the addition of cement clinker of 15%, 20%, and 25% CBR values are found to be higher in soaked condition than the unsoaked condition. The unconfined compressive strength is found to be higher (0.34 to 4.23 MPa) when 25% cement clinker is added to bentonite at 28 days curing period. So, based on the experimental results presented here in, it is observed that when the cement clinker is mixed with bentonite, the dispersive nature of sodium bentonite decreases and its strength increases.

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TABLES

Table 1. Physical properties of sodium bentonite and cement clinker

Sl. No.	Properties	Sodium bentonite	Cement clinker
1	Liquid limit (%) Plastic limit (%) Plasticity index (%)	318 62 256	-
2	Specific gravity	2.74	3.24
3	IS classification	CH	-
4	Free swell index, FSI (%)	610	-
5	Linear shrinkage index, LSI (%)	45	-
6	Optimum Moisture Content (%), Maximum dry density (kN/m^3)	28.6 13.98	14.36 18.01
7	Unconfined compressive strength, σ (kPa)	175.47	110.38

Table 2. Results of double hydrometer test of bentonite-cement clinker mixture

Sl. No.	Degree of dispersion and classification of dispersive soil	Specimen code	% of dispersion by double hydrometer test	Classification
1	<30% - Non-dispersive 30% to 50% - Intermediate dispersive >50% - Highly dispersive	Bentonite	90.66	Highly dispersive
2		BC9505	78.41	Highly dispersive
3		BC9010	49.94	Intermediate-dispersive
4		BC8515	29.96	Non-dispersive
5		BC8020	23.62	Non-dispersive
6		BC7525	16.80	Non-dispersive

Table 3. OMC and MDD values of bentonite–cement clinker mixture

Sl. No.	Specimen code	Specific gravity	Optimum moisture content (%)	Maximum dry density (kN/m^3)
1	BC9055	2.73	26.71	13.15
2	BC9010	2.61	27.59	13.44
3	BC8515	2.62	27.13	13.73
4	BC8020	2.64	29.63	13.64
5	BC7525	2.68	27.64	14.03

FIGURES

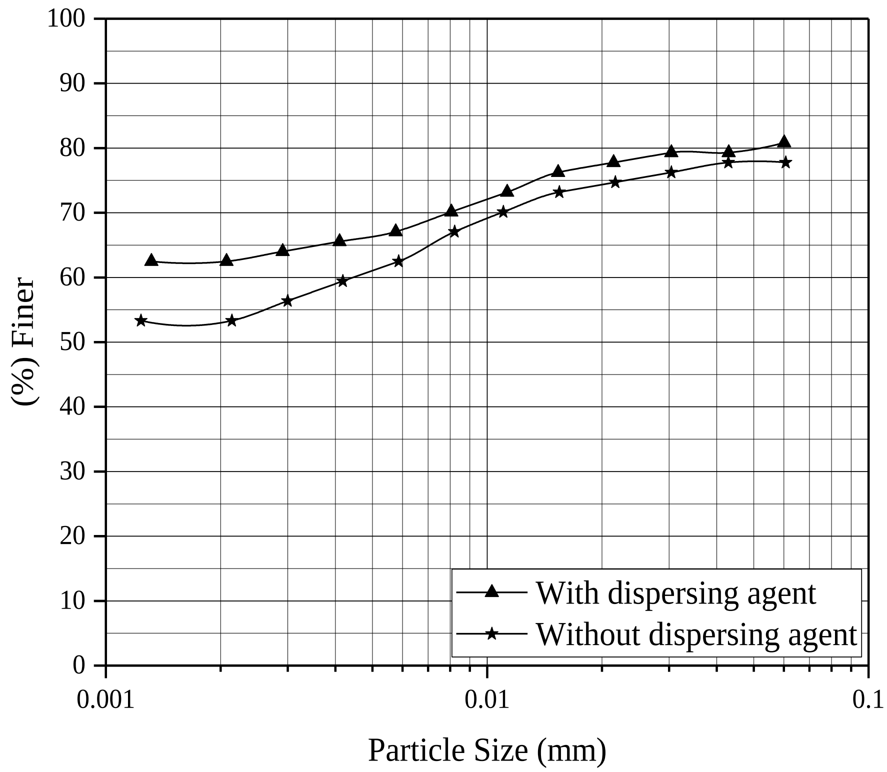


FIG. 1. Double hydrometer test for sodium bentonite

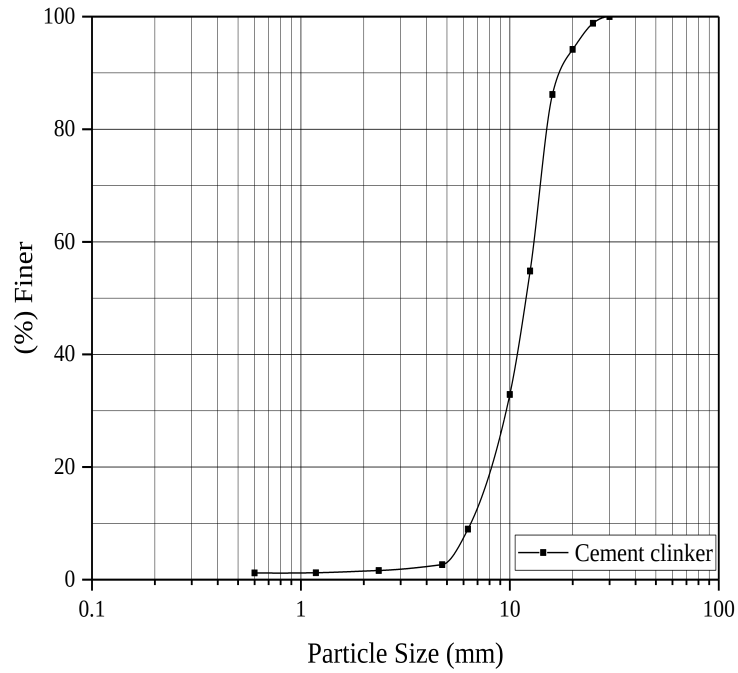
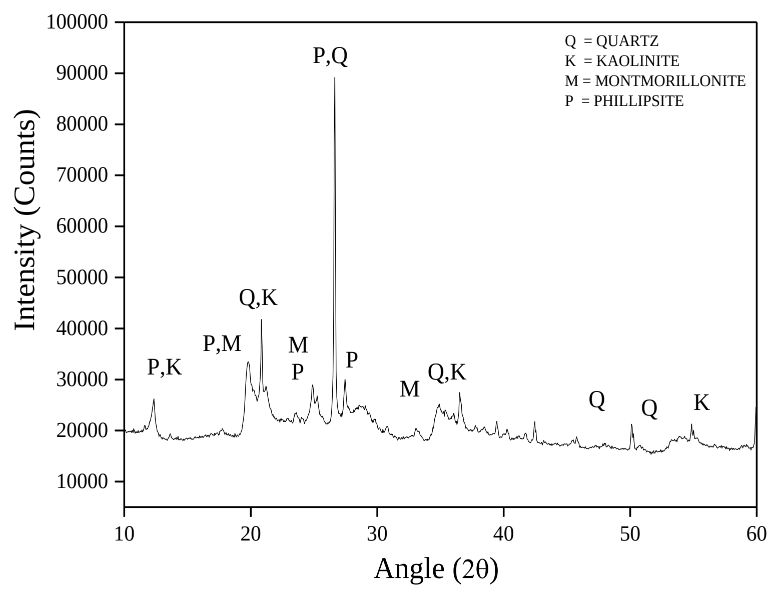
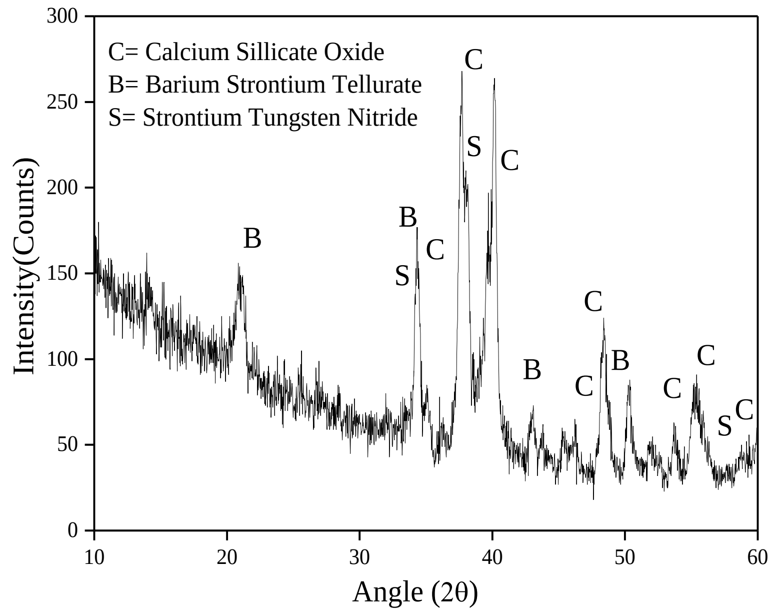


FIG. 2. Grain size analysis curves cement clinker

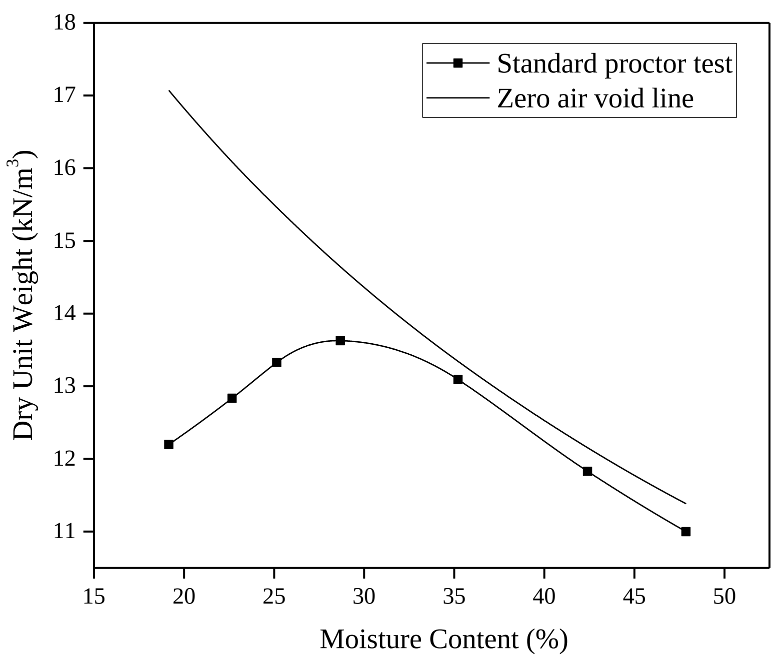


(a)

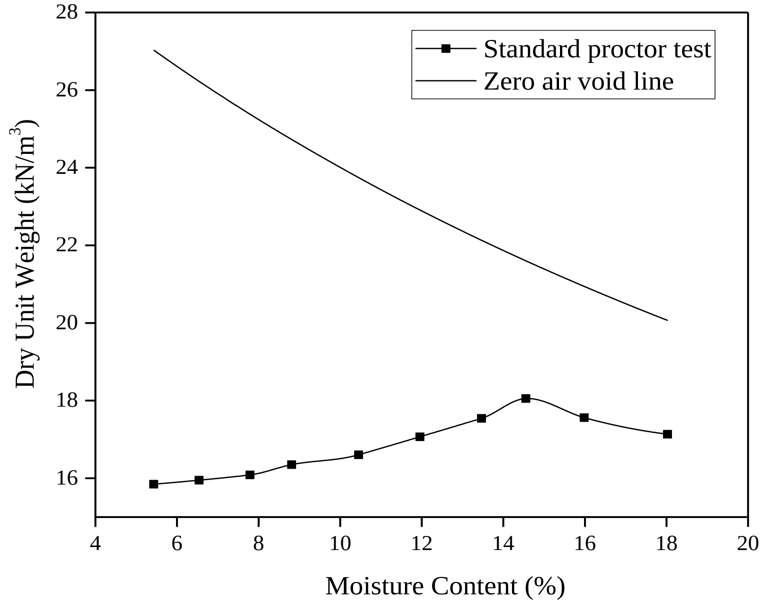


(b)

FIG. 3. XRD analysis of (a) Sodium bentonite (b) Cement clinker

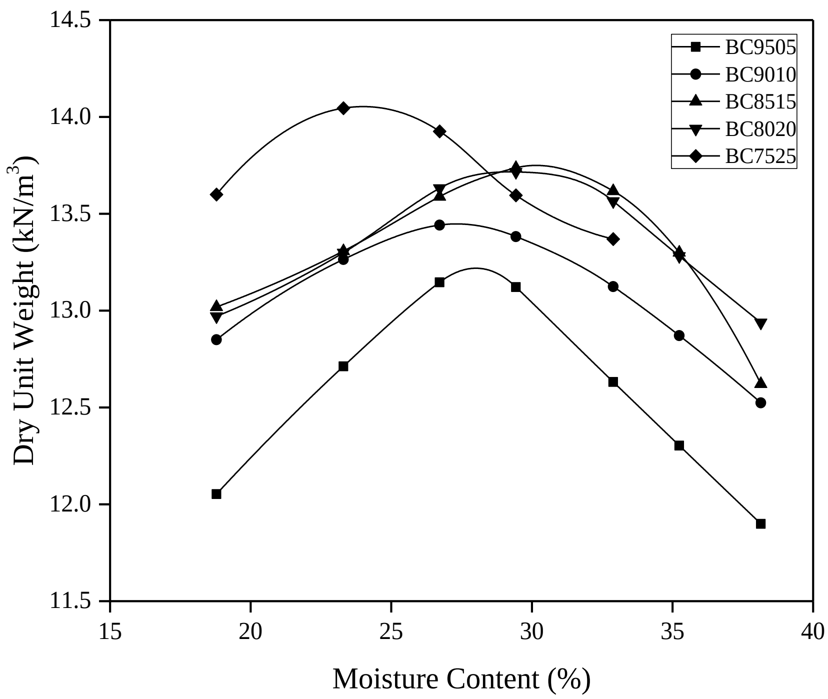


(a)



Standard proctor test
Zero air void line
Dry Unit Weight (kN/m3)
Moisture Content (%)
28
26
24
22
20
18
16
4
6
8
10
12
14
16
18
20

(b)



BC9505
BC9010
BC8515
BC8020
BC7525
Dry Unit Weight (kN/m3)
Moisture Content (%)
14.5
14.0
13.5
13.0
12.5
12.0
11.5
15
20
25
30
35
40

(c)

FIG. 4. Compaction curve of (a) Sodium bentonite, (b) Cement clinker, (c) Bentonite-cement clinker mix

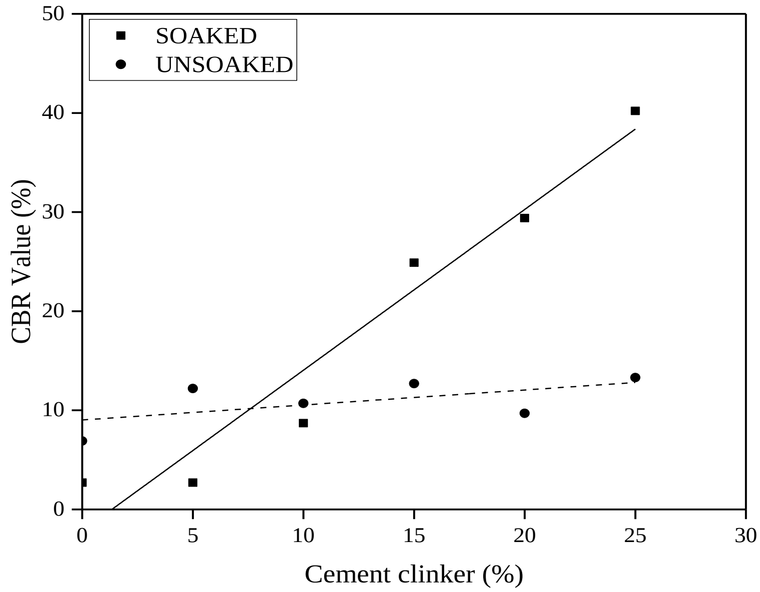


FIG. 5. Variation of CBR with % of Cement clinker content

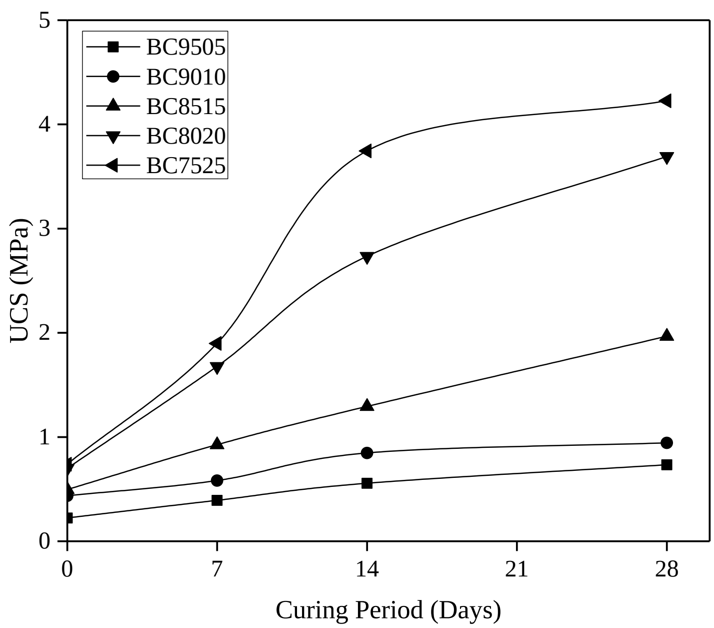


FIG. 6. UCS vs. Curing Period for of Bentonite- cement clinker mix