Stabilization of Dispersive Clays

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***Abstract* –Stabilization of soil refers to changing the physical properties of soil in order to improve its strength, durability or other qualities. It is a method of improving soil properties by blending and mixing other materials. In this study we stabilize dispersive soil. Dispersion is a process that occurs in soils that are particularly vulnerable to erosion by water. In soil layers where clays are saturated with sodium ions, soil can break down very easily into fine particles and wash away. This can lead to a variety of soil and water quality problems, including large soil losses by gully erosion and tunnel erosion, soil structural degradation, clogging and sealing where dispersed particles settle, suspended soil causing turbidity in water and transporting nutrients off the land.**

Here the soil used for the test is calcium bentonite and sodium bentonite. The soil is tested for dispersion using crumb test. Other tests used to identify dispersive characteristics of the soil are double hydrometer test, pin hole test and chemical tests. After identifying dispersion characteristics of the soil, remediation of the soils is carried out using the byproducts of thermal power plant like fly ash and bottom ash. It was found that after adding these materials, the dispersive characteristics were reduced in the soil samples.

Keywords- Stabilization, Dispersion, Bentonite, Crumb

I. INTRODUCTION

Many earth dams, hydraulic structures and other structures like road way embankments have suffered serious erosion problems and have failed due to the presence of dispersive soils. Though the problem has been identified in many parts of the world in recent times, design advances and technical preventive measures are yet to be fully developed and practiced. As the scope and magnitude of the problem which can result from the use of dispersive soil is very high, preventing the failures caused by the dispersibility of the soils has become one of the major concerns of the geotechnical engineers.

Dispersive clay soils, in appearance are like normal clays that are stable and somewhat resistant to erosion, but in reality they can be highly erosive and subject to severe damage and failure. Dispersive clays differ from ordinary, erosion resistant clays because they have a higher relative content of dissolved sodium in pore water. Dispersive clays have an imbalance in the electrochemical forces between particles. This imbalance causes the minute soil particles in dispersive clays to be repulsed rather than attracted to one another. Consequently, dispersive clay particles tend to react as single-grained particles and not as an aggregated mass of particles. It is important to understand the nature of these soils and to be able to identify them so they can be treated or avoided.

II. MATERIAL

A. Sodium bentonite

Sodium bentonite was used for the study. Sodium bentonite expands when wet, absorbing as much as several times its dry mass in water for geotechnical and environmental investigations. The property of swelling also makes sodium bentonite useful as a sealant, since it provides a self-sealing, low permeability barrier. It is used to line the base of landfills, for example. Various surface modifications to sodium bentonite improve some rheological or sealing performance in geo-environmental applications, for example, the addition of polymers. It was purchased from Associate Chemicals, Kochi. The properties of the samples are presented in Table 1. The soil sample was mixed with different quantities lime, fly ash and bottom ash..

TABLE I. PROPERTIES OF SODIUM BENTONITE

PROPERTIES	VALUES
Liquid Limit (%)	33.6
Plastic Limit (%)	40.71
Shrinkage Limit (%)	15.6
Specific Gravity	2.51
Percentage of clay	65
Percentage of silt	11
Unconfined Compressive Strength (kN/m^2)	112.7
Undrained Shear Strength (kN/m^2)	196.76
Optimum Moisture Content (%)	40
Max Dry density (g/cc)	1.256
Soil Classification	CH

B. Calcium Bentonite

Calcium bentonite was also used for the study. Calcium bentonite is a useful adsorbent of ions in solution, as well as fats and oils. It is the main active ingredient of fuller's earth, probably one of the earliest industrial cleaning agents. The engineering properties of the soil are given below in Table 2.

TABLE II. PROPERTIES OF CALCIUM BENTONITE

PROPERTIES	VALUES
Specific Gravity	2.67
Liquid Limit(%)	27.6
Plastic Limit(%)	52
Plasticity Index (%)	22.4
Shrinkage Limit(%)	12.54
Max Dry Density(g/cc)	1.463
OMC (%)	19.12
UCC (kPa)	94.16
Permeability (cm/s)	1.537×10^{-8}

C. *Fly ash*

Fly ash also known as pulverized fuel ash is one of the coal combustion products composed of finer particles driven out of the boiler with the flue gases. Fly ash used in the study is class F. Fly ash was purchased from Thermal Power Plant in Thoothukudi. The chemical properties of Fly ash are given in Table 3.

TABLE III. CHEMICAL PROPERTIES OF FLY ASH

COMPOSITION	PERCENTAGES
SiO_2	57.5
Al_2O_3	33
Fe_2O_3	4.8
TiO_2	1.4
CaO	0.5
MgO	0.2
Na_2O	0.2
K_2O	0.4

D. *Lime*

Lime is a calcium-containing inorganic material in which carbonates, oxides, and hydroxides predominate. In the strict sense of the term, lime is calcium oxide or calcium hydroxide. It is also the name of the natural mineral (native lime) CaO which occurs as a product of coal seam fires and in altered limestone xenoliths in volcanic ejecta.

E. *Bottom Ash*

Bottom ash is produced as a result of burning coal in a dry bottom pulverized coal boiler. Unburned material from a dry bottom boiler consists of about 20% bottom ash. Bottom ash is porous, glassy, dark grey material with a grain size similar to that of sand or gravelly sand. Bottom ash was purchased from Thermal power plant in Thoothukudi. The physical properties of bottom ash are given in Table 4.

TABLE IV. PHYSICAL PROPERTIES OF BOTTOM ASH

PROPERTIES	VALUES
Specific Gravity	2.1-2.7
Dry unit weight (kN/m^3)	7.07-15.72
Plasticity	none
Absorption (%)	0.8-2

III. METHODOLOGY

For the study, crumb test was carried out. A 300 ml non porous container that can fully immerse the sample was placed on a horizontal working space, which should be relatively free of vibration for the next 6h. At 2min, 1h, 6h the soil dispersion grade was determined and recorded according to the following criteria.

Grade 1 (Non dispersive): No reaction, the soil may crumble, slake, diffuse and spread out but there is no turbid water created by colloids suspended in water. All particles settle during the first hour.

Grade 2 (Intermediate): Slight reaction, this is the transition grade. A faint barely visible colloidal suspension causes turbid water near the portions of the soil crumb surface. If the cloud is easily visible assign grade 3.If the cloud is faintly seen is only one small area assign Grade 1

Grade 3 (Dispersive): Moderate reaction, an easily visible cloud of suspended clay colloids is seen around the outside of the soil crumb surface. The cloud may extend up to 10mm away from the soil crumb mass along the bottom of the dish.

Grade 4 (Highly dispersive): Strong reaction, a dense profuse cloud of suspended clay colloids is seen around the entire bottom of the dish.

Interpretation of results

If the dispersive grade changed during the test the 1h reading is normally used for overall test evaluation. If the grade changes from 2 to 3 or from 3 to 4 between 1h and 6h readings, use the 6h reading.

IV. RESULTS AND DISCUSSIONS

The identification of dispersive soils can be found out by crumb test, according to ASTM D6572-12.

1. *Crumb Test(ASTM D6572-12):*

Crumb test was conducted for both calcium and sodium bentonite. When dispersive clays come in contact with water, the clay fraction behaves more like single grained particle with a minimum electro chemical attraction and thereby does not adhere or bond with other soil particles. The inter particle force of repulsion (electrical surface forces) exceed those of attraction (Van der Waals attraction) and as such when the water flows the detached clay particles are carried away with water which leads to piping in many structures. The Fig 1and Fig 2 shows results

Fig 1: Calcium Bentonite at 6 hrs

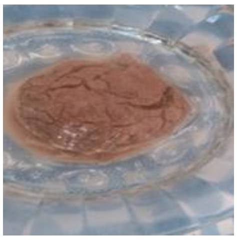

Fig 2: Sodium Bentonite at 6 hrs

TABLE V. GRADE OF SOIL

SOIL TYPE	GRADE(ASTM D6572-12)
Calcium Bentonite	4 (Highly dispersive)
Sodium Bentonite	4 (Highly Dispersive)

It was found that calcium bentonite and sodium bentonite was found highly dispersive in normal condition after 6 hours.

2. *Stabilization of Dispersive Clay*

Dispersive soil has very low permeability. As the water flows velocity is insufficient to move the particles. Generally soil replacement is considered as a remedy which is expensive, so alternative solution such as chemical treatment is usually adopted. The common additives used are lime, fly ash and bottom ash. So the stabilization of the dispersive soil is a physic-chemical process.

a) Stabilization using lime

The tests were conducted using different percentages of lime to find out the optimum lime content for rectifying the dispersiveness of soil. The optimum amount of lime is found to be 3%. At higher concentration more amount of lime was available for flocculation of particles, ion exchange reactions and thus using increasing the force of attraction. Higher percentages only will help in the formation of cementitious compounds which are time dependent.

Fig 3: Sodium Bentonite + 3% Lime

Fig 4: Sodium Bentonite + 3% Lime.

b) Stabilization using lime + fly ash

Test was carried out with different percentages of fly ash. Since the optimum amount of lime is at 3%, this percentage of lime was kept constant and varying amount of fly ash was added to both calcium bentonite and sodium bentonite. It was found that at 5% fly ash and 3% lime the dispersiveness of calcium bentonite and sodium bentonite were reduced.

Fig 5: Calcium Bentonite+5% fly ash+ 3% lime

Fig 6: Sodium Bentonite + 5% fly ash +3% lime

c) Stabilization using bottom ash

Test was carried out for different percentages of bottom ash. It was found that at 1% of bottom ash the dispersive characteristics of the soils were comparatively lower than at 2%, 3%, 4% or 5%.

Fig 7: Calcium Bentonite + 1% of bottom ash

Fig 8: Sodium Bentonite + 1% of bottom ash

V. CONCLUSIONS

Bentonite is an absorbent aluminium phyllosilicate clay consisting mostly of montmorillonite. It was named by Wilbur C. Knight in 1898 after the Cretaceous Benton Shale near Rock River, Wyoming. Bentonite can be used as drilling mud, binder, adsorbents etc. The main aim of the study was to find the dispersive characteristics of Bentonite using the Crumb Test and to remediate it using lime, fly ash and bottom ash. The optimum percentage of lime is 3% where lime induces the flocculation process in both soils. Fly ash alone did not cause any predominant changes in dispersion and addition of lime with fly ash imparts changes in the dispersive characteristics. Fly ash acts as a binding agent. The amount of lime can be increased to remediate the dispersive soils. The optimum percentage of bottom ash was found at 1%. Bottom ash gets in between the voids of bentonite. It can be used as a filler material in embankments etc.

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