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MICROSTRUCTURAL INVESTIGATION ON DISPERSIVE CLAYEY SOIL

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Abstract: Soils that are dislodged easily and rapidly in flowing water of low salt concentration are called dispersive soils. When structures are constructed by the use of such types of soil then they are susceptible to severe erosion. The dispersive nature of soil minerals are its erodability can be assessed by "pinhole test". The degree of dispersion decreases for increasing percentage of additives. In previous research works researchers have added lime as additives. In this experimental study GGBS and silica as additives is used. GGBS stands for Ground Granulated Blast furnace Slag. It is an industrial by product requires an alkali activator for enhancing its pozzolanic reactions with soil. Studies have shown that this binder combination is more economical as compared to other binding agents. Significant increase in unconfined compressive test and reduction in plasticity characteristics where observed improvement of CBR value is also marked after the addition of the binder minimum soft clayey soils have low shear strength, high compressibility and low heat. Various tests like plasticity index, liquidity index, double hydrometer test, pinhole test, crumb test were conducted for determining the increase of decrease in the dispersive property of soft soil.

***Index Terms* – GGBS, pinhole test, Microstructure, dispersive property.**

Introduction

Any phenomenon associated with propagation of individual waves at speeds that depends on their wavelengths is known as dispersion. Soils that are formed by the weathering of volcanic ash is known as dispersive soil. Soils that are dislodged easily and rapidly with flowing water of low salt concentration is known as dispersive soils. Depressiveness of soil is only due to the concentration of sodium ion present in the soil structure. But the presence of Montomorillonite is more necessary for dispersion. Such soils have very low shear strength, high compressibility and low bearing capacity , they experience very large settlement at the time of loading. The erodability of clayey soil at the time of flow of rain water is a critical factor in long term performance of earth structures. Many earth dams and other hydraulic structures and other structures are failed due to the presence of dispersive soils .preventing the failures caused by the dispersibility of soil is one of the major concern now a days. Now a days its found that highly erosive clayey soils also exist in nature. Many earth dams other hydraulic structures road ways have been felt due to the dispersive soils. such problems have been arrived in many countries. The effective advantages of utilization of dispersive soil are very high now a days. So it is necessary to oppose the failures caused by the dispersiveness of dispersive soils. It is a major problem for the Geotechnical engineers. The dispersive soil starts behaving like single grained particle while they come in contact with water. They do not form any bond with other particles. The intermolecular force of repulsion increases.

1.1

Studies and investigations The problems associate with dispersive soils is problem in both Geotechnical and Geoenvironment projects. The soil replacement is expensive and laborious. Therefore alternative solution is the chemical treatment adopted in most projects. The common addictives used before are lime, gypsum, alum and flyash. All normal laboratory tests are not appropriate for the dispersive soils. Different tests are carried out such as pinhole test, double hydrometer test, crumb test, Scanning electrone microscope test(SEM), XRD (X-Ray diffraction). 1.2 Bentonite Bentonite word is derived by knight(1898). He suggested that bentonite is a rock which is formed by clay deposite . Bentonite is composed of crystalline clay. Bentonite contains high amount of Montomorillonite in it. Bentonite is mainly of two types such as sodium Bentonite (swelling bentonite), Calcium Bentonite (non swelling bentonite). In India Bentonite is processed in Ashapura clay tec limited,Gimplex limited, Rjasthan state mines and minerals ltd,Sivashakti bio planttec ltd,Timex Industries ltd.

1.2.1 GGBS

GGBS (Ground granulated blast furnace slag) is a by product of iron producing industries. Iron ores are fed into the furnace and the resulting molten slag is produced. It can be the better substitution of fly ash which can be helpful for improving the geotechnical characteristics of weak soil. It is also economical and environment friendly.

1.2.2 RICE HUSK ASH

Rice husk ash is a pozzolanic material which is obtained from open field burning. It enhances the workability of GGBS. GGBS and sipozz binder combination can be effective in decreasing the depressiveness of soil. present investigation, research objectives Here GGBS and rice husk ash as addictives. GGBS is an industrial by product. It requires alkali activator to increase its polozzoanic reaction with soil. Therefore rice husk ash is used with GGBS to enhance its reactions with soil. Rice husk as is a polozzoanic substace which contains 90% of silica. So the reaction will be enhanced. GGBS and rice husk ash will combinely form a cementitious particle which will increase the binding property for which the dispersion characteristics will be reduced. The binder combination is economical and environmental friendly as compared to other conventional binders. Standard proctor test, Unconfined compressive strength test, atterbergs limits, Free swell index tests, Hydrometer tests, SEM test and XRD tests were conducted. The main purpose of this research work is to indicate the decrease in dispersiveness of bentonite by adding different percentage of GGBS where rice husk ash is maintained constant. By reducing the dispersiveness the clay can be utilized.

3. MATERIALS AND METHODOLOGY

3.1 MATERIALS

A. Bentonite

Bentonite which is used in this research work is collected by commercial purchage from cuttack , Odisha, India. Bentonite is a predominant clay mineral which is used in this study. It is used in many geotechnical and geo environmental projects. The term bentonite was first used for clay found in 1890 in the upper cretaceous tuff near Fort Benton, Wyoming. Bentonite is an impure clay which consistsmontomorillonite .There are few types of Bentonites and their names depend upon the elements present in it, such potassium, sodium, calcium, and aluminium. For industrial purpose 2 types of bentonites are present.sodium bentonite and calcium benyonite.

B. Formation and processing of bentonite

Bentonite usually forms from weathering of volcanic ash mostly when water is present. When Bentonite is derived from weathered volcanic glass the dominant clay species is illite. Other clay species present in other bentonites are montomorillonite and kaolinite.In India Bentonite is processed in Ashapura clay tec limited,Gimplex limited, Rjasthan state mines and minerals ltd,Sivashakti bio planttec ltd,Timex Industries ltd.

FIG.1 Crusher and binding machine for bentonite production

Table 1: LIST OF COUNTRIES BY BENTONITE PRODUCTION

Rank by Sovereign state	Country / Region	Bentonite production(tones)
1	United states	4,620,000
2	china	3,200,000
3	Greece	1,100,000
4	India	1,081,000

Table 2: Chemical analysis of Bentonite

Parameters	Exchangeable cations(meq/L)
Ca^{++}	11.97
Na^{++}	50.01
Mg^{++}	20.03
K^{+}	0.17

C. GGBS (GROUND GRANULATED BLAST FURNACE SLAG)

Ground granulated blast furnace slag (GGBS) is a by product of manufacturing of Iron. It is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a glassy granular product which is then dried and ground into a fine powder(GGBS). GGBS has alkali activator for its pozzolanic reaction with soil. It is more effective binder than flyash as well as environment friendly, because the reaction heat per unit mass of GGBS is only 16. 7% higher than fly ash. for the difference of hydration heats between fly ash and GGBS shows much higher hydraulic activity. So in this study GGBS is choosed as addictive to study the dispersiveness. It is also referred as slag cement by UK, It is also used in Europe and United states and Asia. For this project work GGBS is collected from Toshali cement factory, Choudwar , Cuttack, Odisha, India

TABLE 3: Chemical properties of GGBS

chemicals	Percentage
SIO_2	4.27
Al_2O_3	14.33
Fe_2O_3	1.11
CaO	37.02
Mgo	8.41
SO_3	0.85
K_2O	1.28
Na_2O_3	1.32

D. RICE HUSK ASH

It is the combination of engineered –unnatural sand. It is a suitable addictive which is used for enhancing workability and reactions. It is used as a substitute material of silica. Rice husk ash is produced by the burning of rice husk in 600 to 700 degree centigrade. The furnace temperature is controlled by air volume. For maintaining the temperature the furnace is designed.

3.2 METHODOLOGY

In this research work experimental procedures are carried out to study the investigation of dispersiveness of bentonite clay which is highly dispersive .By using GGBS and rice husk ash binder as additives the dispersivness can be reduced . The optimum percentage of GGBS used is recorded in every tests. Eight samples were prepared by combining different percentages of materials for different laboratory tests. The percentage of rice husk ash is maintained constant in each sample except one. The samples are as follows

Sample(S1)=Bentonite soil only

Sample(S2)=Bentonite soil+15% rice husk ash

Sample(S3)=Bentonite soil+15% rice husk ash+10% GGBS

Sample(S4)=Bentonite soil+15% rice husk ash+20% GGBS

Sample(S5)=Bentonite soil+15% rice husk ash+20% GGBS

Sample(S6)=Bentonite soil+15% rice husk ash+30% GGBS

Sample(S7)=Bentonite soil+15% rice husk ash+40% GGBS

3.2.1 Methods to find reduce dispersiveness

Road way, hydraulic structures, earth dams and other constructed structures have suffered due to serious erosion and are failed due to the presence of dispersive soil . So the reduction of dispersion by using additives is an way to overcome such problems. Though GGBS is an alkali activator wich is helpful to enhance pozzolanic reactions with dispersive soil. Rice husk ash is used as the substitute of silica. Fly ash-lime and GGBS-lime binders were used before to reduce dispersiveness and the percentage of optimum addictives were recorded. Though the use of GGBS is more environment friendly and the binder of GGBS and rice husk ash combinely form cementitious property which is helpful to reduce dispersiveness. Use of GGBS and rice husk ash as binders is a new technique. GGBS is also more hydraulic reactive than flyash. In this project work comparision was carried out. For every test different samples were taken. One is only soil, and in others are soil, rice husk ash and different percentages of GGBS .

A. CLASSIFICATION AND IDENTIFICATION

The classification of bentonite as per IS: 1490-1970 is a dispersive clay.

B. DOUBLE HYDROMETER TEST

AS per IS:2720(part-4)-1985 hydrometer test was carried out to analyse the grain size because bentonite is in powder form so sieve analysis is not appropriate. Upto 24 hours hydrometer readings were taken

C. Determination of water content

As per IS: 2720 (part-2) water content for six samples were determined. The optimum moisture content and maximum dry density were determined for every samples the graphs were compared.

D. Determination of Atterberg's limits

As per IS:2720(part-5)1985 the Atterberg's limits were calculated. Liquid limit by casagrande liquid limit device of only bentonite and bentonite with adding addictives GGBS with different percentage were determined maintaining rice husk ash percentage constant. Plastic limit was also demonstrated for every samples.

E. Determination of compactness

The requirements of compaction mould assembly was used to determine dry density and water content of the samples as per IS: 2720(part-7)1980.

F. Unconfined compressive strength

As per IS:2720(part-10)1991the method for determining the compressive strength for different samples performed. All samples were kept 24 hours for curing. The test gives the quantitative value of compressive strength.

G. Crumb test

According to ASTM D6572 crumb test was carried out to assume the depressiveness of soil and to compare the dispersion percentage for different samples. The samples prepared and kept for 24 hours in room temperature then kept in water for another 24 hours to show the dispersion. For only bentonite the sample dissolved percentage was more. And the dissolved percentage decreased with the increasing percentage of GGBS.

H. Pinhole test

According to ASTM D4647 pinhole test was carried out. The samples were set in the stand in conical flasks and each samples were kept for 24 hours in room temperature for curing. The test method was started with distilled water flowing horizontally under a hydraulic head of 50 mm (2 inch) through 1 mm diameter hole. The test provides the different principles between dispersive and non dispersive clays. Flow from dispersive bentonite was distinctly dark and the hole enlarged rapidly, with an increasing flow rate. Flow from slightly to moderately dispersive clays was slightly dark with a constant hole size and flow rate. Flow from non dispersive clays was completely clear with no measurable increase in hole size .

I. X-RAY diffraction

For different 3 samples i.e. only bentonite, bentonite +15% RA+30% GGBS and bentonite+15% RA x-ray diffraction was analysed by showing the minerals in respective graphs.

4. RESULT AND DISCUSSION

Hydraulic structures have suffered due to serious erosion and are failed due to the presence of dispersive soil . The dispersiveness of soil can be reduced by adding suitable materials like rice husk ash and GGBS with the soil Though GGBS is an alkali activator wich is helpful to enhance pozzolanic reactions with dispersive soil in presence of rice husk ash, used as the binder. Presence of calcium in GGBS with pozzolanic material reduces the dispersiveness. Geotechnica l tests discussed in chapter- 3 were performed to know the dispersive property of Bentonite. After adding addictives the decrease in the dispersive characteristics were also demonstrated and discussed here..

Table 4 : Chemical composition of bentonite

CHEMICALS	PERCENTAGE
SiO_2	48.16
P_2O_3	1.06
Al_2O_3	14.86
Fe_2o_3	4.80
CaO	1.16
Na_2O	1.66
MgO	2.08
K_2O	1.60
TiO_2	0.94

4.1 CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF ROCE HUSK ASH

Rice husk ash is produced by the burning of rice husk at temperature 600 to 700 C. It is used as the replacement of silica. The physical properties and chemical composition are shown below.

Formula	concentration
CO_2	0.10
K_2O	4.50
MnO	0.14
Al_2O_3	0.46
Fe_2O_3	0.47
SiO_2	89.90
P_2O_5	2.45
CaO	1.01
MgO	0.79
S	0<LLD

Table 5: Physical characterisation of Rice husk ash

Characteristics	Average value
Specific surface ,m^2	15
Oversize percent retained on 45 micron IS sieve	10
Oversize percent retained on 45 micron IS sieve variation from average percentage	5
Compressive strength at 7 days as percent of control sample	85
Bulk density	0.23 grams/cc
Physical state	Solid-non-hazardous
Colour	Grey

4.2 EXPERIMENTAL METHODOLOGY

A. DIFFERENTIAL FREE SWELL INDEX TEST(DFS)

samples	Only bentonite	Bentonite+10% GGBS+15% Rice husk ash	Bentonite+30% GGBS%15% rice husk ash	Bentnite+40% GGBS+15% rice husk ash
Free swell index	62.5%	34.75%	33%	16%

As per IS:2720(part-1)1983 differential free swell test was conducted and according to the above table a gradual decrease in swelling was found.

B. ATTERBERG LIMITS

(As per code IS:2720(part5)1985) for liquid limit and plastic limit

Moisture content	39.22	32.56	25.98	19.22
No of blows	17	25	20	10

Sample1(only bentonite)

Liquid limit=32.56%
Plastic limit=26.43%
Plasticity index=6.13

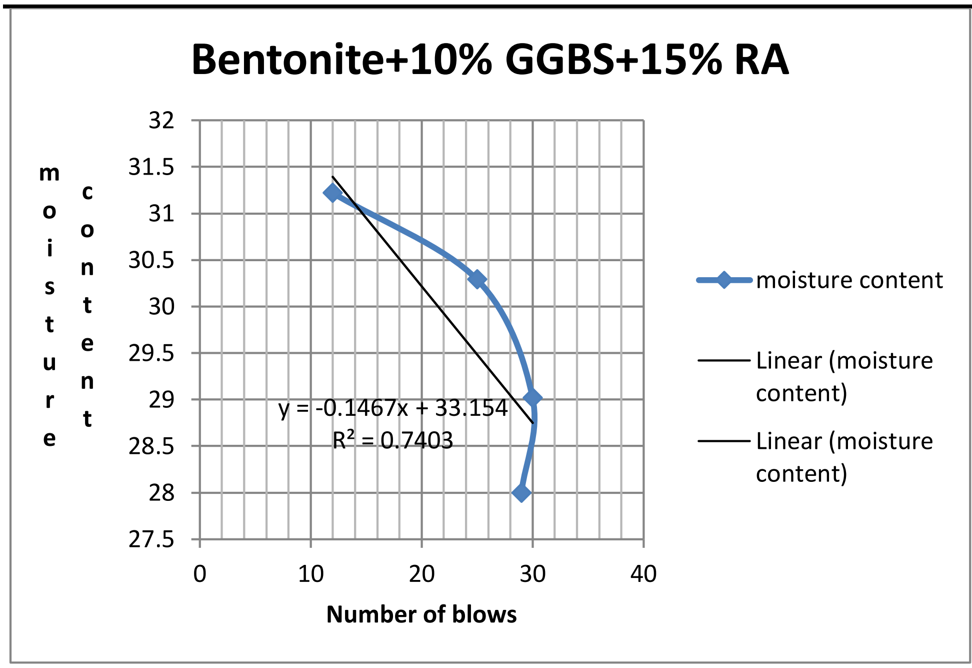

Fig.2 Bentonite + 10% GGBS+ 15% rice husk ash(sample-2)

Moisture content	31.22	30.29	29.02	28
Number of blows	12	25	30	29

Liquid limit=29.5%
Plastic limit=23.9%
Pasticity index=5.6%

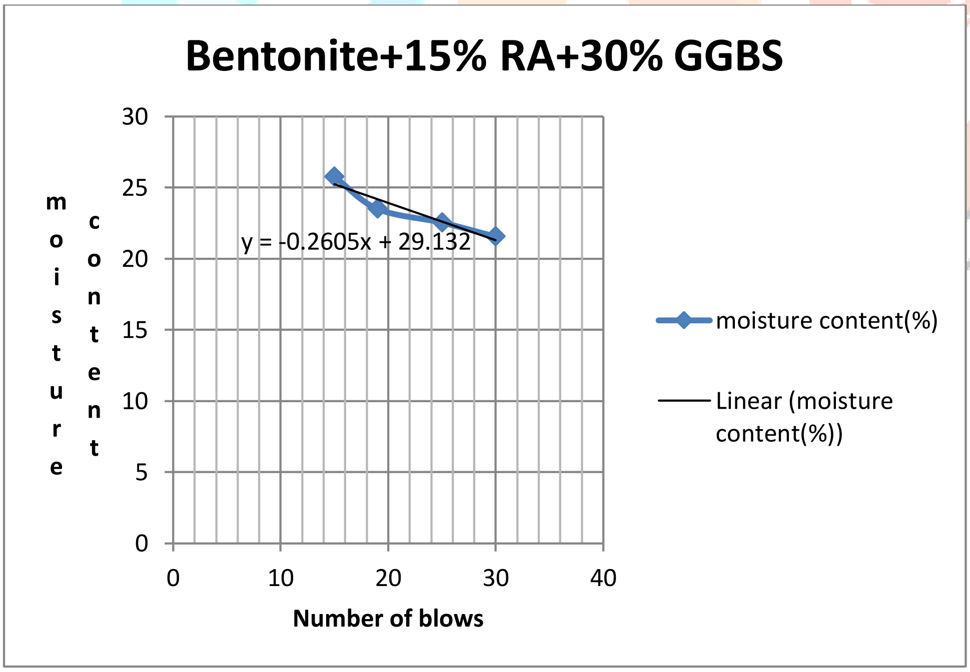

Fig.3 Bentonite + 15% RA+30% GGBS (Sample3)

Moisture content in(%)	25.75	23.5	22.54	21.55
no of blows	15	19	25	30

Liquid limit=22.54%
Plastic limit=18.41%
Plasticity index=4.13%

Sl no	Sample no	Liquid limit	Plastic limit	Plasticity index
1	S1(bentonite)	32.56	26.43	6.13
2	S2(bentonite+ 10% GGBS+15% RA)	29.5	23.9	5.6
3	S3(Bentonite+30% GGBS+15% RA)	22.54	18.41	4.13

From Atterberg's limit experiment liquid limit decreases with the increase in percentage of GGBS and maintaining the rice husk ash percentage same as 15%.For sample 1 it was 32.56,for sample2 it was 29.5 and for sample3 it was 22.54. Plastic limit also decreased with the increase in percentage of additives .They are 26.43, 23.9 and 18.41 respectively. Plasticity index which is the difference between liquid limit and plastic limit also decreased. For sample 1,2 and 3 it was 6.13 , 5.63 and 4.13 respectively. It may be due to the increase in percentage of GGBS and its reaction with silica present in Rice husk ash.

C. CRUMB TEST

As per code ASTM D6572 crumb test carried out for analyzing the dispersive characteristics. This test is appropriate for soils with plasticity index less than or equal to 8.In this test different amount of GGBS were added and samples were prepared as shown in the figure below. Every samples were kept for a day for curing in normal room temperatue and another 24 hours dipped in water. The collapse percentage was determined.

Fig.4 Sample after curing

Fig.5 Only bentonite after melting

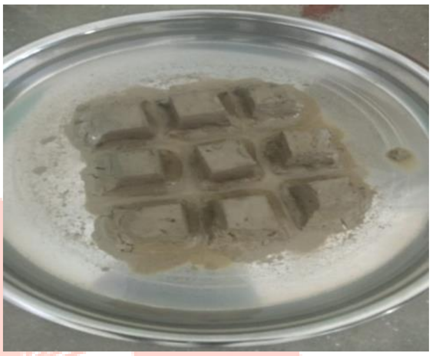

Fig.6 Bentonite+10%GGBS

Fig.7 20% GGBS after melting

Fig.8 30% GGBS after melting

Fig.9 40% GGBS after melting

(**Dispersion percentage for different samples)**

From the above table it is concluded that the portion of sample collapsed depends upon the amount of addictives used. The collapse percent decreases with increasing percentage of GGBS.In case of sample 1 only bentonite is used which is highly dispersive in nature, so the dispersion percentage was the highest(85%). Then in case of sample 2 ,10%GGBS was added and 15% rice husk ash also used, so the % failure decreased. Again in sample 3, 20% in sample4 30% and in sample 5 40% GGBS were added maintaining the Rice husk ash percentage constant . In case of sample 4 the percentage failure was the lowest. It is due to addition of optimum GGBS. The combination of more amount of GGBS makes increases the binding property of soil. So it did not collapse. .

4.3 Optimum moisture content and maximum dry density(Standard proctor test)

This test was conducted as percode IS:2720(part 8)-1983.The optimum moisture content and maximum dry density for different samples were determined by giving number of blows by rammer.

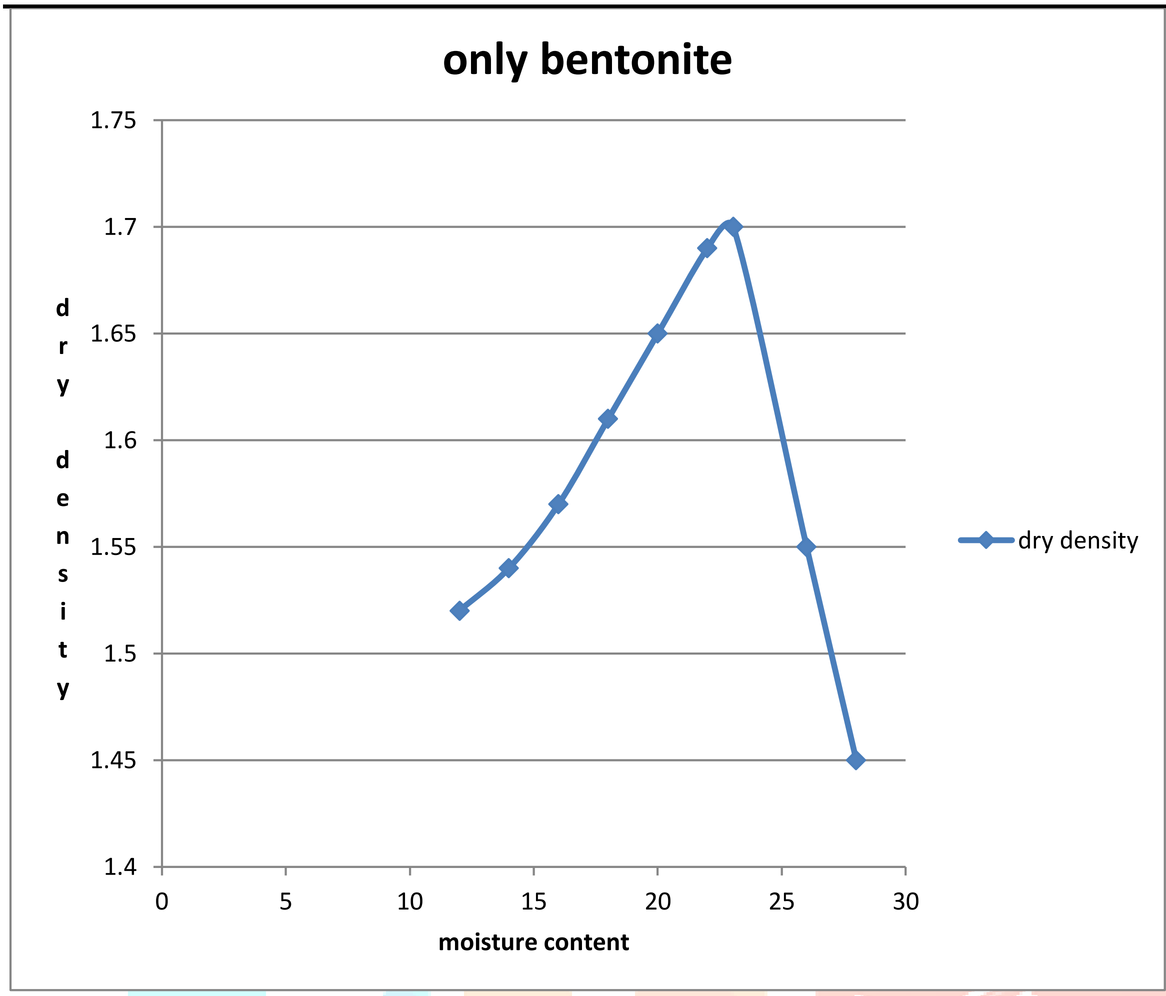

Fig.10 For only bentonite

Moisture content(%)	12	14	16	18	20	22	23.05	26	28
Dry density	1.52	1.54	1.57	1.61	1.65	1.69	1.70	1.55	1.45

OMC=23.05%
MDD=1.7 Kn/m^3

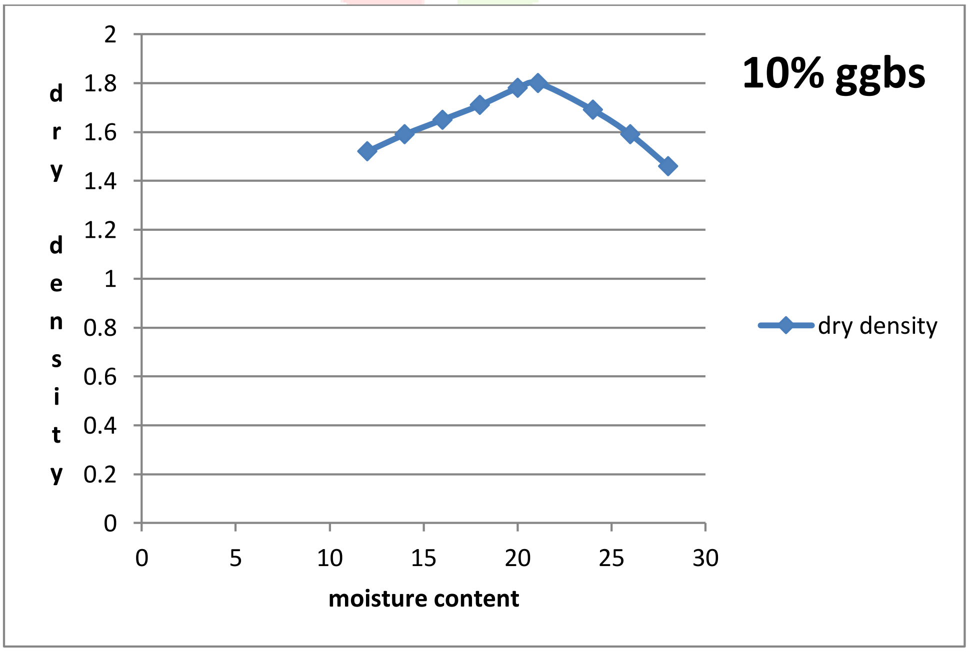

Fig.11 For 10% ggbs

Moisture content	12	14	16	18	20	21.1	24	26	28
Dry density	1.52	1.59	1.65	1.71	1.78	1.80	1.69	1.59	1.46

Omc=21.1%
MDD= 1.8 kn/m^3

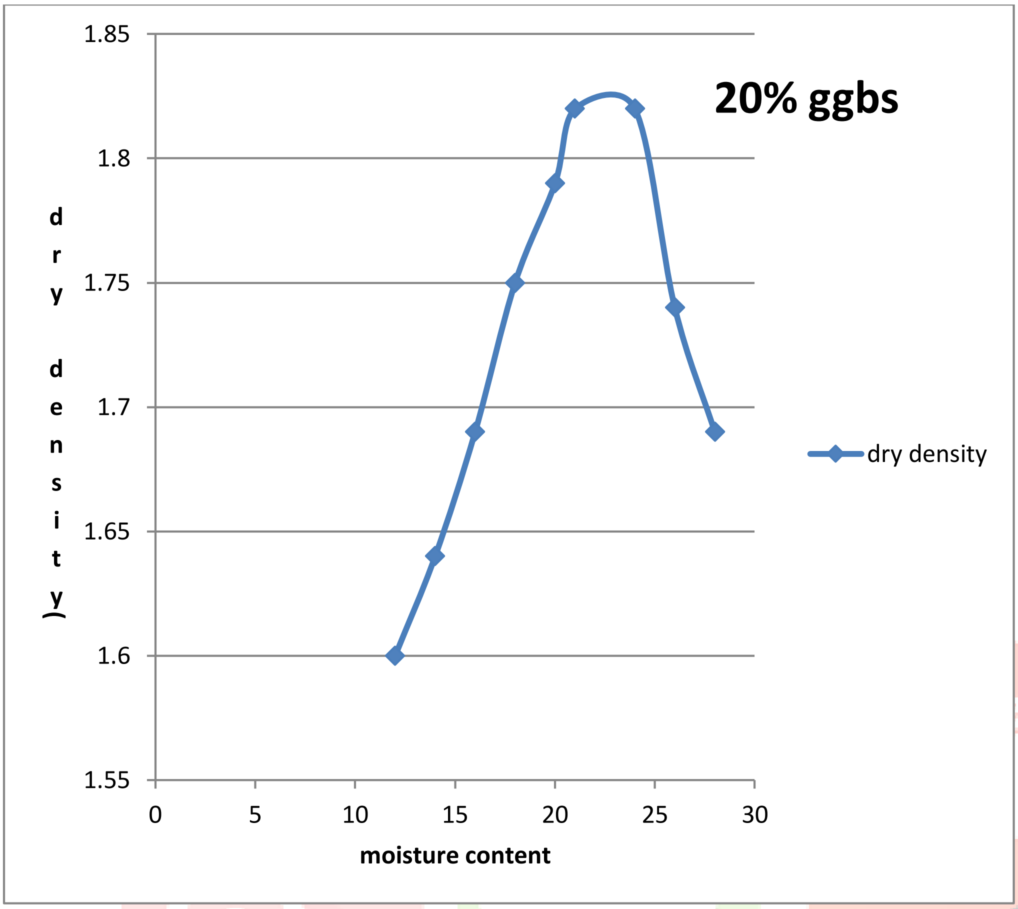

Fig.12 For 20% ggbs

Moisture content%	12	14	16	18	20	21	24	26	28
Dry density(kn/m^3)	1.6	1.64	1.69	1.75	1.79	1.82	1.82	1.74	1.69

Omc=21.05%
mdd=1.82 Kn/m^3

Moisture content(%)	12	14	16	18	20	21	24	26
Dry density(kn/m3)	1.4	1.5	1.6	1.7	1.82	1.86	1.78	1.58

Omc=21%
mdd=1.86Kn/m^3

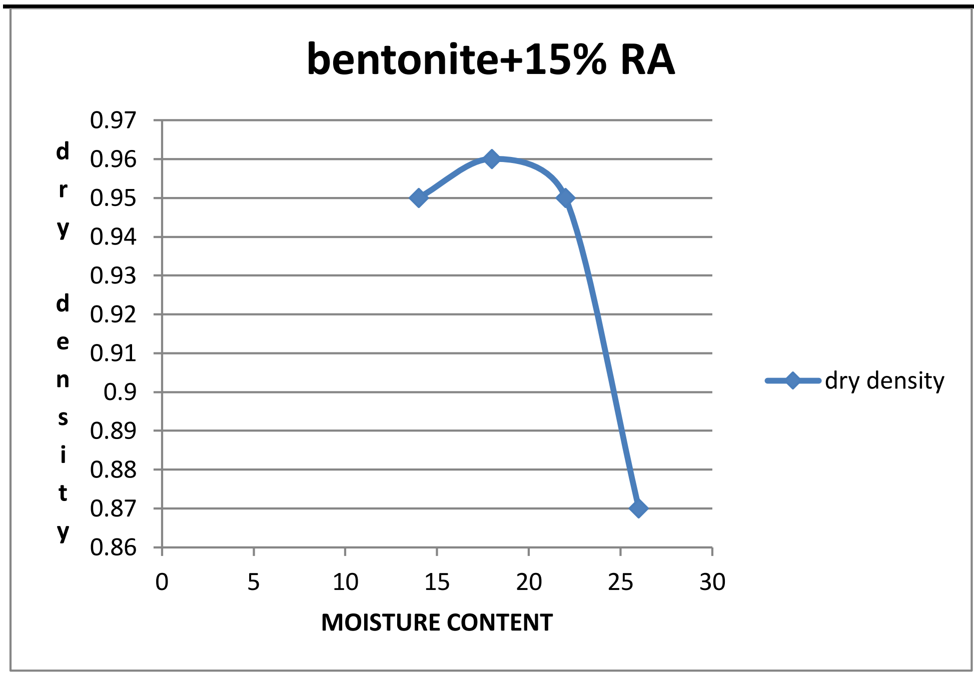

Fig.13 For bentonite+ 15% ggbs

Moisture content(%)	14	18	22	26
Dry density	0.95	0.96	0.95	0.87

omc=20.50%
mdd=0.955 Kn/m3

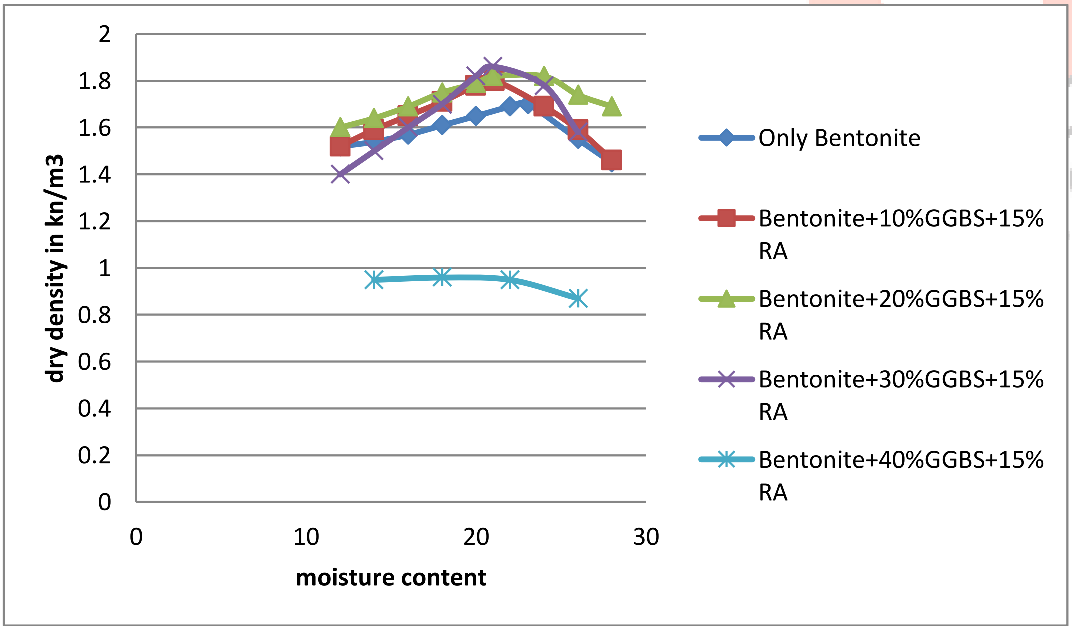

Fig.14 Comparison of for all samples

4.4 Comprehensive graph of OMC and MDD

From the above test it is found that the moisture content decreases with the increase in percentage of addictives. For only bentonite it was 23.05% and after addition of 10% , 20%, and 30% GGBS the OMC became 21.1%, 21.05% , and 21% respectively and 20.50% for only bentonite and 15% rice huskash . There was gradual decrease in the percentage with the increase in percentage of GGBS. In case of 5th sample due to the absence of ggbs the maximum dry density decreased.For aothe 4 samples dry density increased.

4.4.1 XRD ANALYSIS OF BENTONITE CLAY

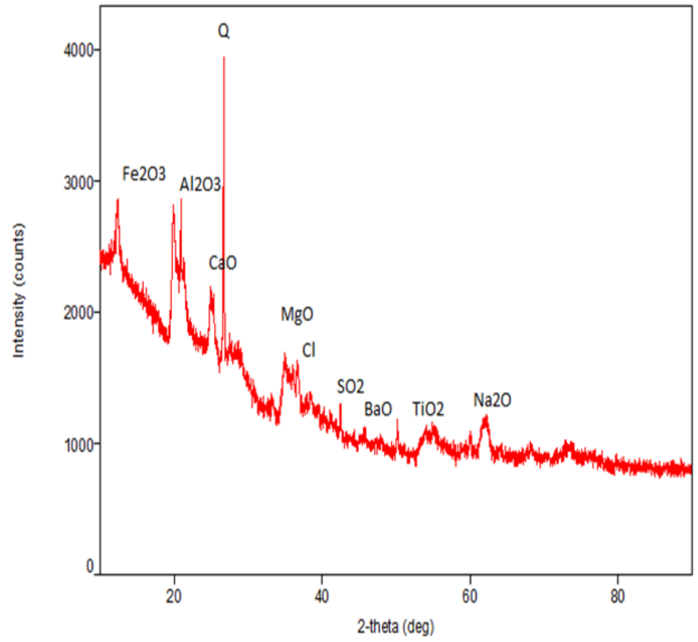

Fig.15 For xrd analysis of bentonite clay

4.4.2 XRD OF BENTONITE+ RICE HUSK ASH+ GGBS

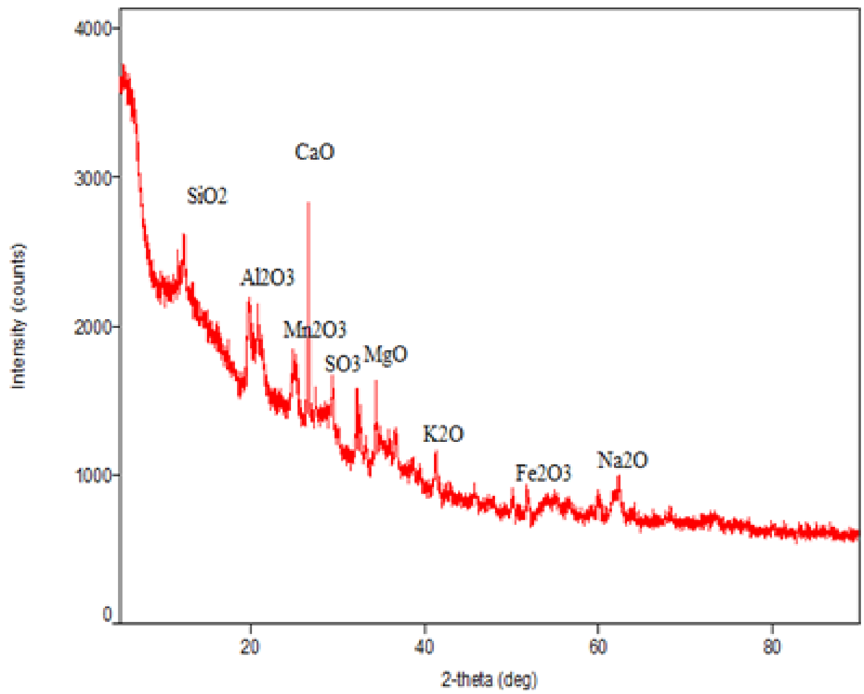

Fig.16 XRD of Bentonite+ rice husk ash+ GGBS

D. Pin hole test

Fig.17 Only bentonite

According to ASTM D4647 pinhole test was conducted after the water injected through the samples collected in measuring cylinder and compared with distilled water kept in another measuring cylinder. The water collected from the sample where the optimum GGBS added was more similar with the distilled water than others. 5 samples were taken. Sample 1(bentonite only), sample 2(bentonite + 15% RA +10% GGBS), Sample 3(bentonite+15% RA +20% GGBS) , Sample3(bentonite+ 15% RA+30% GGBS), sample 4(Bentonite+ 15% RA), Sample5 (Bentonite+15% RA+50% GGBS). The water collected from the sample where 50% GGBS present was most similar to distilled water.

5. CONCLUSIONS

1) Dispersive soils used in constructions cause failure to different earth structures, earthen dams, hydraulic structures road ways. Dispersive soils are available in huge amount as they are formed by the weathering of igneous and metamorphic rocks . They are easily available in flood plains and lake bed deposites. They are abundant in various parts of the world. So it will be helpful if such soils can be utilized.
2) From this study it found that the addition of 40% GGBS and 15% Rice husk ash satisfactory results were found, lowering the percentage of GGBS hardly imacts the dispersiveness. In differential free swell test the swelling percentage was highest 62.5% for only bentonite . Then 10% GGBS was added along with 15% rice husk ash the swelling decreased upto 34.75%, addition of 30% GGBS again decreases the swelling upto 33%. The highest decrease in swelling was found when 40% GGBS was added and it was 16%
3) In case of Atterbrg's limits liquid limit and plastic limit decreased with the increase in percentage of GGBS. For only bentonite liquid limit and plastic limits were 32.56% and 26.43% and plasticity index was 6.13%.In case of Sample2(bentonite+10% GGBS+ 15% rice husk ash) liquid limit and plastic limit were decreased and became 29.5% and 23.9% . The plasticity index became 5.6%, For sample3(bentonite+30% GGBS+15% rice husk ash) liquid limit and plastic limits were lowest than the other 2 samples. They were 22.54% and 18.41% respectively and the liquidity index was 4.13%.
4) By crumb test the percentage failures were noted for 5 samples. For only bentonite the percentage failure was 85% which decreased upto 3% for sample5 (bentonite +40% GGBS+ 15%) rice husk ash. That means the binding property was maximum at 40% GGBS. In this test all the 5 samples were kept for 1 day curing. Optimum moisture content was declined and Maximum dry density was increased with the increasing percentage of GGBS.
5) By pinhole test the water collected from dissolved soil were compared with distilled water for 5 samples. The water collected from sample 1(only bentonite) was the most impure and the water collected from sample5 (bentonie+ 50% GGBS+ 15% rice husk ash) was almost similar to the distilled water kept in the other measuring cylinder. It shows the decrease in flow of the soil or the decrease in dispersion and increase I binding property by adding optimum GGBS. X-ray diffraction for 3 different samples in 0-90 degree radiation range was analysed by graph.

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