“Utilisation of cement kiln dust and red mud for construction of highway embankments in cohesion less soil”

A

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Dr. Ashok Kumar Gupta
(Head of Civil Department)

by

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY
WAKNAGHAT, SOLAN – 173234 HIMACHAL PRADESH, INDIA

MAY-2019

STUDENT’S DECLARATION

This is to certify that the work which is being presented in the project report titled **“Utilisation of cement kiln dust and red mud for construction of highway embankments in cohesion less soil”** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of our work carried out under the supervision of **Dr. Ashok Kumar Gupta,** (Head of Department). This work has not been submitted elsewhere for the reward of any other degree/diploma. We are fully responsible for the contents of our project report.

Signature of Student

Divesh Rana

(151601

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat,

Date:

CERTIFICATE

This is to certify that the work which is being presented in the project report titled

"Utilisation of cement kiln dust and red mud for construction of highway embankments in cohesion less soil"in partial fulfillment of therequirements for the award of the degree of Bachelor of Technology in Civil Engineering andsubmitted to the Department of Civil Engineering, **Jaypee University Of Information Technology**is an authentic record of work carried out by**Divesh Rana (151601)** during a period from August 2018to May 2019 under the supervision of **Dr. Ashok Kumar Gupta,** (Head of Department) Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: -

Signature of Supervisor	Signature of HOD	Signature of External
Mr. Ashok Kumar Gupta	Dr. Ashok Kumar Gupta	External Examiner
Professor and Head	Professor and Head	
Department of Civil Engineering	Department of Civil Engineering	
JUIT, Waknaghat	JUIT, Waknaghat	

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We also want to thank our project guide Dr. Ashok Kumar Gupta (Head of Department) for giving us the correct heading and legitimate direction in regards to the project. Without their dynamic association and the correct direction, this would not have been conceivable.

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Date: -

ABSTRACT

Red mud is the waste product of the steel industry and Cement kiln dust is the waste product of the cement industry. Government of India has to acquire a large amount of land to dump this waste which proves to be very uneconomical and these both wastes has a lot of environmental hazards. In the areas of loose soil, the construction of pavement is not easy so, we decided to use Red mud and CKD mixture with the cohesion less soil. Tests have been done to classify the type of soil we use and various experiments have been done to ensure that the mixture of Red mud, CKD and cohesion less soil proves to be optimum and fit for the use of pavement construction. With the use of these waste products not only a large amount of land is saved from dumping but a good strength is obtained from the mix of waste products which is of no use.

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CHAPTER – 1: INTRODUCTION

Red Mud is the by-product of the Steel Industry. According to report of Central Steel Authority Of India (2017) total red mud produced by steel industry in one year is 90 Million-ton, which is the incombustible residual part of the incinerated waste. The amount of the red mud generated per ton of the alumina processed, varies greatly with the type of the bauxite ore used. Important quantities of metal and minerals are present in these residues and offer many opportunities for recycling. The bayer process produced above 95 percent of the alumina globally, for each tonne of the alumina produced there is the production of approximately 1-1.5 tonnes of residue. In 2015 alumina annual production was around 115 milion tonnes which results in production of around 150 milion tonnes of bauxite residue.

1.1 Composition

Unreacted metallic oxides are main constituents of residue which comes after extraction of component aluminium . The extraction conditions, nature and quality of bauxite ore are factors which are dependent for the percentage oxides produced by a particular alumina refinery. composition ranges for the chemical constituents which are common is shown by the table below but there is variation in the values widely.

Table.1 Chemical Composition of Red Mud

Chemical	Percentage composition
Fe_2O_3	5–60%
Al_2O_3	5–30%
TiO_2	0.3–15%
CaO	2–14%
SiO_2	3–50%
Na_2O	1–10%

Fig.1 Red Mud

1.2 Environmental hazards

Beacause of the alkalinity of redmud it is environmentally hazardous. In 2010, approximately one million cubic meters of red mud which comes from an alumina plant which is near Kolontár in Hungary was released accidentally into the countryside surrounding in the accident at Ajka alumina plant , which kills 10 people and a large area was contaminated. In marcal river all life was said to have been "extinguished" due to the red mud, and Danube had been reached by the mud within few days.

1.3 Residue storage areas (RSA)

Since the original plants were built Tailings storage methods have changed. The practice in early years was to pump the tailings slurry, at a concentration of about twenty% solids, into lagoons or ponds sometimes created in former bauxite mines or depleted quarries. Dams or leaves were used to construct impoundments in other cases, whilst for some operations valleys were dammed and the tailings deposited in these holding areas. For tailings to be discharged into river it was a common practice, estuaries, or the sea via pipelines or barges; in other instances the residue was shipped out to sea and disposed of in deep ocean trenches many kilometres offshore. Kinds of alll disposal into sea, river and estuaries has now been stopped. The mid-1980s dry stacking has increasingly adopted due to residue storage space ran out and concern over wet storage increased, the mid-1980s dry stacking has been increasingly adopted. In this type of method, tailings are thickened upto a high density slurry , and then deposited in a way that it dries and consolidates. An increase in popular storage method called filtration where by a filter cake is produced. With the help of water or steam this cake can be washed to reduce the alkalinity before it is being transported and as a semidried material it is stored. Residue produced in this type of form is ideal for the reuse as it contains lower amount of alkalinity, which is cheaper to be transport, and which is easy to be handle and process.

1.4 Cement kiln dust

Cement kiln dust is finely divided material similar in appearance to Portland cement. A large amount of dust is collected from kiln exhaust gases and disposed in landfills. India is the second largest producer of cement in the world and fuelled by growth in the infrastructure sector, the capacity is expected to increase. Cement kiln dust (CKD) is a fine, powdery material, portions of which contain some reactive calcium oxide, depending on the location within the dust collection system, the type of operation, the dust collection facility, and the type of fuel. CKD is a waste product of cement industry having puzzolanic properties so may be used for embankment construction and soil stabilization.The problem of disposing and managing solid waste materials in the industrial countries has become one of the major environmental, economic and social issues. During manufacturing of cement a waste product, known as cement kiln waste (CKD) is generated which accounts for 15-20% of the cement clinker production. The cement kiln dust (CKD) has cementitious properties that make it an effective stabilizer for certain soil types. CKD represents a potentially useful and cost- effective.

Fig.2 Cement kiln dust

CHAPTER – 2: LITERATURE REVIEW

J.Sudheer and S. Pankaj (2018) studied the geotechnical Properties of Pond Ash Mixed with Cement Kiln Dust and Polypropylene Fiber. Cement kiln dust has pozzolanic properties, which increase the density of the pond ash with polyproplyne

Kumar, A., Gupta, D., (2015) studied the effect of addition of rice husk ash, pond ash, cement and fiber on the compaction and strength behavior of clay, a series of tests were performed. Modified proctor tests were conducted to evaluate the compaction behavior, while unconfined compression tests (UCS) and split tensile strength (STS) tests were conducted to evaluate the strength properties of clay. For testing purpose specimens were prepared with different amount of admixtures. Pond ash (PA) and rice husk ash were added to clayey soil at ranges of 30-45% and 5-20%, respectively. Polypropylene fibers of length 6 mm and 12 mm are used in this study with different contents as 0, 0.5, 1.0 and 1.5% by dry weight of mix whereas cement contents used are 0, 2 and 4%. To study the effect of curing on strength property, the specimens were cured for 7, 14, and 28 days and tested.

Mahto, B., Duggal, A. K (2015) studied use of pond ash and RBI Grade 81 for enhancement in CBR values of clayey and silty soil. The tests like Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California bearing ratio (CBR) and Dynamic cone penetration (DCP) tests were conducted on the soil in the laboratory for different percentages of RBI Grade 81 i.e. 2%, 3% & 4% along with 3%, 6% & 9% pond ash. From the test results it has been observed that the engineering properties of clayey and silty soil can be enhanced considerably, if pond ash added with RBI Grade 81. The optimum combination suggested for clayey and silty soil is 3% RBI Grade 81 and 3% pond ash and also very cost effective. It was found that with the addition of Pond ash along with RBI Grade 81, the C.B.R. increased up to a certain limit but after that the C.B.R. decreased even on more addition of pond ash.

Patil, B. M., Patil, K. A. (2013) has evaluate the use of pond ash and RBI Grade 81 for improvement in CBR values of clayey soil and grade-III materials used for base course of flexible pavement. The pond ash is a thermal power plant waste and RBI Grade 81 is chemical soil stabilizer. The geotechnical properties like Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Unconfined Compressive Strength (UCS), CBRvalue.

Sariosseiri, F., Razavi, M.& Carlson, K. (2011) studied experimental results of the effect of Portland cement and Cement Kiln Dust (CKD) on engineering properties of soils from Aberdeen and Everett in the state of Washington. CKD and cement were added in several different percentages of dry weight of soils. Laboratory tests including Atterberg limits, standard Proctor and unconfined compressive strength were performed. Results of cement and CKD treatment are compared. Results of the investigation showed cement and CKD treatment led to an increase in optimum moisture content, and a decrease in maximum dry unit weight. It was also observed that the unconfined compressive strength and modulus of elasticity of CKD treated soils were lower than that achieved by cement treatment.

Oduola, O.R. (2010) studied effects of the cement kiln dust which is a waste product from the cement industry to stabilize the soil problem of Amatutu in Anambra State, and finds use of this in construction of civil engineering in Nigeria .The test was done on the engineering properties of soil for ex.- CBR, unconfined compression strength, dry density and after CKD was added it shows an improvement in the properties of soil, it seems of an improved pavement performance when mixed with ckd. The results have been proved that CKD which is a waste material from the cement industry can be economically be used and thus contribute to sustainability of the environment and in Nigeria there is green development.

Wang, K.,Mishulovich,A., Shah, S, (2007) activation methods was performed and investigation was done on the effects of these on the strength increment of non clinker cement which are developed from fifty percent cement kiln dust and 50 percent classF flyash. The methods of activation includes two chemical and five percent sodium hydroxide additions; 1 ball mill cogrinding and three elevated temp. curing thirty eight and fifty degree celcius. Compressive strength, particle-size distribution and the hydration product of the ciment kil dust-FA.binders were studied. Ph value along with soluble chloride and alkali content of the CKD-FA pastes have been examined. The outcomes showed that all activation techniques that were used to improve binder strength development. The strength improvisation has been more advantageous at the initial stage than that of at the later stages. Curing which was done at the increased temperature resulted to be the most effective activation methods as compared with grinding and the NaOH addition. Combined activation techniques gave the binder elevated activation effectiveness than that of other single activation techniques. The CKD-FA pastes had shown much elevated alkali and chloride contents but slightly less pH value as compared to the portland cement mixture.

Kim, B. Prezzi, M. & Salgado R. (2005) Study of class F fly ash and the bottom ash which are the solid residue byproduct which are produced by the coal burning electric utility. These are in usually disposes of together as the waste in utility disposal site with the typical disposal rates of eighty percent fly ash and twenty percent bottom ash. The Direct use of these kind of materials in the construction work which consumes a large amount of material, for example highway embankment constructions, which not only provide a promising answer to disposal problems, but also the economic alternatives to use of traditional substances. Representative sample of the class F fly and the bottom ash had been collected from 2 utility power plant in the Indiana and is tested for their mechanical properties like compaction, permeability, strength, and compressibility. Three composition of fly and bottom ash with the different mixtures ratio (ex., 50, 75, and 100% fly ash content through weight) were prepared for the testing. Test result indicates that the ash mixture gets compared favourably with the conventional granular material.

Muntohar, A.S., Widiant, A.,Hartono, E.& Diana,W., studied engineering properties of silty soil stabilized with lime and rice husk & reinforced with waste plastic fiber. The results indicate that the proposed method is very effective to improve the engineering properties of the silty soil in terms of compressive, tensile.& shear strength, which further enhanced the stability and durability of the soil.

Hewish- Freer, R.J. & Ghataora, G.S. performed stabilization of desert sand with cement kiln dust plus chemical additives in desert road construction. The results of laboratory investigation into the stabilization of desert sand with waste product, CKD was achieved, but as large amounts of CKD were needed to meet pavement layer standard, chemical additives were used to reduce the CKD requirement.

CHAPTER – 3: MATERIALS TO BE USED

3.1 RED MUD

Red mud has many names for example bauxite residue, red sludge, or alumina refinery residues called (ARR), which is more alkaline wasteproduct and it is basically comprised mostly of FeO which is produced through alumina industrial production (the Al oxides which is principal raw material and gets used in manufacturing of aluminium metal which is widely used in manufacturing of refractories ceramics etc.). Red special waste of about 77 million tons are produced each year, which causes very serious disposal prob. in the functioning of mining industry. The waste product becomes important due to the scale of production, and storage issues are rediscussed and every chance is determined to find its use.

3.2 CEMENT KILN DUST

Cement kiln dust (CKD) is a fine material, which contains calcium oxide, depending on the location within the dust collection system, the type of operation, the dust collection facility, and the type of fuel. CKD is a waste product of cement industry having puzzolanic properties so may be used for embankment construction along with pond ash. The demand of cement increasing with respect to time as the result there is very much gathering of CKD from the cement plants. The fine dust disposal turns out to be a threat to environment.To find solution, researches are being done in world different parts to find the economical and the most efficient way to use cement kiln dust (CKD) as various forms of applications for example cement production, waste product stabilization and agriculture etc. By Keeping in mind about the use of this bulk in INDIA, it was thought to test these waste materials and develop the specifications to increase the use of the industrial wastes for the construction of embankment. The purpose of using cement kiln dust and red mud is to increase the strength of the highway and to improve its texture and reuse of industrial waste. Cement kiln dust is collected from Jai Industries Jammu &Kashmir(SICOP).

CHAPTER – 4: OBJECTIVE

The objective of the present study is to use two different industrial waste products i.e. Red Mud and cement kiln dust with Cohesion less soil and study the various Geotechnical engineering properties.

The proposed objectives are:

1) To obtain the permeability of cohesion less soil mixed with cement kiln dust and red mud by Constant Head Test.
2) To obtain the maximum dry density of various mix proportion of cohesion less soil mixed with cement kiln dust and red mud.
3) To obtain the California bearing ratio capacity for different mix composition.
4) To obtain the shear strength parameter of the mix using Direct shear test.
5) To examine the internal structure and composition of mix using SEM and EDX test.

CHAPTER -5: EXPERIMENTAL AND METHODOLOGY

5.1 GRAIN SIEVE ANALYSIS

A sieve analysis is a practice or procedure used to assess the particle size distribution of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass.

The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

5.2 CONSTANT HEAD PERMEABILITY TEST

This test deals with the flow of water through a cylendrical column of soil sample under the conditions of constant pressure difference. This test is done in the permeameter or permeability cell whose size vary and is dependent on the grain size which is of the tested material. Soil sample acquires form of cylindrical with the diameter very large so that it can be representated as the tested material of soil. According to the thumb rule , the ratio of diameter of cell to the diameter of the largest grain should be greater than twelve.The common size of cell which is used for the usual sand is 75mm in dia and 260 mm of height which is between the plates of perforated. An adjustable constant reservoir of head is equipped to the testing apparatus and an outlet of reservoir is there to balance the constant head during operation of test .De-aired water is the water which is being used for the test at the constant temperature. A loading piston is equipped to the permeability cell which is used to give the constant axial stress provided to cell during test. Saturation is done to the soil sample before flow measurements are to be recorded. For given intervals of time, the amount of water which flows through the sample of soil is recorded during test.

5.3 LIGHT COMPACTION TEST

Fig. 3. Performing Standard Proctor Test in Laboratory

Proctor compaction test is an experiment used to determine the optimal moisture content at which the soil type used becomes the most dense and gain its maximum dry density. This proctor test is named in the honor of Ralph R. Proctor, in 1993 who showed that dry density of soil depends on the amount of water the soil contains at the period of soil compaction. His test was originally named as the standard proctor compaction test; which was afterwards updated to install the modified proctor compaction.

5.4 CALIFORNIA BEARING RATIO TEST

- Califorina bearing ratio tests were carried out to find CBR value of all specimens.

- CBR (%) =(load at 2.5mm or 5mm penetration/standard load for aggregate)*100

- The following graphs are plotted to show the load penetration curves in CBR test for various %'s of cohesionless soil mixed with red mud mixed with cement kiln dust.

5.5 DIRECT SHEAR TEST

It is a test which is used by the geotechnical engineers to find the shear strength of soil. This test is performed on around 3 or 4 specimens from relatively undisturbed sample of soil. Specimen is to be placed into the shear box which has 2 stacked rings which holds the sample; thus contact between the two rings is at approx. to the mid height of sample. Vertical to specimen, a confining stress is to be applied, until sample fails upper ring is pulled laterally, or through specified strain. The strain induced is recorded for the load applied at the frequent intervals to determine the curve of stress and strain. At varying stresses different specimens are tested to determine the shear strength parameters, the cohesion of soil and the angle of internal friction called the friction angle. when the tets are performed on different specimens the results are plotted on the graph with peak stress on to the y axis and confining stresses on the x axis. Cohesion is the y intercept of the curve which fits to the result of test, and angle of friction is the slope of the curve

5.6 SCANNING ELECTRON MICROSCOPE TEST

SEM is a test which is used to analyse the surface of particles, fibers and materials to obtain the fine details of the sample and can be assessed through image analysis. Scanning electron microscope provides a path to the industry to solve many problems of contamination, identifies the unknown particulates, to investigate component failure and it studies interaction among the substances and their substrates.It can provide the information which can be used to benefit the research process of materials, biological samples and chemicals.

There is no direct and clear processes of determining the images of scanning electron microscope. For tasks such as including interpretation of the surface pitting on components of the metal the identification of the particulates and to determine the physical and chemical characterstics of the material scanning electron microscope turns out to be an appropriate technique if correct sample preparation techniques have been used and analysis is to be done by the microscopists which are experienced.

By using scanning electron microscope test for the minerals, materials, surfaces, films, food, dust, plastics, catalysts, contaminants, biological tissues, and other unknown substances the experts brings images of high resolution, observations are made which are pertinent and the measurements. Internal structures of the samples can also be examined through various cross section techniques by using SEM. If the sample preparation and sample analysis are done accurately then the results produced are valuable.

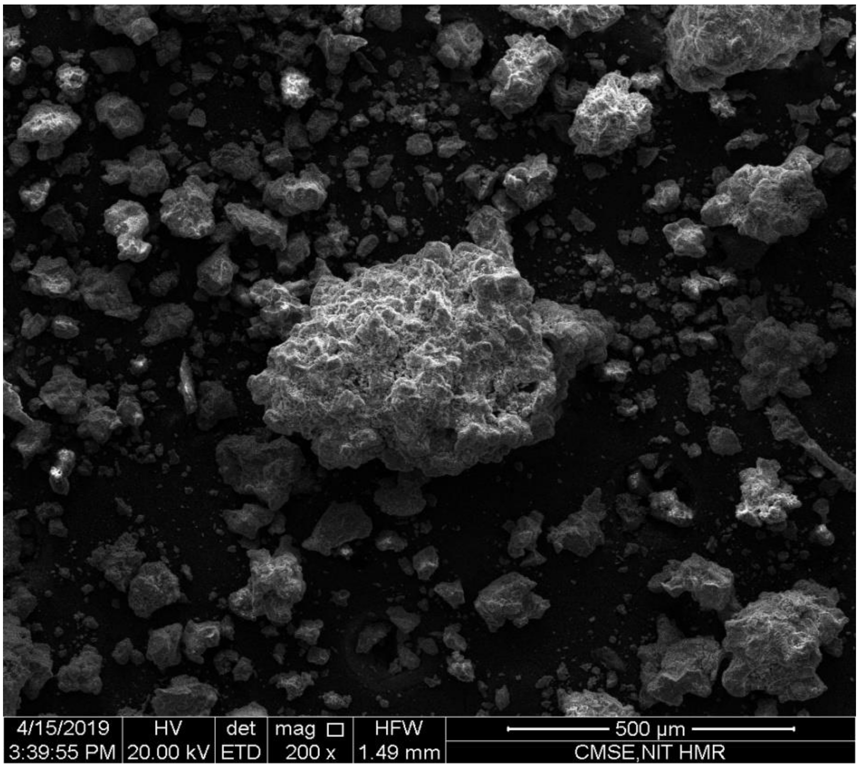

Fig 4. SEM for Red mud

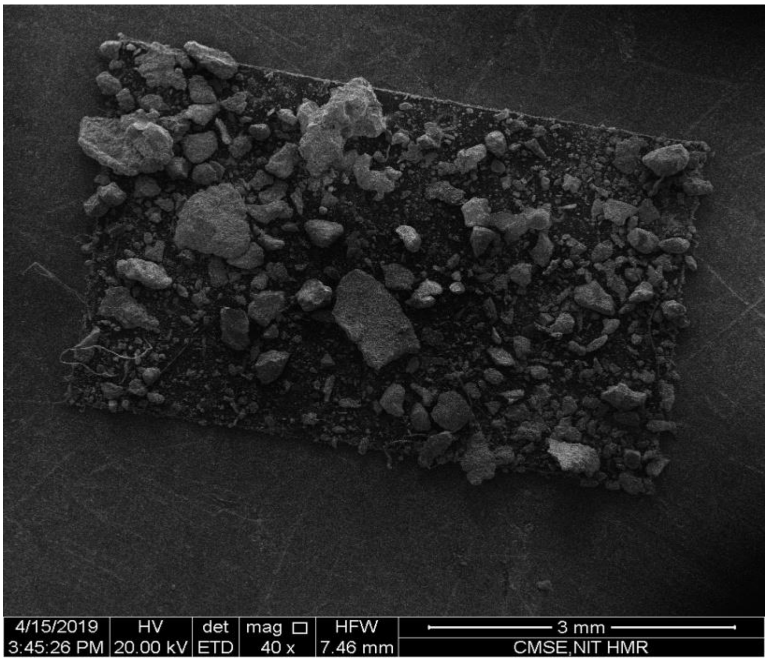

Fig 5. SEM for Cement kiln dust

5.7 EDX TEST

EDX which stands for the energy dispersive x-ray analysis is a x-ray technique which is used to determine the material elemental composition. It consists of applications such as troubleshooting, product research, deformulation etc.

EDX systems basically are attachments which are provided to Electron Microscopy instruments (Scanning Electron Microscopy or Transmission Electron Microscopy) instrument where imaging capability of microscope identify specimen of the interest. EDX analysis generates data which corresponds to elements showing the true composition of sample which is analysed . Possibilities of elemental mapping of sample and analysis of image also occur.

EDX is very powerful in multi technique approach, especially in industrial forensic investigations and contamination analysis . Technique used can be quantitative, semi-quantitative, qualitative and through mapping spatial distribution of elements is also provided.

The technique used in this is non destructive and examination of specimen of interest in situ with no sample or little sample preparation..

Where EDX and combined microscopy are unable to determine a specimen, other techniques are also available, such as raman microscopy, typically infrared microscopy , surface analysis, nuclear magnetic resonance spectroscopy or time of flight secondary ion mass spectrometry etc.

6.1 GRAIN SIEVE ANALYSIS

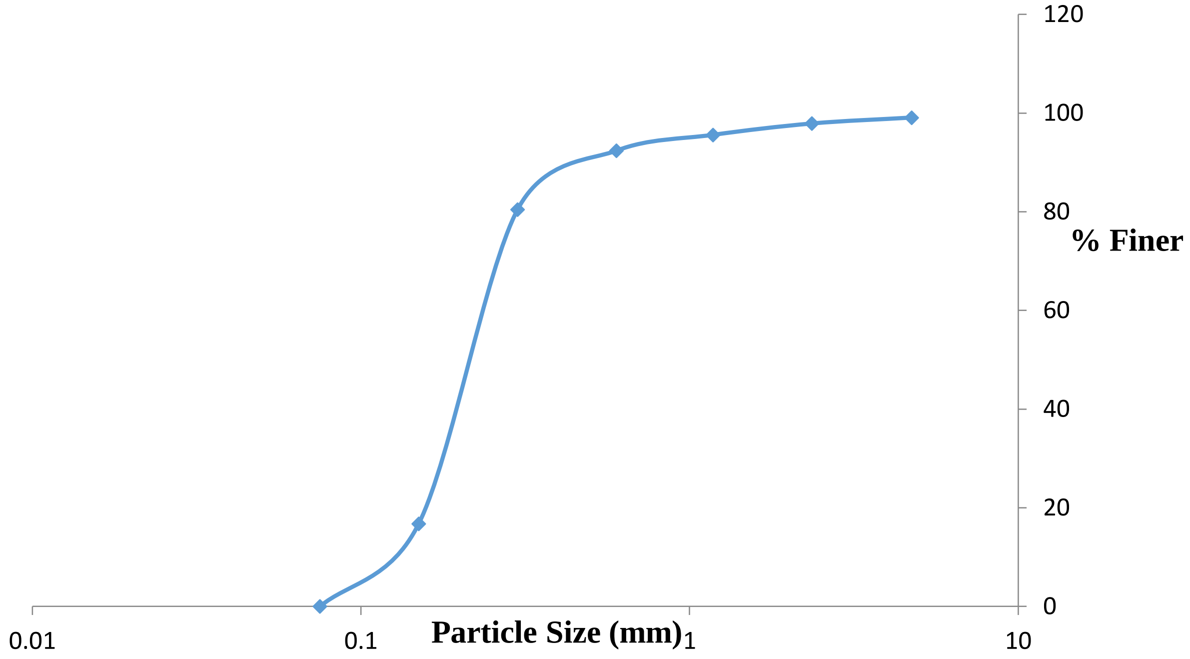

Fig6. Grain Size Analysis of cohesion less soil

From Fig 6, It is clear that the soil is poorly graded soil.During the construction of road in desert area or over the such soil it becomes important to stabalise the cohessionless soil. In this study using Cement kiln Dust and Red Mud to increase the strength of cohessionless soil to check the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) various test were performed. Also to check the shear strength parameter of the best mix test were performed by using Direct Shear Test (DST).

6.2 CONSTANT HEAD PERMEABILITY TEST

Table 2 Permeability of Cohesionless soil mixed with red mud

Cohesionless soil %: Red Mud%(CL%:RM%)	**Permeability K (cm/s)**
100:0	0.014
90:10	0.0096
80:20	0.0088
70:30	0.0029
60:40	0.0043

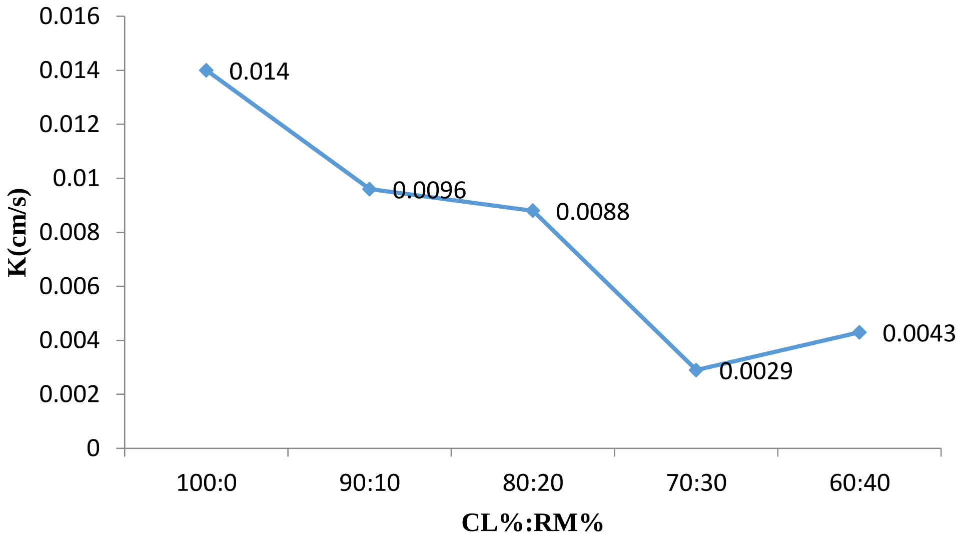

Fig.7 Permeability of Cohesionless soil mixed with red mud

Table 3: Permeability of Cohesionless soil mixed with red mud and cement kiln dust

CL%:RM%:CKD%	K (cm/s)
70:30:05	0.004
70:30:10	0.003811
70:30:15	0.003211
70:30:20	0.003011
70:30:25	0.0029
70:30:30	0.00271

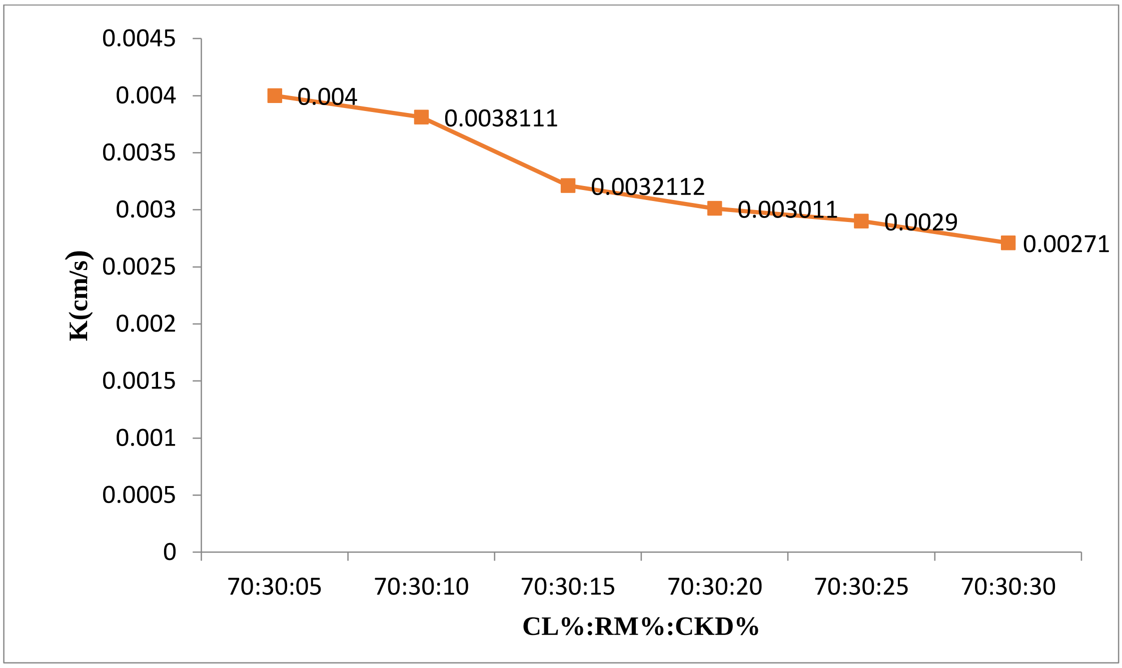

Fig8. Permeability of Cohesionless soil mixed with red mud and cement kiln dust

From Fig.7 and Fig.8 it is clear that with the addition of Red Mud and Cement Kiln Dust into the cohesionless soil decrease the permeability of the mix.

6.3 LIGHT COMPACTION TEST

Compaction curve for different mix

1. 70% CL :30%RM :05% CKD

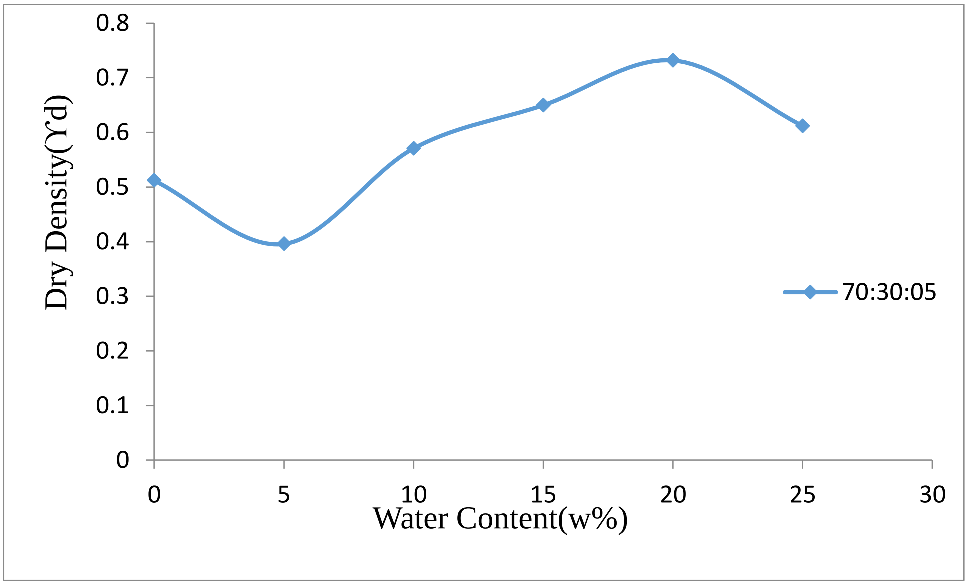

Fig. 9 MDD and OMC curve of **70% CL :30%RM :05% CKD**

From Fig.9 it is clear that, the maximum dry density and optimum moisture content for 70% CL: 30%RM: 05% CKD is 0.732g/cc and 20% respectively.

2. 70% CL :30%RM :10% CKD

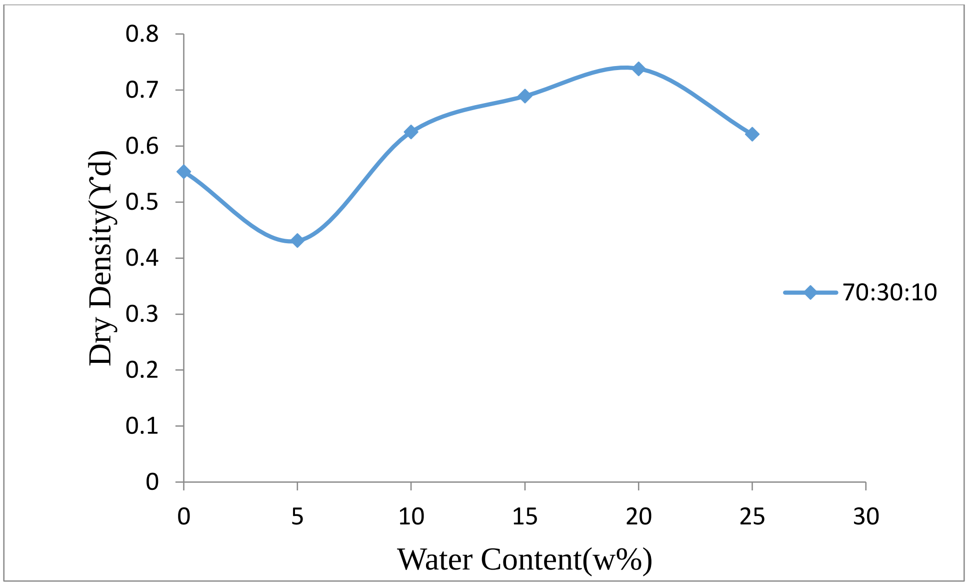

Fig. 10 MDD and OMC curve of 70**% CL: 30%RM: 10% CKD**

From Fig.10 it is clear that, the maximum dry density and optimum moisture content for 70% CL: 30%RM: 10% CKD is 0.738 g/cc and 20% respectively.

3. 70% CL :30%RM :15% CKD

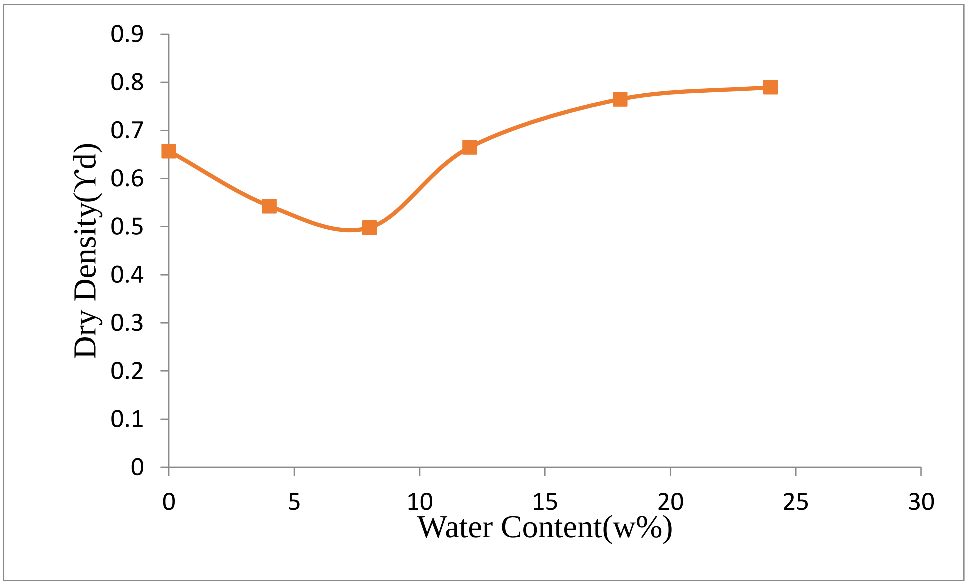

Fig. 11 MDD and OMC curve of 70**% CL: 30%RM: 15% CKD**

From Fig.11 it is clear that, the maximum dry density and optimum moisture content for 70% CL: 30%RM: 15% CKD is 0.79 g/cc and 19 % respectively.

4. 70% CL :30%RM :20% CKD

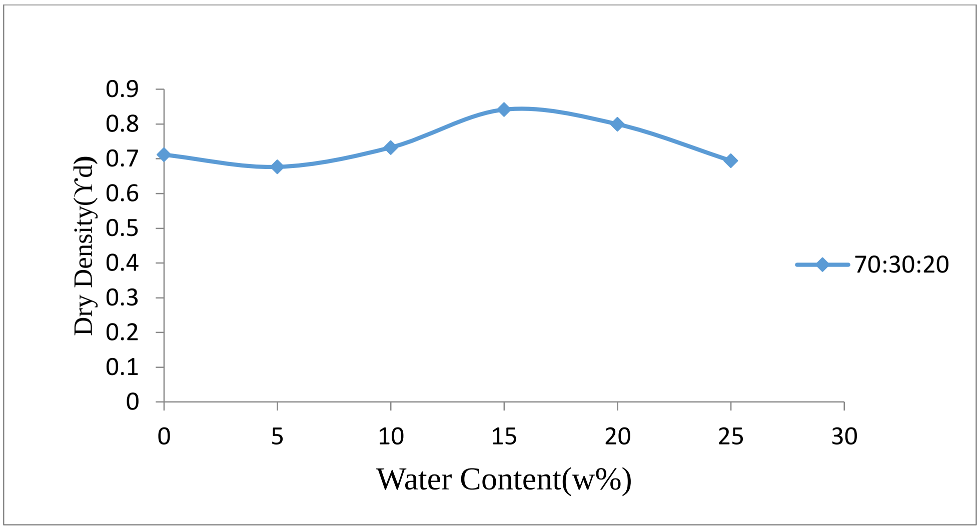

Fig. 12 MDD and OMC curve of 70**% CL: 30%RM: 20% CKD**

The maximum dry density and optimum moisture content for 70% CL: 30%RM: 15% CKD is 0.832 g/cc and 15% respectively.

5. 70% CL :30%RM :25% CKD

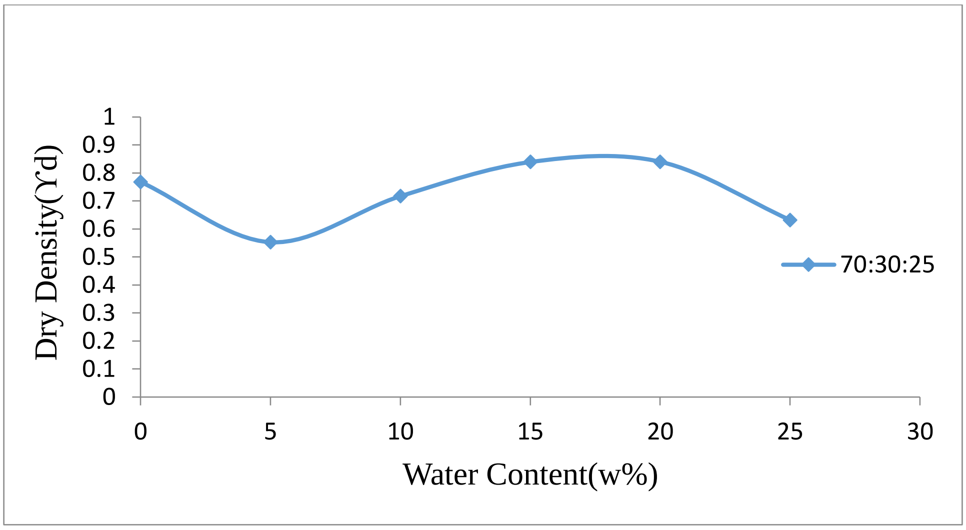

Fig. 13 MDD and OMC curve of 70**% CL: 30%RM: 25% CKD**

The maximum dry density and optimum moisture content for 70% CL: 30%RM: 15% CKD is 0.84 g/cc and 20 % respectively.

6. 70% CL :30%RM :30% CKD

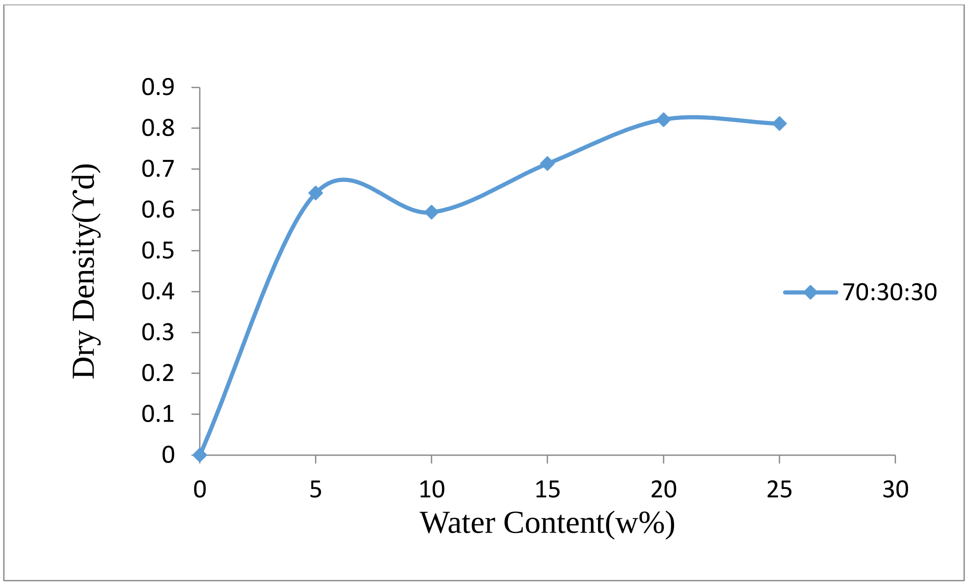

Fig. 14 MDD and OMC curve of 70**% CL: 30%RM: 30% CKD**

The maximum dry density and optimum moisture content for 70% CL: 30%RM: 15% CKD is 0.821 g/cc and 20 % respectively.

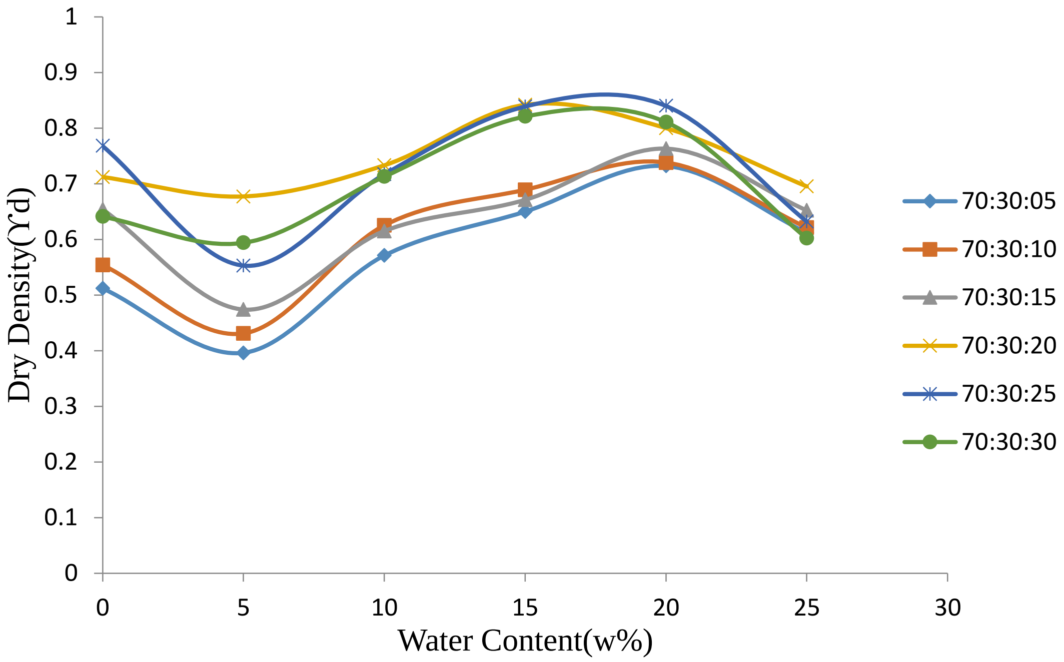

Fig. 15 MDD and OMC curve of different mix

The MDD (Maximum dry density) and OMC (optimum moisture content) value for best mix (70%CL: 30RM%: 25% CKD) is 0.842 g/cc and 20% respectively. From the Fig15, it can be seen that the mix of 70% cohesionless soil,30% Red Mud and 25% Cement Kiln Dust gives the maximum dry density, at 20% of Optimum Moisture Content. It is found that the curve first decrease to some extent after that the value of density starts increasing,this is because of bulking nature sand.

6.4 CALIFORNIA BEARING RATIO TEST

TYPES OF MIX

(cohesionless soil:Red Mud:Cement kiln Dust)

- 70:30:0
- 70:30:5
- 70:30:10
- 70:30:15
- 70:30:20
- 70:30:25
- 70:30:30

6.4.1 MIX - 1

70%CL:30%RM:0%CKD

TABLE-4 CBR test of 70%cl:30%rm

Penetration(mm)	Divisions
0	0
0.5	100
1	190
1.5	230
2	290
2.5	340
3	398
4	440
5	490

CBR VALUE AT 2.5MM=24.8%

CBR VALUE AT 5MM=23.84%

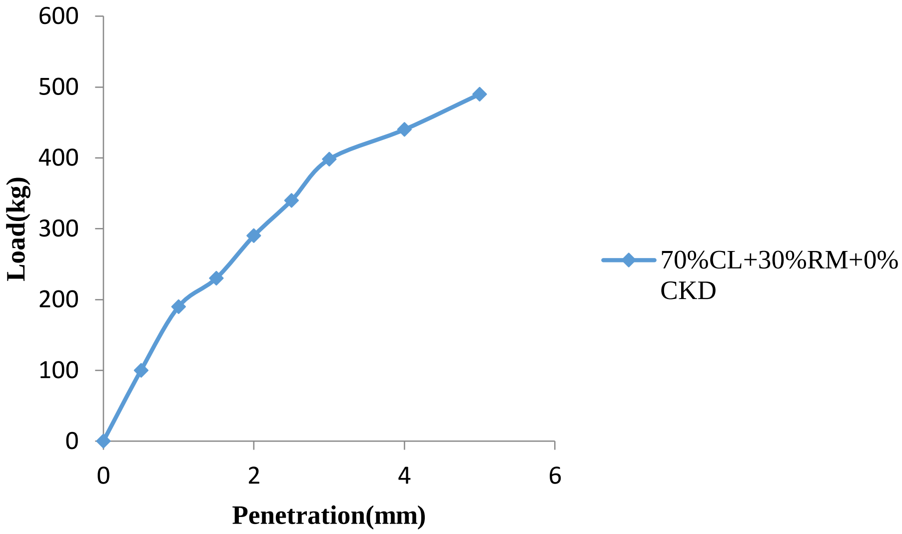

Fig. 16 Load vs. penetration curve of 70%CL:30%RM:0%CKD

6.4.2 MIX - 2

70%CL:30%RM:5%CKD

TABLE 5 CBR test of 70%cl:30%rm:5%CKD

Penetration(mm)	Division
0	0
0.5	209
1	270
1.5	300
2	390
2.5	498
3	540
4	670
5	710

CBR VALUE AT 2.5MM=36.35%

CBR VALUE AT 5MM=34.5%

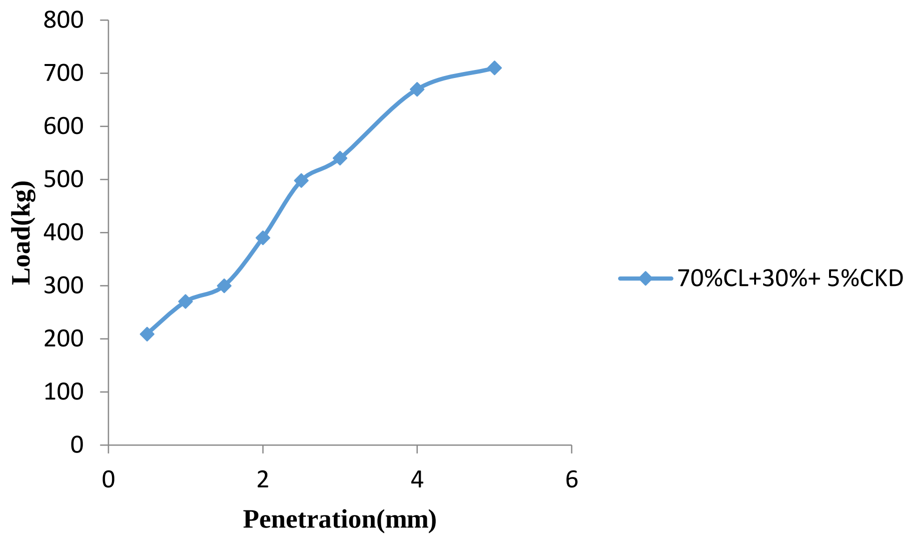

Fig 17. Load vs. penetration curve of 70%CL:30%RM:5%CKD

6.4.3 MIX - 3

70%CL:30%RM:10%CKD

TABLE-6 CBR test of 70%cl:30%rm:10%CKD

Penetration(mm)	Division
0	0
0.5	230
1	289
1.5	367
2	456
2.5	546
3	678
4	786
5	987

CBR VALUE AT 2.5MM=39.85%

CBR VALUE AT 5MM=48.02%

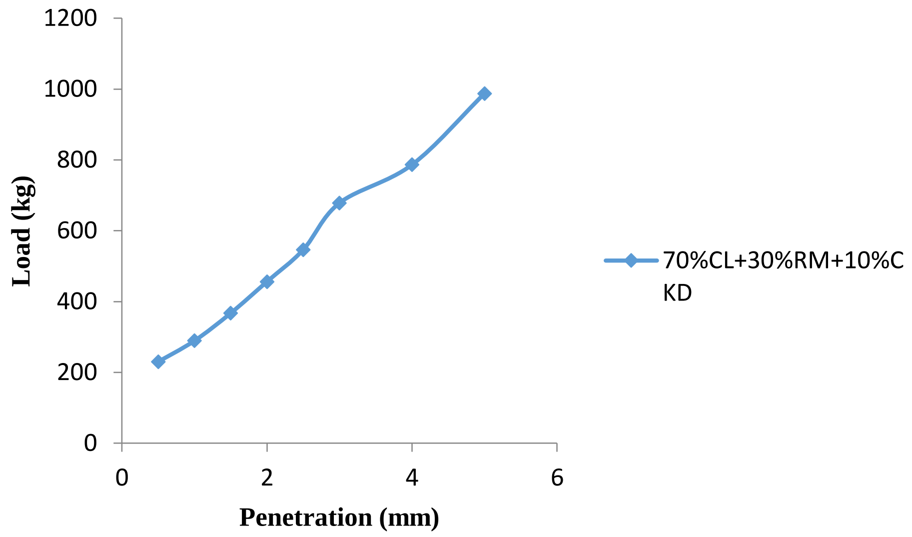

Fig.18 Load vs. penetration curve of 70%CL:30%RM:10%CKD

6.4.4 MIX - 4

.70%CL:30%RM:15%CKD

TABLE-7 CBR test of 70%cl:30%rm:15%CKD

Penetration(mm)	Division
0	0
0.5	333
1	434
1.5	567
2	678
2.5	890
3	990
4	1123
5	1679

CBR VALUE AT 2.5MM=64.96%

CBR VALUE AT 5MM=81.70%

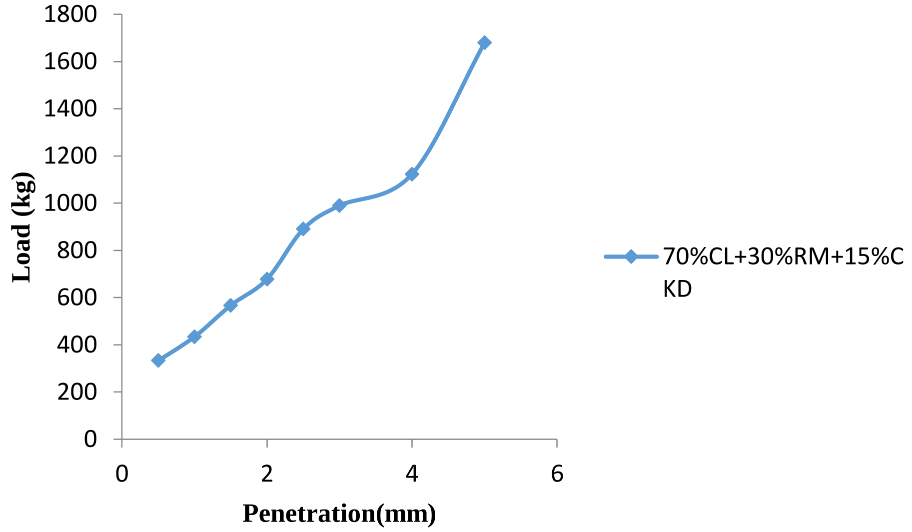

Fig.19 Load vs. penetration curve of 70%CL:30%RM:15%CKD

6.4.5 MIX - 5

70%CL:30%RM:20%CKD

TABLE-8 CBR test of 70%cl:30%rm:20%CKD

Penetration(mm)	Division
0	0
0.5	387.11
1	812.931
1.5	1161.33
2	1664.573
2.5	2206.53
4	3600.123
5	3967.88

CBR VALUE AT 2.5MM=161.0%

CBR VALUE AT 5MM=193.08%

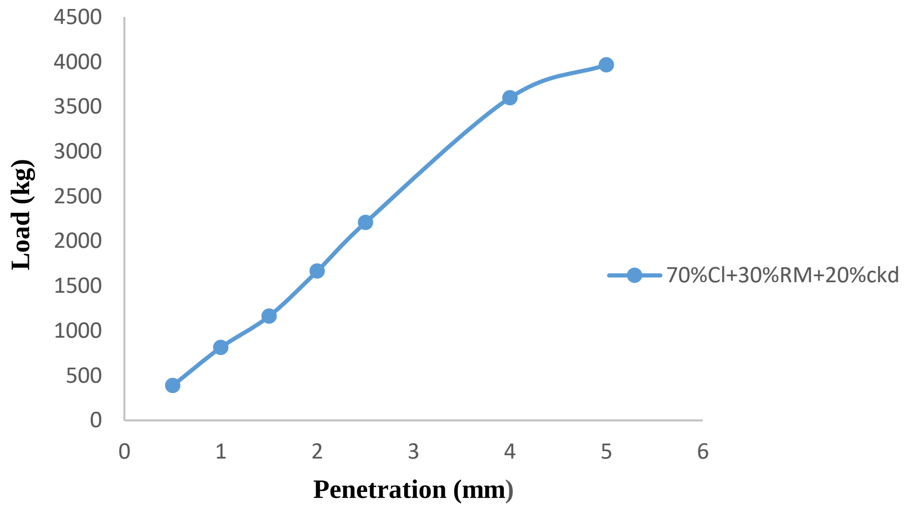

Fig. 20 Load vs. penetration curve of 70%CL:30%RM:20%CKD

6.4.6 MIX-6

70%CL:30%RM:25%CKD

TABLE-9 CBR test of 70%cl:30%rm:25%CKD

Penetration(mm)	Division
0	0
0.5	522.5985
1	994.8727
1.5	1509.729
2	2032.328
2.5	2678.801
3	3298.177
4	4393.699
5	4517.574

CBR VALUE AT 2.5MM=195.53%

CBR VALUE AT 5MM=219.83%

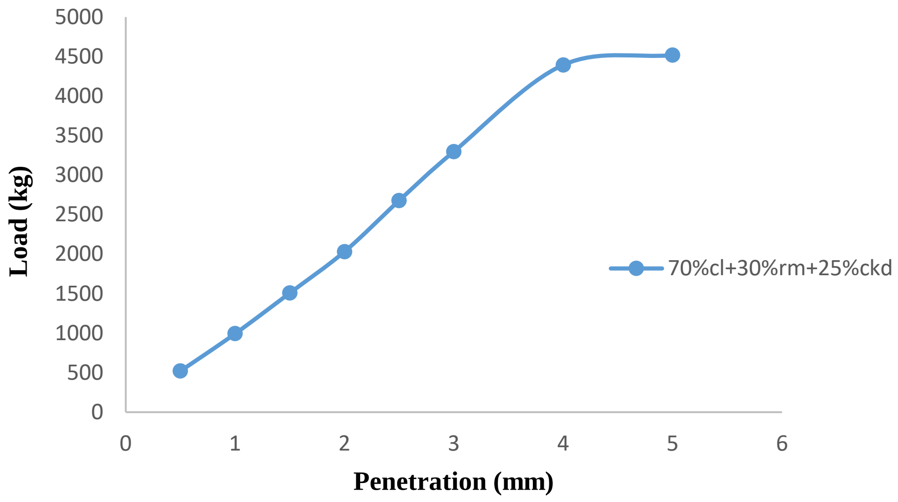

Fig. 21 Load vs. penetration curve of 70%CL:30%RM:25%CKD

6.4.7 MIX - 7

70%CL:30%RM:30%CKD

TABLE-10 CBR test of 70%cl:30%rm:30%CKD

Penetration(mm)	Division
0	0
0.5	520
1	990
1.5	1500
2	2020
2.5	2676
3	3298
4	4393
5	4490

CBR VALUE AT 2.5MM=195.32%

CBR VALUE AT 5MM=218.49%

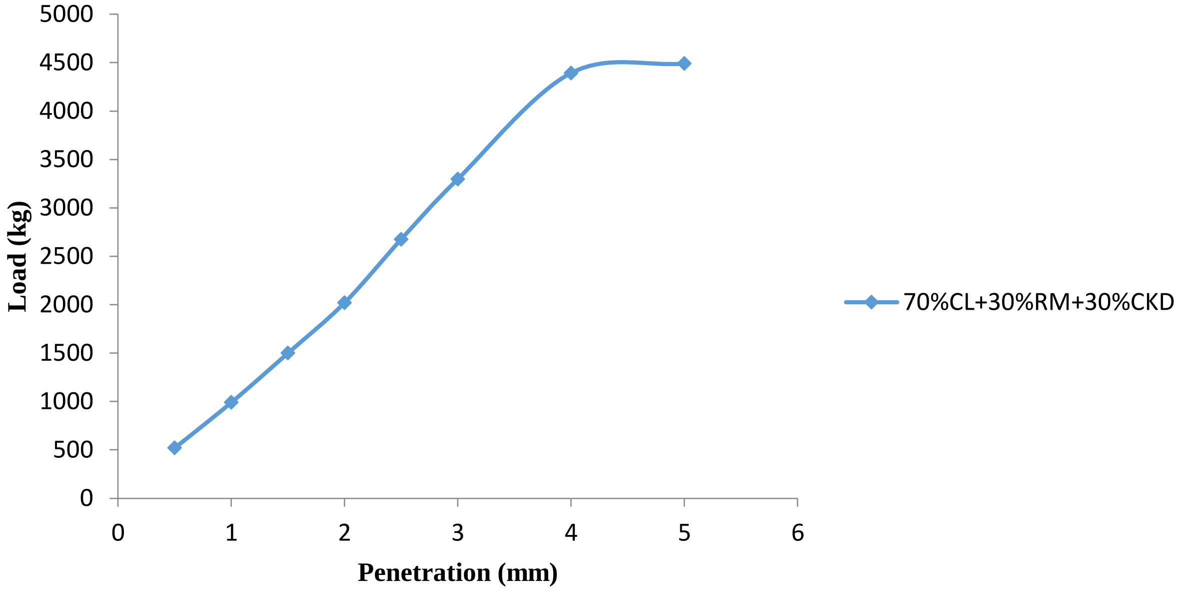

Fig. 22 Load vs. penetration curve of 70%CL:30%RM:30%CKD

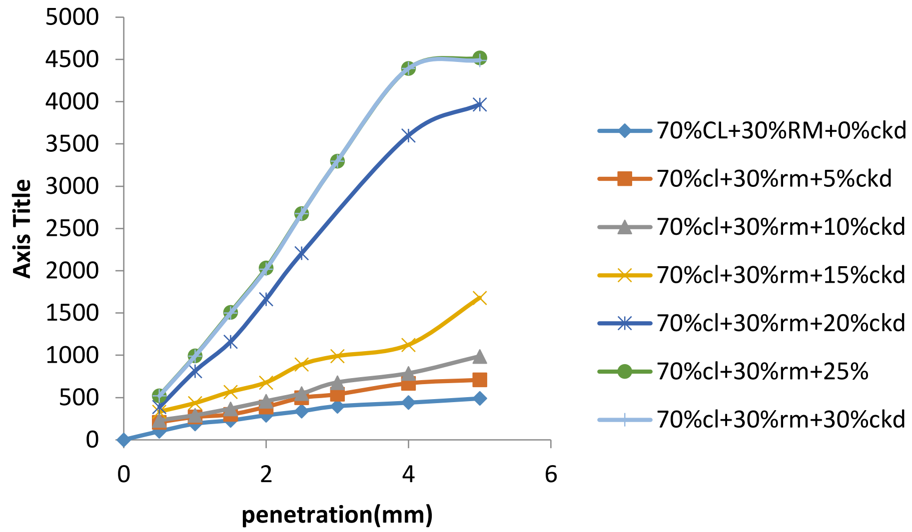

Fig. 23 Load vs. penetration curve of all mixes

The CBR value of the mix 70%cl:30% is 24.8 % and the maximum CBR value is obtained at the mix of 70%cl:30%:rm:25%CKD is 219.8% and 70%cl:30%rm:30%CKD is 218.49% ,hence 70%cl:30%:rm:25%CKD is found to be optimum for construction of subgrade.

6.5 DIRECT SHEAR TEST

6.5.1 MIX -1

Pure cohesionless soil

Box size=6cm*6cm*2.2Cm^2

Area of box=3600cm^2

TABLE-11 DST test of Pure cohesion less soil

Normal stress kN/m^2	Shear stress at Failure kN/m^2	Shear displacement at failure (mm)
50	34	13

100	67	13.5
150	100	13.5

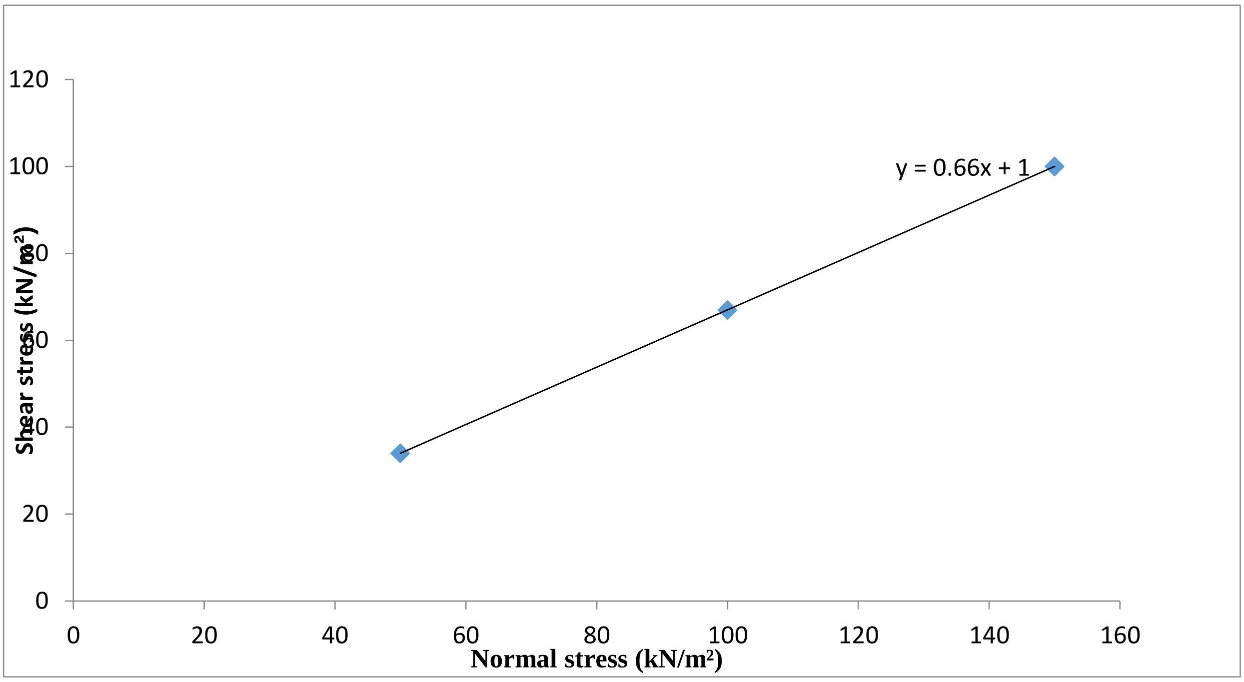

Fig 24. Curve for DST of pure cohesionless soil

6.5.2 MIX 2

70%cohesionless soil +30% redmud

Box size=6cm*6cm*2.2cm

Area of box=3600cm^2

TABLE-12 DST test of 70%cl:30%rm

Normal stress kN/m^2	**Shear stress at failure kN/m^2**	**Shear displacement at failure (mm)**
50	40	13
100	85	13.5
150	118	13.5

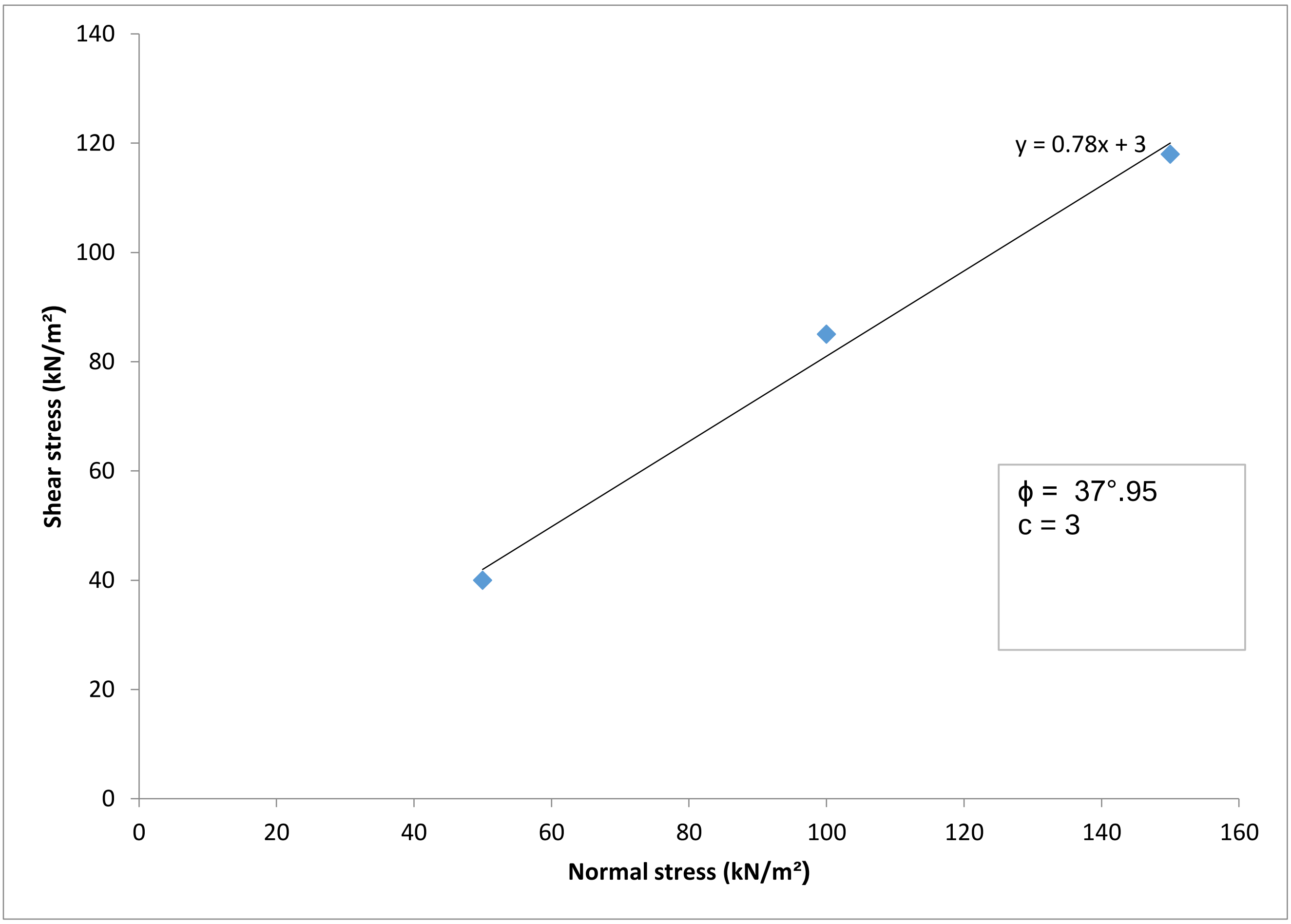

Fig 25. Curve for DST of 70%cl:30%rm

6.5.3 MIX-3

70%cohesionless soil+30%Redmud+25%CKD

Box size=6cm*6cm*2.2cm

Area of box =3600cm^2

TABLE-13 DST test of 70%cl:30%rm:25%CKD

Normal stress kN/m^2	**Shear stress at failure kN/m^2**	**Shear displacement at failure (mm)**
50	55	13
100	80	13.5
150	140	13.5

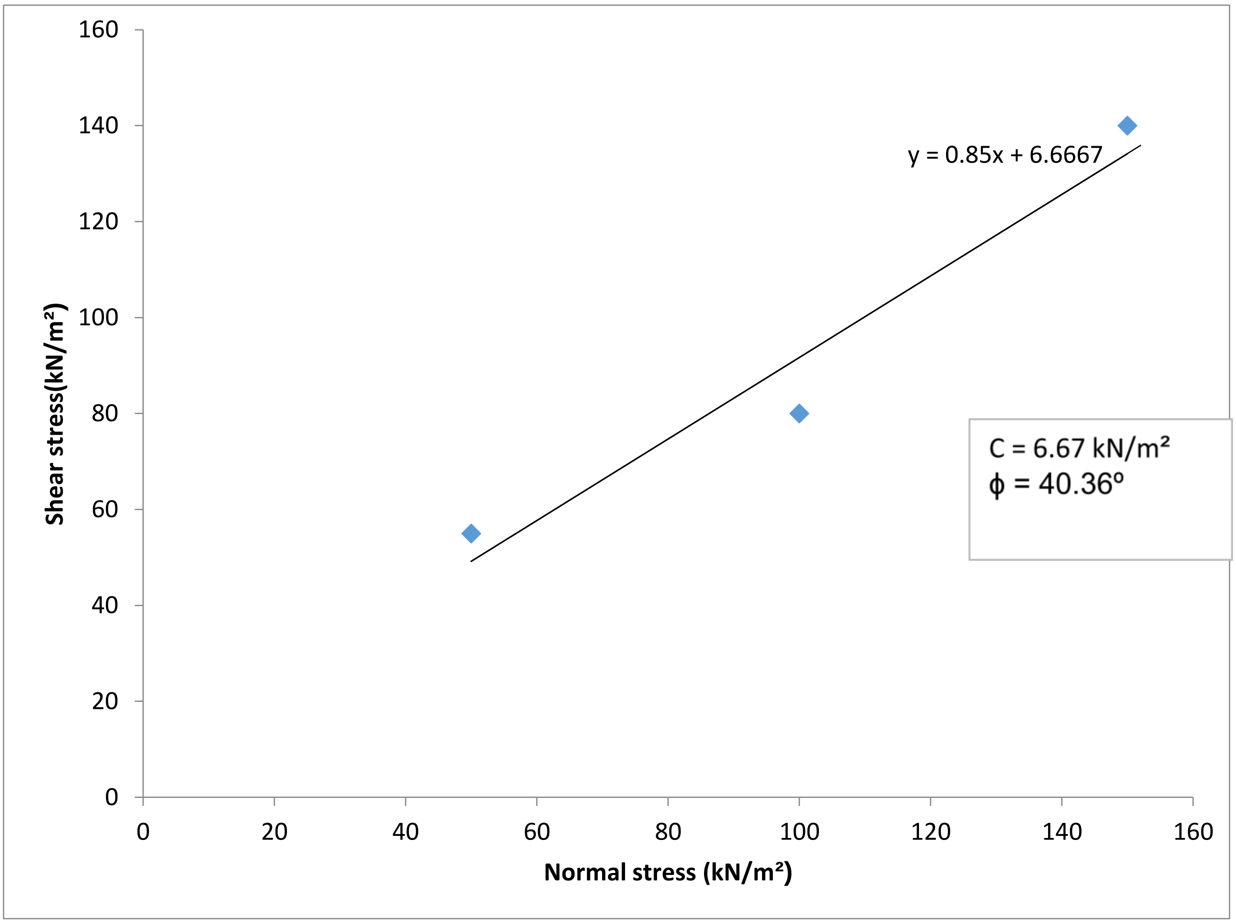

Fig 26. Curve for DST of 70%cl:30%rm:25%CKD

6.5.4 COHESION AND ANGLE OF FRICTION

TABLE-14 Cohesion and angle of friction value

	100%cohesionless soil	**70%cohesionless soil+30%red mud**	**70%cohesionless soil+30%red mud+25% ciment kiln dust**
cohesion	1	3	6.67
Angle of friction	33.42	37.95	40.36

The cohesion (c) and angle of friction(Φ) of the 100%cohesionless soil increases with the addition of red mud and it further increases with the addition of CKD. The maximum value of cohesion and angle of friction is obtained at the mix of 70%cohesionless soil+30%red mud+25% cement kiln dust .Value of c increases from 1 to 6.67 and Φ increases from 33.42 to 40.36.

We know that, $\tau = c + \sigma \tan\Phi$ shows that the shear strength is directly proportional to cohesion and angle of friction which shows that the shear strength increases with c and Φ which is maximum for the mix 70%cohesionless soil+30%red mud+25% ciment kiln dust.

6.6 SCANNING ELECTRON MICROSCOPE TEST

6.6.1 Red mud

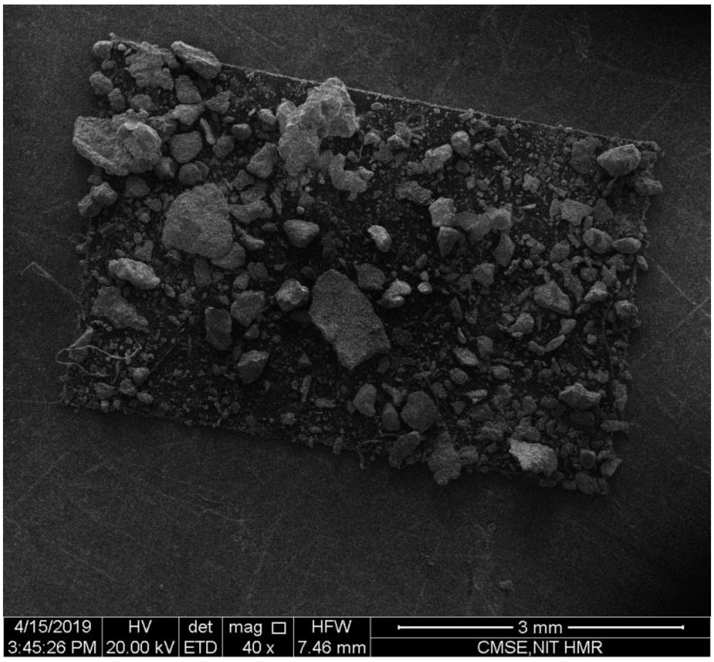

Fig. 27 Red mud at 40x magnification

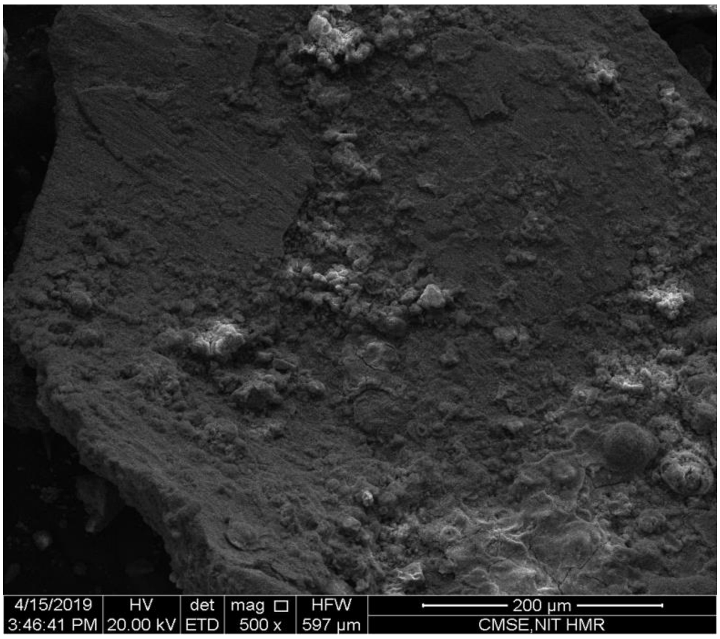

Fig 28 Red mud at 500x magnification

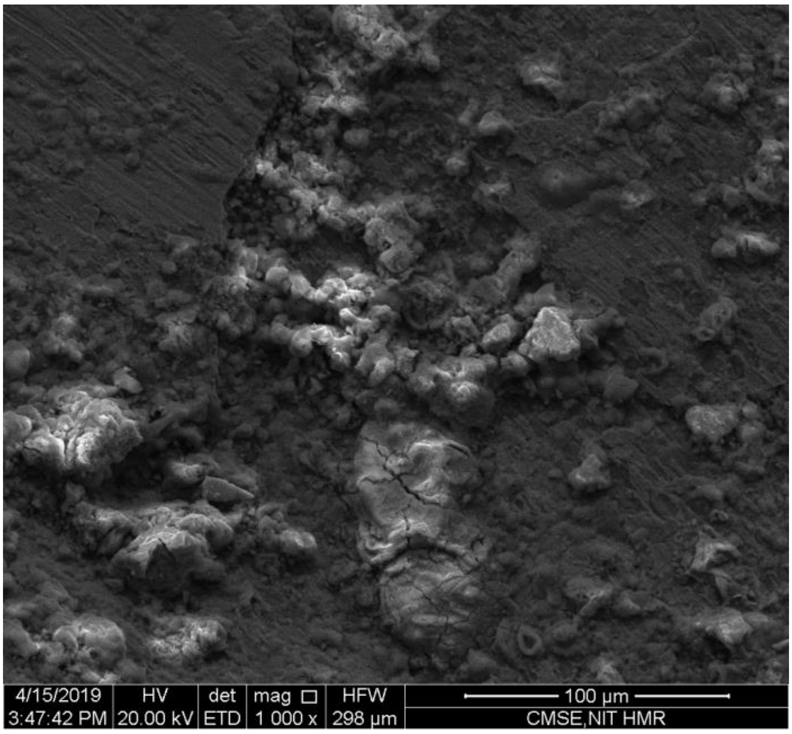

Fig 29 Red mud at 1000x magnification

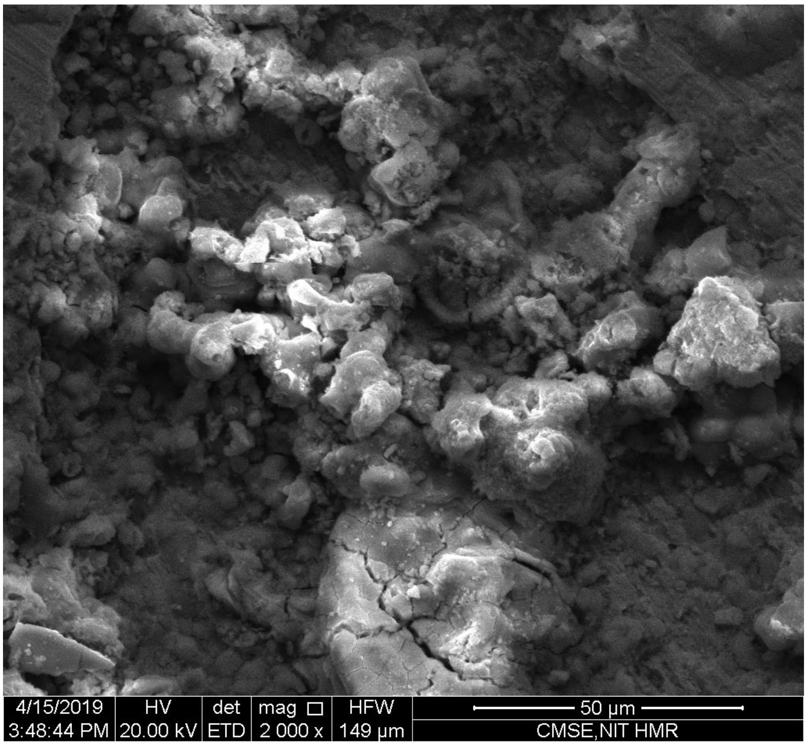

Fig 30 Red mud at 2000x magnification

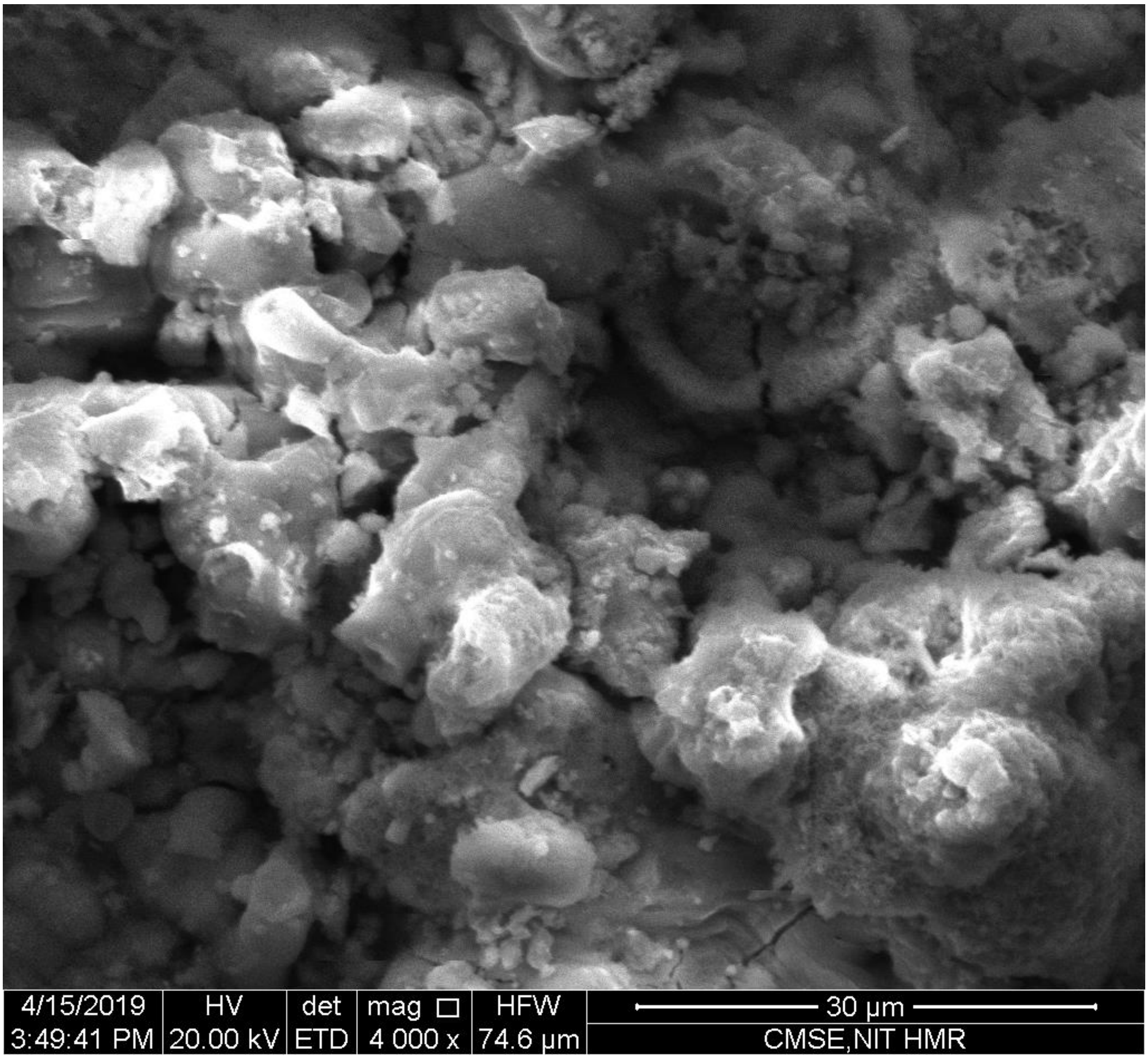

Fig 31 Red mud at 4000x magnification

These figures show that red mud has voids in its structure which are filled by the needle like structure of CKD that helps in formation of strong bond (Kumar, J. Sudheer, Janewoo, U. (2016).

6.6.2 cement kiln dust

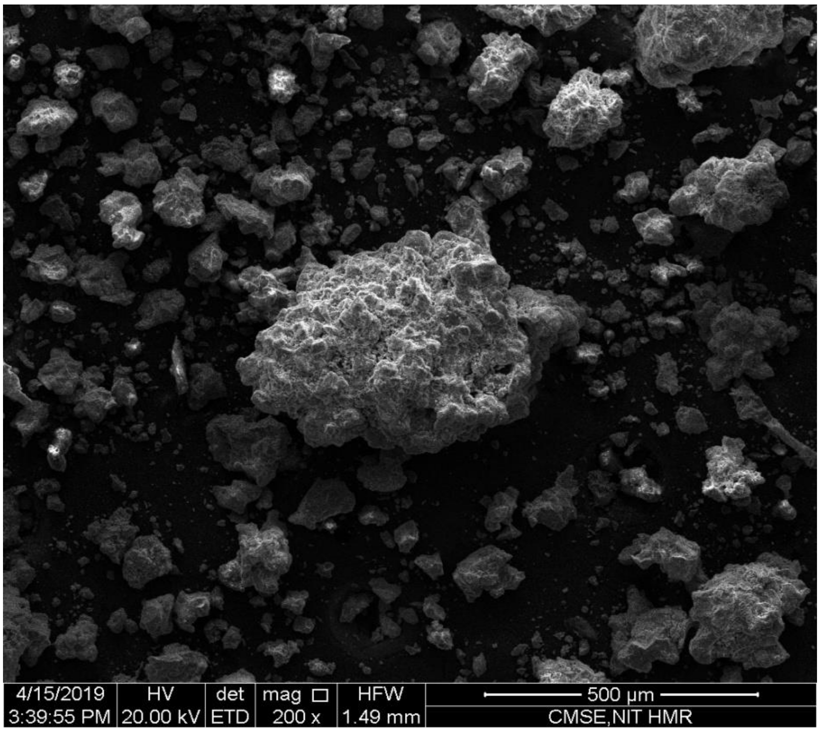

Fig 32 CKD at 200x magnification

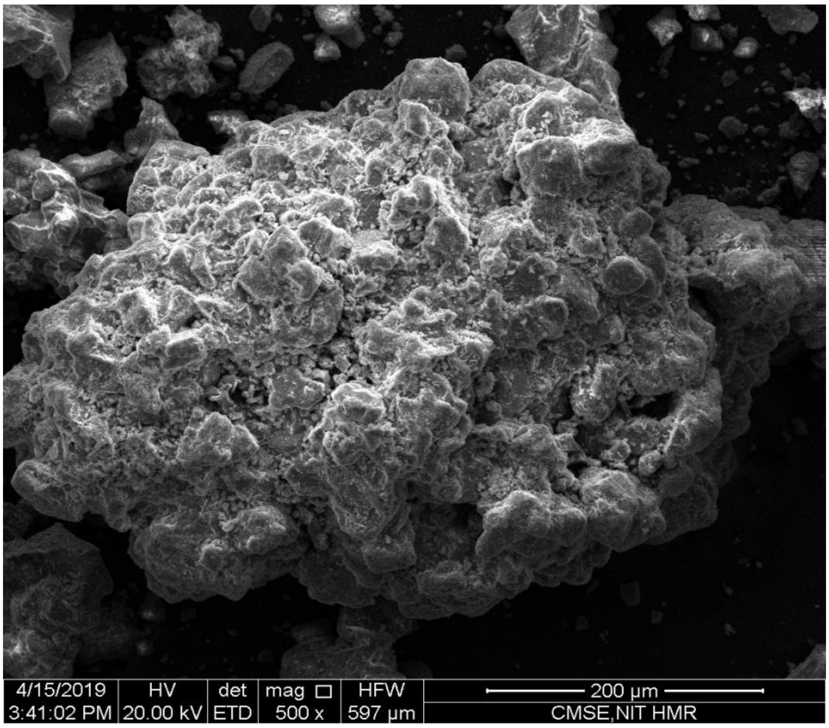

Fig 33. CKD at 500x magnification

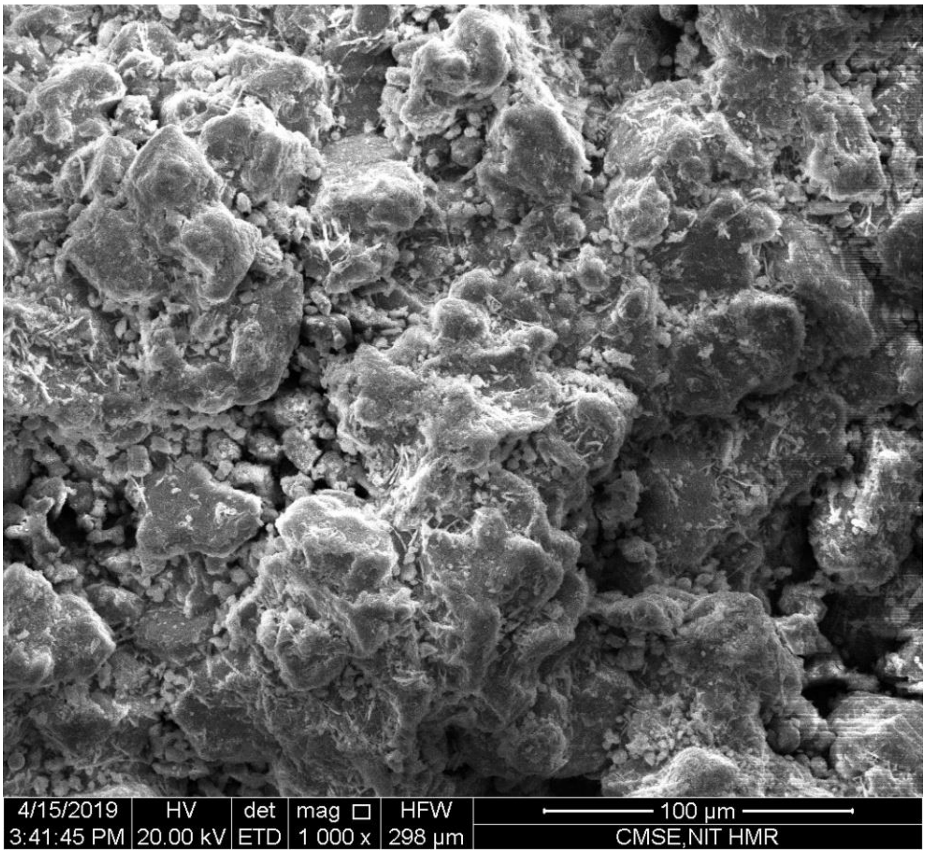

Fig 34. CKD at 1000x magnification

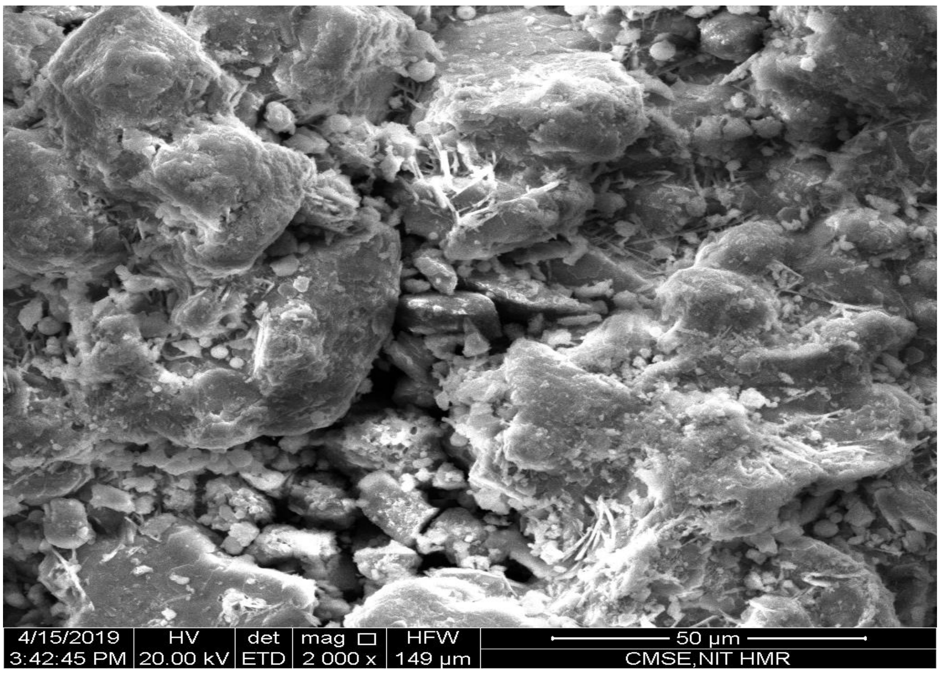

Fig.35 CKD at 2000x magnification

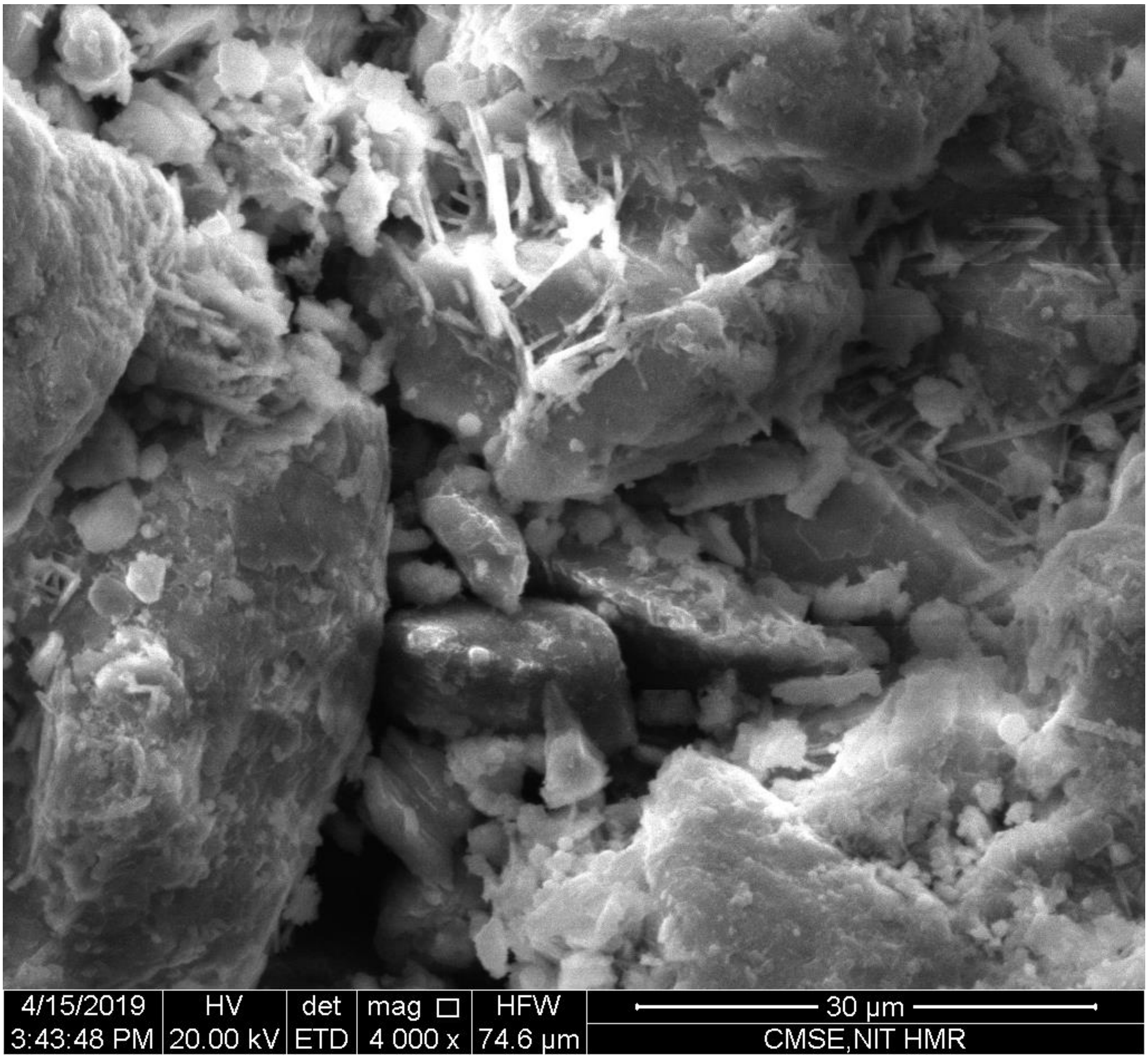

Fig36. CKD at 4000x magnification

These figure shows that CKD has needle like structure which fill the voids of the redmud and form strong bond which withstand the heavy load on it.Structure of CKD is similar to the structure of clay (Kumar, J. Sudheer, Janewoo, U. (2016).which attain cohesion property and helps in bonding.

6.7 EDX TEST

6.7.1 EDX FOR RED MUD

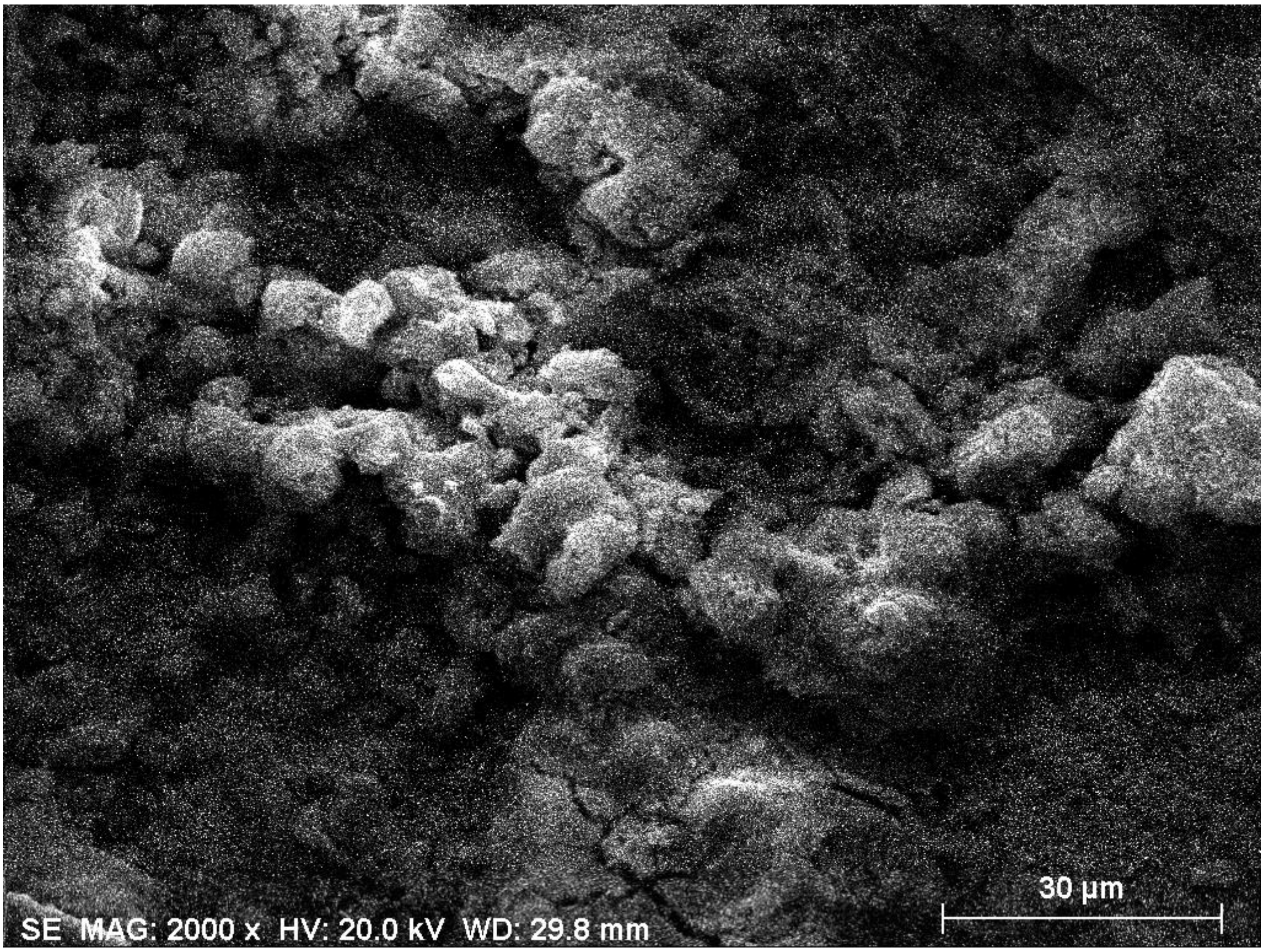

Fig 37.EDX for redmud at 2000x magnification

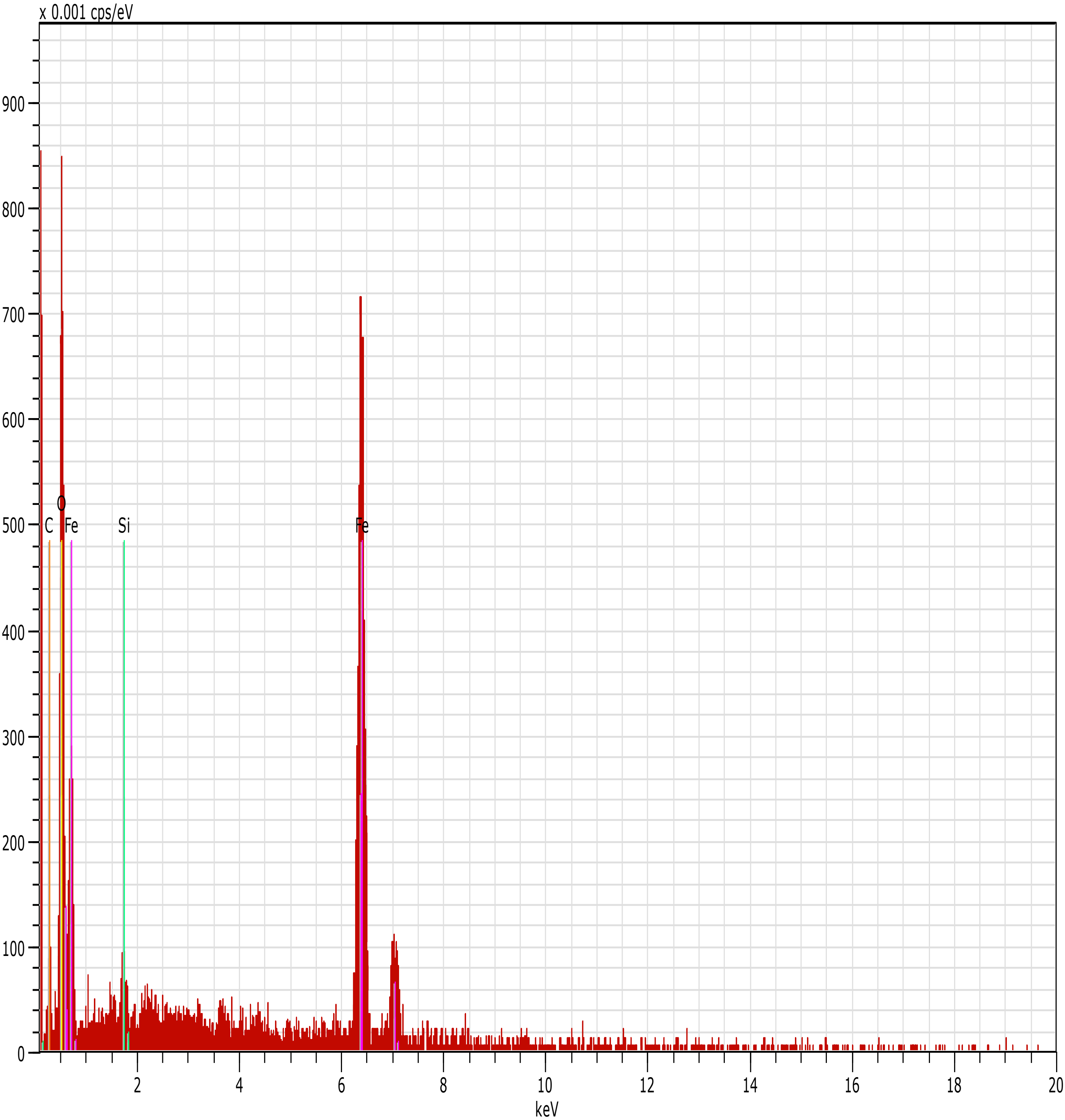

Fig38. EDX element representation of red mud

From the EDX test of redmud depicts that red mud has oxygen,carbon,silica.silica has good bonding property. oxygen bonds with calcium of CKD and becomes har

6.7.2 EDX FOR CKD

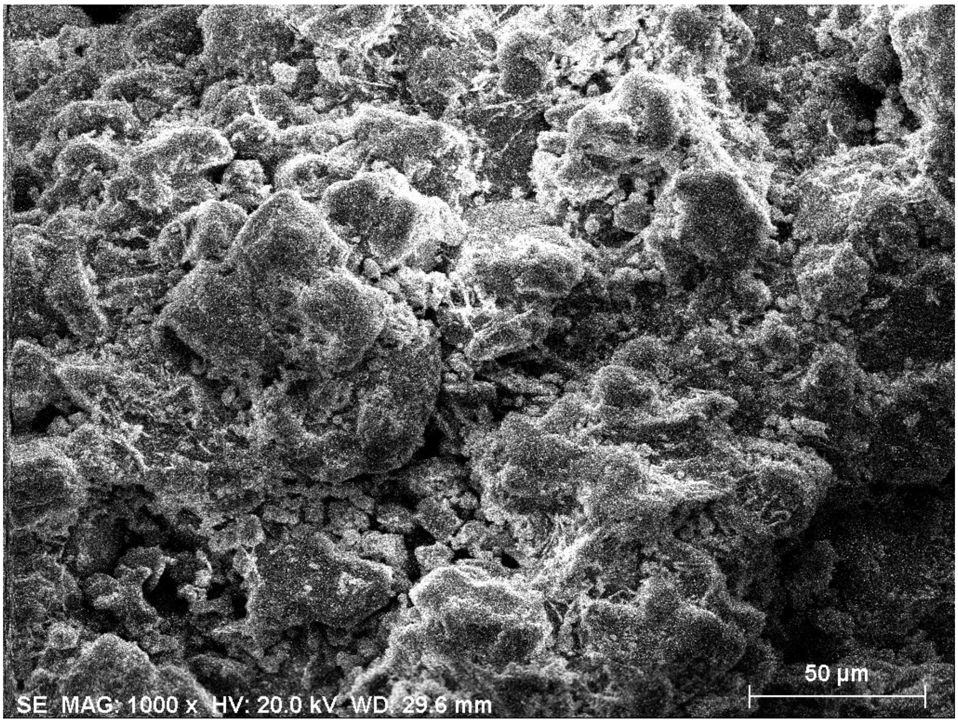

Fig 39. EDX for CKD at 1000x magnification

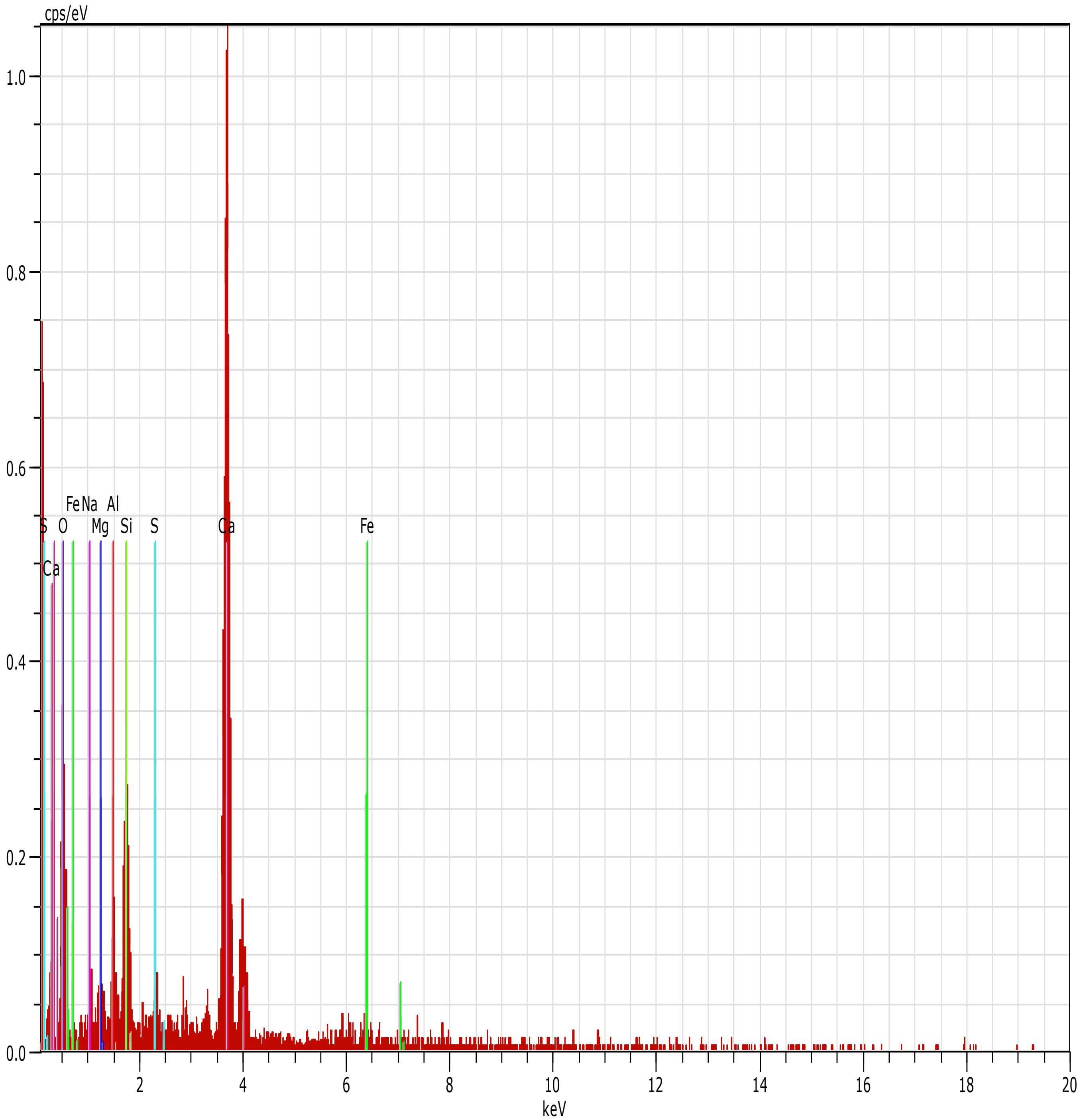

Fig40 .EDX element representation of CKD

This graph depicts that CKD has iron ,calcium ,alumina,silica etc.

Iron,alumina and silica are major component of clay also which helps in providing strength and durability to the mix and calcium is major component of cement having pozzolanic property which increase the binding capacity of mix.

CHAPTER – 7: CONCLUSION

1) With addition of red mud and cement kiln dust into Cohesionless soil decrease the permeability of mix because red mud fill the air voids of Cohesion less soil and cement kiln dust gives pozolonic properties which help in binding the mix.
2) From the various test Maximum dry density (MDD) and Optimum Moisture Content(OMC) curve it is found that 70% of cohessionless soil and 30% of red mud mixed with 25% of cement kiln dust gives Maximum Dry Density that is 0.84g/ccat 20% Optimum Moisture Content.
3) The Dry Density of pure sand found to be 0.65g/cc and for the best mix the maximum dry density value is increased upto 0.84g/cc which is 29% more than the pure sand.

4) The CBR value of the mix 70%cl:30% is 24.8 % and the maximum CBR value is obtained at the mix of 70%cl:30%:rm:25%CKD is 219.8% and 70%cl:30%rm:30%CKD is 218.49% ,hence 70%cl:30%:rm:25%CKD is found to be optimum for construction of subgrade.

5) In direct shear test the cohesion (c) and angle of friction(Φ) of the 100%cohesionless soil increases with the addition of red mud and it further increases with the addition of CKD. The maximum value of cohesion and angle of friction is obtained at the mix of 70% cohesionless soil+30%red mud+25% cement kiln dust.Value of c increases from 1 to 6.67 and Φ increases from 33.42 to 40.36. We know that, $\tau = c + \sigma \tan\Phi$ shows that the shear strength is directly proportional to cohesion and angle of friction which shows that the shear strength increases with c and Φ which is maximum for the mix 70% cohesionless soil+30%red mud+25% cement kiln dust.

6) These figures show that red mud has voids in its structure which are filled by the needle like structure of CKD that helps in formation of strong bond (Kumar, J. Sudheer, Janewoo, U. (2016))

6) These figure shows that CKD has needle like structure which fill the voids of the redmud and form strong bond which withstand the heavy load on it. Structure of CKD is similar to the structure of clay (Kumar, J.Sudheer, Janewoo, U.(2016)) which attain cohesion property and helps in bonding.

7) From the EDX test of redmud depicts that red mud has oxygen, carbon, silica. silica has good bonding property. oxygen bonds with calcium of CKD and becomes hard.

8) This graph depicts that CKD has iron, calcium, alumina, silica etc. Iron, alumina and silica are major component of clay also which helps in providing strength and durability to the mix and calcium is major component of cement having pozzolanic property which increase the binding capacity of mix.

CHAPTER -8: SCOPE OF THE WORK

DESIGN OF HIGHWAY PAVEMENT

The mix of CKD and Red Mud may be used for the design purpose of highway embankment.

CKD and Red mud have high angle of internal friction. The mix form strong bond when compacted at optimum moisture content. This will help the subgrade in forming hard bond, so that it can withstand against heavy rain. The mix provides great bond which makes the highway pavement strong.

SUBGRADE STABILITY

The optimum mix of CKD and Red mud may be used to stabilize sub grade that can impart great strength to the embankment. They will also make the highway embankment durable. The mix used in the embankment ensures a great bond and makes the embankment strong and can be used for long time.

COMPACTION CHARACTERSTICS

The CKD and Red mud optimum mix stabilization will produce a subgrade layer whose strength is increased that will act as solid platform when compaction of subsequent aggregate layers thereby enabling higher densities which is achieved in the aggregate layers.

LOW LAND RECLAMATION

CKD and Redmud are the industrial wastes. Red mud is the industrial waste of the steel industry and CKD is the waste of the cement industry. When the iron is extracted from the ore red mud is produced which is waste for the steel industry and of no use. CKD are the unburnt cement clinckers which are of no use and considered as a waste.

Government require a large amount of land to dump this waste and which requires a large cost and no land reclamation. By using these industrial waste for the construction of highway embankment will reduce the land reclamation.

STRUCTURAL FILL AND REINFORCED EARTHWORK

The optimum mix of Red mud and CKD may be used for the structural fill and reinforced earthwork. The mix provides great strength to the structure with its bonding and structure is filled with strong bond which makes the structure to withstand the heavy loads.CKD will impart strength to the red mud and reinforced the earth and resist the tensile load.

HIGHWAY WITH HIGH SHEAR STRENGTH

The shear strength is directly proportional to cohesion and angle of friction. The optimum mix of red mud and CKD has high cohesion and angle of friction. As a result this optimum mix provides high shear strength to the highway embankment and makes it durable to the constant rubbing.

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