CHARACTERISTICS OF SOIL, SAND, FLY ASH AND CERAMICS MIX FOR USE AS SUBGRADE MATERIAL

MAJOR PROJECT

By

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HAMIRPUR – 177 005

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A MAJOR PROJECT

Submitted in partial fulfillment of the

requirement for the award of the degree

of

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in

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CANDIDATE'S DECLARATION

We hereby certify that the work which is being presented in the project entitled **"CHARACTERISTICS OF SOIL, SAND, FLY ASH AND CERAMICS MIX FOR USE AS SUBGRADE MATERIAL"**, in the partial fulfillment of the requirement for the award of the Degree of Bachelor of Technology and submitted in the Department of Civil Engineering of the National Institute of Technology, Hamirpur, is an authentic record of my own work carried out during a period from January, 2012 to April, 2012 under the supervision of Dr R.K. Sharma, NIT Hamirpur. The matter presented in the project has not been submitted by me for the award of any degree of this or any other Institute/ University.

DIKSHIT (08129) **ABHISHEK SHARMA (08105)**

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This is to certify that the above statement made by the candidates is correct to the best of our knowledge.

Prof. R. K. Sharma

Project Guide

Department of Civil Engineering,

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Preparation of material	10	2	2	2	2	2	10
Finding index properties	20	4	4	4	4	4	20
Compaction properties of MIXTURE A	15	3	3	3	3	3	15
Compaction properties of MIXTURE B	10	2	2	2	2	2	10
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Suggesting the best mix (CBR)	10	3	2	2	3	0	10
Report	10	2	3	3	2	0	10
Total	100	21	21	21	21	16	100

PERCENT CONTRIBUTION

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ABSTRACT

The most concerning problem today with the Thermal power plant is the disposal of Fly ash. The use of Fly ash as landfill causes great environmental pollution like, groundwater contamination, since coal contains trace levels of heavy metals. Similarly, waste ceramic too causes great environmental problem. So, there is a need to utilize these materials by exploiting their inherent properties to solve the environment and disposable problem. This report brings out the results of an experimental programme carried out to evaluate the effectiveness of using Fly ash with randomly distributed discrete waste ceramic for soil stabilization by studying the compaction and strength characteristics for use as subgrade material. The influence of different mix proportions of Clay, Sand, Fly ash and Ceramic on compaction, drainage and CBR values has been studied. The results show that addition of Fly ash increases the OMC and decreases the MDD, but increased the CBR. The designed composite may be used effectively for construction of subgrade, embankment and foundations of low cost roads.

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Chapter 1

INTRODUCTION

1.1 General

Clays exhibit generally undesirable engineering properties. They tend to lose strength on wetting or other physical disturbances. They can be plastic and compressible and they expand when wetted and shrink when dried. Some types expand and shrink greatly upon wetting and drying – a very undesirable feature. Cohesive soils can creep over time under constant load, especially when the shear stress is approaching its shear strength, making them prone to sliding. For these reasons, clays are generally poor materials for foundations. The annual cost of damage done to engineering structures constructed on expansive soils is in billions of dollars worldwide.

Soil stabilization has been widely recommended for developing countries for the construction of various elements of the pavements. The reasons usually put forward are that the use of locally available materials will lead to lower costs. The characteristics of compacted soil, if improved, resulting from residue utilization like fly ash, blast furnace slag, rice husk ash etc mostly brings environmental and economic benefits. However on a comparative scale the use of fly ash has found limited application.

Fly ash is a waste by-product from thermal power plants, which uses coal as fuel. At present about 100 thermal power plants in India produce about 130 million tones of fly ash every year. Concurrent generation of fly ash in bulk qualities is a matter of serious concern not only because of the issue associated with its disposal and utilization, but also because of threat to public health and ecology. In spite of the continuous efforts made and incentives offered by the government, it is not being used fully for gainful purposes like brick making, cement manufacturing, soil stabilization and as fill material. Coal based thermal power plants spatially distributed all over the world and produce fly ash as waste by-product. The huge quantity of fly ash being accumulated is likely to pose problem for its disposal and pollution. Due to the increasing production of fly ash a need has arisen for using this vast amount of produced fly ash for some beneficial purposes in order to meet the demand for its disposal. The construction of the roads not only helps to consume bulk quantities of fly ash solving its disposal problems to certain extent but also satisfies construction requirements. Engineers are facing great challenges containing the degradation of land and atmospheric pollution caused by ever mounting deposits of fly ash at power plants.

A ceramic is an inorganic, nonmetallic solid prepared by the action of heat and subsequent cooling. Ceramic materials may have a crystalline or partly crystalline structure, or may be amorphous (e.g., a glass). Floor tiles, crockery, sanitary wares and many more are the ceramic products. But such materials have been used little for engineering purposes, and the overwhelming majority of them have been placed in storage or disposal sites.

Soil stabilization involving addition of fly ash and ceramics aims to improve the engineering performance of the soil. This is typically used for a soft, clayey sub-grade beneath a road that will experience repeated loading. Fly ash is used as a mineral filler to fill the voids and provide contact points between larger aggregate particles in the asphalt concrete mixes. The hydrophobic nature of fly ash gives pavements better resistance to stripping. Recently fly ash has been used to generate a binder comparable to a hydrated Portland cement but with drastically reduced CO_2 emissions. Other environmental benefits of recycling the fly ash include reducing the demand for virgin materials that would need quarrying and substituting materials that may be energy intensive to produce.

The usage of fly ash along with sand and ceramics has not been studied in detail yet. This study has been undertaken to explore the possibility of using fly ash in combination with sand and ceramics. The engineering properties of the composite material (i.e. soil + fly ash + sand + ceramics) have been studied. The results have been discussed to bring out the possibility of using fly ash in the construction of road.

1.2 Objective

Both Fly ash and ceramic are the waste materials imposing hazardous effect on the environment and human health. These materials cannot be disposed properly and their disposal is not economically viable. But if these are blended with other construction materials like clayey soil and sand then they can be used for various construction purposes like sub-grade, foundations and embankments.

In this project work, an attempt is made to study how fly ash and ceramic may be effectively utilized in combination with the clayey soil and sand to get an improved soil material which may be used in various soil structures. Fly ash used was obtained from ACC

Cement factory, Bilaspur, Himachal Pradesh. Locally available clayey soil and Beas sand has been used in this experimental investigation.

Various geotechnical properties like specific gravity, particle size distribution, liquid limit and plastic limit, compaction characteristics of the materials have been investigated individually as well as for different combinations. The CBR characteristics of different combinations of Clay, Sand and Fly ash have also been determined. The CBR characteristics of the most appropriate combination of the three materials with varying percentage of ceramics has been studied at the optimum moisture content and maximum dry density. Empirical relationships have been developed showing the variation of MDD versus percentage of sand, OMC versus percentage of sand, MDD versus percentage of clay, OMC versus percentage of sand MDD versus percentage of clay and OMC versus percentage of fly ash, CBR. The results show that the most appropriate combination of the material consists of Sand, Clay, Fly ash and Ceramics.

Chapter 2

LITERATURE REVIEW

Fly ash is one of the most plentiful and versatile industrial by-products. It is generated in large quantities as a by-product of burning coal at electric power plants. Fly ash offers economic alternatives for a wide range of soil stabilization applications. Fly ash is commonly used to supplement Portland cement in concrete production, where it can bring both technological and economic benefits, and is increasingly finding use in the synthesis of geo-polymers and zeolites.

There has been steady progress in the utilization from 1990; we have a long way to go to achieve the target of 100% utilization of fly ash. Mathur etal (2003,2005) have used fly ash in embankment with the technique of reinforced earth with a view to use this waste in road work. Thaweesak Jirathanathwom (2003) reported that by using fly ash mixed with small amount of lime, it is possible to improve some of the engineering properties of clayey soil including hydraulic conductivity as well as strength. Basha et al (2005) reported that the Malaysian residual soil stabilized with Rice Husk Ash (RHA) and cement resulted in reduction of maximum dry density and an increase in the value of optimum moisture content. Kumar and Singh (2007) have suggested the use of fly ash reinforced with propylene fibers in low volume rural roads. Shankar et al. (2008) reported that the addition of Pond Ash (PA) resulted in reduction of maximum dry density of blend with slight increase in optimum moisture content. Further addition of ordinary portland cement resulted in improvement of strength characteristics. P. Eskioglou and N. Oikonomou (2008) showed that the addition of ash increased the optimum moisture content in the compaction tests. The increase in optimum moisture content contributes to the increase of the stabilized soil's capacity. Ramakrishna and Pardeep Kumar (2008) concluded that with the addition of Rice Husk Ash (RHA) and lime to black cotton soil, the maximum dry density decreases and optimum moisture content increases. The proper proportions of black cotton soil-RHA-lime mix improve the CBR value. Chauhan et al (2008) observed that optimum moisture content increase sand maximum dry density decreases with increased percentage of fly ash mixed with silty sand. Bhatta N. (2008) concluded that the addition of river sand to pond ash improved the CBR value so that it could be used for construction of sub grade. Dr. D S V Prassad et al (Oct, 2011) studied the behavior of Reinforced fly ash Sub base for flexible pavement and it was seen that with increase in reinforcement CBR was improved. To enhance the utilization of fly ash in road works, demonstration projects on construction of rural roads using fly ash were taken up by Central Road Research Institute (CRRI). Many researchers have carried out the investigation on soil, fly ash and soil fly ash mixtures.

At present, about 10% ash is utilized in ash dyke construction and land-filling and only about 3% of ash is utilized in other construction industries. So far the combination of flyash, river sand and ceramics (used in construction) has not been studied in detail.

In this project, a study will be undertaken on the engineering properties of different proportions of fly ash, sand and ceramics in combination and to bring out the possibility of usage of the above composite in the various construction purposes. The detailed objectives of this study

a) Determination of geotechnical properties of Beas River sand e.g. grain size distribution, compaction characteristics, CBR etc.
b) Determinations of geotechnical properties of fly ash e.g. grain size distribution, compaction characteristics, CBR etc.
c) Determination of optimum moisture content and maximum dry density of various combinations of fly ash and sand with varying percentages of lime.
d) Determination of bearing capacity of various combinations of fly ash and sand with varying percentages of ceramic. The tests have been conducted as per Indian Standards to determine different characteristics of the basic materials and composites formed as above.

Chapter 3

THEORETICAL CONSIDERATIONS AND SCOPE

As concluded from literature study, research with regard to use of fly ash in areas like Flowable fill, Asphalt concrete, Geopolymers, Roller compacted concrete has been widely carried out, however the potential of fly ash and waste ceramic combination for improving sub-grade characteristics of clay- sand combinations is still under exploration. The high percentage of siliceous materials in the fly ash makes it an excellent material for stabilization. When these materials are combined with clayey soils and sand- Resulting material have a frictional characteristic, cohesive characteristics as well as good reinforcing characteristics. The study indicates that the material can be effectively used in the construction of sub-grades, embankments and foundation bases.

In countries where fly ash and ceramic are abundant and considered as waste material, use of fly ash in the construction of roads, airfields, grounds and other earthworks may particularly become attractive, because of reduced construction costs, reduced disposal costs and environmental damage and conservation of high grade construction materials.

The use of fly ash as landfill causes great environmental pollution like, groundwater contamination, since coal contains trace levels of arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury, its ash will continue to contain these traces and therefore cannot be dumped or stored where rainwater can leach the metals and move them to aquifers. Also waste ceramic large scale disposal problems and its long life pose a serious threat to the environment. Also Exposure to fly ash through skin contact, inhalation of fine particle dust and drinking water may well present health risks. The National Academy of Sciences noted in 2007 that "the presence of high contaminant levels in many CCR (coal combustion residue) leachates may create human health and ecological concerns." Proper uses of waste material like fly ash and waste ceramic has many advantages like it will generates revenue for the government and prevents environmental degradation. According to experts, present day utilization of fly Ash in India is at its infancy. And only an insignificant amount is being put to proper use. A lot of work is expected to be done at government level, especially by way of framing and implementing policy decisions like adequate incentive, concessions in taxes and duties, popularization campaigns etc.

Chapter 4
EXPERIMENTAL PROGRAMME

4.1 Materials

For the establishment of the present study of compaction and subgrade characteristics of clay soil blended with fly ash and waste ceramic (tile based), the tests were performed in the geotechnical laboratory of Department of Civil Engineering, NIT Hamirpur.

This chapter gives the details of the experimental procedures for various tests.

4.1.1 Clay Soil

Clay is a naturally occurring material composed primarily of fine-grained minerals, which show plasticity through a variable range of water content, and which can be hardened when dried or fired. The clay soil used in the experiments was obtained from NIT campus(Near New Dispensary), Hamirpur region in Himachal Pradesh.

Figure 4. 1: Clay soil used

4.1.2 Beas River Sand

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. Sand particles range in diameter from 0.0625mm (or $^1/_{16}$ mm, or 62.5 micrometers) to 2 millimeters. The sand used in the experiments was obtained from Beas river sand.

Figure 4. 2: Beas river bed Sand

4.1.3 Fly Ash

The properties of fly ash is studied mainly under three head :-

1. Loss on Ignition :-It is a measurement of unburned carbon (coal) remaining in the ash and is a critical characteristic of fly ash.
2. Fineness :-The fineness of fly ash is most closely related to the operating condition of the coal crushers and the grindability of the coal itself. Fineness is one of the primary physical characteristics of fly ash that relates to its pozzolanic activity, and is measured by wet sieving over a 45µm sieve. Particles > 45µm show little or no reactivity under normal conditions; actually, the pozzolanic activity of ashes would be directly proportional to the amount of particles < 10µm.
3. Chemical composition :- The chemical composition of fly ash relates directly to the mineral chemistry of the parent coal and any additional fuels or additives used in the combustion or post-combustion processes

The Ash used in experiments has been obtained from ACC Cement Factory, Burmana, Bilaspur.

Figure 4. 3: Fly ash

4.1.4 Waste Ceramic (Tile based)

The ceramic used in the project has been obtained from waste tiles of NIT Hamirpur (tile waste of newly constructed dispensary).The size of the ceramic are in between the range of 4.75mm and 0.075mm.

Figure 4. 4: Ceramic

4.2 Test Program

The tests were carried out in the following sequence

a. Basic tests on Clay
b. Basic tests on Sand
c. Basic tests on fly ash
d. Compaction tests for Clay – Sand combinations.
e. Compaction tests for Composites (Clay + Sand+ fly ash)

f. Compaction tests for Composites (Clay + Sand+ fly ash + Ceramic)

g. California Bearing Ratio test for Composites (Clay + Sand + fly ash+ Ceramic)

h. California Bearing Ratio test for Clay

i. California Bearing Ratio test for Clay-Sand Combination

j. Permeability test for clay sand combination

k. Permeability test for best combination.

a. Tests on Clay

The following tests were carried out on Clay to study its properties

1. Particle size distribution- wet sieve analysis and Hydrometer analysis
2. Specific Gravity
3. Consistency Limits(liquid limit and plastic limit)
4. Proctor test for Compaction

b. Tests on Beas River Sand

The following tests were carried out on Sand to study its properties

1. Particle size distribution
2. Specific Gravity
3. Consistency Limits
4. Proctor test for Compaction

c. Tests on fly Ash

The following tests were carried out on fly ash to study its properties

1. Particle size distribution- Hydrometer analysis
2. Specific Gravity
3. Consistency Limit (liquid limit)
4. Proctor test for Compaction

d. Compaction tests for Clay – Sand combinations

IS light compaction tests were carried out on different proportions of Clay and Sand so as to study their compaction characteristics. The different proportions of Clay and Sand used are as follows:

Table 4. 1 : Different proportions of Clay and Sand for Compaction test

Sr. No.	CLAY	SAND
1.	90%	10%
2.	80%	20%
3.	70%	30%
4.	60%	40%
5.	50%	50%

e. Compaction tests for Composites (Clay + Sand+ fly ash)

Based on IS light compaction tests the following two samples were selected to be tested with addition of fly ash in percentages of 5, 10, 15 and 20.

Table 4. 2 : Proportions of Clay and Sand used for compaction test for Composites

Clay	Sand
60%	40%
70%	30%

The different combinations of composites tested are shown below:

Table 4. 3 : Different proportions of Clay, Sand and Fly ash for Compaction test

Clay + Sand	Fly ash
Clay : Sand :: 60 : 40	5%
Clay : Sand :: 60 : 40	10%
Clay : Sand :: 60 : 40	15%
Clay : Sand :: 60 : 40	20%
Clay : Sand :: 70 : 30	10%
Clay : Sand :: 70 : 30	20%
Clay : Sand :: 70 : 30	30%
Clay : Sand :: 70 : 30	40%

f. Compaction test for Composites (Clay + Sand+ fly ash) and ceramic

Table 4. 4 : Different proportions of Clay, Sand, Fly ash and Ceramics for Compaction tests

Serial no	Combination of the material
1	Clay : Sand : Fly ash :: 70 : 30 :5) + 2% Ceramic
2	(Clay : Sand : Fly ash :: 70 : 30 :5) + 4% Ceramic
3	(Clay : Sand : Fly ash :: 70 : 30 :5) + 6% Ceramic
4	(Clay : Sand : Fly ash :: 70 : 30 :5) + 8% Ceramic
5	(Clay : Sand : Fly ash :: 70 : 30 :10) + 2% Ceramic
6	(Clay : Sand : Fly ash :: 70 : 30 :10) + 4% Ceramic
7	(Clay : Sand : Fly ash :: 70 : 30 :10) + 6% Ceramic
8	(Clay : Sand : Fly ash :: 70 : 30 :10) + 8% Ceramic

The following table gives a summary of all the tests performed.

Table 4. 5 : Test Plan

Materials	Tests					
Clayey Soil	Sieve analysis	Hydrometer Analysis	Specific Gravity	Consistency Limits	Proctor Test	-------
Beas Sand	Sieve analysis	------------	Specific Gravity	--------	Proctor Test	-------
Fly ash	Sieve analysis	-----------	Specific Gravity	Consistency Limits	Proctor Test	------
Clayey Soil + Beas Sand	Sieve analysis	--------	--------	--------	Proctor Test	CBR & Permeability
Clayey Soil + Beas Sand + fly ash	--------	--------	--------	--------	Proctor Test	-------
Clayey Soil + Beas Sand + fly ash + Ceramic	--------	--------	--------	--------	Proctor test	CBR & Permeability

4.3 Test procedures

4.3.1 Particle size distribution

The percentage of various sizes of particles in a given dry sample was found by particle size analysis. In the Indian Standard (IS: 460-1962), the sieves are designated by size of aperture. Sieves used for fine analysis are : 4.75mm, 2.36mm, 1.18mm, 600μ, 425 μ, 300 μ, 150μ and 75μ IS sieves. For particles finer than 75μ, hydrometer analysis is used to determine grain size distribution. Particle size is determined using,

$$D= 10^{-5}*F\ (He/t)^{1/2}$$

The results of mechanical analysis are plotted to get a particle size distribution curve with percentage finer N as ordinate and particle diameter as abscissa, diameter being plotted on logarithmic scale. The curve gives us an idea about the type and gradation of sample.

The uniformity coefficient, $Cu= D_{60}/D_{10}$, is a measure of particle size range and coefficient of curvature, $Cc= D_{30}^2/ (D_{10} * D_{60})$, represents the shape of the particle size curve.

Figure 4. 5: Sieves arranged in sieve shaker

4.3.2 Specific Gravity

The specific gravity of Clay, Sand and Rice Husk Ash is determined using 50 ml gravity bottle. It is computed using the following equation

$$G= M_2- M_1/ (M_4-M_1)-(M_3-M_2)$$

Where M_1 is the mass of empty, dry bottle, M_2 is the mass of oven dried soil/ash plus mass of bottle, M_3 is the mass of bottle, sample and water and M_4 is the mass of clean empty bottle filled with deaired water to the top.

Figure 4. 6: Pycnometer

4.3.3 Consistency limits for Clay soil

Liquid limit is the water content corresponding to the arbitrary limit between the liquid and plastic state of clay/ rice husk ash. The liquid limit determined in lab with the help of standard liquid limit apparatus designed by Casagrande given in IS: 2720(Part 5)-1985.

About 120 g of specimen passing through 425μ sieve is mixed thoroughly with distilled water to form a uniform paste. A portion of the paste is placed in the cup over the spot where the cup rests on the base, squeezed down and sprayed into position and the groove is cut. The handle is rotated at the rate of about 2 revolutions per second, and the no. of blows are counted until the two parts of the sample come into contact at the bottom of the groove along a distance of 10mm. The liquid limit is determined by plotting the graph between no. of blows as abscissa on a logarithmic scale and the corresponding water content as ordinate. The water content corresponding to 25 blows is taken as liquid limit.

Plastic limit is the water content corresponding to and arbitrary limit between plastic and the semi-solid states of consistency of soil. Soil specimen passing through 425μ sieve is mixed thoroughly with distilled water until the soil becomes plastic enough to be easily moulded with fingers. A ball of 8g of plastic soil is rolled between fingers and glass plate and on reaching 3mm dia, soil is remoulded again. Rolling and remoulding is repeated till the thread just starts crumbling at a dia of 3mm and corresponding water content is determined.

Figure 4. 7: Liquid limit apparatus

Plasticity index which indicates range of consistency within which a soil exhibits plastic properties, is determined as follows:

$$I_p = w_L - w_p$$

4.3.4 Compaction test

Compaction is a process by which all soil particles are artificially rearranged and packed together into a closer state of contact by mechanical means in order to decrease porosity and thus increase dry density. As per IS: 2720 (Part VII), a mould of 1000 ml capacity with internal dia 100 mm and internal effective height of 127,5 mm is used and automatic compacting machine is used to compact. Soil moulded at different water contents is compacted in three equal layers, each layer given 25 blows, scratched to have uniform composition and its dry density is determined. A compaction curve is plotted between the water contents as abscissa and cores corresponding dry density as ordinates. The dry density increases with increase in water content.

Figure 4. 8: Automatic compaction machine

4.3.5 California Bearing Ratio test

This a penetration test designed by the California Division of Highways, as a method of evaluating the stability of soil sub-grade and other flexible pavement materials. CBR value is used as an index of soil strength and bearing capacity. The laboratory CBR apparatus consists of mould of 150mm diameter and a base plate and collar, a loading frame with a cylindrical plunger of 50mm dia and a dial gauge to measure penetration values. The cylindrical plunger of 50 mm dia penetrates a pavement component material at 1.25mm/minute. The load values causing 2.5 and 5mm penetration are recorded and expressed as percentages of standard load values at respective deformation levels to obtain CBR value. The standard load values for crushes stone are 1370 and 2025 kg for 2.5 and 5mm penetration respectively.

Figure 4. 9: Computerized CBR apparatus

4.3.6 Permeability test

Permeability is defined as the property of a porous material which permits the seepage of water through its interconnecting voids. The falling head permeability test is used for relatively impermeable soils where discharge is small. This is used to determine permeability at Maximum Dry density and Optimum moisture content. Soil is compacted at OMC in three layers in the 1 liter permeameter mould with 25 blows of automatic compaction machine given to each layer, collar is removed and base plate is attached. The sample is soaked in water and then checked for fall in head (h_2-h_1) using stand pipes of known cross sectional area a in time t.

$$\text{Permeability, } k = 2.3 * aL/At * \log_{10}(h_2/h_1)$$

Chapter 5
Analysis and Discussion

The tests mentioned in the previous chapter were performed in the geotechnical Laboratory in accordance with the Indian Standards. The results thus obtained are discussed and analyzed in the following section.

5.1 Properties of Fly-ash

Various tests on Soil are discussed are:

1) Particle size distribution curve.
2) Consistency limit.
3) Proctor Test.
4) Picnometer Test
5) Constant head Permeability test.

5.1.1 Particle size distribution curve

The results of mechanical analysis are plotted to get a particle size distribution curve with the percentage passing as the ordinate and the particle diameter as abscissa, the diameter being plotted on a logarithmic scale. The following figure 5.1 shows the particle size distribution curve for fly-ash.

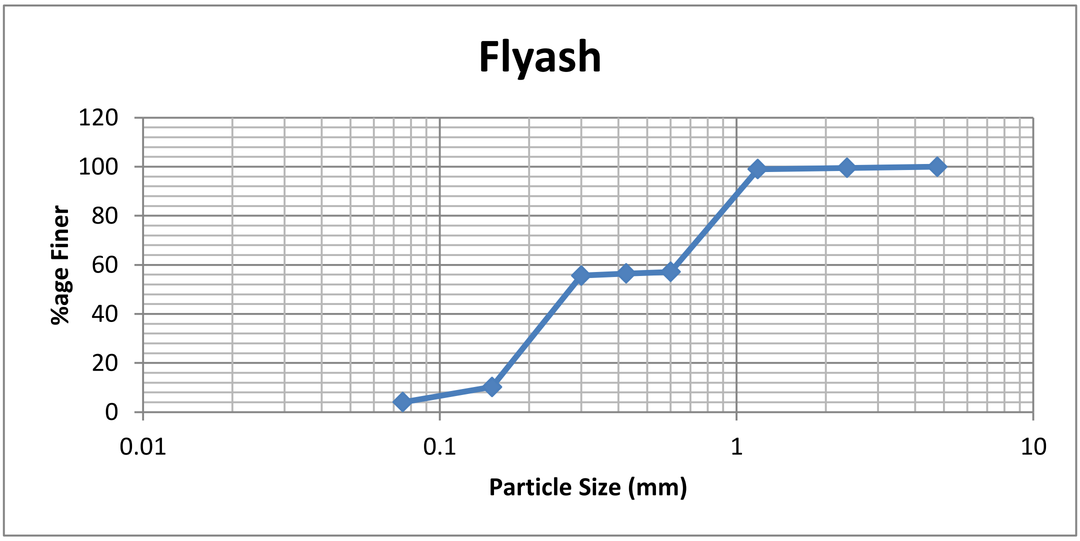

Figure 5.1: **Particle size distribution curve for fly-ash.**

5.1.2 Compaction Test

A compaction curve is plotted between the water content as abscissa and the corresponding densities as ordinates. The dry density goes on increasing till maximum density is reached the water content corresponding to the maximum density is known as optimum moisture content. The following figure 5.2 shows the compaction characteristics of Fly-ash.

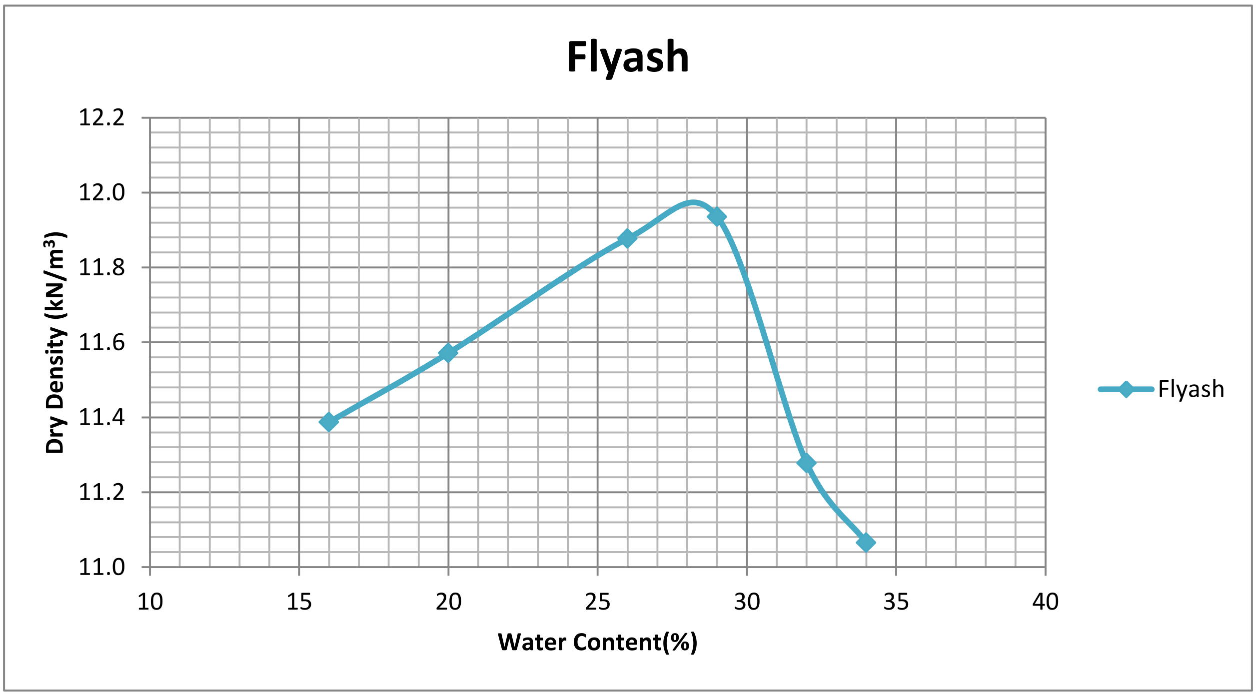

Figure 5.2: Compaction characteristics of Fly-ash

The Maximum Dry density of fly ash is 11.96 kN/m^{3}obtained at optimum moisture content of 28.5 percent.

5.1.3 Consistency limit of Fly Ash

The consistency limits of fly ash are determined in the laboratory as per procedure laid by Indian standard (IS: 9259-1979).the liquid limit is found from the Figure 5.3 given below.

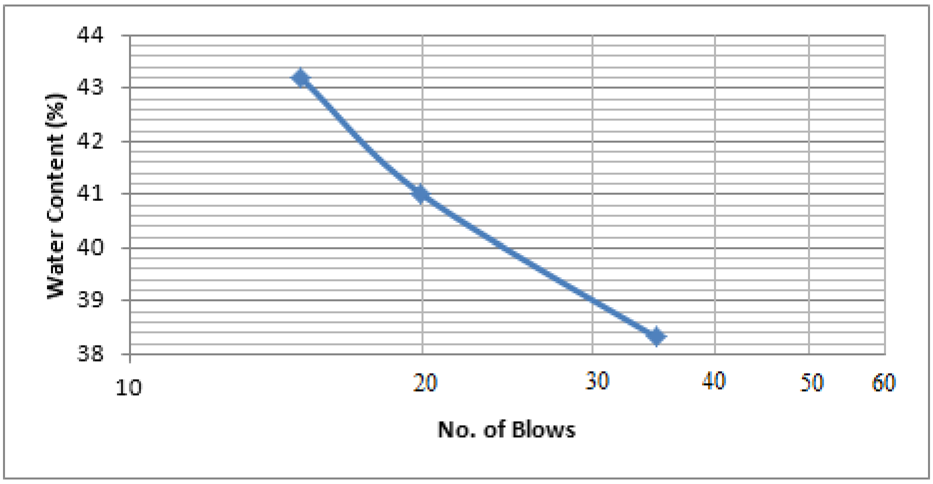

Figure 5.3: Liquid limit curve for Fly-ash

The following table 5.1 tabulates the properties of fly-ash:

TABLE 5.1 Parameters of Fly-ash

Parameters	Values
Average size of particles D_{50}	0.27mm
Coefficient of uniformity C_u	5.72
Coefficient of curvature C_c	0.64
Specific Gravity	2.348
Liquid Limit	41.2%
Maximum Dry Density MDD	1.22kN/m^3
Optimum Moisture Content OMC	28.5
Permeability	8*10^{-6}m/s

5.2 Properties of Sand

Various tests on Soil are discussed are:

1) Particle size distribution curve.
2) Consistency limit.
3) Proctor Test.
4) Picnometer Test
5) Constant head Permeability test.

5.2.1 Particle size distribution curve

The results of mechanical analysis are plotted to get a particle size distribution curve with the percentage passing as the ordinate and the particle diameter as abscissa, the diameter being plotted on a logarithmic scale. The following figure 5.4 shows the particle size distribution curve for sand.

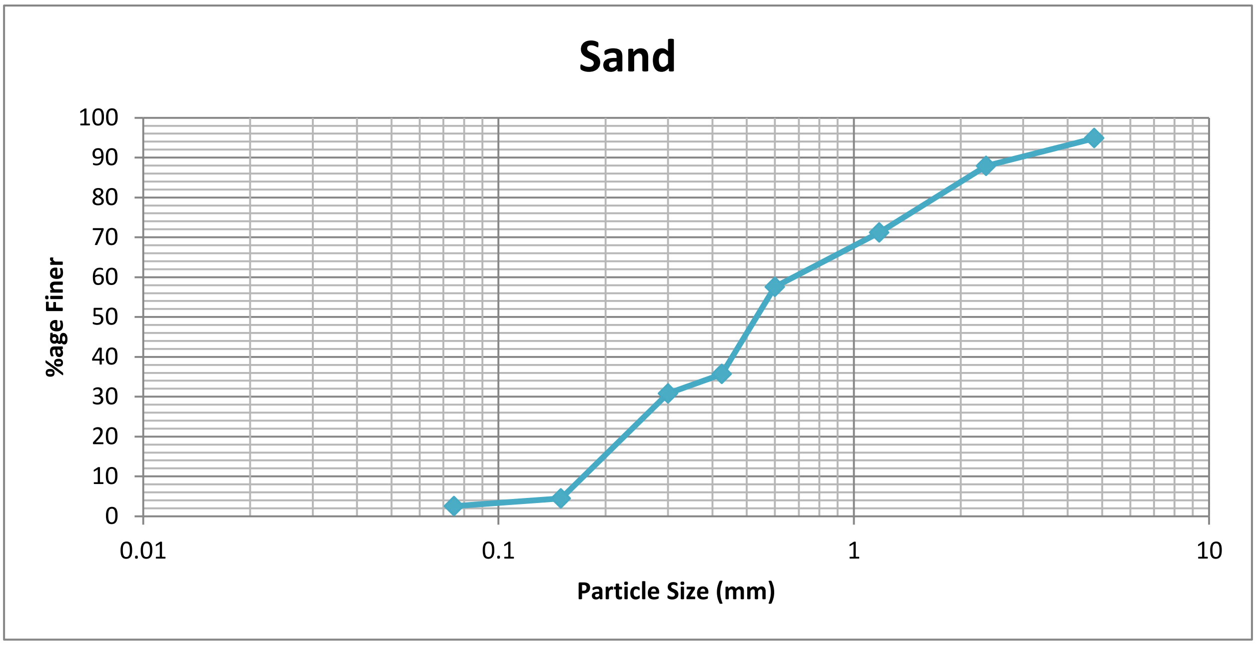

Figure 5.4: Particle size distribution of sand

5.2.2 Compaction Test

A compaction curve is plotted between the water content as abscissa and the corresponding densities as ordinates. The dry density goes on increasing till maximum density is reached the water content corresponding to the maximum density is known as optimum moisture content. the following figure shows the compaction characteristics of Sand. Sand has its own characteristics compaction curve as shown in Figure 5.5.

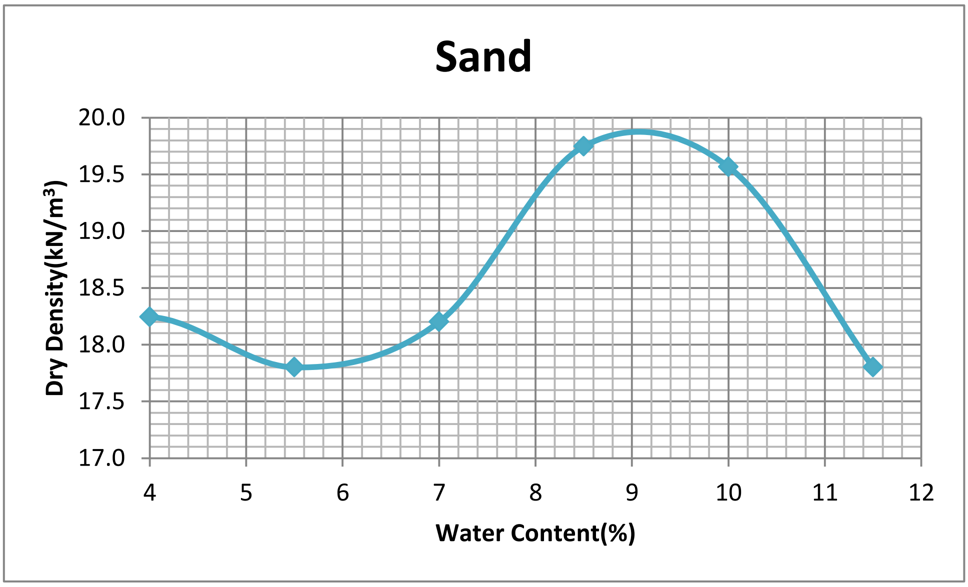

Figure 5.5: Compaction characteristics of sand

The Maximum Dry density of Sand is 19.8kN/m^3obtained at optimum moisture content of 9.0%.

The following table 5.2 tabulates the properties of Sand:

TABLE 5.2 Parameters of Sand

Parameters	Values
Average size of particles D_{50}	0.54
Coefficient of uniformity C_u	3.61
Coefficient of curvature C_c	0.74
Classification as per IS1498-1970	SP
Specific Gravity	2.625
Maximum Dry Density MDD	19.8
Optimum Moisture Content OMC	9.0%
Permeability	$6.3*10^{-4}$m/s

5.3 Properties of Soil

Various tests on Soil are discussed are:

1) Particle size distribution curve.
2) Consistency limit.
3) Proctor Test.
4) CBR Test.
5) Picnometer Test
6) Constant head Permeability test.

5.3.1 Particle size distribution curve

The results of mechanical analysis are plotted to get a particle size distribution curve with the percentage passing as the ordinate and the particle diameter as abscissa, the diameter being plotted on a logarithmic scale. The following figure 5.6 shows the particle size distribution curve for soil.

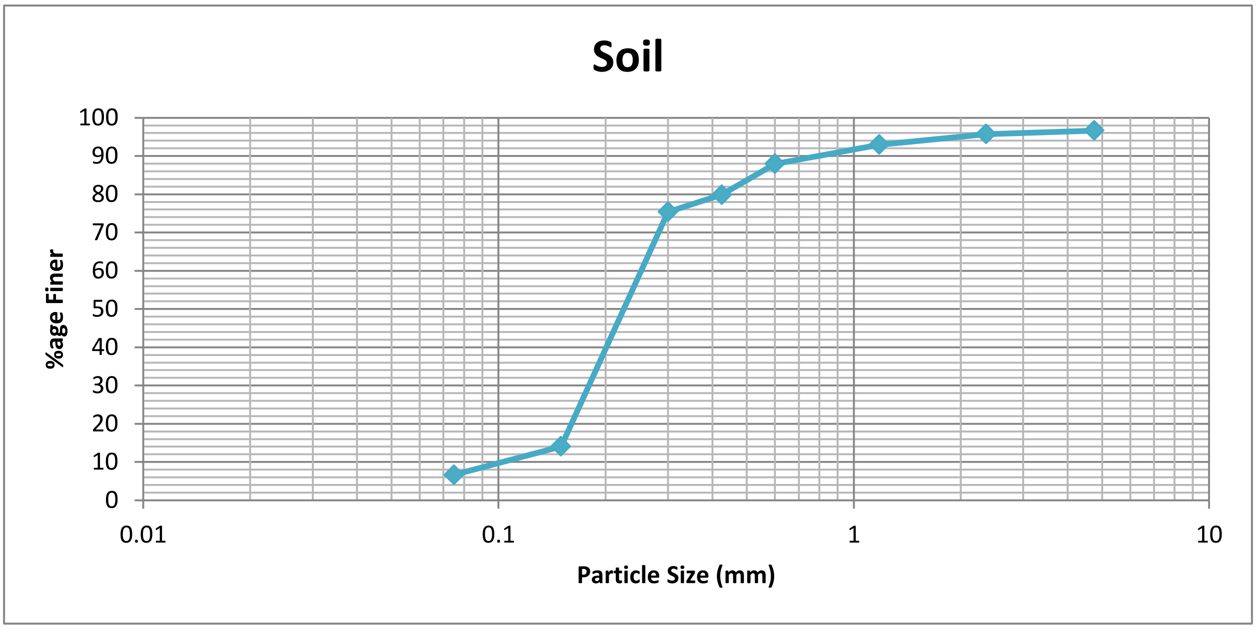

Figure 5.6: Particle size distribution of soil

5.3.2 Compaction Test

A compaction curve is plotted between the water content as abscissa and the corresponding densities as ordinates. The dry density goes on increasing till maximum density is reached the water content corresponding to the maximum density is known as optimum moisture content. The following figure 5.7 shows the compaction characteristics of soil.

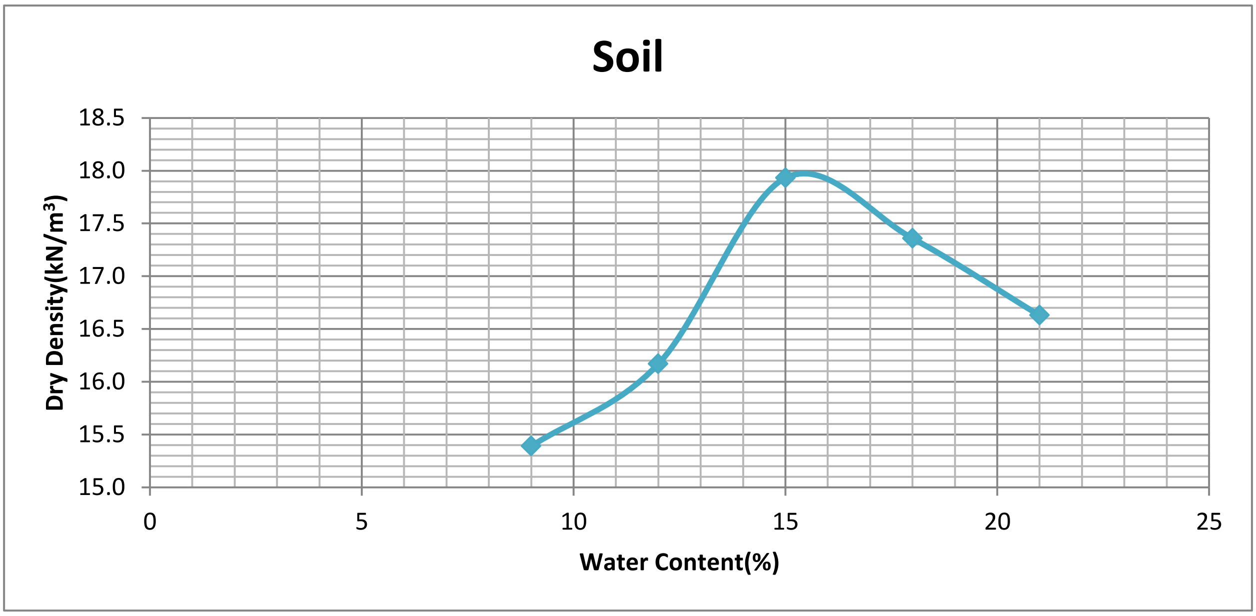

Figure 5.7: Compaction characteristics of soil

The Maximum Dry density of Soil is 18kN/m^3 obtained at optimum moisture content of 15.5%.

5.3.3 Consistency limits:

The consistency limits of clayey soil are determined in the laboratory as per procedure laid by Indian standard (IS: 9259-1979). The liquid limit, plastic limit and plasticity index are determined as per prescribed code and shown in figure 5.8.

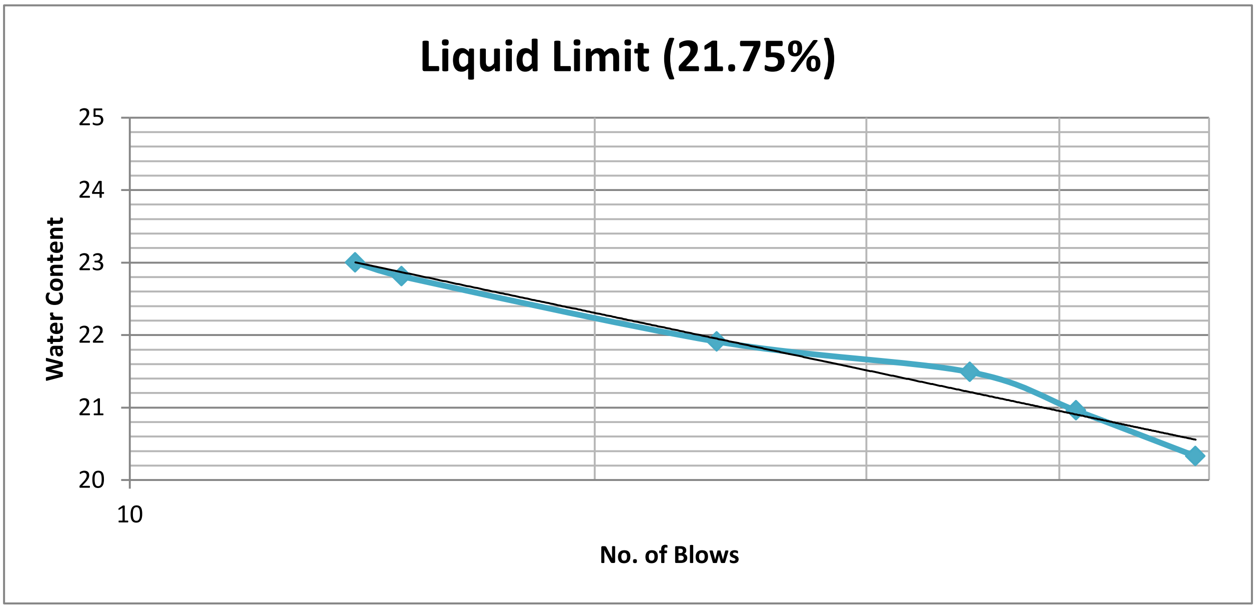

Figure 5.8: Graph showing liquid limit of Soil

Soil has a Liquid Limit of 21.75% and Plastic-Limit of 17.48%.

The following table 5.3 tabulates the properties of Soil:

TABLE 5.3 Parameters of soil

Parameters	Values
Average size of particles D_{50}	0.23mm
Coefficient of uniformity C_u	2.38
Coefficient of curvature C_c	1.23
Classification as per IS1498-1970	CL-ML
Specific Gravity	2.568
Liquid Limit	21.75%
Maximum Dry Density MDD	18kN/m3
Optimum Moisture Content OMC	15.50%
CBR	5.11%
Permeability	$1.2*10^{-5}$m/s

5.4 Properties of Ceramics

Various tests on Soil are discussed are:

1) Particle size distribution curve.
2) Consistency limit.
3) Proctor Test.
4) CBR Test.
5) Picnometer Test

5.4.1 Particle size distribution curve

The results of mechanical analysis are plotted to get a particle size distribution curve with the percentage passing as the ordinate and the particle diameter as abscissa, the diameter being plotted on a logarithmic scale. The following figure 5.9 shows the particle size distribution curve for Ceramics.

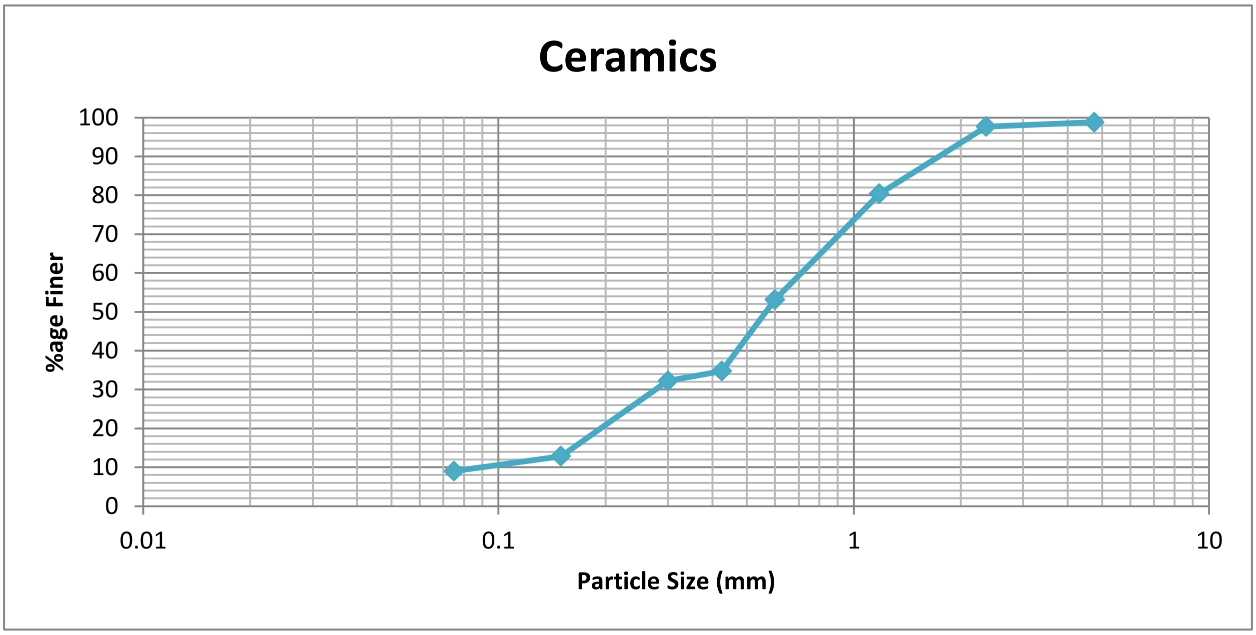

Figure 5.9: Particle size distribution for ceramics

5.4.2 Compaction Test

A compaction curve is plotted between the water content as abscissa and the corresponding densities as ordinates. The dry density goes on increasing till maximum density is reached the water content corresponding to the maximum density is known as optimum moisture content. The following figure 5.10 shows the compaction characteristics of Ceramics.

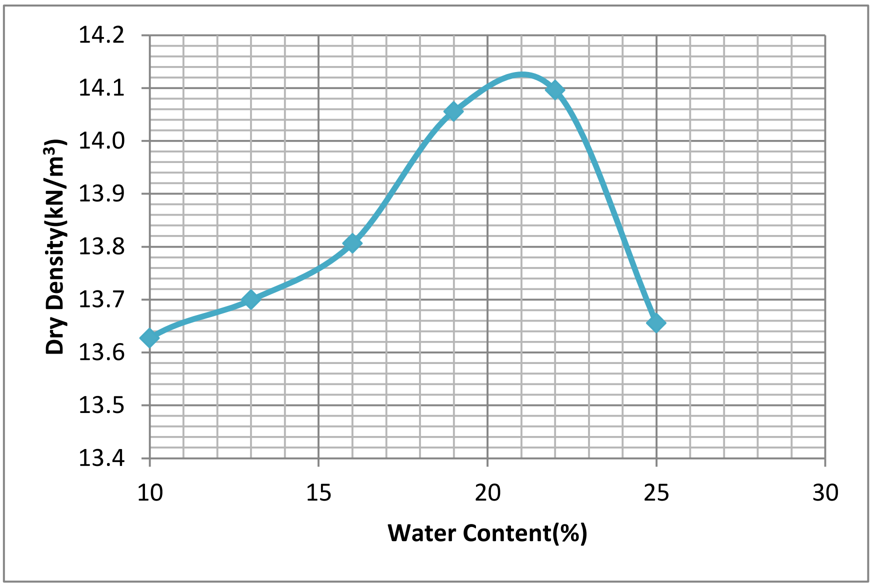

Figure 5.10: Compaction characteristics of Ceramics

The Maximum Dry density of ceramics is 14.1 obtained at optimum moisture content of 21%.

The following table tabulates the properties of ceramics:

TABLE 5.4 Parameters of Ceramics

Parameters	Values
Average size of particles D_{50}	0.58
Coefficient of uniformity C_u	7.00
Coefficient of curvature C_c	1.08
Specific Gravity	1.837
Maximum Dry Density MDD	14.1
Optimum Moisture Content OMC	21

5.5 Compaction characteristics of composite sample of Soil and Sand.

The variation of compaction characteristics of various composite samples are discussed in this section. IS light compaction tests were conducted on the composite samples described in previous chapter to make desired 'Mixture A'.

The following figure 5.11 represents the variation of compaction characteristics for different combination of Soil and Sand.

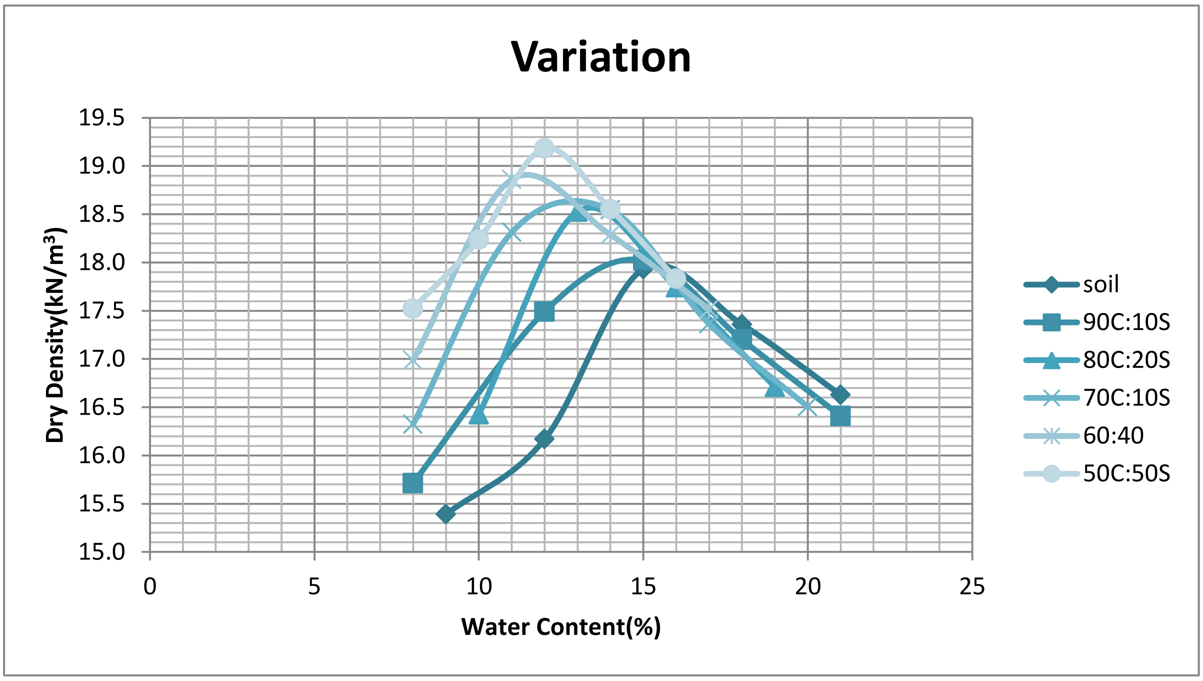

Figure 5.11: Variation in compaction characteristics with soil-sand mixture

The following table 5.5 givers the corresponding values of MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) as obtained from the above Figure 5.11

TABLE 5.5: Variation in MDD and OMC with soil and sand mixture

Mixture	Dry Density (kN/m^3)	Optimum Moisture Content (%)
100C:0S	18.0	15.5
90C:10S	18.1	15.0
80C:20S	18.5	13.5
70C:30S	18.6	13.0
60C:40S	18.9	12.5
50C:50S	19.2	12.0

Hence 70C:30S and 60C:40S are chosen as Mixture A, and fly-ash will be added to it to make Mixture B.

5.6 Compaction characteristics for Clay + Sand and F/A (Fly Ash)

After conducting the Procter tests on the various combinations of clay and sand, the best combinations on the basis of MDD & OMC were chose. 70% clay + 30% sand and 60%

clay + 40% sand were found best in all and further Proctor test were done with F/A. From this the best combination was obtained. The compaction characteristics of material for clay: sand: fly ash found out with standard Proctor Test as per procedure lay in IS: 2720 (Part VII) 1980/87. In the compaction characteristics maximum dry density and optimum moisture content of material are found out. The tests results for 70% clay + 30% sand + fly-ash were as shown in figure 5.12:

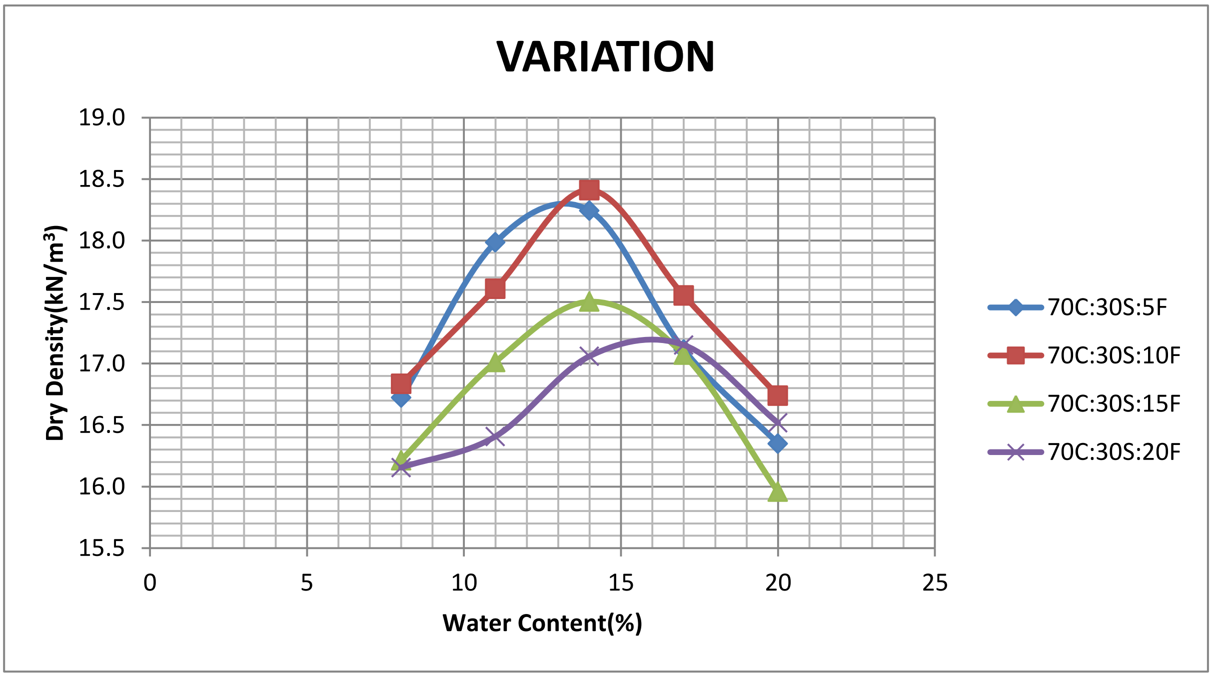

Figure 5.12: Variation of MDD and OMC with increase in Fly-ash content

The following table 5.6 givers the corresponding values of MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) as obtained from the above Figure 5.12

TABLE 5.6: Variation in MDD and OMC with soil-sand-fly ash mixture.

Ratio	Maximum Dry Density (KN/m^3)	Optimum Moisture Content (%)
(70C:30S):5F	18.6	13
(70C:30S):10F	18.2	14
(70C:30S):15F	17.6	15
(70C:30S):20F	17.2	16.5

Test results for 60% clay + 40% + Fly-ash are:

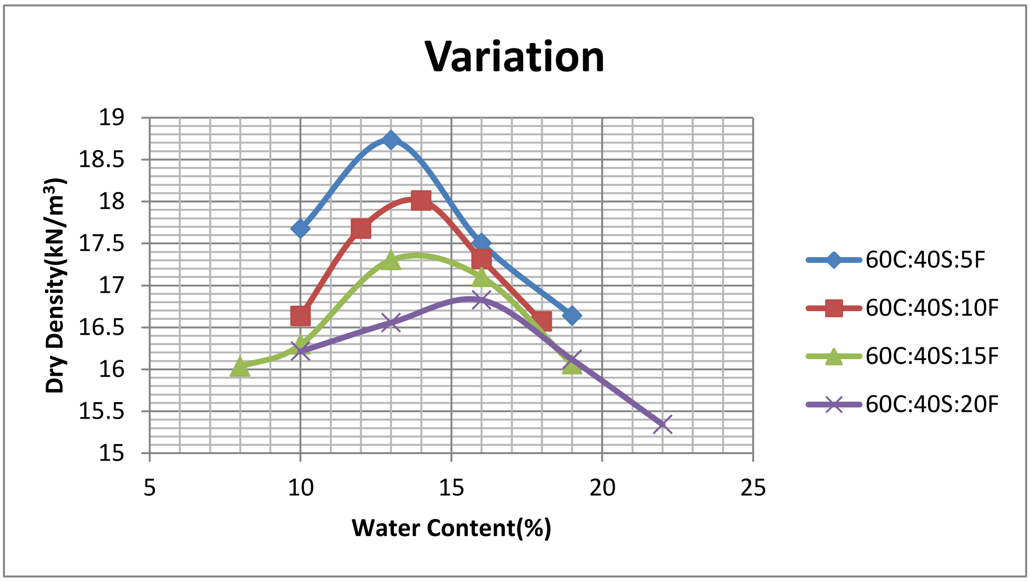

Figure 5.13: Variation by adding Fly-ash

TABLE 5.7 Variation in MDD and OMC with soil and sand mixture

Ratio	Maximum Dry Density (KN/m^3)	Optimum Moisture Content (%)
60C:40S:5F	18.4	13.0
60C:40S:10F	18.0	14.0
60C:40S:15F	17.4	15.0
60C:40S:20F	16.9	16.0

Figure 5.13 depicts the variation between the percentage of F/A and MDD in combinations with (Clay:Sand::60:40) and (Clay:Sand::70:30). It is found that with increase in the percentage of F/A , MDD of the combinations decreases and figure 5.14 shows the relationship between the percentage of F/A and MDD, in which MDD is represented by ***'y'*** and water content is represented by ***'x'.***

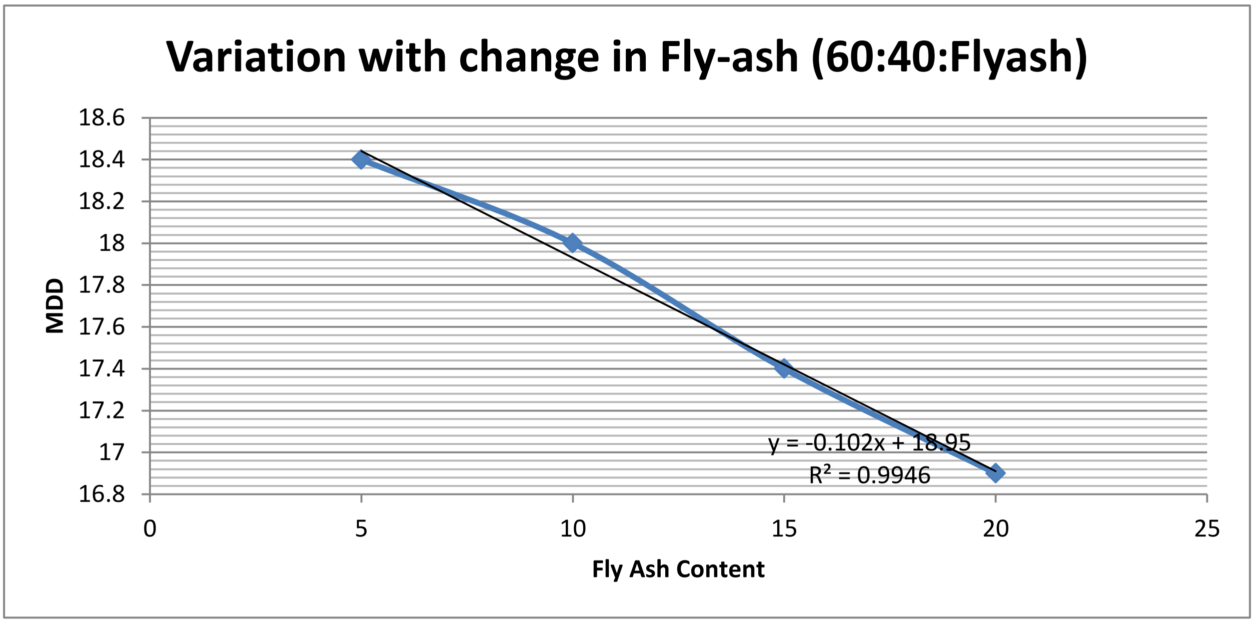

Figure 5.14: Graph showing the effect of Fly-ash on MDD

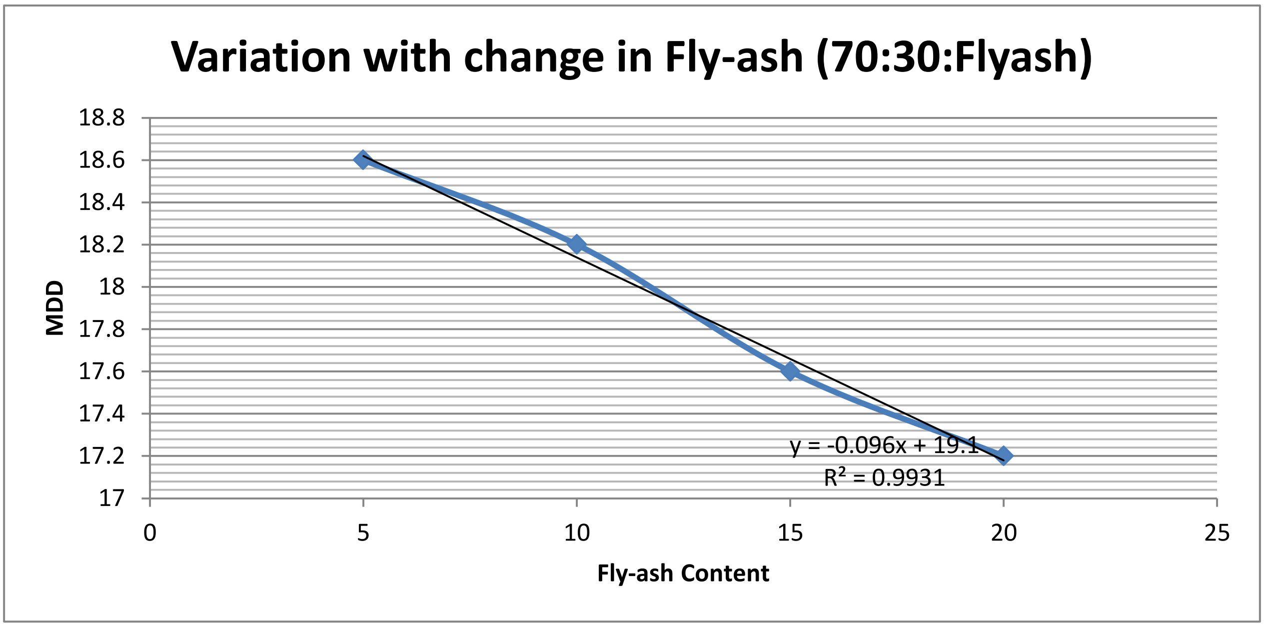

Figure 5.15: Graph showing the effect of Fly-ash

5.7 Compaction characteristics for Clay + Sand + F/A and ceramics

After conducting the Procter tests on the various combinations of clay and sand, the best combinations on the basis of MDD & OMC were chosen. It was found that adding 5% of Fly-ash provides us enough strength and gives best results in proctor tests conducted. From this the best combination was obtained. Ceramics was added in percentage of total weight of the mix, i.e. the clay + sand + fly ash. The standard Proctor Test as per procedure lay in IS: 2720 (Part VII) 1980/87 were performed on the various combinations of clay + sand + F/A and Ceramics as shown in figure 5.16:

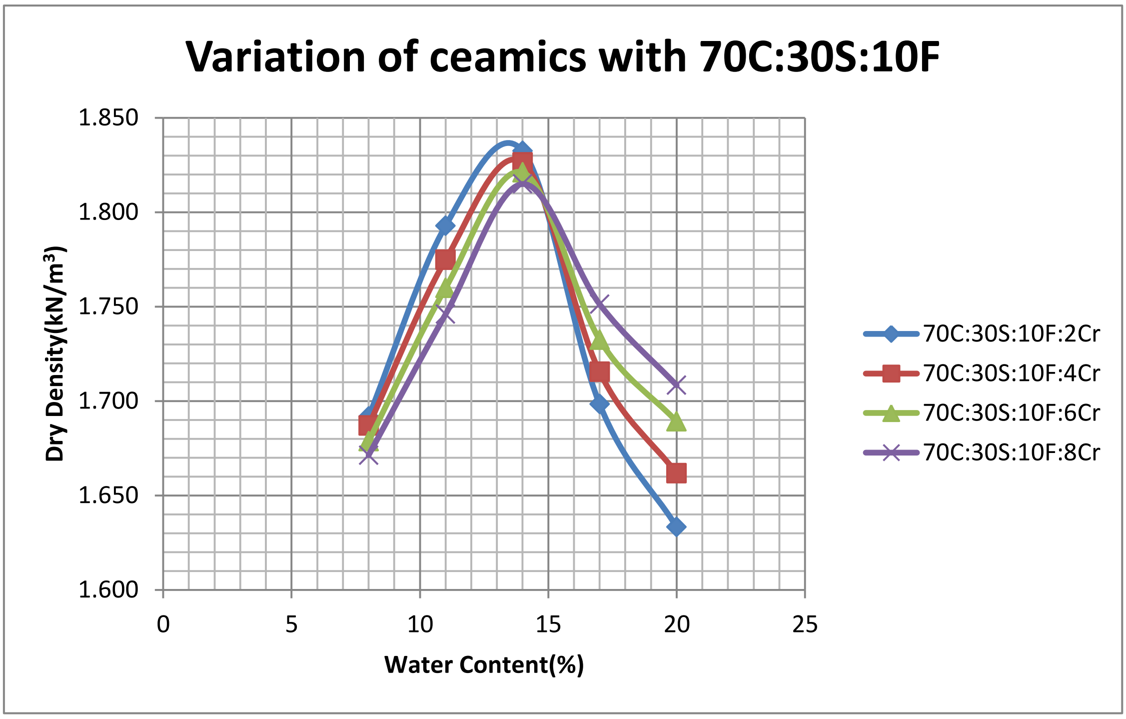

Figure 5.16: Graph showing variation of curves due to addition of ceramics

TABLE 5.8: Values of MDD and OMC for various ratios of Ceramics for 70C:30S:10F

Ratio	Maximum Dry Density (KN/m^3)	Optimum Moisture Content (%)
(70C:30S):10F:2Cr	18.0	13.5
(70C:30S):10F:4Cr	17.9	14
(70C:30S):10F:6Cr	17.8	14
(70C:30S):10F:8Cr	17.8	14.2

As from this table we can see that maximum Dry density comes with 2% ceramics in the mixture and the variation with ceramics in the next Graph. Even the graph depicts this trend of decreasing MDD with increase in ceramics.

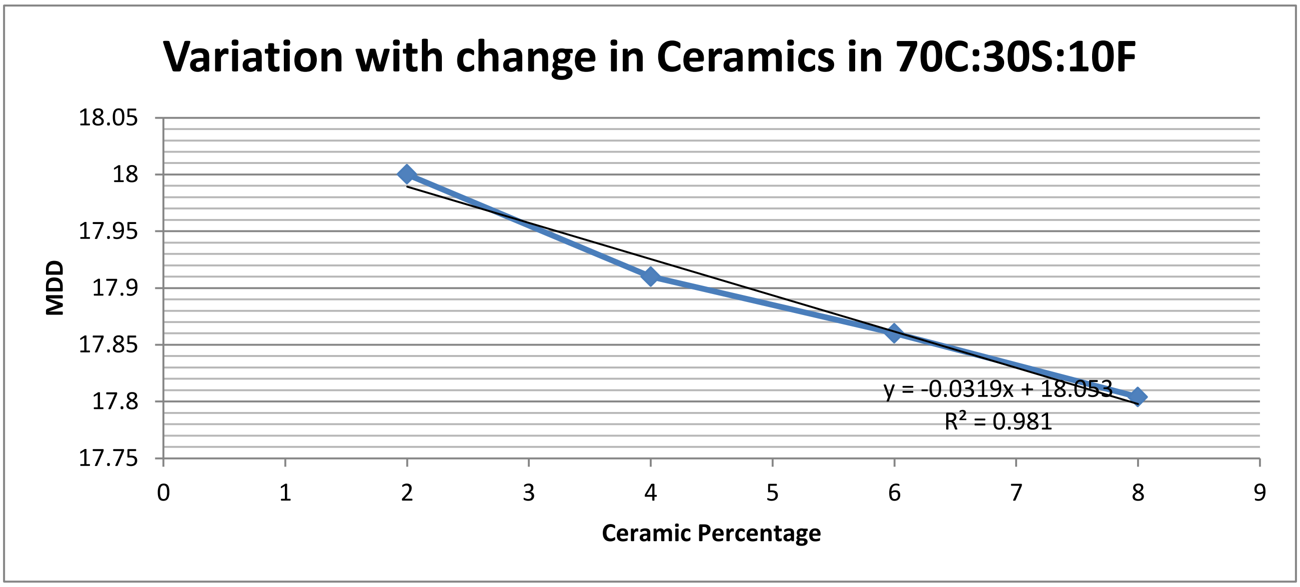

Figure 5.17: Graph showing effect of ceramics on MDD

Test results for 60C:40S:10F: ceramics are as:

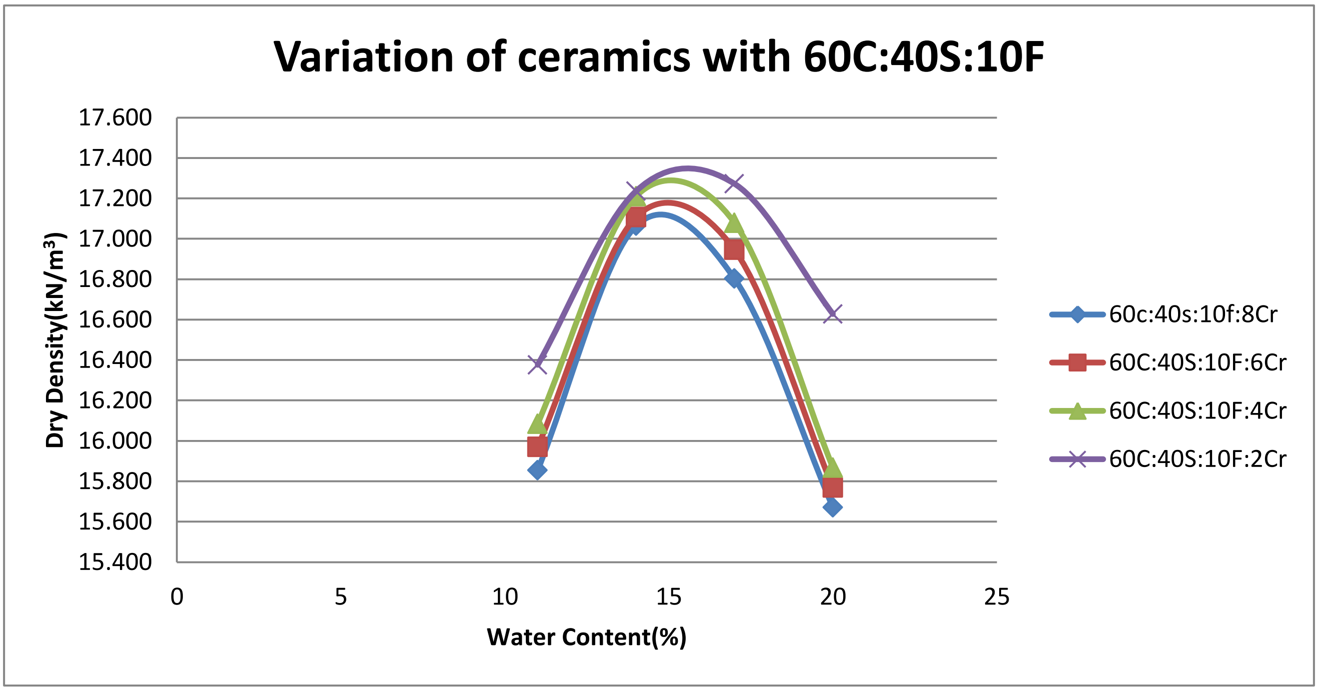

Figure 5.18: Variation of compaction curves due to variation of ceramics

TABLE 5.9: Values of MDD and OMC for various ratios of Ceramics for 60C:40S:10F

Ratio	Maximum Dry Density (KN/m^3)	Optimum Moisture Content (%)
60C:40S:10F:2Cr	17.3	15.9
60C:40S:10F:4Cr	17.2	15
60C:40S:10F:6Cr	17.1	14.8
60C:40S:10F:8Cr	17.0	14.5

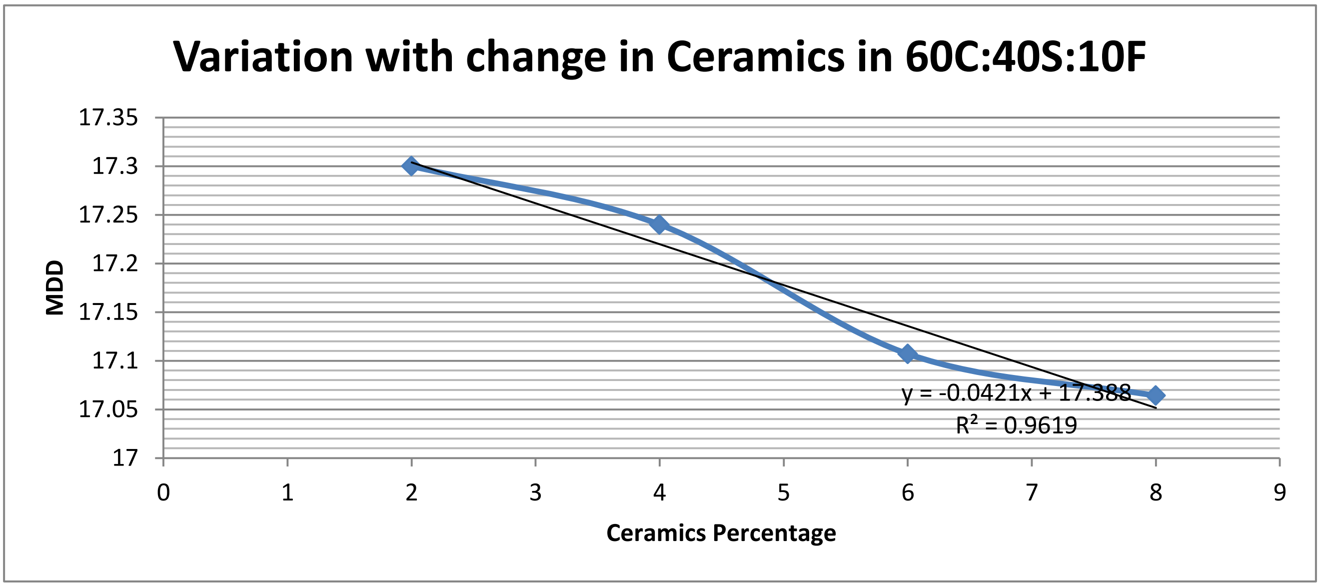

Figure 5.19: **Variation of MDD with changes of ceramics**

5.8 Computerized California Bearing Ratio Tests for Clay, Sand, Fly ash and Ceramic Combination

5.8.1 CBR (Un-soaked) of Clay

The computer controlled test was conducted for Clay as per guidelines laid by IRC. The experimental investigation was conducted for un-soaked conditions. The curve between load and penetration value is shown in figure 5.20.

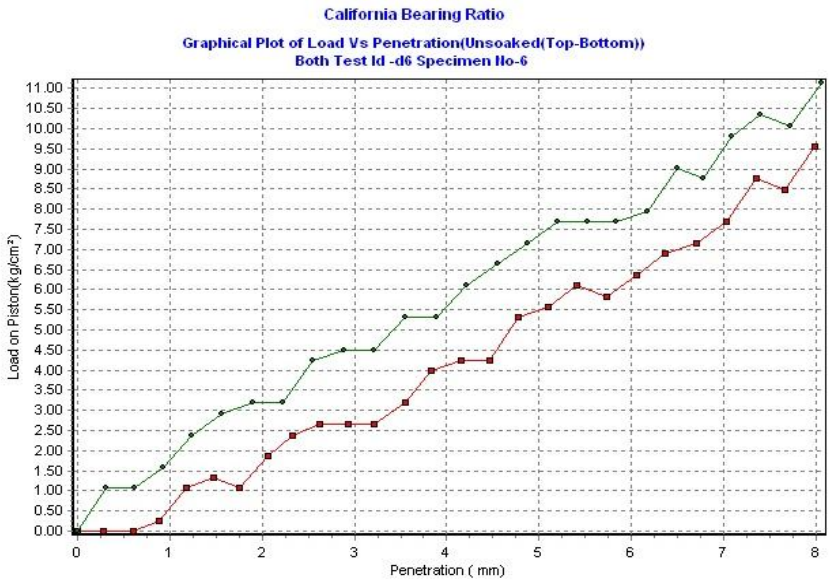

Figure 5.20: Computerized CBR (Un-soaked) of Clay-5.11%

5.8.2 CBR (Un-soaked) of (Clay : Sand :: 70 : 30)

The computer controlled test was conducted for proportion of (Clay : Sand:: 70 : 30) as per guidelines laid by IRC. The experimental investigation was conducted for un-soaked conditions. The curve between load and penetration value is shown in figure 5.21

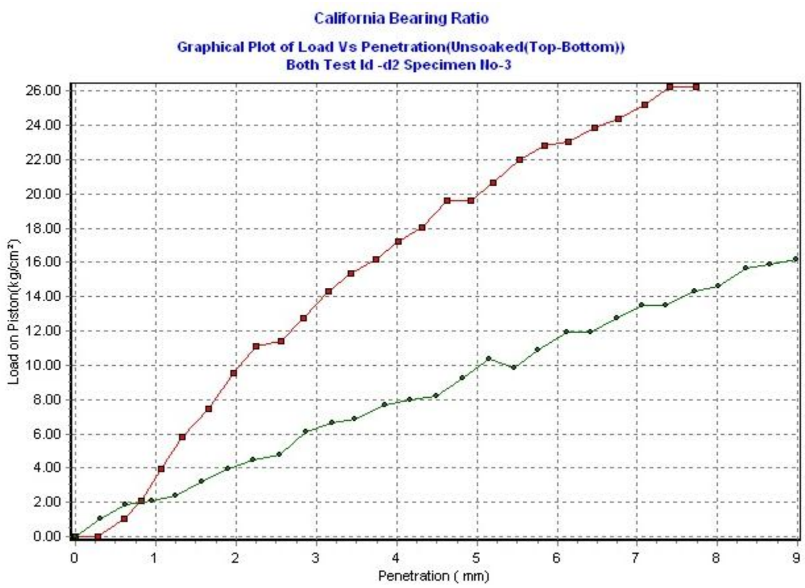

Figure 5.21: Computerized CBR (Un-soaked) of Clay:Sand::70:30 - 9.36%

5.8.3 CBR (Un-soaked) of (Clay : Sand:: 60 : 40)

The computer controlled test was conducted for proportion of (Clay : Sand:: 60 : 40) as per guidelines laid by IRC. The experimental investiga1tion was conducted for un-soaked conditions. The curve between load and penetration value is shown in fig 5.22

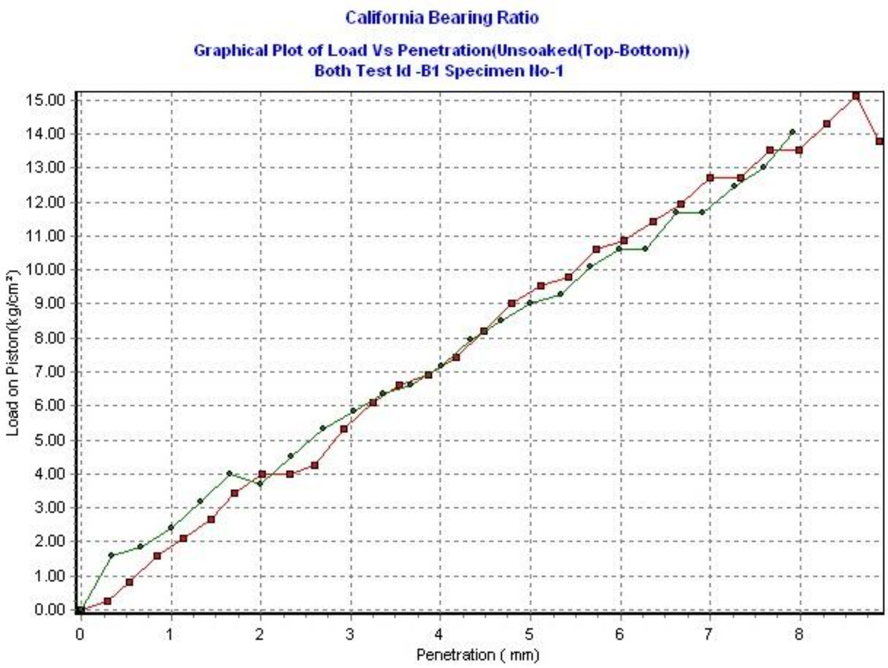

Figure 5.22 Computerized CBR (Un-soaked) of Clay:Sand::60:40 - 8.58%

5.8.4 CBR (Un-soaked) of (Clay : Sand : Fly ash :: 70: 30 :10)

The computer controlled test was conducted for proportion of (Clay : Sand : Fly ash :: 70 : 30 :10) as per guidelines laid by IRC. The experimental investigation was conducted for un-soaked conditions. The curve between load and penetration value is shown in fig 5.23

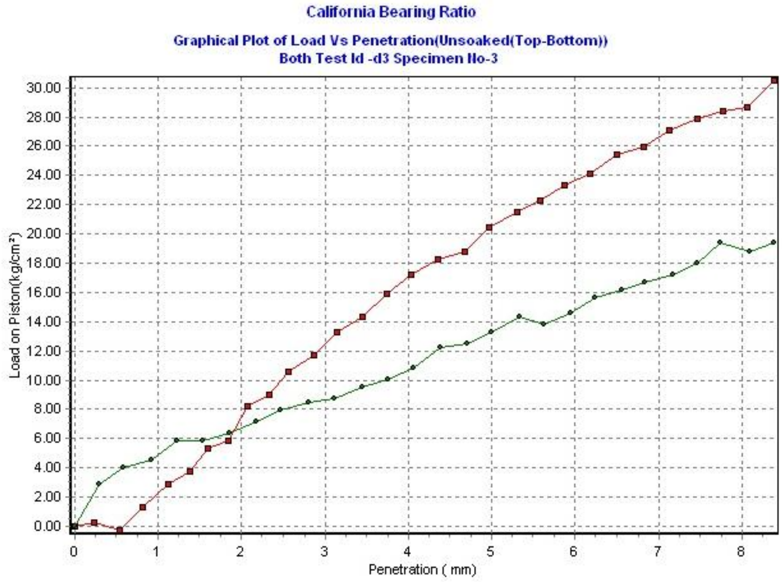

Figure 5.23 : Computerized CBR (Un-soaked) of Clay:Sand:Flyash::70:30:10 - 12.70%

5.8.5 CBR (Un-soaked) of (Clay : Sand : Fly ash :: 60 : 40 :10)

The computer controlled test was conducted for proportion of (Clay : Sand : Fly ash :: 60 : 40 :10) as per guidelines laid by IRC. The experimental investigation was conducted for un-soaked conditions. The curve between load and penetration value is shown in figure 5.24.

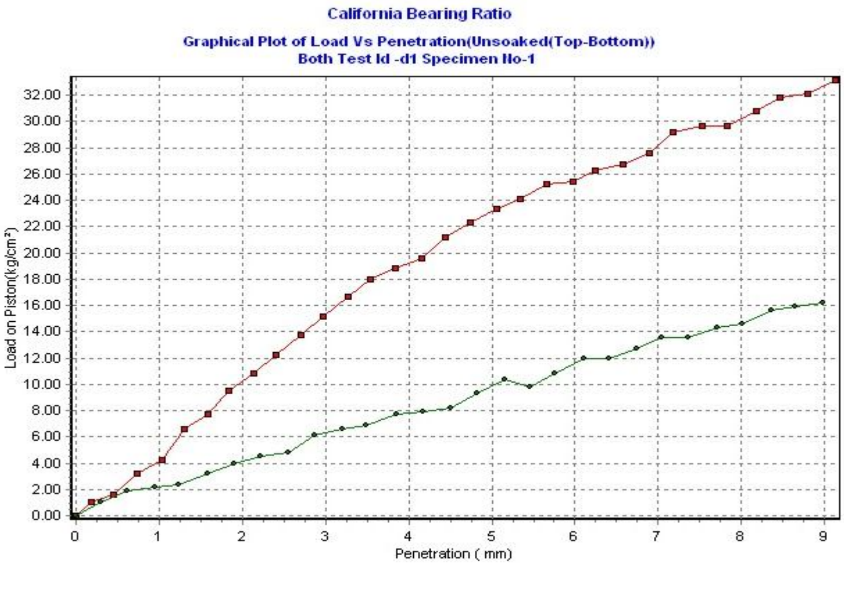

Figure 5.24 : Computerized CBR (Un-soaked) of Clay:Sand:Flyash::60:40:10 - 12.18%

5.8.6 CBR (Un-soaked) of (Clay : Sand : Fly ash: Ceramic :: 70 : 30 :10:2)

The computer controlled test was conducted for proportion of (Clay : Sand : Fly ash :: 70 : 30 :10 : 2) as per guidelines laid by IRC. The experimental investigation was conducted for un-soaked conditions. The curve between load and penetration value is shown in figure 5.25.

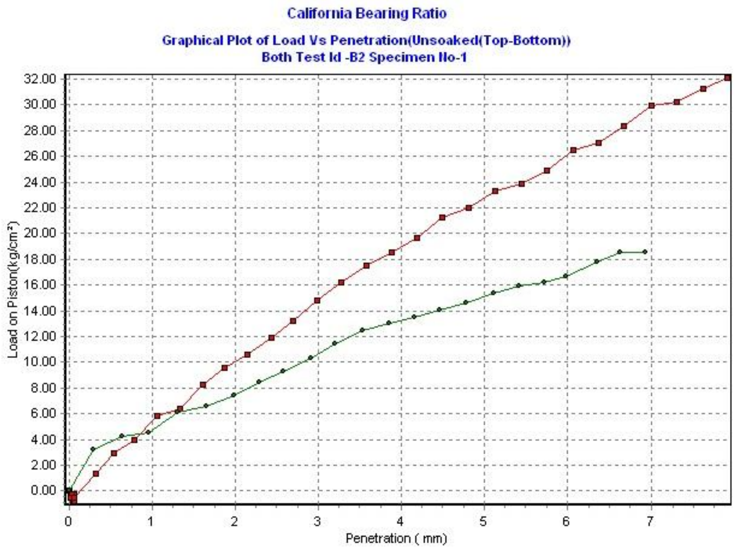

Figure 5.25 : Computerized CBR (Un-soaked) of Clay:Sand:Flyash:Ceramic::70:30:10:2 - 14.44%

5.8.7 CBR (Un-soaked) of (Clay: Sand : Fly ash: Ceramic :: 70 : 30 :10:4)

The computer controlled test was conducted for proportion of (Clay : Sand : Fly ash :: 70 : 30 :10 : 4) as per guidelines laid by IRC. The curve between load and penetration value is shown in figure 5.26.

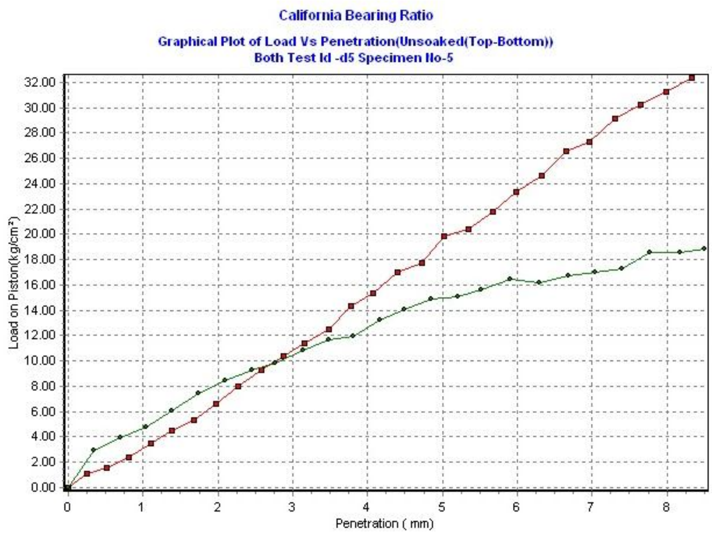

Figure 5.26 : Computerized CBR (Un-soaked) of Clay:Sand:Flyash:Ceramic::70:30:10:4 - 14.11%

The CBR values of various percentages of plastic fibers are as follow

Table 5.10 CBR values of various proportions.

Combination	CBR (%)
Clay	5.11
Clay:Sand::70:30	9.36
Clay:Sand::60:40	8.58
Clay:Sand:Flyash::70:30:10	12.70
Clay:Sand:Flyash::60:40:10	12.18
Clay:Sand:Flyash:Ceramic::70:30:10:2	14.44
Clay:Sand:Flyash:Ceramic::70:30:10:4	14.11

From the above table 5.10, it can be interpreted that the CBR value increased due to addition of Sand and again increase with the addition of fly ash. The CBR values for same ratio of Clay, Sand and Flyash with varying Ceramic showed the decreasing CBR trend.

5.9 Permeability tests

The permeability tests were done on different proportion of Clay, Sand, Flyash and Ceramic. It was done with Constant head permeameter. The results are shown in the following table 5.11

Table 5.11 Permeability values of various proportions

Composition	Permeability (m/s)
Clay	1.2×10^{-5}
Fly ash	8×10^{-6}
Sand	6×10^{-4}
Clay : sand:: 70:30	7.28×10^{-5}
Clay : sand : fly ash :Ceramic :: 70:30:10:2	2.56×10^{-5}

From the the above we concluded that prmiability increases with increase with the concentration of sand in the mixture and then decreases with the addition of fly-ash.

Chapter 6

CONCLUSION

Fly-Ash is a waste produced by burning of coal in thermal plant and has low specific gravity and CBR value. The addition of Sand, Ceramics and Fly-ash improves the properties of the composite thus formed, and allows its application in the construction of roads leading to safe disposal of Fly-Ash. Based upon the above study the following conclusions can be drawn.

1) The Gradation of soil was gradually altered by adding sand to it. The addition of sand resulted in an increase in MDD and decrease in OMC. Further there was also a significant increase in the CBR value with the addition of sand. The ratios of 60C:40S and 70C:30S were taken as base mixture A and all further the tests (with the addition of other ingredients) were conducted on them.
2) The composites of 60C:40S and 70C:30S were further tested with the addition of Fly-ash in them. The addition of fly-ash further led to a decrease in MDD but there was also an increase in the CBR value and the composite was found to be more stable. Out of all ratios the most stable was with 10% of fly ash and compaction tests were done on ratios (60C:40S):10F and (70C:30S):10F.
3) The composites of (60C:40S):10F and (70C:30S):10F were further tested with the addition of ceramics in them. The addition of ceramics further led to a decrease in MDD but there was an increase in the CBR value and the composite was found to be more stable. Out of all ratios the most stable was with 2% of ceramics.
4) Permeability value was increased with the addition of sand in the Soil – Sand mixture. Further addition of Fly-ash in the composite resulted in the decrease in permeability and addition of ceramics increased the permeability.

Based on the results it was suggested that 70(soil):30(sand):10(fly-ash):2(ceramics) was the best composite mixture. The final composite was having the CBR value of 14.44% and MDD of 18.0 kN/m^3 and permeability of 2.56 X 10^{-5} m/s. The final composite can be considered for applications in construction of embankments, soil sub-grade and foundation bases particularly in rural roads and low cost roads.

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