GEOTECHNICAL PROPERTIES OF FIBER REINFORCED POND ASH

A THESIS SUBMITTED IN PARTIAL FULFILMENT
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CERTIFICATE

This is to certify that the thesis entitled **"GEOTECHNICAL PROPERTIES OF FIBER REINFORCED POND ASH"** submitted by **ABHISEK SWAIN & SOMYA RANJAN NAYAK** in partial fulfillment of the requirements for the award of **Bachelor of Technology** Degree in **Civil Engineering** at National Institute of Technology, Rourkela is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

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ABSRACT

In the recent past huge amount of Fly ash and Pond ash are generated by the thermal power plants. It is a major cause of concern for the people living around the power plants. The current rate of deposition of Pond ash in India has reached 170 million tons per annum. About 90,000 acres of precious land is used for the storage of abandoned Pond ash. But current rate of utilization of ash is only about 35-40%.The unused ash leads to an ever increasing ponding area for storing ash and related environmental issues for the people around the power plants.

Besides this, over the last few years, the construction of highways and roads has taken a boost. This requires a huge amount of natural soil and aggregates to excavated or to be deposited. Again this is an environmental issue and economical too. These are some issues now-a-days which motivates in development of alternative methods to overcome those environmental and also the economic issues. This leads to the reuse of suitable industrial byproducts which can fix those issues and also fulfill the specifications. Pond ash is one such byproduct. It is a non-plastic and lightweight material.

During this work, the effect of moisture content, degree of compaction, synthetic fiber as a reinforcement etc. on various geotechnical properties of pond ash are studied.

A series of tests such as direct shear test, CBR test, light compaction as well as heavy compaction test, Unconfined compression test are done to estimate the strength characteristics of compacted pond ash using synthetic fiber as a reinforcement as well as tests like specific gravity test, grain size distribution test by mechanical sieve analysis and hydrometer test etc. are performed to obtain some physical properties of the pond ash.

These results will be very much helpful for the successful application of pond ash in different fields such as embankment construction, road base and sub-base construction, designing of retaining walls etc. as well as the disposal of pond ash in an ecofriendly manner.

CONTENTS

I. LIST OF FIGURES

II. LIST OF TABLES

Chapter 1
INTRODUCTION

1. INTRODUCTION

Thermal power plants release waste materials as by-products which are threat to environment. Disposal of them is a major concern now-a-days. It requires a large area and also has many environmental issues. Major by-products are Fly ash, Bottom ash and Pond ash. Fly ash is collected from the flue gases of the power plants by mechanical or electrostatic precipitator. Bottom ash is collected from the bottom of the boilers. Pond ash is derived from the mixture of both fly ash and bottom ash. The power plants produce very large amount of pond ash as compared to fly ash and bottom ash. So the goal is to utilize the pond ash in some other fields to minimize its potential hazard to the environment.

As compared to the natural soil, the weight of pond ash is very less and it has self-draining capability. It is necessary to know the strength characteristics of pond ash before its successful application in various fields. During the construction of embankments, abutments, earthen dams and other retaining structures a huge amount of soil is needed. Due to rapid industrialization and the scarcity of availability of natural soil the scientists thought to utilize the waste products of power plants as a replacement to the natural soil. This will solve the environmental issues due to the deposition of the by-products and also reduce the scarcity of natural soil.

At present scenario the use of pond ash in India in other fields is negligible. Only about 35% of the pond ash is being used commercially. It shows that in order to preserve the valuable natural soil it is necessary to utilize the pond ash to the maximum extent. Recently Pond ash is being used as a filler material in low lying areas. This is also used for embankment construction in some areas. However, its use is limited due to lack of sufficient knowledge about its characteristics and some other physical properties.

The strength of the pond ash is less as compared to the conventional earth material because of less angle of friction and interlocking between the particles as the shape of pond ash particles is sub rounded. Use of reinforcing materials with the pond ash will enhance its geotechnical properties like in case of reinforced earth. For that, the knowledge about the strength characteristics of soil mass and the reinforcement is very much essential.

Chapter 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1. Pond ash:

Pond ash is the product of combination of Fly ash ,Bottom ash and Coal which are by-products of thermal power plants. Together these are mixed with water to form a slurry. That slurry is pumped to the ash pond. In ash pond area, excess water is removed and the ash settles as residue. This residual deposit is called pond ash. This is used as filling materials including in During construction of roads, dams & embankments, pond ash is used as a filler material . Some special type of pond ash is used for manufacturing of building materials like lime fly ash bricks/ blocks etc.

Thermal power plants contribute a major quantity of pond ash. Besides this aluminium, steel, and copper plants also produce a substantial amount of pond ash.

2.2. Reinforcing Fibers:

- Fibers are the load-carrying constituents of composites and occupy the largest volume in a composite laminate.
- Fiber strength is the highest along the longitudinal direction and lowest in the transverse or radial direction.
- Fibers can be continuous or discontinuous. The strength and modulus of composites produced from continuous fibers are greater than those produced from discontinuous fibers.
- A single continuous fiber is called a filament and it has extremely small diameter, which makes it difficult to handle for practical purposes. To obviate this difficulty, a large number of filaments are gathered together into a bundle to produce a commercial form

called a strand. The average tensile strength and modulus of fiber strands are smaller than those of single filaments.

- Strands can be bundled together to produce reinforcing elements in a number of forms, such as uniaxial reinforcements (e.g., reinforcing bars and prestressing strands) and fabrics.
- Fabrics are produced to meet the strength requirements in different directions. Also, fabrics keep fibers aligned prior to resin impregnation.

Types of fibers: Fibers are divided into two categories mainly.

- Natural
- Man-made

Natural fiber: These type of fibers include coir, cotton, sisal, any type of animal hair etc.

Advantages:

- ✓ Coir & Jute are abundantly available in India.
- ✓ Production cost is less. When used for erosion control, saves useful topsoil.
- ✓ Hard, strong and require no pretreatment.
- ✓ Extensive use where temporary reinforcement is required.
- ✓ Being an eco-friendly product, natural fibers, can be used for sustainable development of infrastructure.

Man-made fiber: It includes carbon fiber, polyester, glass fiber, polyvinyl, acrylic etc.

Advantages:

- ✓ Cheaper to produce
- ✓ Stronger
- ✓ More resistant to rot
- ✓ Can be made continuous in any length
- ✓ Can be made to float

Fiber classifications:

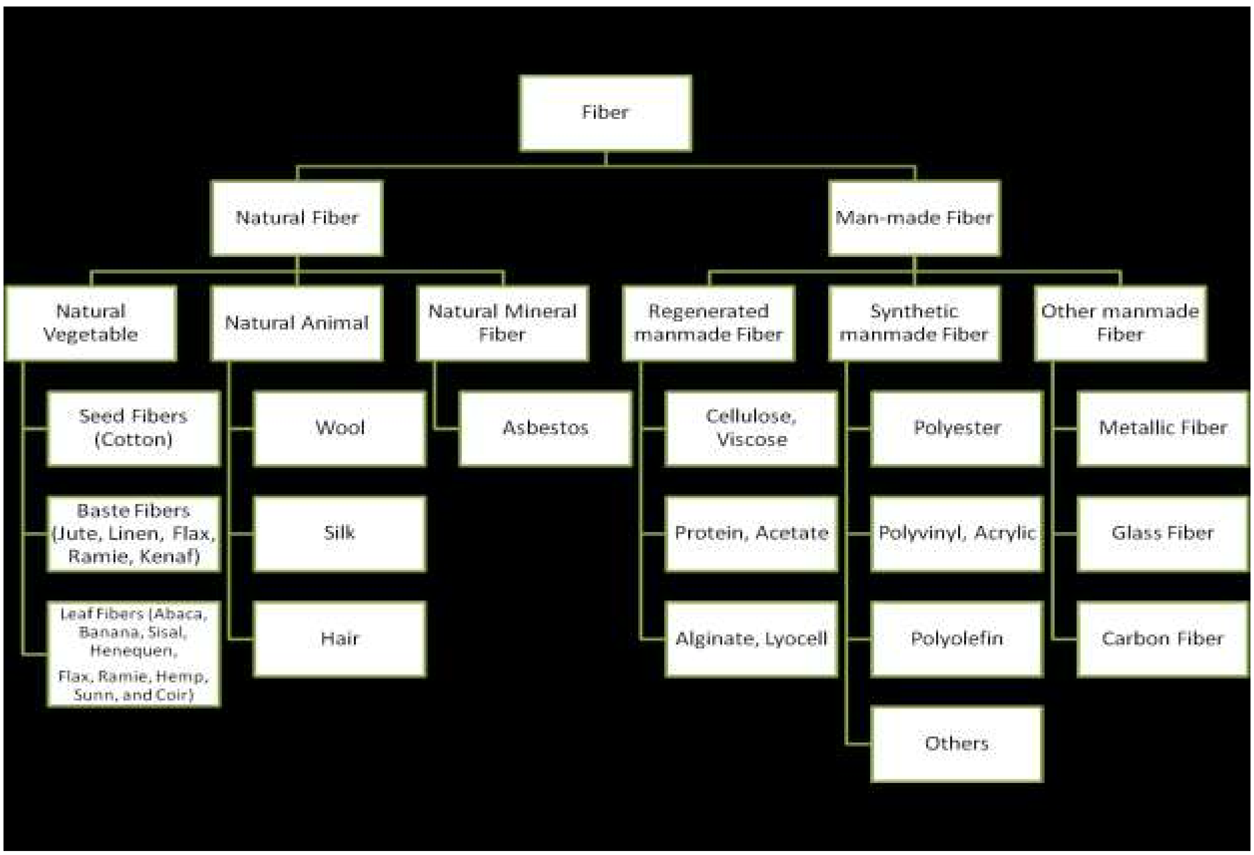

Fig 2.2

Here we are using RECRON-3S as the reinforcing fiber. It is a polyester fiber.

Recron-3S:

Use of Recron-3S as a reinforcing material is to increase the strength in various applications like cement based precast products, filtration fabrics etc.

It also provides resistance to impact, abrasion and greatly improves the quality of construction during foundation, retaining wall design etc.

Roles of Recron-3S

- ✓ Controls cracking
- ✓ Reduce water permeability
- ✓ Increases flexibility
- ✓ Easy to use

2.3. LITERATURE ON REINFORCED POND ASH

PAST STUDY:

Kumar et al. (1999) reported the results of laboratory tests conducted on pond ash & silty sand specimens with randomly distributed polyester fibers. The results showed that the use of fiber as a reinforcing material in soils increases the peak friction angle , peak compressive strength, CBR value, and ductility of the specimens. It also obtained that the optimum fibre content to be used for both pond ash & silty sand is approximately 0.3%- 0.4% of the dry density.

Bera et al. (2007) presented the effect of compaction on the strength characteristics of pond ash.The change in strength due to different compaction, controlling parameters, such as layer thickness, compaction energy, tank size, moisture content, mould area, and specific gravity on the dry unit weight of pond ash are obtained.Same tests were carried out for three different types of pond ash.

It was found that the MDD of pond ash varied within the range of 8.40–12.25 kN/m^3 and the OMC of pond ash varied within the range of 29–46% where as the degree of saturation at OMC was found to vary within the range of 63–89%.

Using multiple regression analysis, an empirical model has been developed for the estimation of the dry density of pond ash in terms of specific gravity, compaction energy and moisture content. To estimate MDD and OMC in the field at any level of compaction energy, numerous linear empirical models have also been developed. These models may be helpful for the engineers in the field for the planning of the field compaction control and for the preliminary estimation of MDD and OMC without much difficulty.

Bera et al. (2007) implemented the effective utilization of pond ash, as a foundation medium.

A series of laboratory tests had been carried out using strip, square and rectangular footings on pond ash. Various tests had been carried out to determine the effects of degree of saturation, dry density of pond ash, shape & size of footings on the ultimate bearing capacity of the shallow foundations. Local shear failure of a square footing at 37% of moisture content (optimum moisture content) was observed to be at a dry density of 11.20 kN/m3 and general shear failure took place at the dry unit weight of 11.73 kN/m3. These experimental results show that the degree of saturation affects the ultimate bearing capacity of shallow footing significantly.

How the size of footing alters the ultimate bearing capacity of pond ash for all types of footings viz. strip, square and rectangular footings are enlightened.

Chand et al. (2007) presented how the lime stabilization affects the strength and durability aspects of pond ash. The lime constituent was as low as 1.12%. Subsequently lime contents of 10% - 14% were used, and the samples were cured with curing temperature of around 30°C for different curing periods of 28days, 45days, 90 and 180 days. Samples were subjected to rebound hammer test, unconfined compression test as well as point load strength test and slake durability test.Unconfined compressive strength (UCS) was obtained to be of 4.8Mpa and 5.8 MPa and the slake durability indices to be 98 and 99% after 180 days of curing for the samples with 10% and 14% lime respectively. Good correlations ,particularly suitable for lime stabilized materials have been derived from point load strength tests , UCS tests and Schmidt rebound hammer tests and also for UCS and slake durability index.

Bera et al. (2009) studied the shear strength of reinforced pond ash. A series of undrained unconsolidated (UU) triaxial tests have been conducted on both unreinforced as well as reinforced pond ash. In the present scenario the effects of confining pressure σ_3, number of reinforcing layers (N), and types of reinforcing fibers on the shear strength of pond ash are studied. The results show that the normal stress at failure σ_{1f} increases with the increase in confining pressure σ_3 .

The rate of increase of σ_{1f} is maximum at 3 layers of reinforcement while the percentage increase in σ_{1f} is around 103%, when the reinforcement layers increase from 2 layers to 3 layers of reinforcement. With the increase in confining pressure σ_3 the increment in normal stress at failure occurs and attains a peak value at a certain confining pressure after which it becomes less or more constant. The peak value of confining pressure σ_3 depends on the type of pond ash and its N value, dry density (γ_d) and also on the type of fiber.

Ghosh et al. (2010) presented the laboratory test results of pond ash (unstabilized) and stabilized with different percentages of lime content of about 4%, 6%, and 10%) to determine the suitability of lime stabilized pond ash for base and sub-base construction of roads. Light and heavy compaction tests have been conducted to obtain the compaction characteristics of the lime stabilized pond ash. California Bearing Ratio tests also have been conducted on the specimens, compacted at MDD and OMC obtained from light compaction tests in both un-soaked and soaked conditions. In this paper the effect of lime content and curing period on the bearing ratio of stabilized pond ash is highlighted. Multiple empirical models have been developed to calculate the bearing ratio for the stabilized pond ash through multiple regression analysis method. Linear empirical relationship also has been presented to estimate the soaked bearing ratio from the un-soaked bearing ratio of lime stabilized pond ash. These experimental results show that the pond ash-lime mixes have the potential for applications in road base and sub-base construction.

Jakka et al. (2010) studied the geotechnical characteristics of pond ash samples, sampled from the outflow and inflow points of two ash pond areas in India. Strength characteristics were obtained using CD (consolidated drained) and CU (consolidated undrained) triaxial tests with pore water pressure measurements, conducted on loose and compacted specimens of pond ash samples under different confining pressures. Ash samples collected from the inflow point of ash pond area exhibited similar behaviour to sandy soils in many aspects. Their strength were higher than the reference material (Yamuna sand), though their specific gravity and MDDs are significantly lower than sands. Ash samples from the outflow point of ash pond area exhibited significant differences in their values and properties as compared to the samples from the inflow point of the ash pond area. Samples from the outflow point had low Shear strength particularly in loose state in which case static liquefaction is observed.

Sharan A. (2011) conducted various tests on pond ash and found that the dry density of compacted specimens changed from 10.90 to 12.70kN/m^3 with the change in the compaction energy from 357 to 3488kJ/m3, whereas the OMC decreased from 38.82 to 28.09%. It is also concluded that by reducing the percentage of water content from the OMC, the UCS value will be increased at a sustained DOS of 13% and 14 % and then, will be decreased in standard proctor density as well as in modified proctor density due to the lubrication of the surface of ash particles. A linear relationship was found to exist between the unconfined compressive strength and the compaction energy. When pond ash is reinforced with fiber, its ductility is increased.

PRESENT STUDY :

From the past study it is pretty clear that several attempts have been made already by the researchers to understand the mechanism of fiber inclusions incorporated into pond ash to improve its geotechnical properties as well as strength by interacting with the pond ash particles mechanically through surface friction as well as by interlocking.

However, the present study is an attempt that has been made to improve the geo-engineering properties of compacted pond ash using polyester fibre (Recron-3S) as the reinforcing material.

Chapter 3
Experimental Work

3.1 Introduction

Experiments were done to determine geotechnical characteristic of pond ash and change in the behavior of pond ash using Recron as a reinforcing material. Physical and chemical parameters of the pond ash were measured. After that engineering property of unreinforced pond ash was measured. Then same experiments were repeated by changing the percentage of fibre in pond ash.

3.2 Material used

1. **Pond ash**
2. **Recron 3s** as reinforcing material

3.2.1 Pond ash

Pond ash sample was collected from NSPCL, Rourkela. The sample passing through the sieve of 2mm dia was used in experiments.

3.2.1.1 Physical parameters of pond ash

Physical parameter of pond ash is represented in table 3.1

Table 3.1 Physical parameters of pond ash

parameter	**value**
color	Light grey
shape	Sub-rounded
Uniformity coefficient	1.93
Coefficient of curvature	1.5
Plasticity Index	Non-Plastic

3.2.1.2 Chemical compositions

Chemical composition of pond ash is represented in table 3.2.

Table 3.2 Chemical parameters of pond ash

Parameter	Value in percentage
SiO_2	59-61
Al_2O_3	28-28.8
Fe_2O_3	2.70-5.52
Na_2O	0.24-0.50
K_2O	1.26-1.76
CaO	0.7-1
MgO	1.40-1.90
LOI	0.5-2.5

3.2.2 Recron 3S

Recron 3S is modified polyester. It is generally used as reinforcing material in concrete and soil to increase their performance. Recron 3S sample used in experiment was of size 12mm and manufactured by RIL.

3.2.2.1 Physical parameters of Recron 3S

Physical parameters of Recron 3S is represented in table 3.3.

Table 3.3 Physical parameters of Recron 3s

Parameter	Value
Cross section	depends
Diameter	35-40 micron
Elongation	>100%
Cut length	3mm,6mm,12mm
Melting point	240-260 C
Softening point	220 C
Specific gravity	1.34-1.40
Colour	white

(By ICC Evaluation Services Inc USA)

3.3 List of experiments which are done:

1. Specific gravity of pond ash
2. Grain size analysis of pond ash
3. Compaction test
4. Direct shear test
5. Unconfined compression test
6. CBR test
7. Footing load test

3.3.1 Specific gravity test (IS 2720(III/SEC-I): 1980

The specific gravity of pond ash was determined by density bottle and illustrated in table 3.4.

Table 3.4 Observations for specific gravity test

Mass of bottle	99.04	103.17	120.9
Mass of bottle + soil	149.04	153.17	170.9
Mass of bottle + soil+ water	376.95	380.43	398.26
Mass of bottle + water	347.9	351.43	369.2
Specific gravity	2.38	2.38	2.38

3.3.2 Determination of grain size distribution (IS 2720(IV):1985)

Pond ash consists of both coarse and fine particles. Sieve analysis was carried out for coarse particle. Hydrometer method was applied to finer particle. Particle size distribution curve was plotted between percent finer vs. particle size. Coefficient of uniformity and co-efficient of curvature were found out using the following formula.

Coefficient of uniformity, $C_u = D_{60} / D_{10}$

Coefficient of curvature, $C_v = (D_{30})^2 / (D_{60} * D_{10})$

3.3.3 Compaction test (IS 2720(VII):1980)

Compaction tests are generally used to determine moisture content-dry density relationship of soil. In light compaction test pond ash at different water content was compacted in the mould in three layers with 25 blows in each layer given by a rammer of 2.6 kg with a drop of 310mm. in case of heavy compaction test pond ash at different water content was compacted in the mould in five layers with 25 blows in each layer given by a rammer of 4.5 kg with a fall of 450mm. a graph was plotted between moisture content and dry density. From which OMC and MDD values were found out. Compaction tests were carried out for different compaction energy by increasing or decreasing number of blows given by rammer and presented in table 3.5.

Table 3.5 MDD and OMC of pond ash at different compaction energy

Sl no.	Compaction energy E(kJ/m3)	MDD	OMC
1	595	1.054	38.8
2	893.6	1.102	38.2
3	2139.2	1.183	35.5
4	2674	1.225	33.6

3.3.4 Direct shear test (IS 2720(XIII):1986)

The c and Φ values of pond ash are found out by direct shear test. It consist a box with a dimension 60x60x50mm depth. Specimen of size 60x60x24 was prepared at MDD and OMC and sheared with a constant strain for different normal stress. A graph is plotted between shear stress vs normal stress. From which c and Φ values are found out. Direct shear test was conducted for the soil samples at light compaction density and heavy compaction density with varied fibre content and results are shown in table 3.6 and 3.7.

Table 3.6 Shear parameters of pond ash at light compaction MDD and OMC

Sl no	Fiber content (%)	C (kg/cm^2)	Φ (°)
1	0	0.163	28.88
2	0.2	0.23	30.35
3	0.5	0.27	30.96
4	0.75	0.29	31.38
5	1	0.3	32.62

Table 3.7 Shear parameters of pond ash at heavy compaction MDD and OMC

Sl no	Fiber content (%)	C (kg/cm^2)	Φ (°)
1	0	0.19	32.2
2	0.2	0.27	34.6
3	0.5	0.3	35.75
4	0.75	0.32	37.5
5	1	0.33	39.0

3.3.5 Unconfined compression test (IS 2720(X):1991)

This test was performed to determined unconfined compressive strength of pond ash. sample was prepared at MDD and OMC. Then it was filled in the split mould of 5cm dia and 10cm height. Sample was extracted by sample ejector. Then the sample was tested in a compression testing machine. A graph was plotted between stress vs. strain. From which UCS value was found out. Unconfined compression test was carried out for the soil samples at light compaction at light compaction density and heavy compaction density with varied fibre content. Results are shown in table 3.8 and 3.9.

Table 3.8 UCS values for different fiber contents at light compaction MDD and OMC

Sl no	Fiber content (%)	UCS (kg/cm^2)
1	0	0.23
2	0.2	0.28
3	0.5	0.36
4	0.75	0.40
5	1	0.42

Table 3.9 UCS values for different fiber contents at heavy compaction MDD and OMC

Sl no	Fiber content (%)	UCS (kg/cm^2)
1	0	0.36
2	0.2	0.42
3	0.5	0.48
4	0.75	0.52
5	1	0.54

3.3.6 Unsoaked CBR test (IS 2720(XVI):1987)

Unsoaked CBR test was used to evaluate the sub grade strength of pond ash. Sample was prepared at MDD and OMC and compacted in a mould of 15cm dia, 17.5cm height. The whole arrangement with a surcharge load was kept for penetration test. For different values of penetration, load readings were recorded. Unsoaked CBR value was determined corresponding 2.5 and 5 mm penetration value. Similar test was carried out for samples at light compaction at light compaction density and heavy compaction density with varied fibre content. Results are shown in table 3.10 and 3.11.

Table 3.10

Unsoaked CBR values for different fiber contents at light compaction MDD and OMC

Sl no.	Fiber content (%)	CBR value corresponding to 2.5mm penetration (%)	CBR value corresponding to 5mm penetration (%)
1	0	10.34	10.29
2	0.2	15.4	15.01
3	0.5	20.9	19.2
4	0.75	24.8	22.1
5	1	28.9	24.8

Table 3.11

Unsoaked CBR values for different fiber contents at heavy compaction MDD and OMC

Sl no.	**Fiber content (%)**	**CBR value corresponding to 2.5mm penetration (%)**	**CBR value corresponding to 5mm penetration (%)**
1	0	19.37	17.2
2	0.2	26.04	25.65
3	0.5	31.3	28.9
4	0.75	36.03	32.7
5	1	38.9	36.5

3.3.7 Footing load test

This test was carried out to determine the ultimate bearing capacity of pond ash for a circular footing of dia 5cm. sample was prepared at MDD and OMC and compacted in a mould of 25.8cm dia and 30.4 cm height. A circular footing of 5cm dia was placed on the sample and the whole arrangement was tested in compression testing machine. A graph was plotted between stress and strain. From this graph bearing capacity of pond ash was found out. Similar test was carried out for different degree of saturation and results are shown in table 3.12.

Table 3.12 Ultimate bearing capacity of pond ash at different degree of saturations (light compaction MDD and OMC)

Sl no.	**MDD (gm/cc)**	**Degree of saturation (%)**	**Ultimate bearing capacity(kN/m^2)**
1	1.054	33.43	157.8
2	1.054	53.43	313.0
3	1.054	63.43	417.0
4	1.054	73.43	454.9
5	1.054	83.43	571.7
6	1.054	93.43	519.9
7	1.054	100	174.2

Chapter 4
Graphs and Results

4.1 Index Properties:

4.1.1 Specific gravity:

The Specific gravity of pond ash was found to be 2.38.

4.1.2 Liquid limit:

Liquid limit is the minimum water content at which soil is in liquid state but possesses small shear strength against flowing. As the pond ash is non plastic, the liquid limit can't be found out.

4.1.3 Plastic limit:

Plastic limit is the minimum water content at which soil begin to crumble when it is rolled into a 3mm dia thread. Due to non plastic nature of pond ash, plastic limit can't be found out.

4.1.4 Grain size distribution

Grain size distribution curve was determined by sieving and hydrometer analysis. Grain size distribution curve is represented in figure 4.1. The coefficient of curvature and coefficient of curvature were found to be 1.93 and 1.5 respectively.

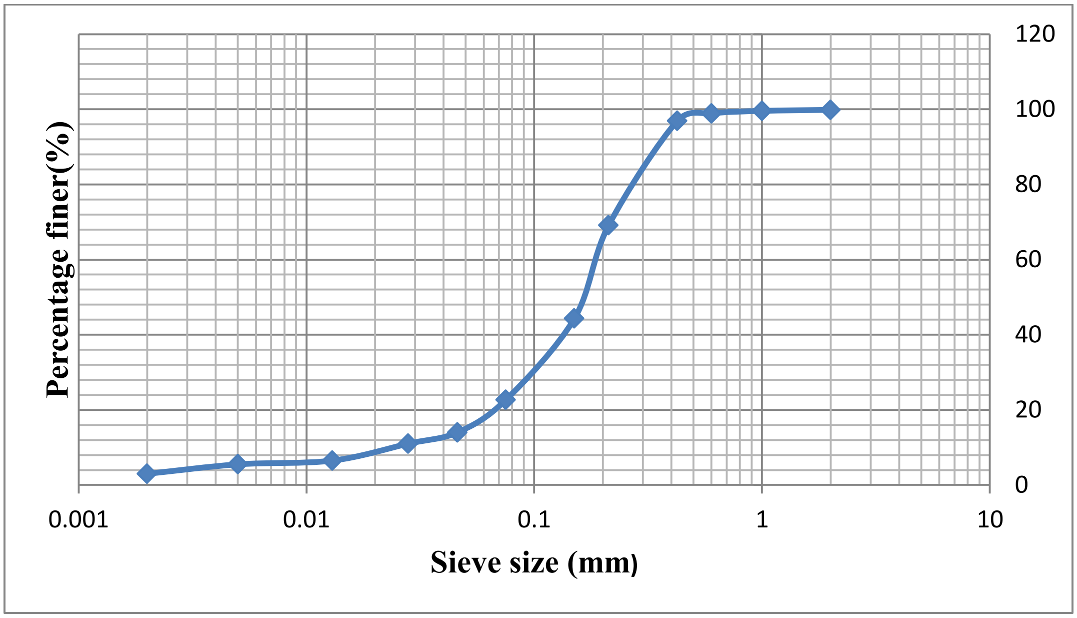

Fig 4.1.4. Grain size distribution curve

4.2 Engineering Properties:

4.2.1 Compaction test

Compaction tests were carried out at different compaction energy (595kJ, 893.6kJ, 2139.2 kJ and 2674kJ) and corresponding MDD and OMC were found out. In experiment we can see the dry density increases with increase in moisture content up to achieve MDD. Further addition of water decreases the dry density. Results are shown in table. Maximum dry density of pond ash is increasing with increase in compaction energy where as optimum moisture content is decreasing with increase in compaction energy. Figure 4.2 to 4.5 shows the graph related to compaction test.

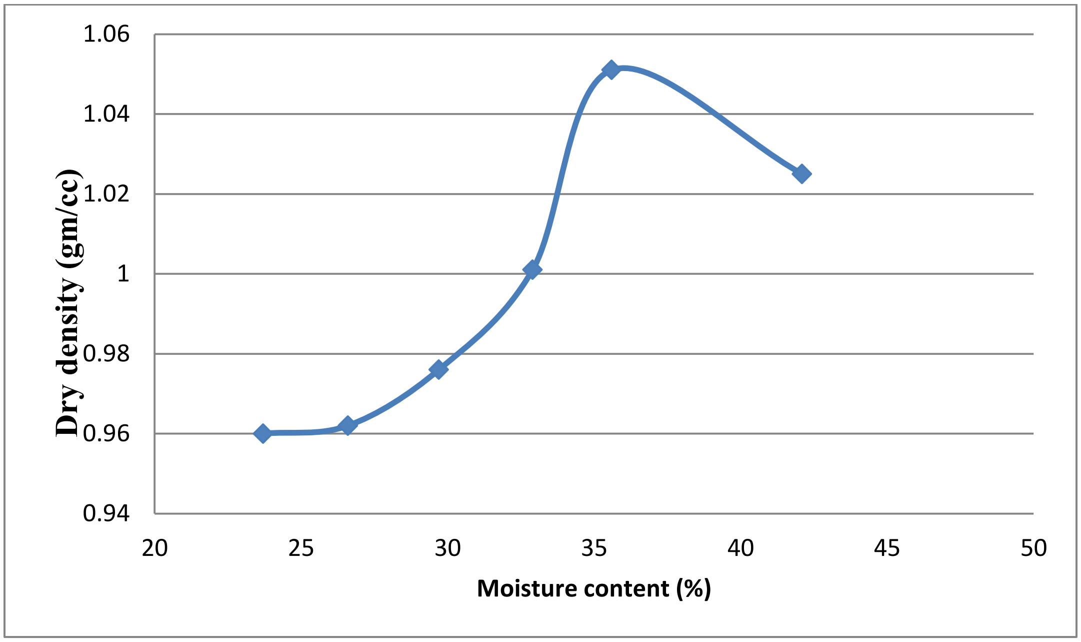

Fig4.2.1.1 Variation of dry density with moisture content at compaction energy 595kJ/m^3

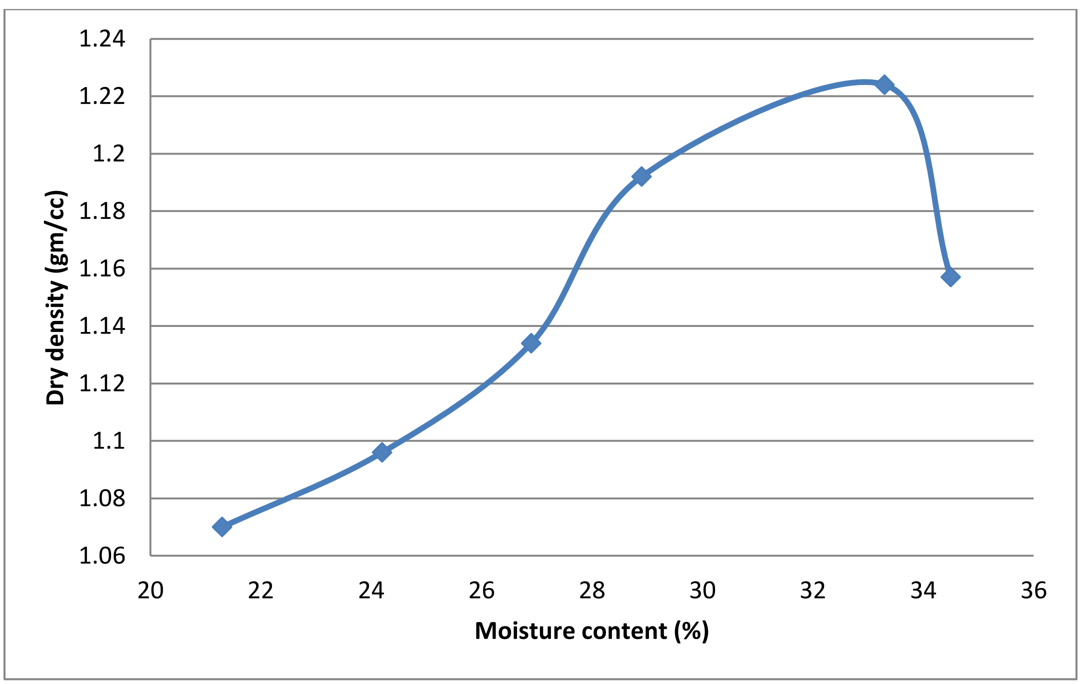

Fig4.2.1.2 Variation of dry density with moisture content at compaction energy 2674kJ/m^3

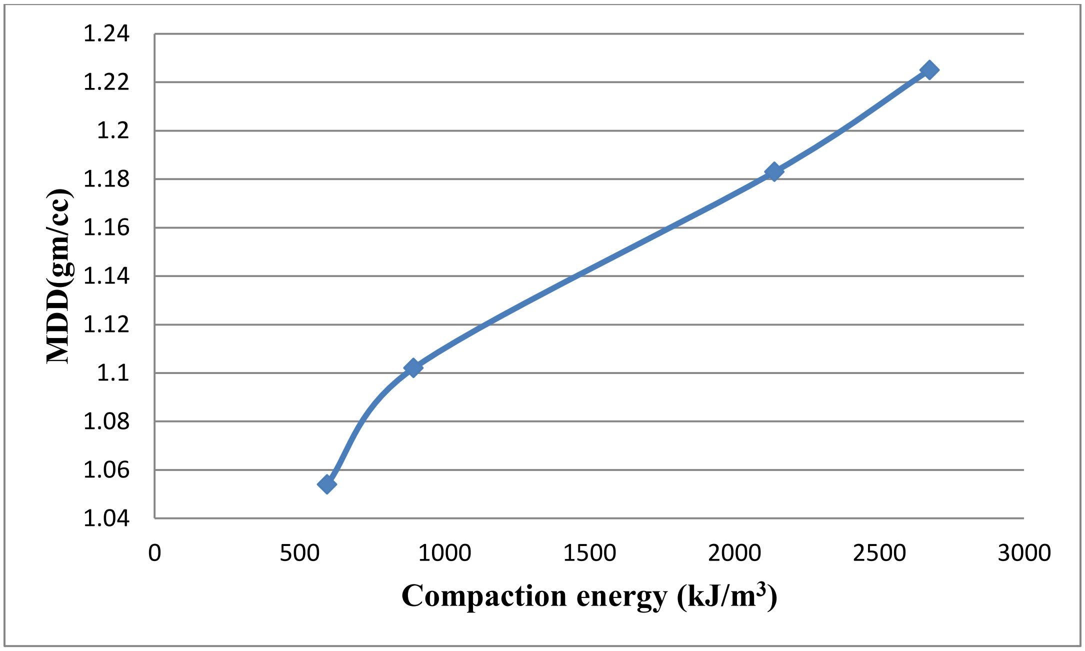

Figure 4.2.1.3. Variation of dry density with compaction energy

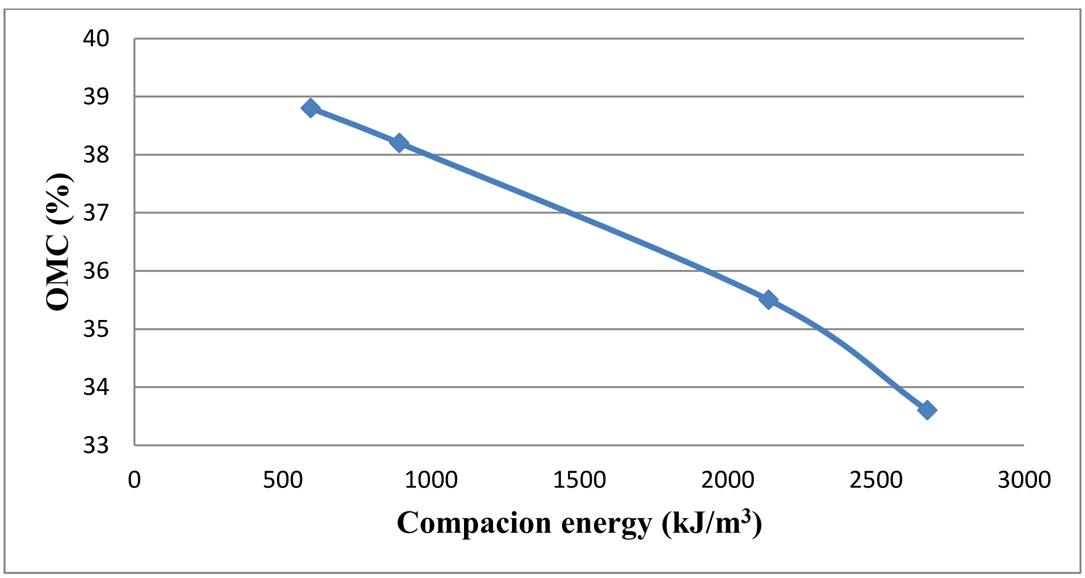

Figure 4.2.1.4. Variation of moisture content with compaction energy

4.2.2 Direct shear test

Direct shear test was conducted for unreinforced pond ash at MDD and OMC corresponding to light compaction test and heavy compaction test. Shear parameters were determined from the graph between normal stress vs. shear stress. Then the same test was carried out by changing the percentage of fibre (0.2%-1%) in pond ash and shear parameters were determined by same process. Results are shown in table 3.6 and 3.7. Figure 4.6 to 4.9 Show the graph related to direct shear test. The value of Shear parameters are increasing with increase in percentage of fibre in pond ash. When the soil was compacted at light compaction density and moisture content, the unit cohesion and angle of friction vary from 0.163-0.3 kg.cm2 and 31.38-33.82 with change in percentage of reinforcement from 0-1%. In case of heavy compaction density and moisture content unit cohesion and angle of friction vary from 0.19-0.33 and 30.11-38.0 with change in percentage of reinforcement from 0-1 %.

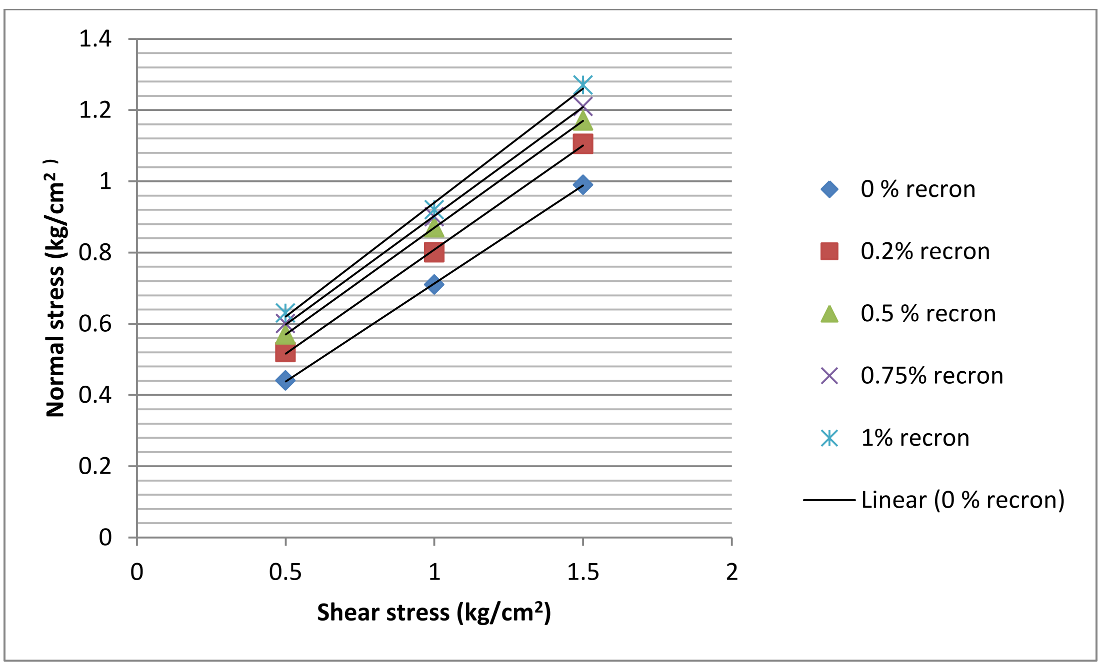

Figure 4.2.2.1 Normal stress vs. Shear stress (light compaction MDD and OMC)

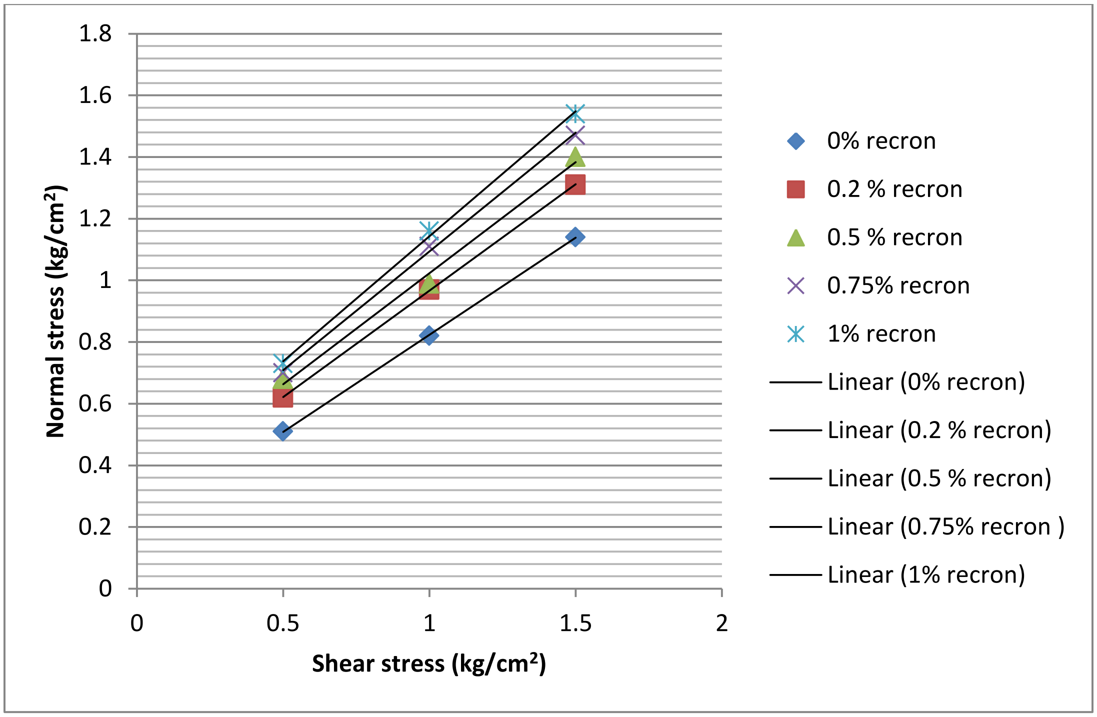

Figure 4.2.2.2 Normal stress vs. shear stress (heavy compaction MDD and OMC)

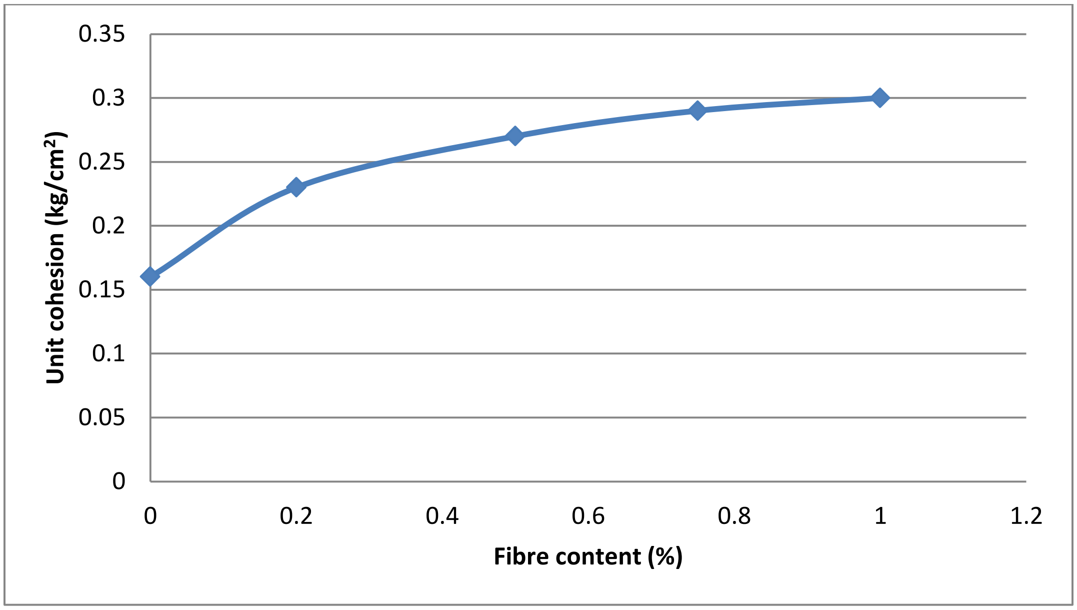

Figure 4.2.2.3 Variation of unit cohesion with fiber content (light compaction MDD)

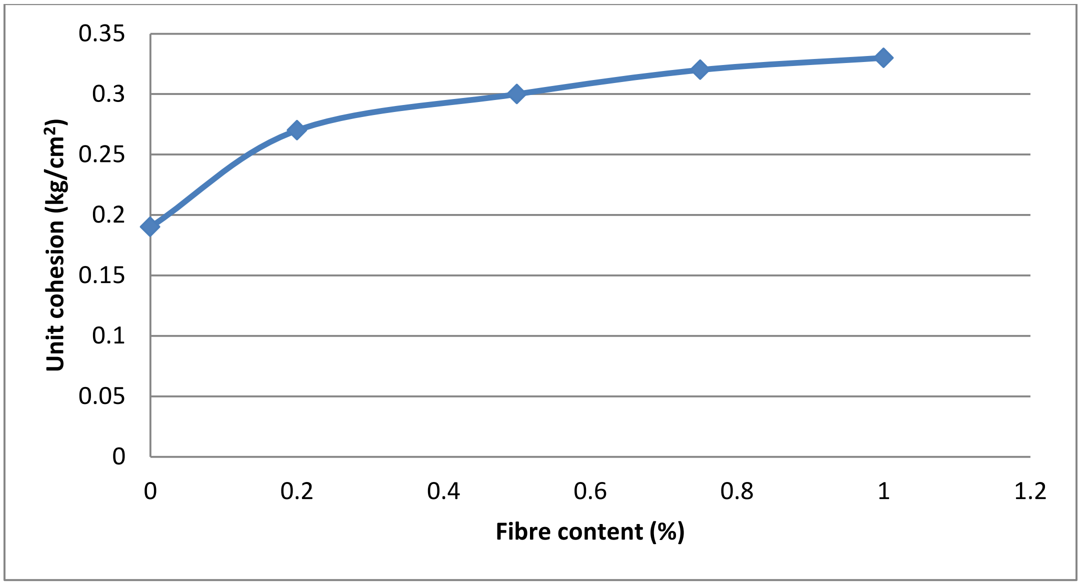

Figure 4.2.2.4 Variation of unit cohesion with fiber content (heavy compaction MDD)

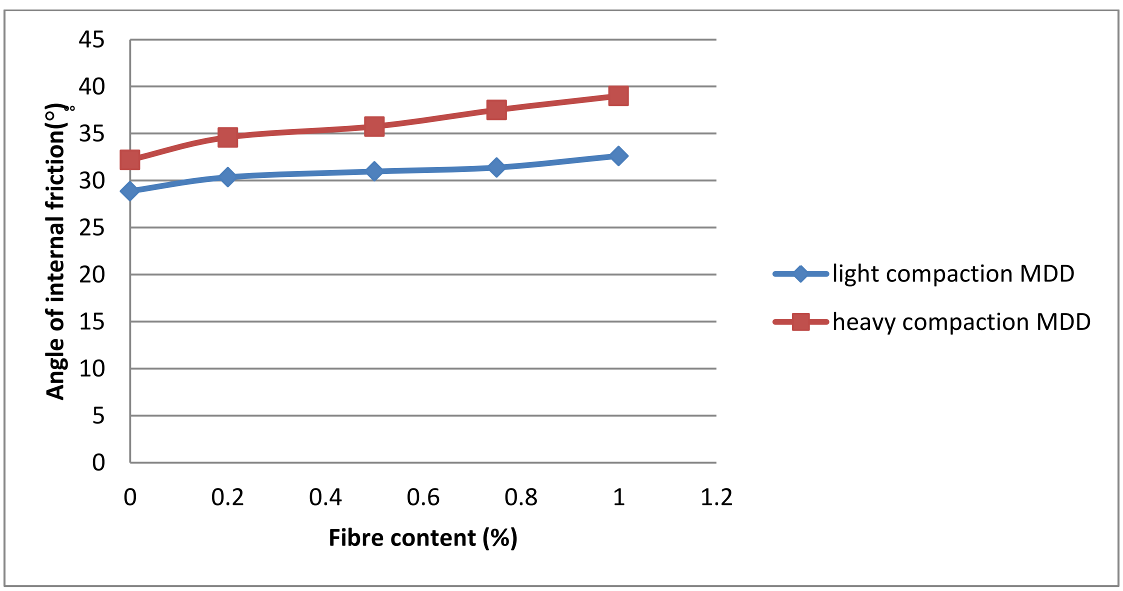

Figure 4.2.2.5 Variation of angle of internal friction with fiber content

4.2.3 Unconfined compression test

Pond ash with and without fibre content was prepared at MDD and OMC corresponding to light compaction test and heavy compaction test. Unconfined compression was carried out to determine UCS value of these samples. Results are given in table 3.8 and 3.9. Stress strain relationship for unreinforced pond ash and reinforced pond ash are shown in figure 4.10 to 4.13.The UCS value varies from 0.23-0.42 with change in fibre content 0-1% at light compaction MDD and OMC. Similarly UCS value varies from 0.23-0.42 with change in fibre content 0-1% at heavy compaction MDD and OMC. The UCS value is increasing with increase in percentage of fibre in pond ash. The rate of increasing is not constant. Initially the rate of increment in UCS is more; gradually it decreases with increase in percentage of fibre content.

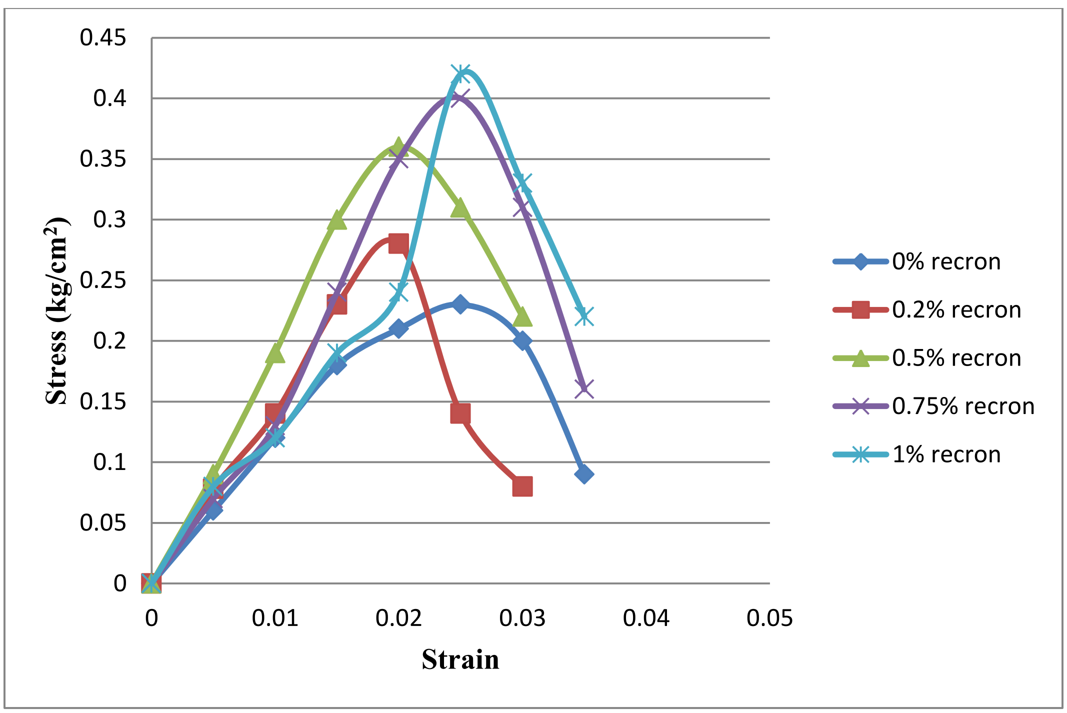

Figure 4.2.3.1 Stress vs. strain relationship (light compaction MDD)

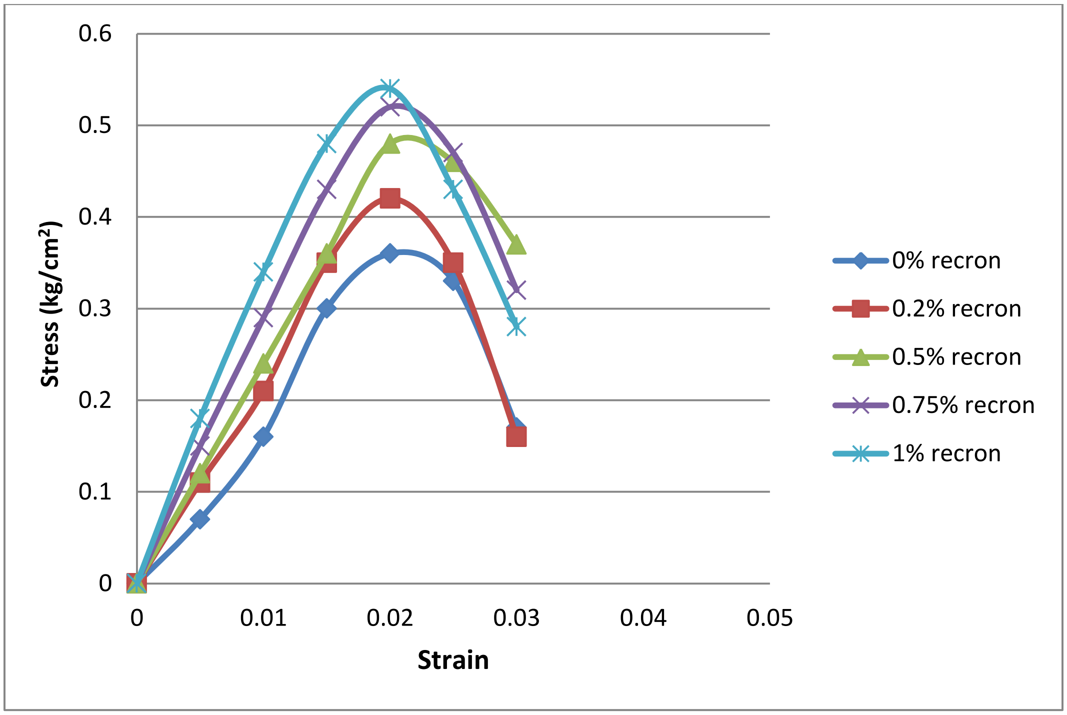

Figure 4.2.3.2 Stress vs. strain relationship (heavy compaction MDD)

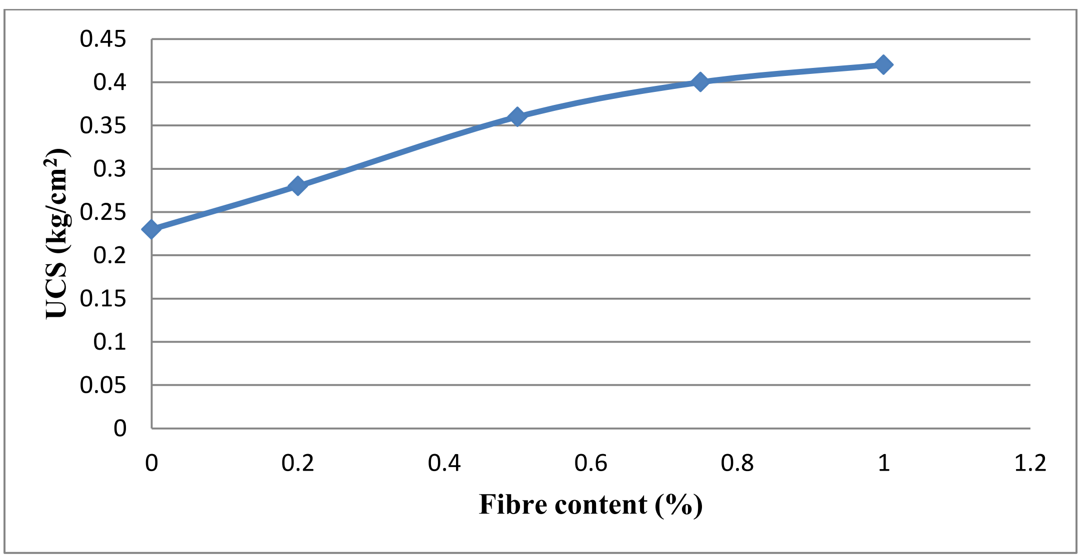

Figure 4.2.3.3 Variation of UCS with fiber content (light compaction MDD)

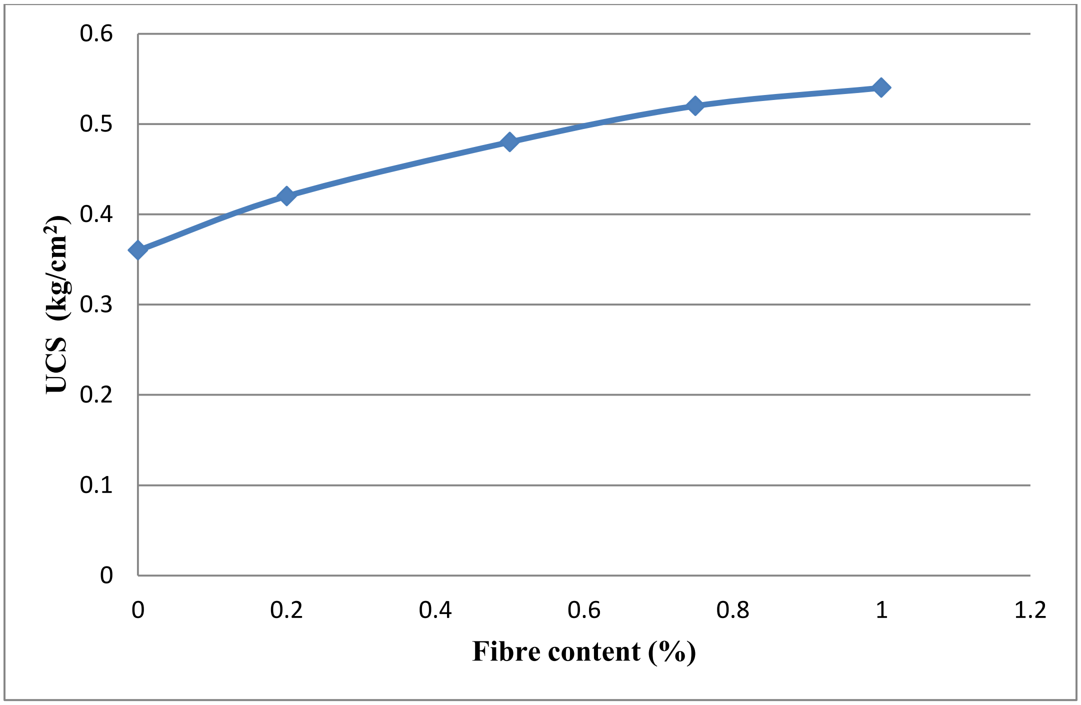

Figure 4.2.3.4 Variation of UCS with fiber content (heavy compaction MDD)

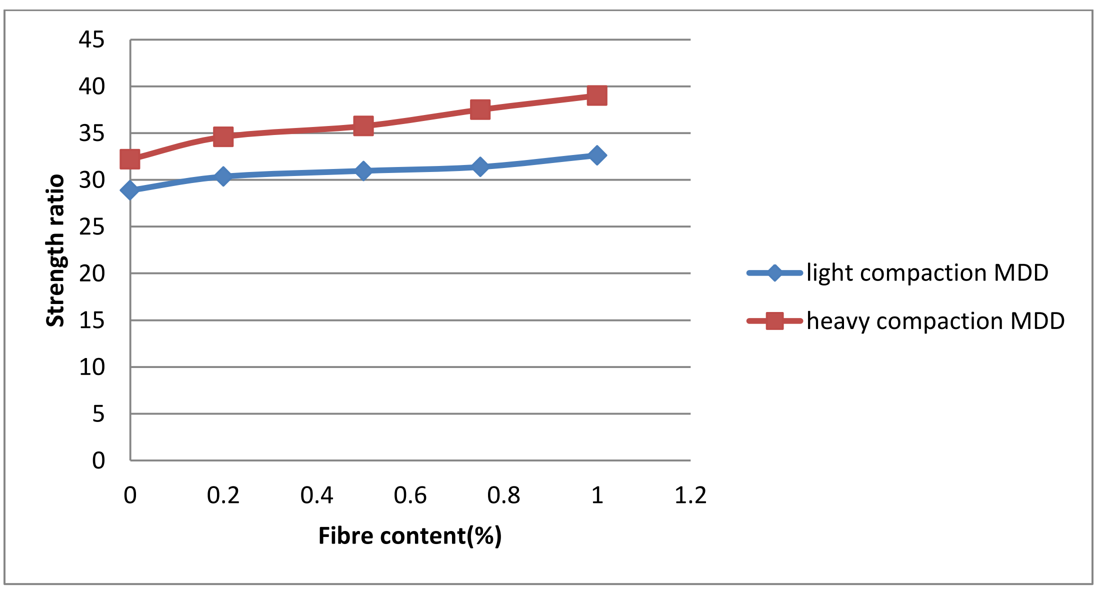

Figure 4.2.3.5 Variation of strength ratio with fiber content

4.2.4 Unsoaked CBR Test

Unsoaked CBR tests were conducted for unreinforced pond ash at MDD and OMC corresponding to light compaction test and heavy compaction test. Load vs. penetration curve was plotted for each test. Unsoaked CBR values corresponding 2.5mm and 5mm penetration are given in table 3.10 and 3.11. Unsoaked CBR value for 5mm penetration is always less than CBR values corresponding 2.5 mm penetration. Load vs. penetration curve for different percentage of fibre is given in figure 4.14 and 4.15. Unsoaked CBR value at light compaction MDD and OMC was increased from 10.34-28.9 % (CBR corresponding 2.5mm penetration) with change in fibre content 0-1%. In case of heavy compaction test it varies from 19.37-38.9%.

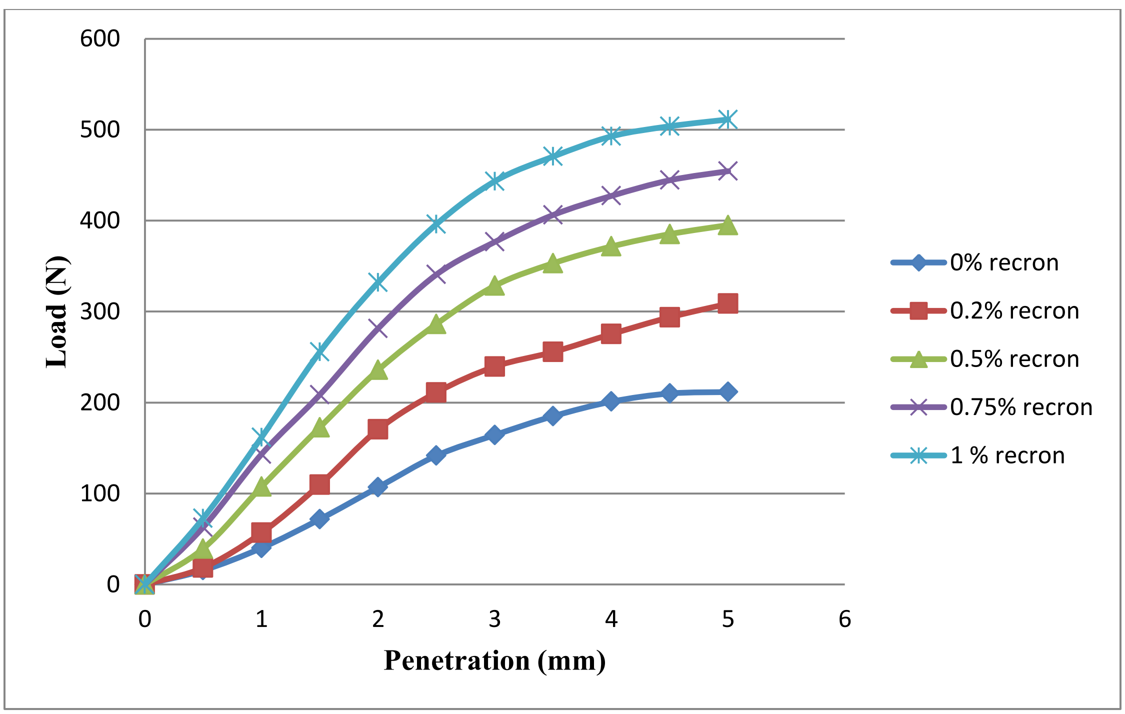

Figure 4.2.4.1 Load vs. penetration curve (light compaction MDD)

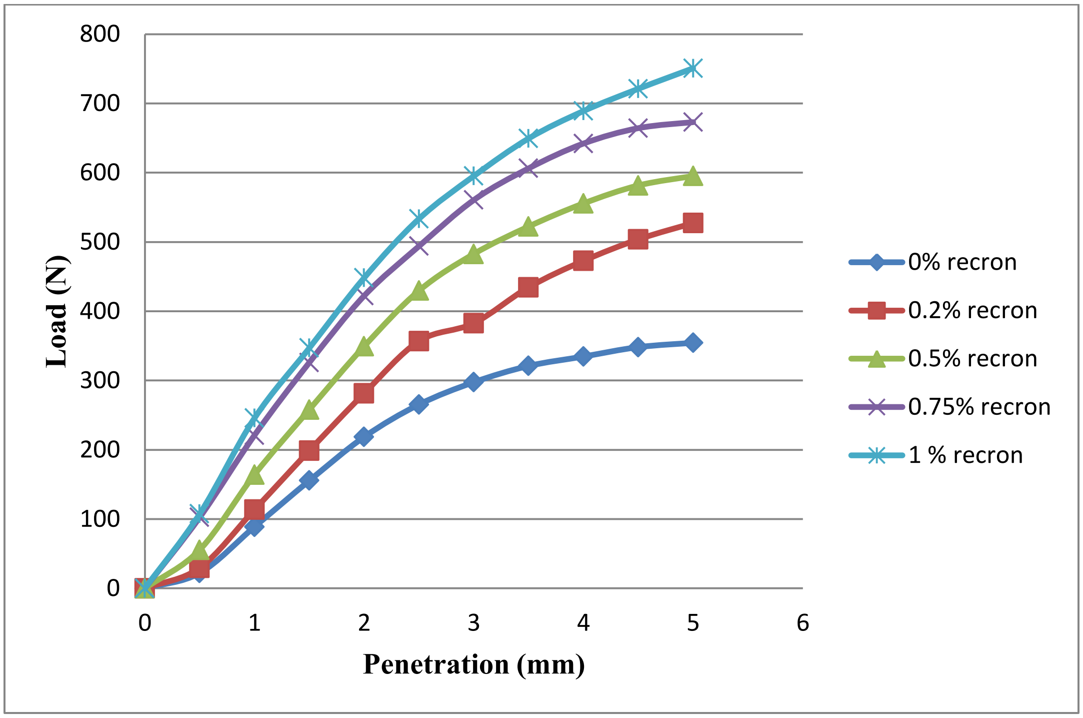

Figure 4.2.4.2 Load vs. penetration curve (heavy compaction MDD)

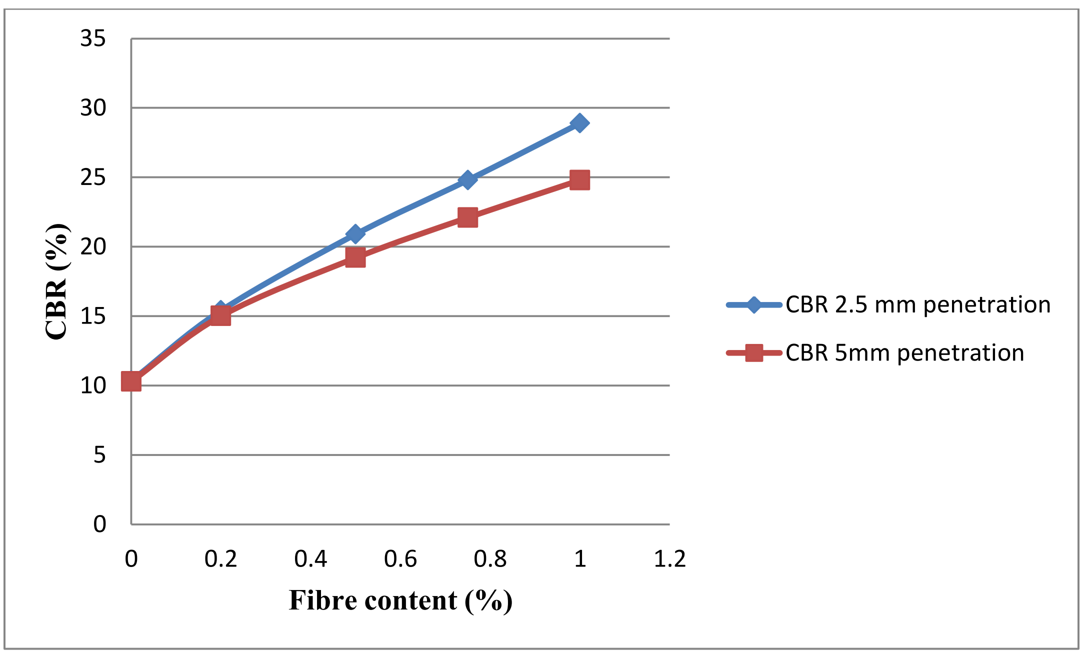

Figure 4.2.4.3 Variation of CBR value with percentage of fiber (light compaction MDD)

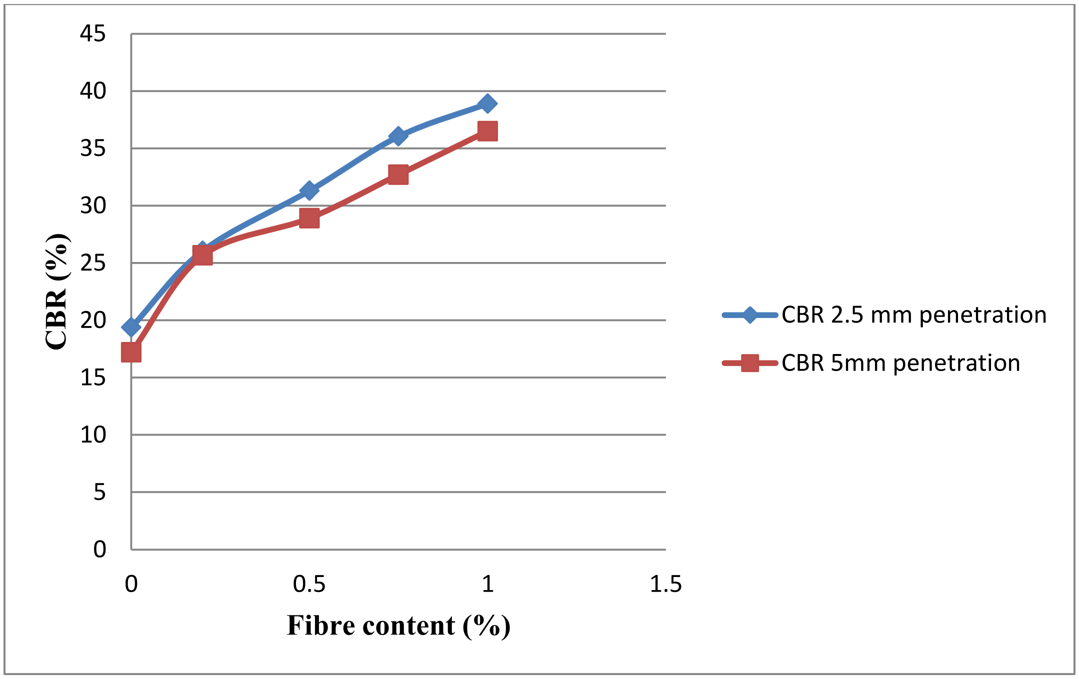

Figure 4.2.4.4 Variation of CBR value with percentage of fiber (heavy compaction MDD)

4.2.5 Footing load test

This test was conducted to determine ultimate bearing capacity of pond ash for circular footing at different values of degree of saturation. Bearing resistance vs. settlement curve was plotted for different values of degree of saturation. Results are shown in table 3.12. Ultimate bearing capacity of pond ash increases with increase in degree of saturation with some extent, after that it starts decreasing. Graphs between bearing capacity vs. settlement for different value of degree of saturation are given below. The graph between ultimate bearing capacities vs. degree of saturation is given in figure 4.18.

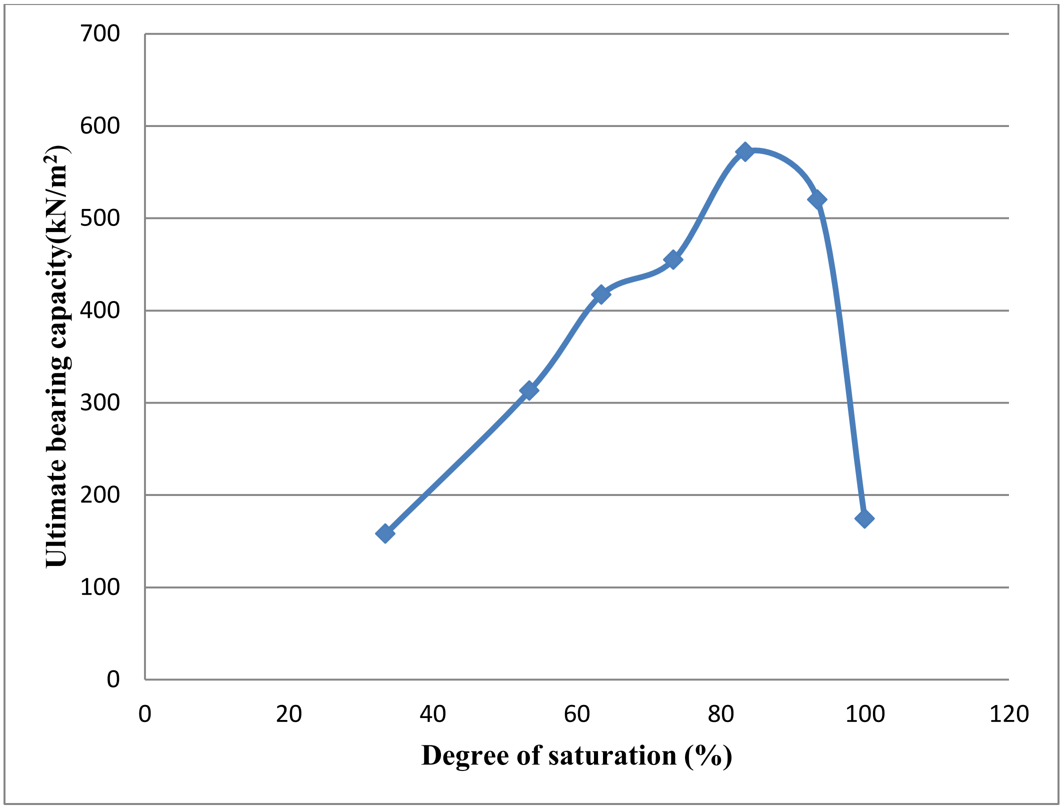

Figure 4.2.5.1 Ultimate bearing capacity vs. degree of saturation (light compaction density)

4.3 Conclusions:

- The specific gravity of pond ash is 2.38. This property helps in building light embankments over soft soil.
- Particle size distribution curve represents a well graded soil. Generally contains fine sand particles and silt particles.
- Pond ash is non plastic in nature so atterburgs limit can't be determined.
- Maximum dry density varies from 1.054gm/cc to 1.225gm/cc with change in compactive effort from 595kJ/m^3 to 2674kJ/m^3.
- Optimum moisture content varies from 38.8% to 33.6% with change in compactive effort from 595 kJ/m^3 to 2674 kJ/m^3.
- Increase in compaction energy increases the maximum dry density.
- However MDD is not linearly dependent to compaction energy.
- Increase in compaction energy decreases the optimum moisture content.
- Cohesion value and angle of friction increases with increase in percentage of fibre content in pond ash.
- Cohesion value increased up to 76 % and with change in percentage of fiber from 0 to 1 % at light compaction MDD and OMC.
- Cohesion value increased up to 82% with change in percentage of fiber from 0 to 1 % at heavy compaction MDD and OMC.
- Cohesion value is not linearly dependent to change in percentage of fibre. The increase in cohesion value at fiber content 0-0.5% is more than fiber content 0.5-1%.
- Angle of friction is not much affected by reinforcement.

- UCS value of pond ash increases with increase in percentage of fiber content in pond ash.
- UCS value increased from 0.23 kg/cm^2 to 0.42 kg/cm^2 with change in percentage of fiber content from 0 to 1 % at light compaction MDD and OMC.
- UCS value increased from 0.36 kg/cm^2 to 0.54 kg/cm^2 with change in percentage of fiber from 0 to 1 % at heavy compaction MDD and OMC.
- The increase in UCS is non- linear with respect to fibre content.
- The ductility characteristic was increased by using fiber.
- Unsoaked CBR value of unreinforced soil compacted at light compaction MDD and OMC found to be 10.38%. Unsoaked CBR value was increased up to 28.9% by increasing the fiber content to 1 %.
- Unsoaked CBR value of unreinforced soil compacted at heavy compaction MDD and OMC found to be 19.38%. CBR value was increased up to 38.7% by increasing the fiber content to 1 %.
- The rate of increment of Unsoaked CBR value is not linear with fiber content.
- Unsoaked CBR value corresponding 2.5mm penetration is always greater than 5mm penetration.
- Reinforced pond ash can be used for sub base as its Unsoaked CBR value is more.
- Ultimate bearing capacity of pond ash was increased with increase in degree of saturation up to 83.93 %, and then decreased.

Reinforced pond ash shows good engineering properties as conventional earth material. So pond ash can replace the conventional earth material in some of the geotechnical constructions.

Chapter 5
References

5. References

- IS: 2720(Part 2), 1973 Methods of Test for Soils, Determination of water content.
- IS 2720(III/SEC-I): 1980 Methods of Test for Soils, Determination of specific gravity.
- IS 2720(VII):1980 Methods of Test for Soils, Determination of water content dry density relation using light compaction.
- IS 2720(XIII):1986 Methods of Test for Soils, direct shear test
- IS 2720(X):1991 Methods of Test for Soils, determination of unconfined compression test.
- IS 2720(XVI):1987 Methods of Test for Soils, determination of CBR.
- IS 2720(IV):1985 Methods of Test for Soils, determination of grain size analysis.
- Punmia B.C. "Soil Mechanics & Foundations" Laxmi Publications
- Sharan A. (2011)" Strength characteristics of fibre reinforced compacted pond ash" M .tech thesis, NIT, Rourkela.
- Jakka R.S., Ramanna G.V., Datta M. (2010) "Shear Behaviour of Loose and Compacted Pond Ash" Geotech Geol Eng Vol.28:763–778.
- Raj P. (2010) "Compaction characteristics and shear parameters of pond ash "B .tech thesis, NIT, Rourkela.
- I.V. Suresh, C. Padmakar, Prabha Padmakaran, M.V.R.L. Murthy, C.B. Raju, R.N. Yadava, K. Venkata Rao, (1998),"Effect of pond ash on ground water quality: a case study",Environmental Management and Health, Vol. 9 Iss: 5 pp. 200 -208