LOAD CARRYING CAPACITY OF REINFORCED POND ASH BEDS

A Dissertation submitted in partial fulfilment of the requirements
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MASTER OF TECHNOLOGY

IN

GEOTECHNICAL ENGINEERING

By

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CERTIFICATE

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Date:-21 June 2015

This is to certify that report entitled **"LOAD CARRYING CAPACITY OF REINFORCED POND ASH BEDS"** by **LALAN KUMAR PASWAN** is the requirement of the partial fulfilment for the award of Degree of **Master of Technology (M.Tech)** in **Geotechnical Engineering** at **Delhi Technological University**. This work was completed under my supervision and guidance. He has completed his work with utmost sincerity and diligence. The work embodied in this project has not been submitted for the award of any other degree to the best of my knowledge.

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ABSTRACT

It is required to increase the usage of coal ashes. Pond ash is the waste product of thermal power plants. Pond Ash is a non-plastic cohesion less material that can be used as a fill material in Geotechnical structures like retaining wall, embankment. Soil reinforcement technique is used for improvement of poor soils. Geo-textiles, Geo-grid sheets, Metal strips, Synthetic geo-textiles, Natural geo-textiles, at random distribution used as reinforcing materials to the soil. The soil reinforcement causes important improvement in shear strength, physical property, bearing capacity and economy. Soil reinforcement is an easy technique for ground improvement. Experimental study is going to be done using geo-textile and sand layer. The geo-textile layers are placed at different depths from top of the mould. By the suitable reinforcement the strength of the compacted pond ash fills can be retained partially. The compacted pond ash beds are reinforced with fibreglass sheet. The position of the reinforcement, the number of layers of reinforcement and overlain sand layer thickness was varied. In first set of experiments a series of California bearing test (CBR tests) were conducted on pond ash beds reinforced by fibreglass sheet. The CBR values of these specimens were found out and these are compared with that of the unreinforced pond ash bed compacted to MDD at OMC. In second set of experiments the CBR value of compacted pond ash beds overlain by sand layer compacted to different relative densities and different moisture contents are evaluated. After a series of CBR test on pond ash beds reinforced by fibreglass sheet and pond ash beds overlain by sand layer, it can be concluded that with the increase in depth of reinforcement the CBR value decreases. When the depth of reinforcement is 2 times the diameter of the plunger, practically there is no improvement in the CBR value of reinforced pond ash. When the number of layers of fibreglass reinforcement increases; the CBR value of reinforced pond ash beds increases. CBR value increases with the increase in thickness of overlain sand layer, so the CBR value of compacted pond ash can be improved by putting a layer of sand over it. When the water content of sand layer increase; the CBR value of reinforced pond ash beds increases.

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CHAPTER 1
INTRODUCTION

1.1 GENERAL

It is required to increase the usage of coal ashes. Pond ash is the waste product of thermal power plants. Pond Ash is a non-plastic cohesion less material that can be used as a fill material in Geotechnical structures like retaining wall, embankment. Soil reinforcement technique is used for improvement of poor soils. Geo-textiles, Geo-grid sheets, Metal strips, Synthetic geo-textiles, Natural geo-textiles, at random distribution used as reinforcing materials to the soil. The soil reinforcement causes important improvement in bearing capacity, shear strength, physical property and economy. Soil reinforcement is an easy technique for ground improvement. Experimental study is going to be done using geo-textile and sand layer. The geo-textile layers are placed at different depths from top of the mould.

1.2 OBJECTIVES

- The effect of reinforcement placement position on the CBR value of the compacted pond ash.
- The effect of water content on the CBR value of compacted sand.
- The effect of the overlain sand layer in improving the CBR value of compacted pond ash.

1.3 SCOPE OF STUDY

Limited work has been done to investigate the effectiveness of reinforcements in improving the load carrying capacity of the compacted pond ash. Keeping this in mind a series of laboratory tests were conducted to investigate: 1.The effect of reinforcement size and placement position on the CBR value of the compacted pond ash. 2. The effect of water content on the CBR value of compacted sand and the effect of the overlain sand layer in improving the CBR value of compacted pond ash.

1.4 UTILIZATION OF POND ASH

a) Pond ash is suitable for back fill of low lying area and, dyke rising.
b) It is also used for the manufacture of Portland cement.
c) Pond ash is also used for stabilization of soil with appropriate amount of cement or lime, which leads in the decrement of the cost of foundation and pavement.

d) It is also used for filling of reinforced earth wall pavements and flyover approaches.

e) It is used as stowing materials for mines.

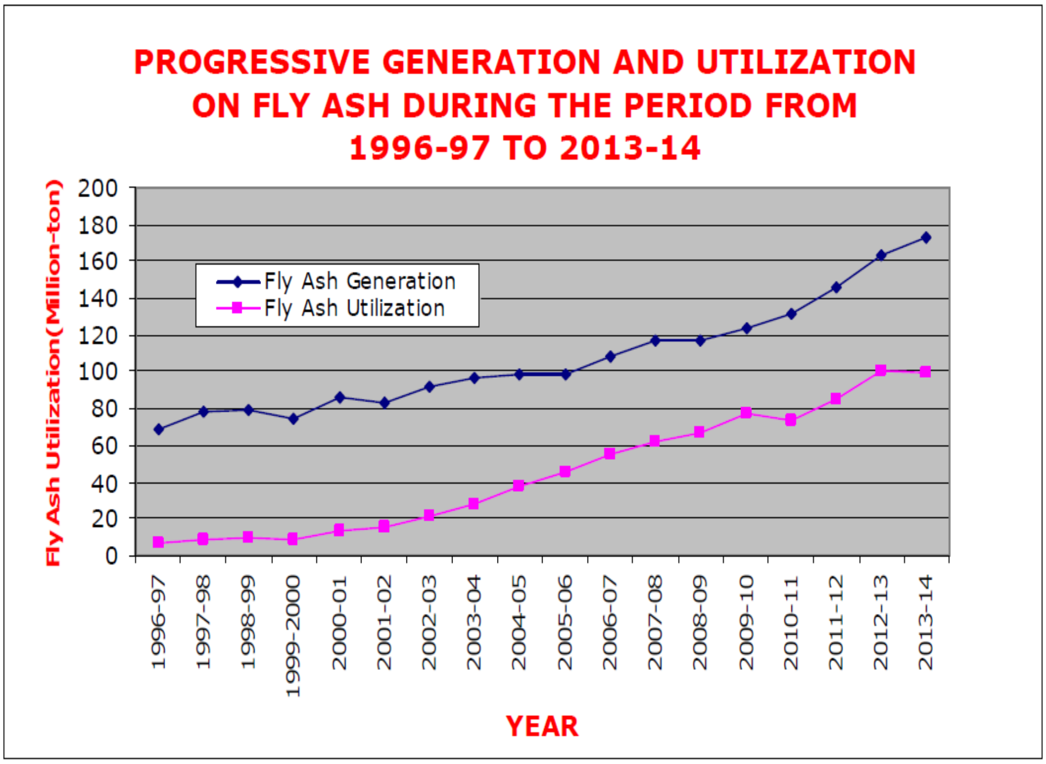


Fig.1.1 Graph showing generation of fly-ash and its utilization for the period from 1996 - 1997 to 2012 - 2013

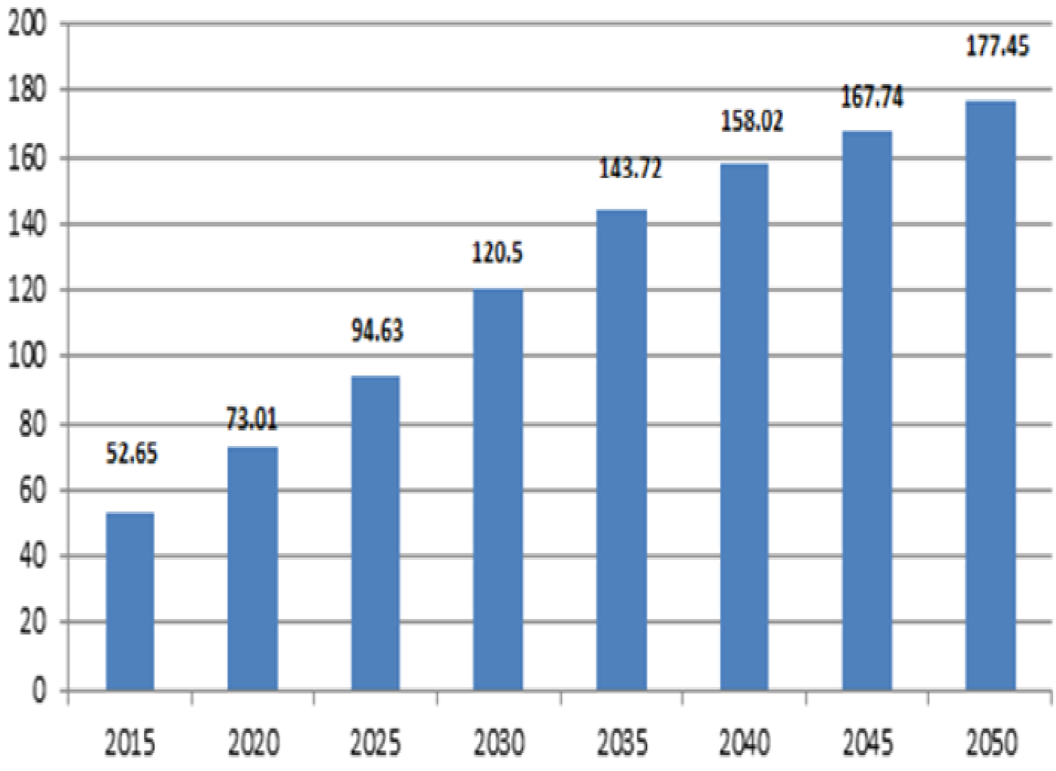


Fig.1.2 Expected absorption of Fly-ash in cement per year in million tons

CHAPTER 2
LITERATURE REVIEW

2.1 BEARING CAPACITY OF NON-WOVEN GEO -TEXTILE REINFORCED POND ASH

M.V.S. Sreedhar, et al. [2011] Increasing the utilisation of coal ashes which is possible only through better knowledge and understanding of their engineering properties. A lot of efforts and experiments are to be performed to investigate the behaviour of Pond Ash reinforced with a non-woven Geo-textile. Load bearing method is investigated in terms of the effect of overburden and the effect of depth of placement of the reinforcement. In many cases the maximum bearing capacity of reinforced pond ash beds is coming out at depth 2 cm from top.

2.2 BEARING CAPACITY IMPROVEMENT OF POND ASH USING FIBRE REINFORCEMENT

Sharan A., S. P. Singh; [2011] They were performed a series of CBR tests on pond ash reinforced with fibre. They concluded that the bearing resistance increases as the fiber content increases. At low strain levels the bearing resistance is found to remain almost constant with fiber content. However, the bearing resistance is found to increase substantially to increase in fiber content at higher strain level. This shows that the higher strain is required to mobilize the strength of the fiber; it is observed that as fiber content increases for a given compacted density the initial stiffness decreases but the failure strains increases. This shows that the fiber content gives ductility to the specimens. It can further be observe that for the unreinforced sample the reduction in the post peak strain is comparatively lower than the reinforced.

Goutham Kumar Pothal et.al; [2007], were conducted triaxial test and load tests on reinforced pond ash and according improvement in bearing capacity. Bera et.al., Have reported conducting laboratory load tests on pond ash at its MDD, reinforced with 3 types of plastic Geo-textiles and one variety of jute geo-textile. They reported that, ideal depth of placement was 0.255B, wherever B is the dimension of the model footing. The modification in strength may be due to completely different controlling and compaction parameters such as layer thickness, compaction energy, tank size, wetness content, the mould dimension which correspond the area of mould and relative density on the dry unit weight of pond ash are obtained.

Kumar et.al; [1999] given the results of laboratory investigations conducted on loose sand and pond ash specimens reinforced with arbitrarily distributed polyester fibers. The test results indicated that compressive strength increases will the inclusion of fibers in soils. The result also indicated that the CBR value, peak friction angle increases will the inclusion of fibers in soils. It's complete that the optimum fiber content for both loose sand and pond ash is approximately 0. 3 to 0.4 % of volume unit weight.

2.3 BEARING CAPACITY IMPROVEMENT OF SOIL USING REINFORCEMENTS

Binquet, et al. [1975] they were the first to report a systematic study on bearing capacity of reinforced soil beds. They performed model plate load tests with parametric variation and proposed a method of analysis and design. They selected 76.2mm wide strip footing on sand reinforced with aluminium strips and conducted model tests. They performed the test under following three conditions:

1. Homogeneous sand layer
2. Sand layer over layer of very soft material simulating soft clay or peat
3. Sand layer above a finite sized pocket of a very soft material.

H.P. Singh et al., [2012] ware conducted experimental study on soil reinforcement with jute geo-textile layers. The jute geo-textile layers are placed inside the soil sample in several combinations. CBR values were determined in each soaked and un-soaked condition comparable to each combination of reinforcing layer. Further, these test results were compared therewith of unreinforced soil. It was found that inclusion of Jute Geo-textile layer increases the CBR value of soil.

2.3.1 BEARING CAPACITY IMPROVEMENT OF SOIL USING FIBER REINFORCEMENT

Lindh and Eriksson [1990] They were used monofilament polypropene fiber at fiber content of 0.25% and 0.5% to reinforce the sand (C_u = 3.5 and D_{50} = 0.5mm). They were performed a field experiment by placing a reinforced sand layer on the present road surface for field experiment. Their result shows that no rutting is taken place.

Maher and Gray [1990] Have reinforced the coarse sand of nine varieties at C_u=1 to 4, D_{50} = 0.09 to 0.6mm, 100% wet content with rubber (diameter =1.1mm), glass (diameter = 0.3mm), reed fiber (diameter = 0.3). Their Drain triaxial tests show that low modulus fibers (rubber) contribute very little to strength despite higher interface friction. Failures surface is plain and adjusted at (45+Φ/2). An increase in particle sphericalness is higher in crucial confining pressure and lower fiber contribution. Higher aspect ratio resulted lower confining pressure and increasing shear strength.

Bauer and Fatani; [1991] They were concentrated on study of silty sand (with C_u = 5, D_{50} = 0.9, c = 10kN/m^2, Φ=470 at optimum moisture content) reinforced with copper (flexible, diameter = 0.8mm, and 32 fibers aligned), steel fiber (rigid, diameter = 3mm) and They conducted the pull out test and direct shear test at modified proctor density test of 2.08 t/m^3 and moisture content of 8.9%, Φ=370 and δ=23°. The result shows that the residual strength of composite is 200th to 300th above unreinforced soil and well graded soil provide highest anchorage capacity.

Fatani et al. [1991] Have studied on the silty sand with C_u = 5, D_{50} = 0.9, c =10 kN/m^2, Φ=470 and reinforced with 70 mm long monofilament fiber and random, number varies from 5 to 32. They performed Drained direct test at modified proctor dry density γ = 20.8 kN/m^3 and optimum water content 8.9%, orientation of fiber is at right angle to the shear plane. On the basis of result it can be concluded that fiber placed parallel to test plane of direct shear box caused reduction in shear strength. In at random place, only 10 -20% fibers cross the shear plane is really imparting the strength.

Michalowski and Zaho [1996] They used polyamide monofilament and steel fibers (dia0.3, 0.4 mm aspect ratio 85 and 180, fiber length and content 25 mm and 0.5% respectively) to reinforce the dry sand (with C_u = 1.52 and D_{50} = 0. 89).The result obtained from triaxial test shows that the addition of steel fibers increases the peak stress by 20%.

2.3.2 BEARING CAPACITY IMPROVEMENT OF SOIL USING SHEET REINFORCEMENT

Chandra et al.; [2008] have used polypropylene fiber of 0.3mm diameter to reinforce the three types of soil clay, silt and sand. The fibers were cut into pieces of 15mm, 25mm, and 30mm in length and aspect ratio of 50, 80 and 100 respectively and with 0.75%, 1.5%, 2.25% and 3% by dry weight of soil. Triaxial test of reinforced and unreinforced soil was conducted. Their result shows that the uniaxial compressive strength is 3.824, 4.836 and 9.712MPa respectively.

CHAPTER 3
MATERIALS USED

3.1 POND ASH: Pond ash in bulk quantities were collected from NTPC, Badarpur. Before testing pond ash was dried in the oven at temperature 105°-110°

3.1.1 Collection of Pond Ash

Fig.3.1 Collection of Pond Ash from Badarpur (NTPC Ash Pond)

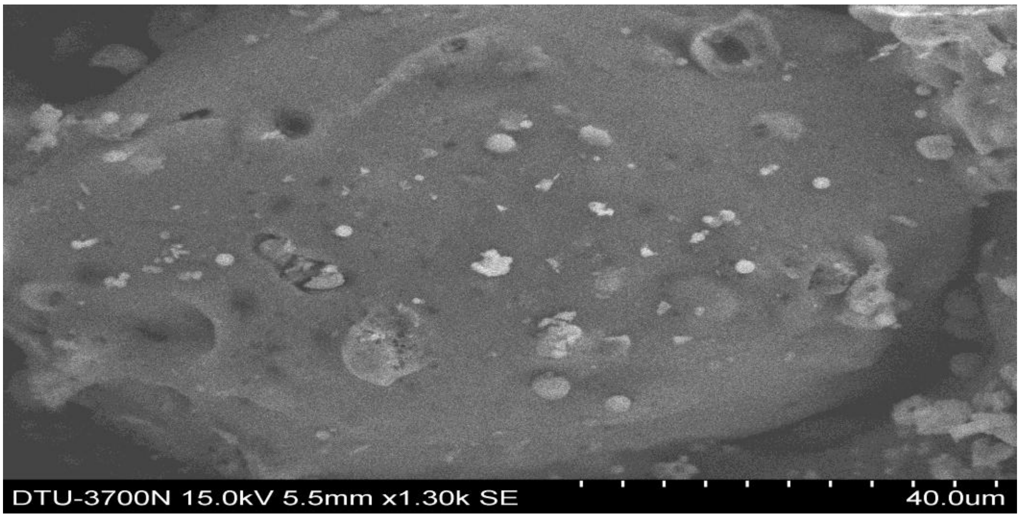
3.1.2 Properties of Pond Ash

Table.3.1 Properties of Pond Ash

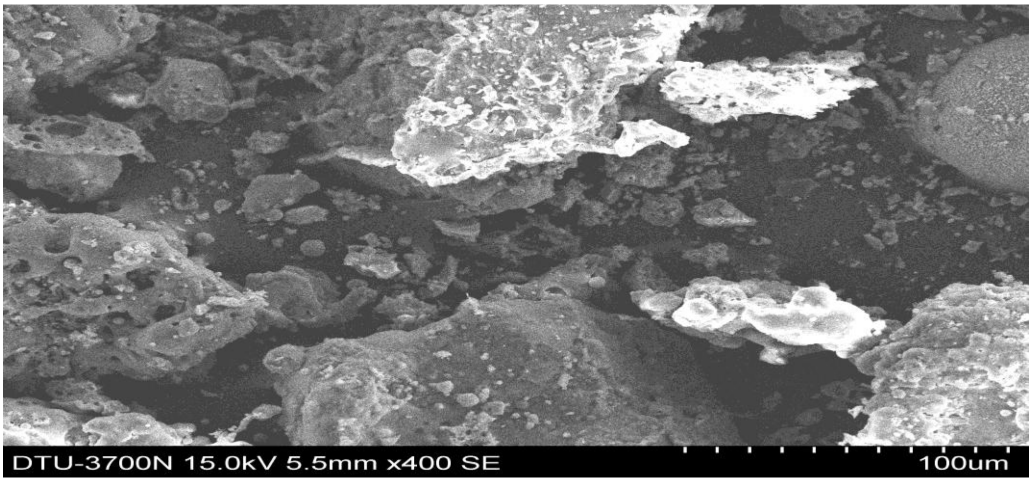
Constituents in Percentage	**Badarpur Pond Ash**
SiO_2	49.50
Al_2O_3	25.01
MgO	1.21
Fe_2O_3	9.81
CaO	4.48
Loss of Ignition	9.79
Others	0.08

3.1.3 Scanning Electron Microscope (SEM) analysis of Pond ash

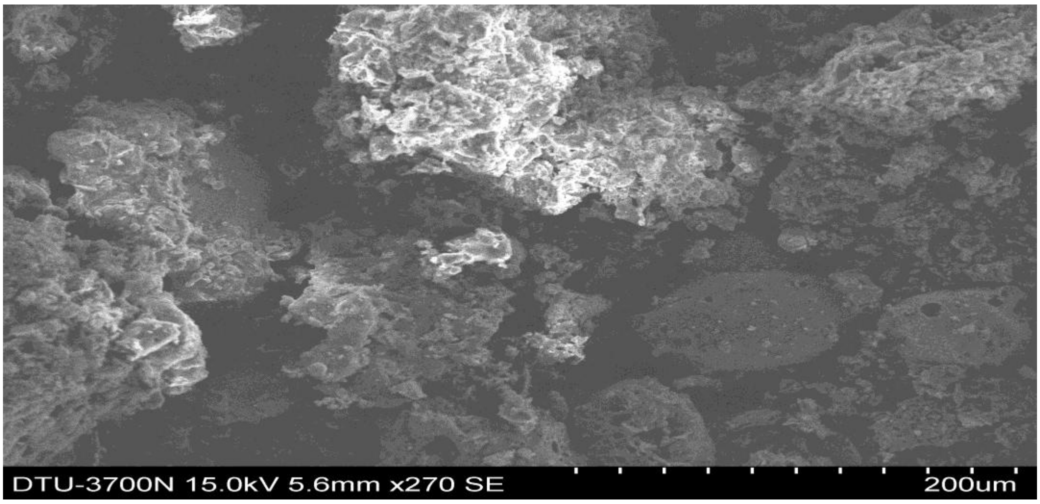
Mineralogy characterizing of the samples can be done in many ways, but SEM is one of the best way. The SEM identifies the morphology of the structure. The SEM of Pond Ash is shown in Figs. 3(a), 3(b) and 3(c). These figures reveal better bonding among pond-ash particles. Figs. 3.1(a), 3.1(b) and 3.1(c) shows the Scanning Electron Microscope (SEM) of sand. The scale used for pond ash and sand are 40μm, 100μm, 200μm.



(a) SEM image of pond ash at 40µm scale



(b) SEM image of pond ash at 100µm scale

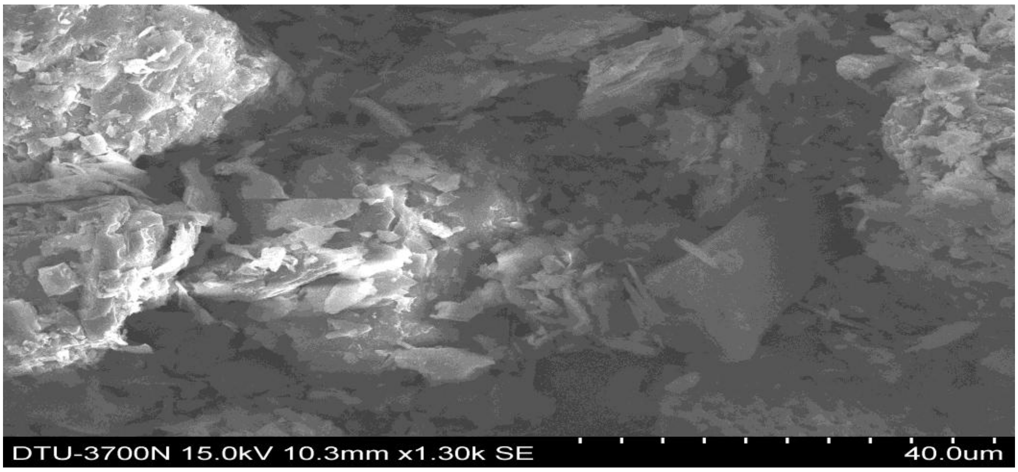


(c) SEM image of pond ash at 200µm scale

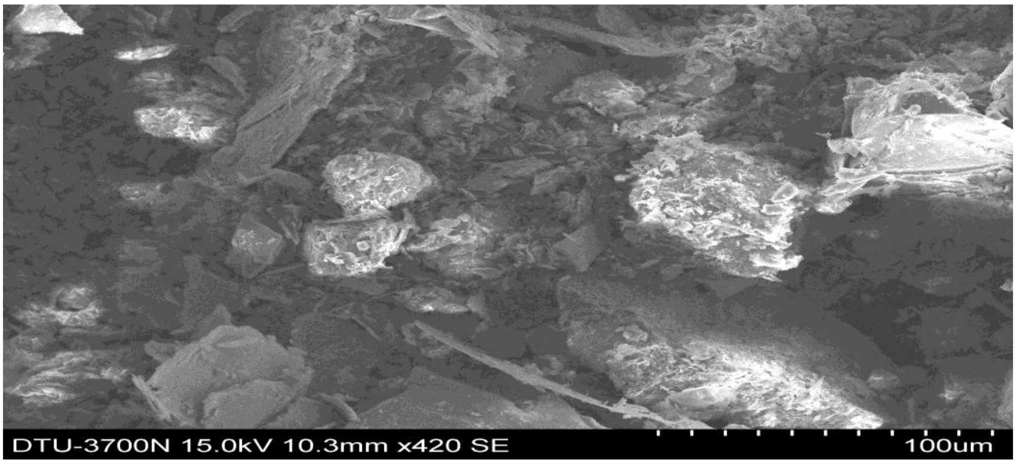
Fig.3.2 SEM image of Pond Ash at 40µm, 100µm, 200µm scale

3.2 SAND: The sand in bulk quantities were collected from Yamuna River, Delhi

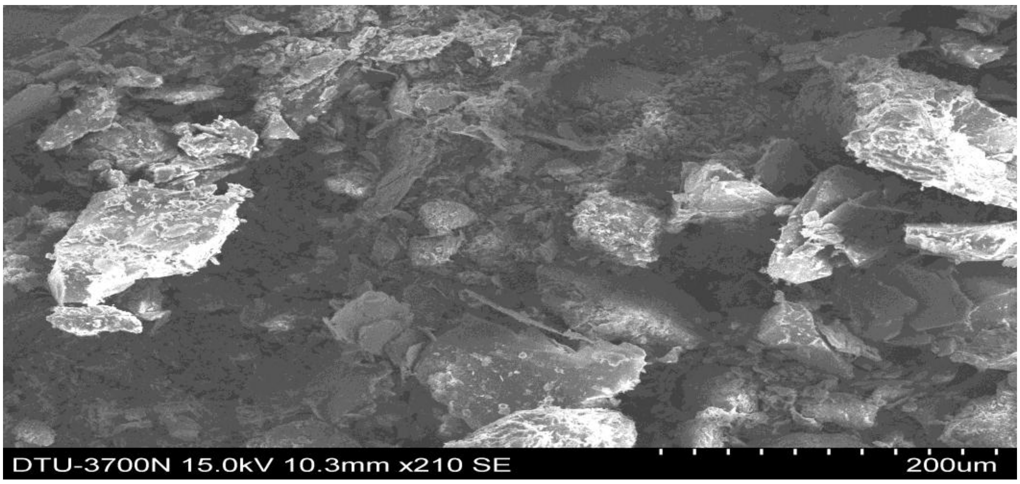
3.2.1 Scanning Electron Microscope (SEM) analysis of sand



(a) SEM image of Sand at 40μm scale



(b) SEM image of Sand at 100μm scale



(c) SEM image of Sand at 200μm scale

Fig.3.3 SEM image of Sand at 40μm, 100μm, 200μ scale

3.3 REINFORCING MATERIAL: The fibreglass sheet is used as reinforced material.

3.3.1 Tensile strength of reinforcing material

Table.3.2 Tensile strength characteristics of reinforcing material

Maximum Load (kN)	Tensile extension at maximum Load (mm)	Tensile stress at maximum Load (MPa)	Length (mm)
0.49016	60.04566	28.11093	26.6700
Thickness (mm)	Width (mm)	Area (mm^2)	Extension at break (Standard)(mm)
0.93000	12.0000	11.16000	65.21327
Tensile strain at Break (standard) (mm/mm)	Maximum Extension (mm)	Load at Maximum Extension (N)	Modulus (Automatic) (MPa)
2.45689	65.21327	313.71797	24.50550
Modulus (Automatic) (MPa)	Final area (cm^2)		
24.50550	0.03600		

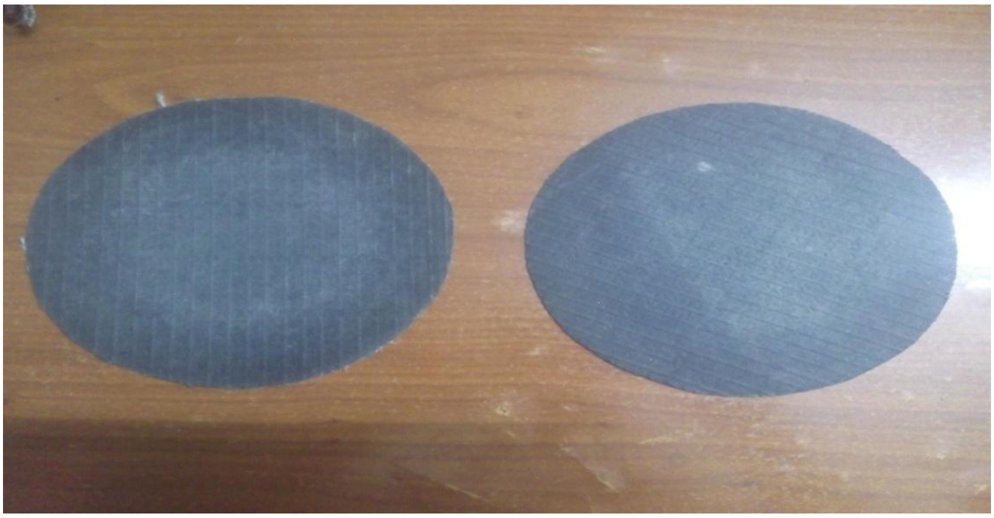
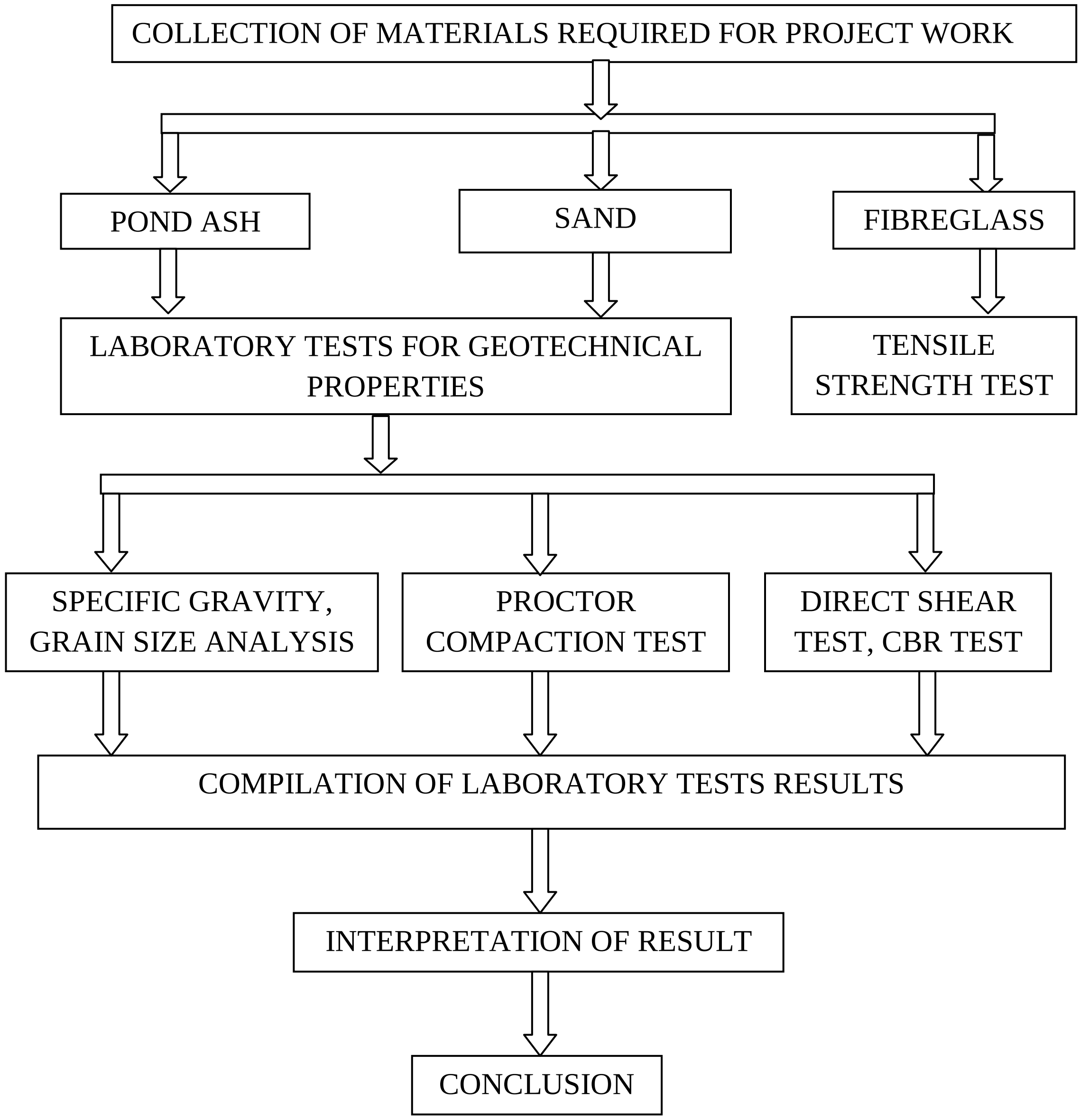


Fig.3.4 Fibreglass sheet used to reinforce the pond ash beds

CHAPTER - 4
METHODOLOGY

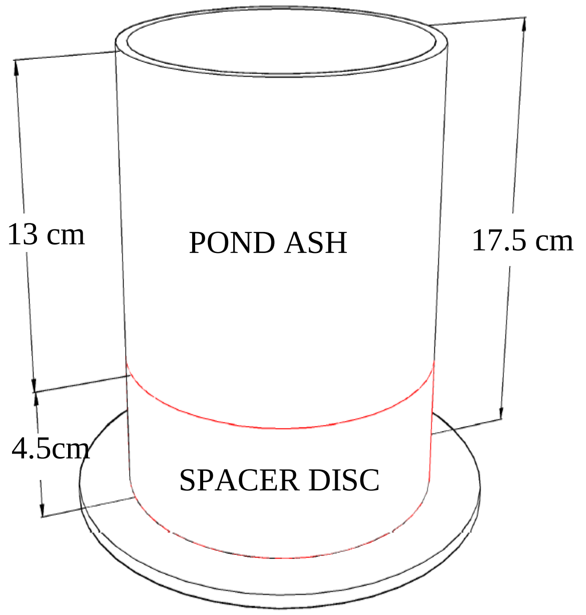
Proper planning is required for successful completion of any project in terms collection of materials used, series of data collection and a methodology which is then executed to achieve the objectives of the project work. A series of laboratory experiments such as specific gravity, grain size analysis, Proctor compaction test, direct shear test and CBR test were performed. The pond ash is collected from Badarpur (NTPC Ash Pond) then tested in the laboratory. The series of data collection and the methodology followed is as given in the flow chart:

4.1 FLOW CHART

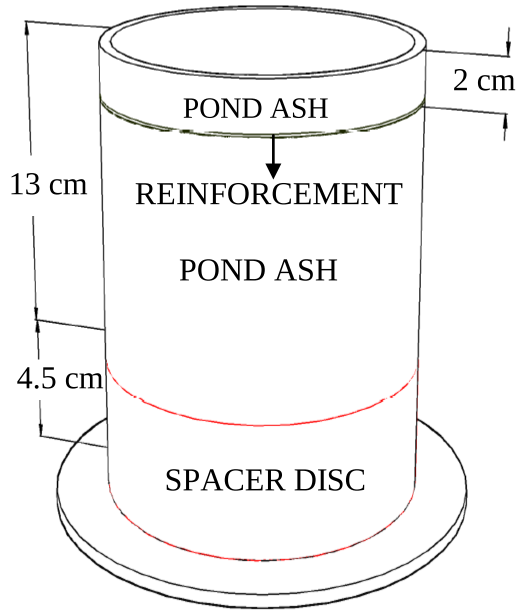


4.2 EXPERIMENTAL SET-UP OF CBR TEST

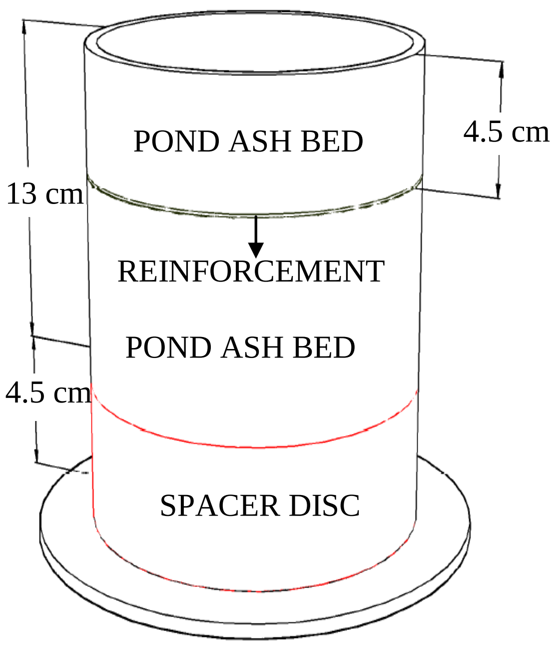
4.2.1 Reinforcement position variation



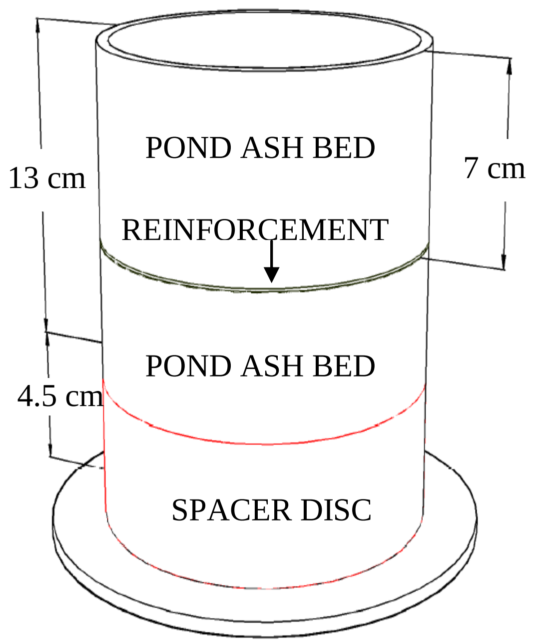
(a) Pond Ash without reinforcement



(b) Pond Ash bed reinforced at 2.0 cm

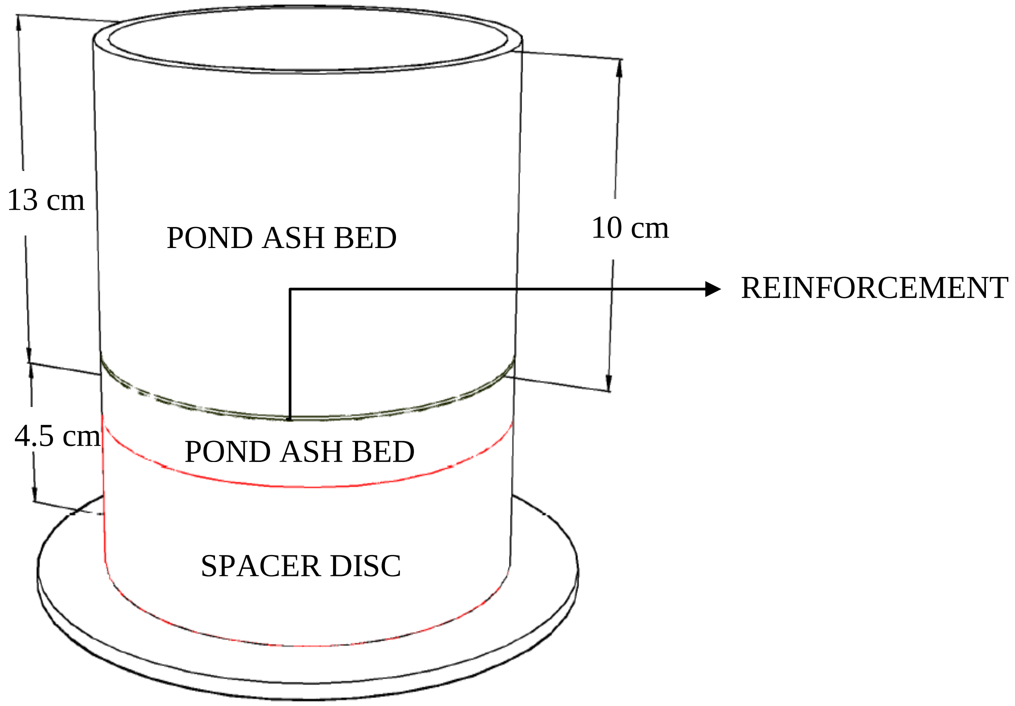


(c) Pond Ash bed reinforced at 4.5cm



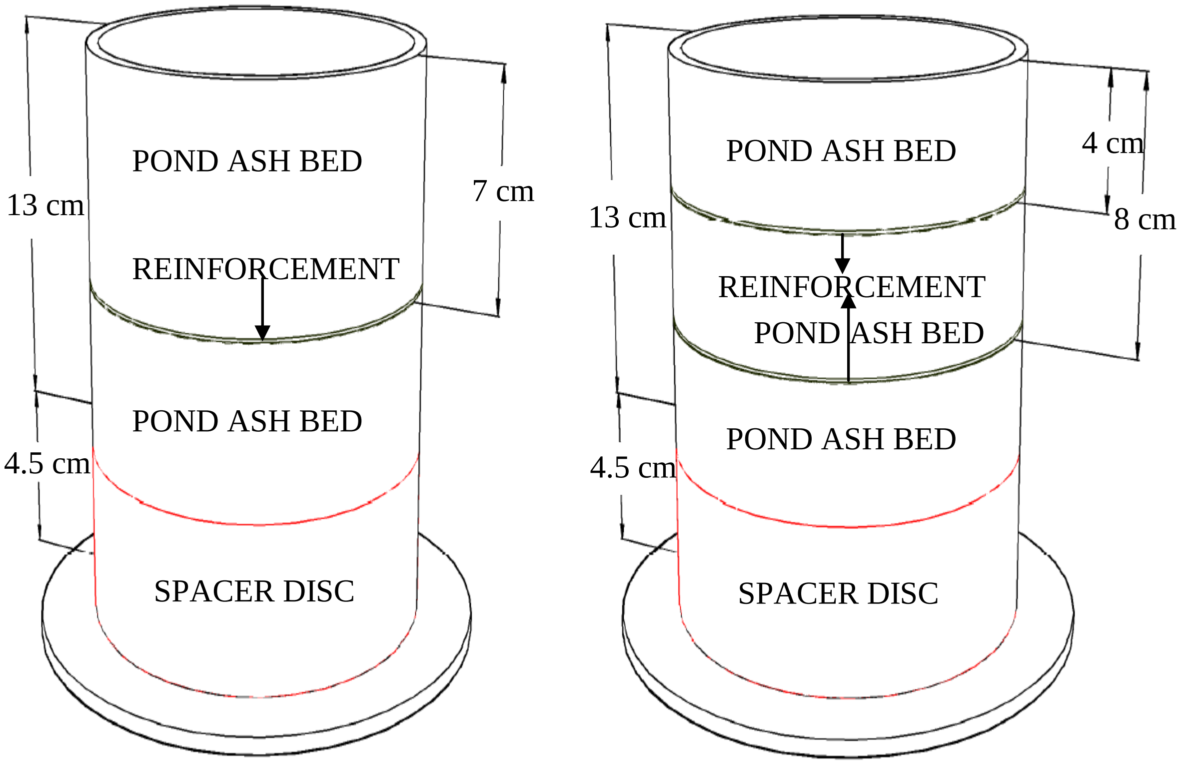
(d) Pond Ash bed reinforced at 7.0 cm

Fig.4.1 CBR mould with pond ash reinforced by fibreglass sheet.



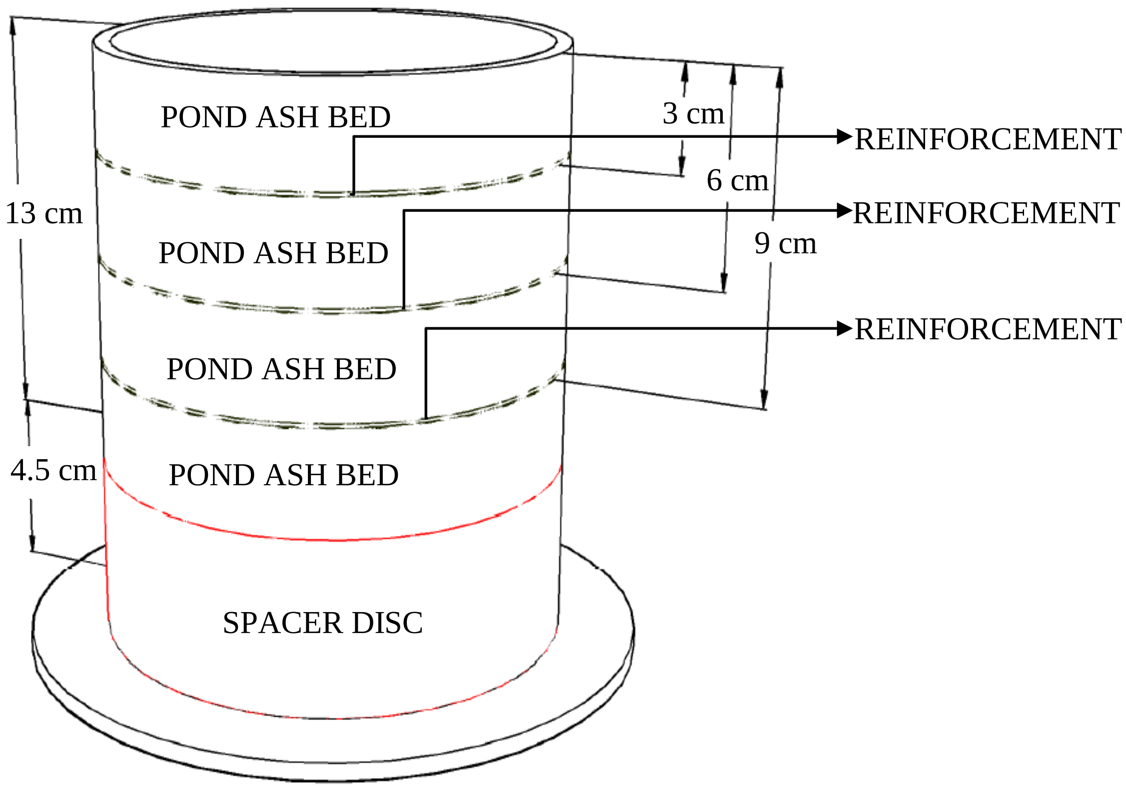
(e) Pond Ash bed reinforced at 10.0 cm

4.2.2 Number of Reinforcement Layers variation



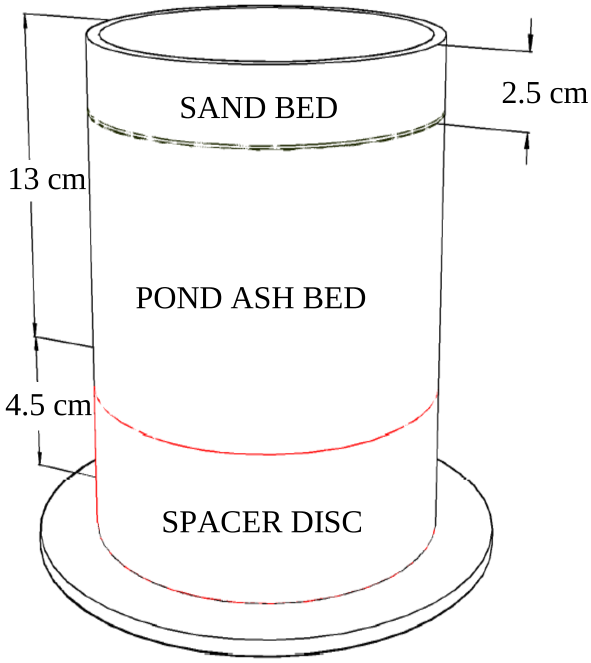
(a) Single layer of reinforcement at 7.0cm (b) Double layer of reinforcement at 4 and 8cm

Fig.4.2 CBR mould with pond ash reinforced by various layers of fibreglass sheet.

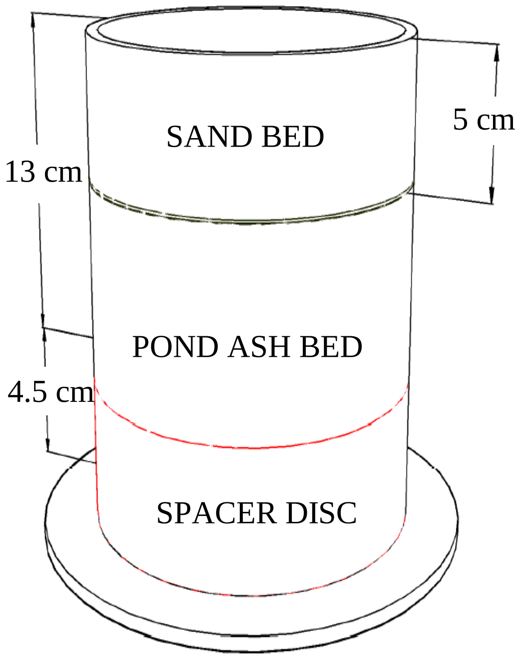


(c) Three layer of reinforcement at 3, 6 and 9 cm

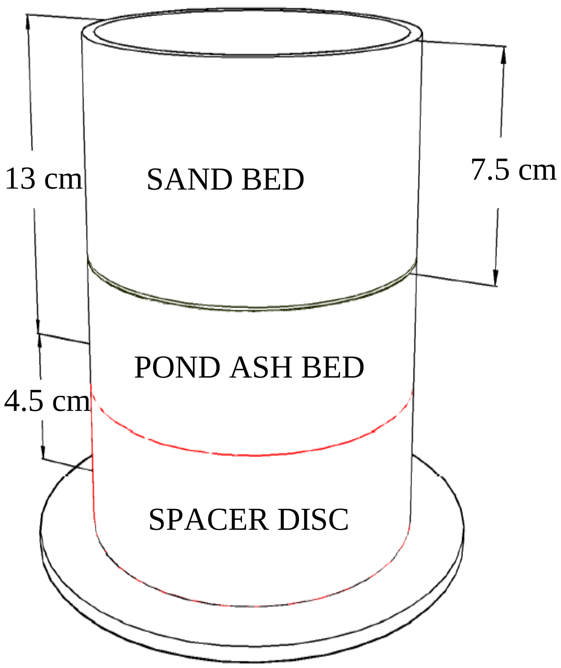
4.2.3 Sand Layer Thickness variation



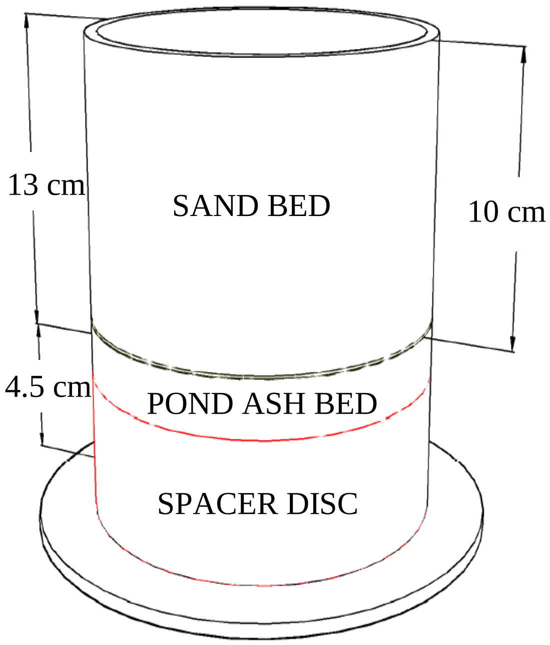
(a) Overlain sand layer thickness 2.5cm
With reinforcement at 2.5cm



(b) Overlain sand layer thickness 5.0 cm
with reinforcement at 5.0 cm



(c) Overlain sand layer thickness 7.5 cm
With reinforcement at 7.5cm



(c) Overlain sand layer thickness 10 cm
with reinforcement at 10 cm

Fig.4.3 CBR mould with pond ash beds overlain by varying thickness of sand layer

CHAPTER – 5
LABORATORY EXPERIMENTS AND THEORETICAL ANALYSIS

5.1 POND ASH PROPERTIES

The pond ash in bulk quantity is collected from Badarpur (NTPC Ash Pond) was used to perform laboratory experiments. Pond ash properties such as MDD, OMC, specific gravity, shear parameters and its gradation are estimated. To determine these properties following tests were performed:

5.1.1 SPECIFIC GRAVITY TEST

The specific gravity of the pond ash is defined as the ratio of the weight of a given volume of pond ash at a stated temperature to the weight of an equal volume of distilled water at that temperature. The pycnometer bottle is used to determine the value of specific gravity.

$$G = \frac{(M_2 - M_1)}{\{(M_2 - M_1) - (M_3 - M_4)\}} \qquad \text{…...... Eq. 5.1}$$

Where, M_1 = Mass of empty pycnometer bottle in gram

M_2 = Mass of pycnometer in gram + Mass of pond ash sample in gram

M_3 = Mass of pycnometer in gram + Mass of pond ash sample in gram + Mass of water in gram

M_4 = Mass of pycnometer in gram + Mass of water in gram

Table 5.1: Calculation of specific gravity of pond ash

	Sample 1	**Sample 2**	**Sample 3**
M_1 (g)	695.96	697.17	696.36
M_2 (g)	895.41	898.30	897.96
M_3 (g)	1636.17	1634.11	1693.12
M_4 (g)	1569.57	1568.11	1569.36
G	1.501	1.488	2.589
G_{avg}	$\frac{1.501+1.488+2.589}{3} = 1.85$		

The average value of the specific gravity of three samples i.e. **G_{avg} = 1.85.**

5.1.2 GRAIN SIZE ANALYSIS

The grain size analysis of the pond ash sample was carried out to find the particle size distribution. The sieves of different size were arranged in decreasing size from top to bottom and the mass retained on each sieve was noted. The table below shows the calculation of percentage finer particles for each sieve. A semi-log graph was then prepared between the percentage finer and the sieve size (on log scale) and the value C_c and C_u were calculated using the formula:

$$C_U = \frac{D_{60}}{D_{10}}$$ ………..... Eq. 5.2

$$C_C = \frac{D_{30}^2}{D_{10} \times D_{60}}$$ ………..... Eq. 5.3

Where, C_c = coefficient of curvature

C_u = coefficient of uniformity

D_{10} = particle size such that 10 percent of sample is finer

D_{30} = particle size such that 30 percent of sample is finer

D_{60} = particle size such that 60 percent of sample is finer

Table 5.2: Result Data for Sieve Analysis for pond ash

Sieve size mm	Mass retained(g)	Percentage mass retained	Cumulative percentage retained	Percentage Finer (%)
4.75	1.71	0.171	0.1717	99.829
2.36	2.405	0.241	0.412	99.588
1.18	8.41	0.841	1.253	98.747
0.60	19.723	1.972	3.225	96.775
0.425	400.31	40.031	43.256	56.744
0.30	101.46	10.146	53.402	46.598
0.15	295.34	29.534	82.936	17.064
0.075	87.05	8.705	91.641	8.359
Pan	83.58	8.358	99.999	0.001

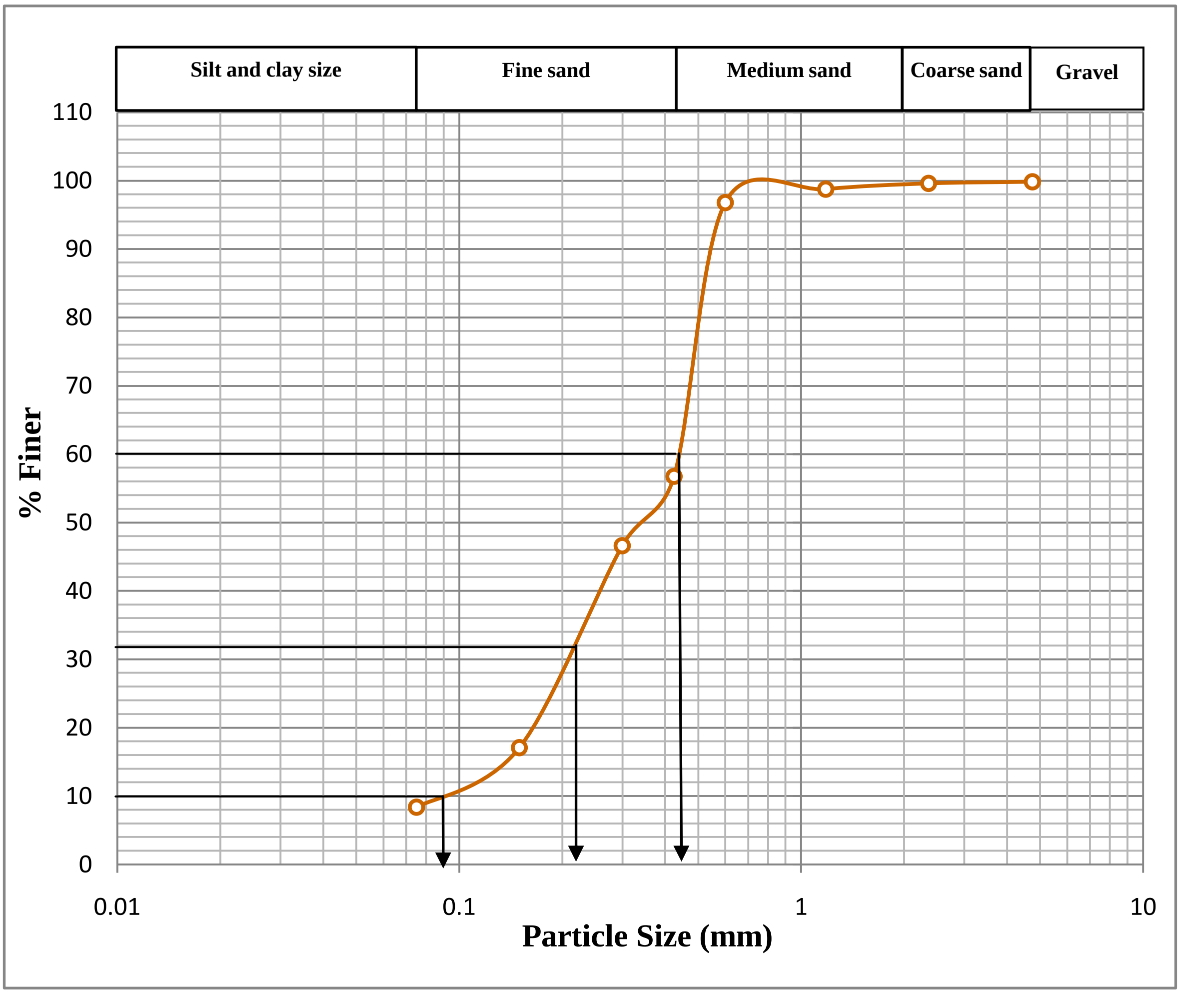


Fig. 5.1 Grain size analysis curve for pond ash

From the semi-log graph plotted between percentage finer and sieve size (on log scale), the value of D_{10} = 0.092 mm, D_{30} = 0.21 mm, D_{60} = 0.45 mm, thus the corresponding value of C_C and C_U are 1.07 and 4.89 respectively. More than 80% particles are passing through 4.75 mm IS sieve and more than 80% particles are retained on 75µ IS sieve. On the basis of above results I can conclude that the pond ash nature may be similar to sand. According to, depending upon the C_c and C_u value the pond ash may be classified as poorly graded sand i.e. SP.

5.1.3 PROCTOR COMPACTION TEST

The main purpose of a laboratory compaction test is to calculate the exact amount of water that can be mixed in the soil sample so that, when compacting the soil sample in the field the resulting degree of denseness should be maximum at optimum moisture content(OMC). With the help of Proctor test the MDD of the soil corresponding to the OMC is obtained.

Table.5.3 Result Data for proctor compaction test for pond ash

Mass of mould + P.A (g)	Mass of P.A (g)	Density of P.A (ρ) (g/cc)	Water content w (%)	Dry density (ρ_d) (g/cc)	Dry unit weight (Υ_d) (kN/m^3)
5310	995	1.110	8.60	1.02	10.006
5360	1045	1.167	15.00	1.03	10.104
5460	1145	1.278	21.33	1.05	10.301
5620	1305	1.475	28.928	1.14	11.183
5710	1395	1.558	34.20	1.16	11.379
5690	1375	1.530	42.670	1.07	10.496

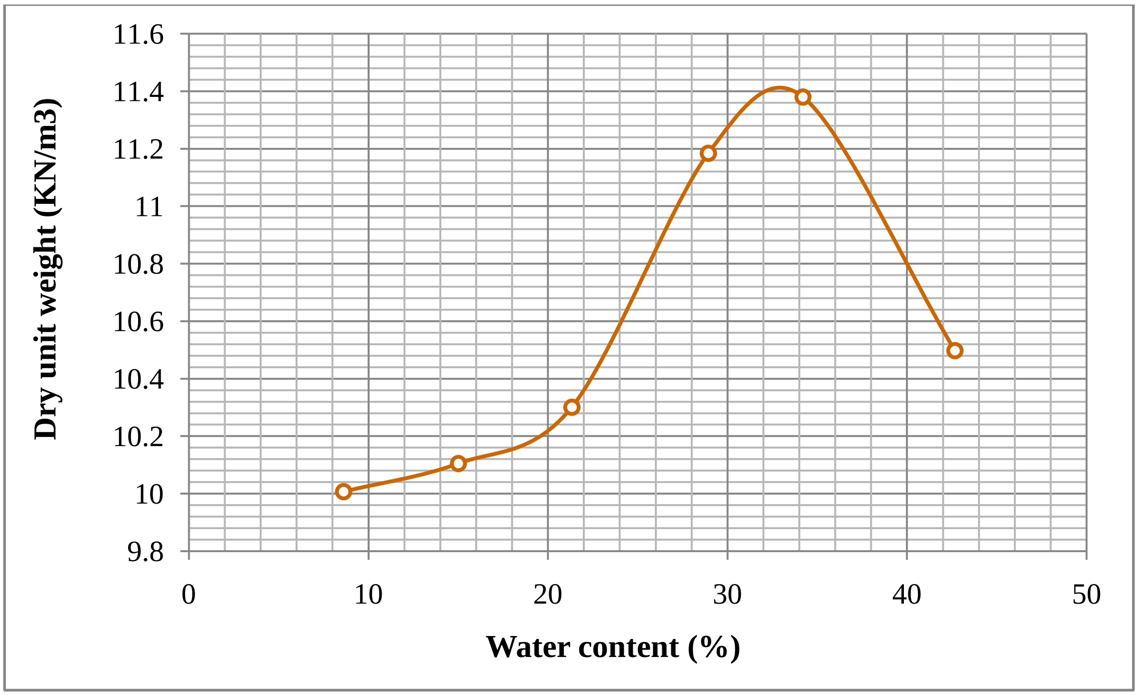


Fig. 5.2 Graph of proctor compaction test for pond ash

Fig. 5.2 shows the proctor compaction curve of pond ash, the maximum dry density and the optimum water content of 11.40 kN/m^3 and 33.00% respectively.

5.1.4 DIRECT SHEAR TEST

Depending upon the application of shear load, the direct shear test is of two types, controlled strain and controlled stress. The controlled strain test is simpler and provides accurate results and is, therefore, recommended.The shear strength of pond ash depends on its cohesion value (c) and internal angle of friction (ϕ). In direct shear test the maximum horizontal load, that a soil can resist without failure, was found corresponding to the different normal stresses of 50 kN/m^3, 100 kN/m^3 and 150 kN/m^3.

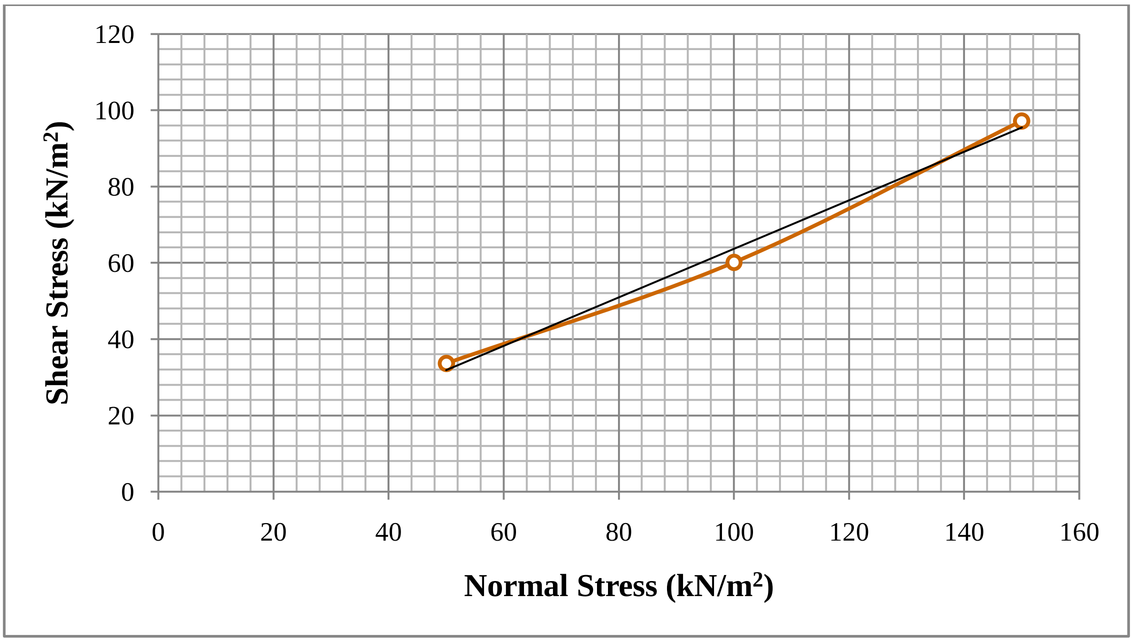


Fig. 5.3 Normal stress versus Shear stress curve for pond ash

The cohesion value 'c' and angle of internal friction 'ϕ' are obtained from the plot of shear stress versus normal stress curve of the given pond ash are c = 0.006 kN/m^2 and $\phi = 32.56^{o}$

5.2 SAND PROPERTIES

The sand in bulk quantity is collected from Yamuna River, was used to perform laboratory experiments. Sand properties such as maximum dry density (MDD), optimum moisture content (OMC), specific gravity, cohesion (c), and its grain size distribution are estimated. To determine these properties following tests were performed:

5.2.1 SPECIFIC GRAVITY

The specific gravity of the sand is defined as the ratio of the weight of a given volume of sand at a stated temperature to the weight of an equal volume of distilled water at that temperature. The pycnometer method is used to determine the value of specific gravity.

$$G = \frac{(M_2 - M_1)}{\{(M_2 - M_1) - (M_3 - M_4)\}}$$

Table 5.4: Calculation of specific gravity of sand

	Sample 1	Sample 2	Sample 3
M_1(g)	694.28	695.17	694.81
M_2(g)	893.24	896.82	896.90
M_3(g)	1686.58	1689.173	1687.77
M_4(g)	1563.40	1565.35	1564.31
G	2.623	2.590	2.569
Gavg	$\frac{2.623+2.590+2.569}{3}=2.594$		

The average value of the specific gravity of three samples i.e. $\mathbf{G_{avg} = 2.594}$.

5.2.2 GRAIN SIZE ANALYSIS

The grain size analysis of the sand sample was carried out to find the particle size distribution. The sieves of different size were arranged in decreasing size from top to bottom and the mass retained on each sieve was noted. The table below shows the calculation of percentage finer particles for each sieve. A semi-log graph was then prepared between the percentage finer and the sieve size (on log scale)

Table 5.5: Result Data for Sieve Analysis for sand

Sieve size mm	Mass retained(g)	Percentage mass retained	Cumulative percentage retained	Percentage Finer (%)
4.75	26.37	2.637	2.637	97.363
2.36	7.40	0.733	3.37	96.63
1.18	12.66	2.273	5.643	94.357
0.60	11.86	0.1899	5.833	94.167
0.30	640	63.967	69.80	30.20
0.15	248	24.829	94.629	5.371
0.075	25.86	2.583	97.212	2.788
Pan	16.54	1.648	98.86	1.14

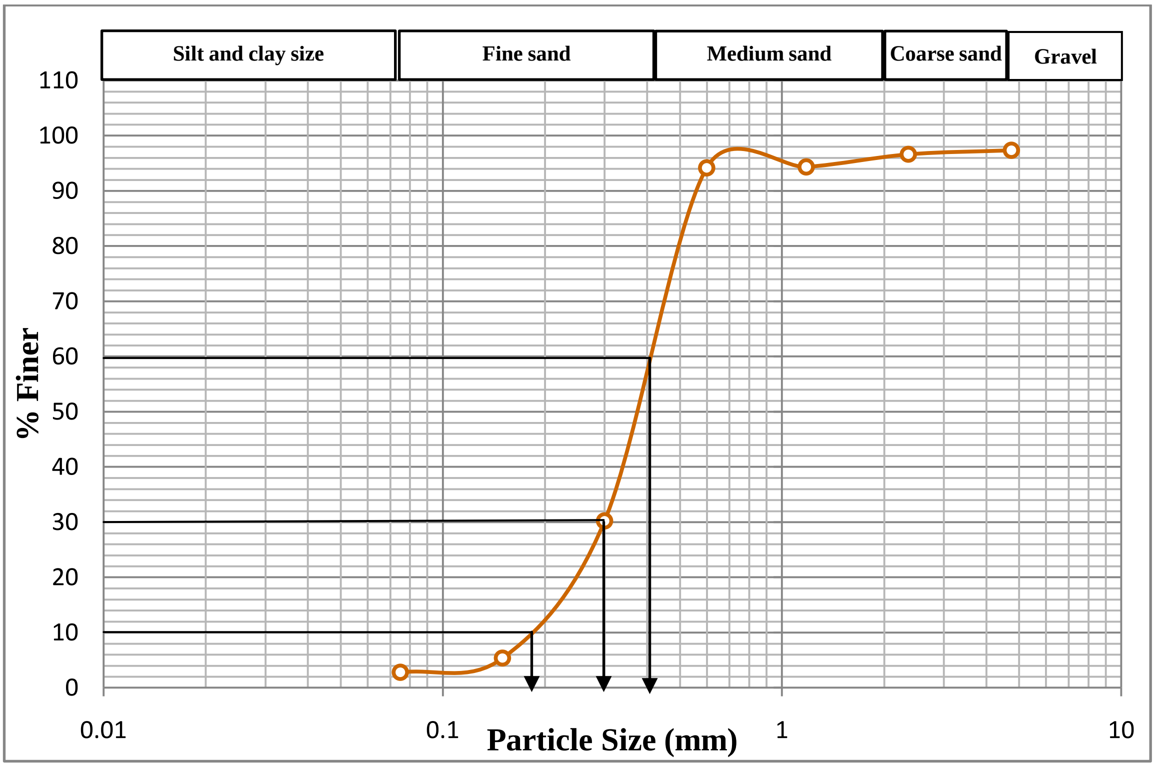


Fig. 5.4 Grain size analysis curve for sand

From the semi-log graph plotted between percentage finer and sieve size (on log scale), the value of D_{10}= 0.18 mm, D_{30}= 0.30 mm, D_{60}= 0.41 mm, thus the corresponding value of C_C and C_U are 1.22 and 2.28 respectively. More than 90% particles are passing through 4.75 mm IS sieve and more than 90% particles are retained on 75µ IS sieve. On the basis of above results I can conclude that the sand nature may be poorly graded. Depending upon the C_c and C_u value the sand may be classified as poorly graded sand i.e. SP.

5.2.3 PROCTOR COMPACTION TEST

Table.5.6 Result Data for Proctor compaction test for sand

Mass of mould + Soil (g)	Mass of Soil (g)	Density of Soil (ρ) (g/cc)	Water content w (%)	Dry density (ρ_d) (g/cc)	Dry unit weight (Υ_d) (kN/m^3)
5870	1580	1.503	5.10	1.503	14.74
5980	1690	1.554	8.75	1.554	15.24
6120	1830	1.623	12.74	1.623	15.92
6080	1790	1.530	16.99	1.530	15.00
5980	1700	1.402	21.20	1.402	13.75

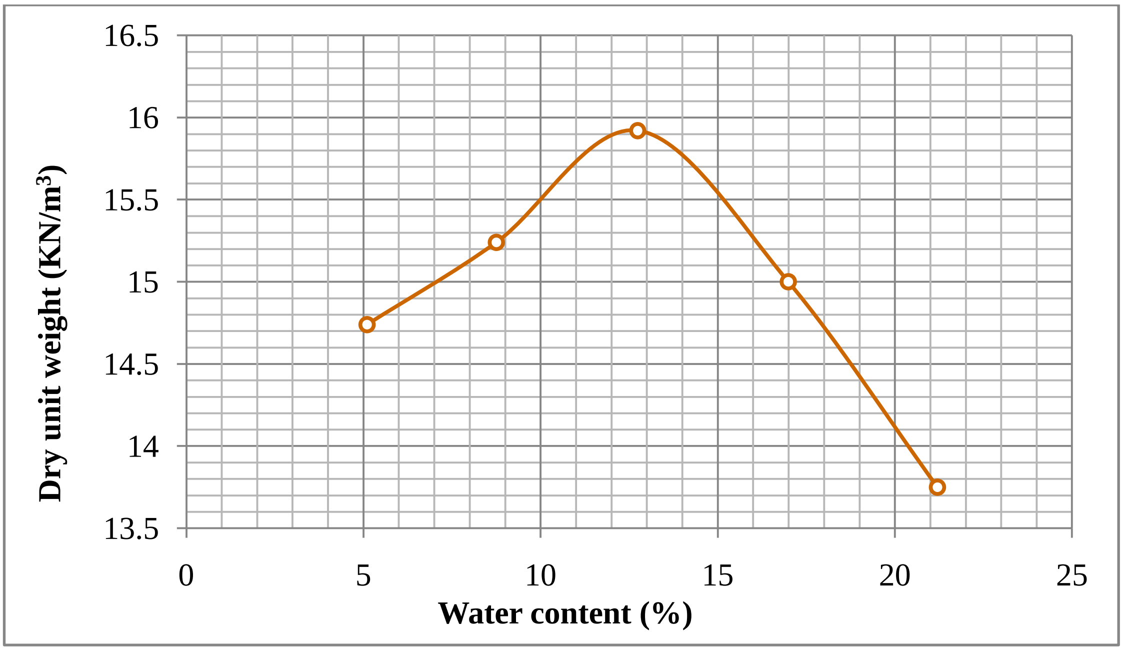


Fig. 5.5 Graph of proctor compaction test for sand

Fig. 5.5 shows the proctor compaction curve of sand. The maximum dry density and the optimum water content of 15.92 kN/m^3 and 12.60 % respectively.

5.2.4 DIRECT SHEAR TEST

Depending upon the application of shear load, the direct shear test is of two types, controlled strain and controlled stress. The controlled strain test gives accurate results and easy to perform, therefore this test is preferred.

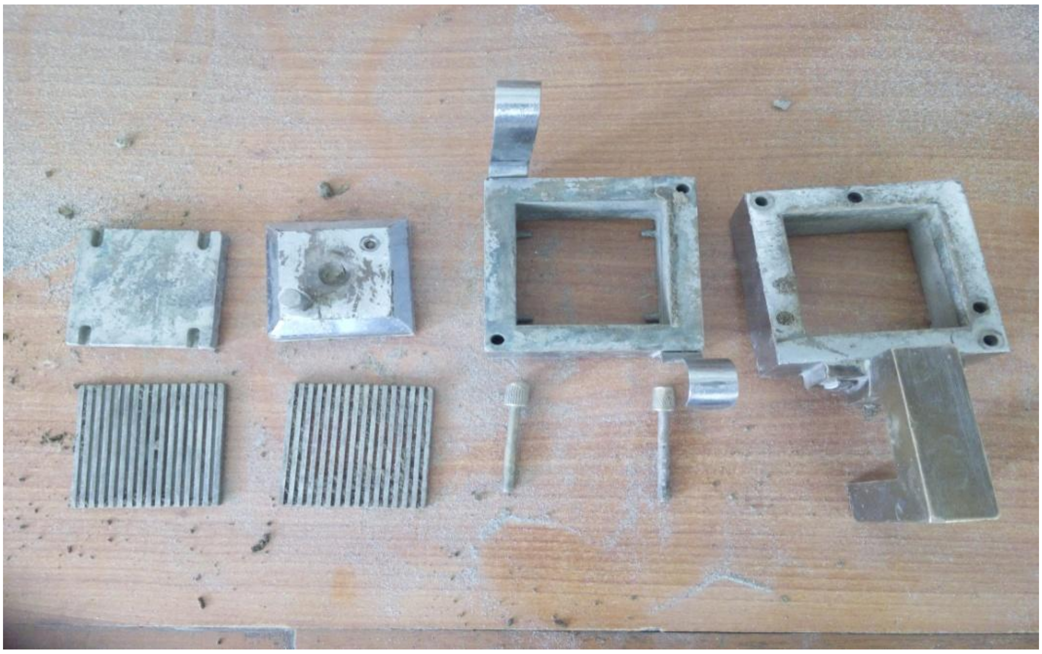


Fig.5.6 Components of direct shear test apparatus

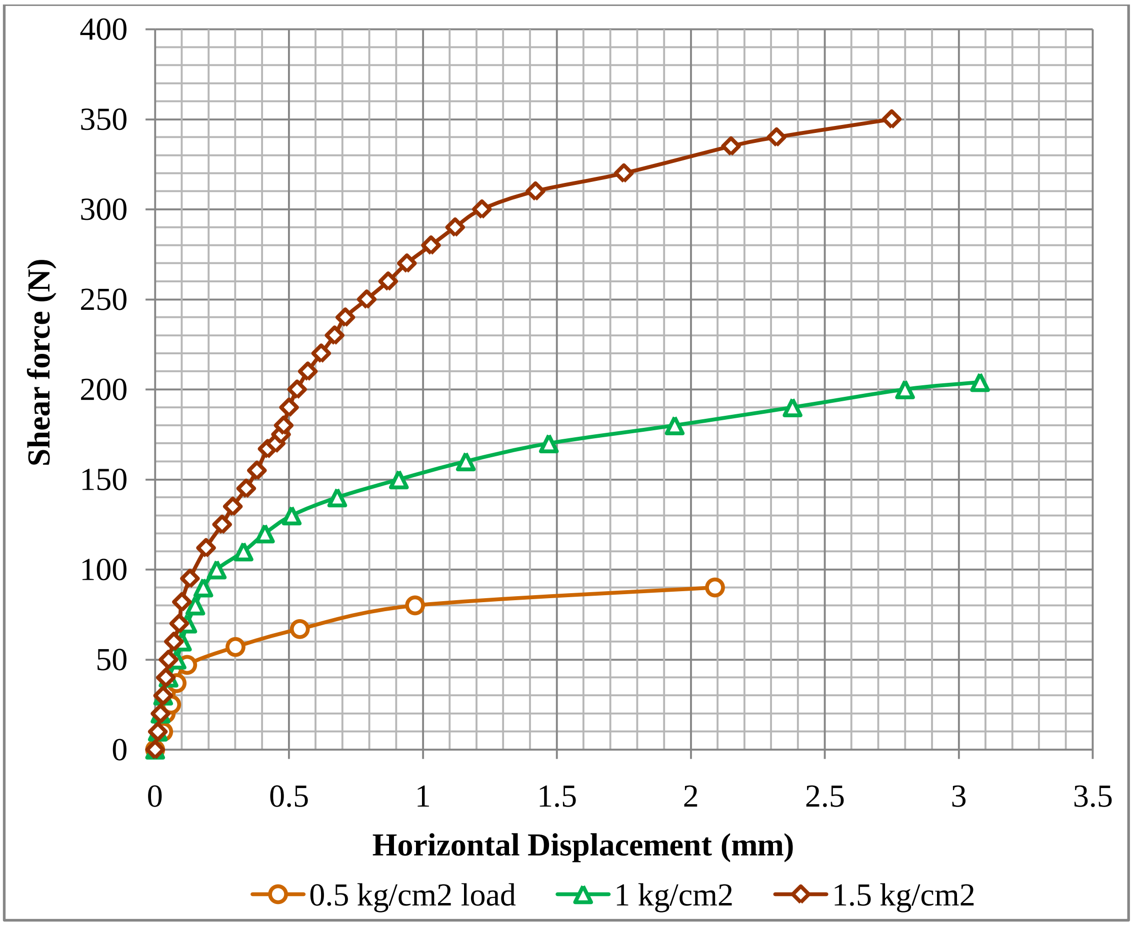


Fig. 5.7 Shear force vs. horizontal displacement curve for different loading conditions for sand

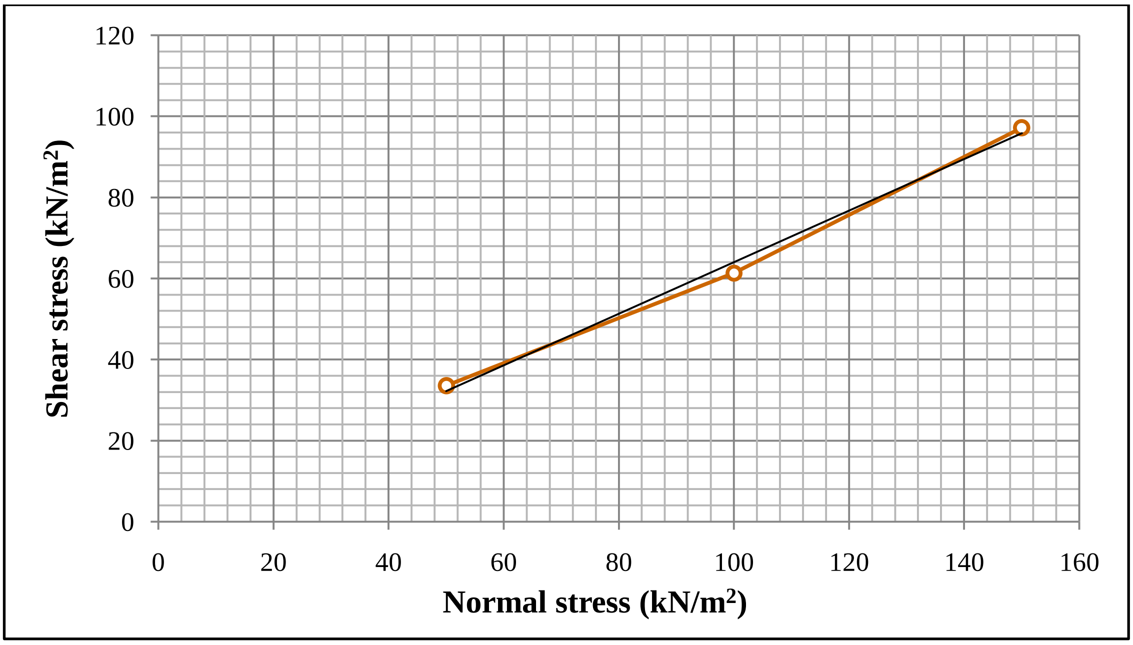


Fig. 5.8 Normal stress versus Shear stress curve for sand

The cohesion value ‘c’ and angle of internal friction ‘ϕ’ are obtained from the plot of Normal stress versus Shear stress curve for sand is c = 0.423 kN/m^2 and ϕ = 32.456^o

5.3 DETERMINATION OF CALIFORNIA BEARING RATIO:

The design of pavement includes the necessity of study of the properties of sub base and base of the soil. This includes the determination of bearing capacity and strength of the soil; this can be accomplished in the field by finding the California bearing ratio index of the soil.

5.3.1 CBR VALUE OF COMPACTED POND ASH:

A cylindrical mould of dimensions 175 mm height, 150 mm diameter, is used. At MDD and OMC the sample is prepared; over the sample spacer disc is placed and compacted with the compaction rammer. The compacted mould is placed on the CBR test apparatus. Now a surcharge simulating the field conditions is placed at the middle of the mould, and with a movable base set up the load is applied at a constant strain rate of 1.2 mm/min. The piston applying load was 50 mm diameter. To assess the stability of pond ash the above test was conducted on the un-soaked condition, according to Indian Standard code IS: 2720 (Part XVI) -1987.

5.3.2 PREPRATION OF POND ASH BEDS BY PLACING REINFORCEMENT

Fig.5.9 Preparation of pond ash beds and placement of reinforcement

5.3.3 CBR VALUE OF POND ASH OVERLAIN BY SAND:

A series of CBR tests were done on compacted pond ash overlain by a layer of sand with varying relative density and with different thickness and reinforcement is also placed at the interface of pond ash and sand. The graph will be shown later which will show the variation of CBR value with sand layer thickness variation.

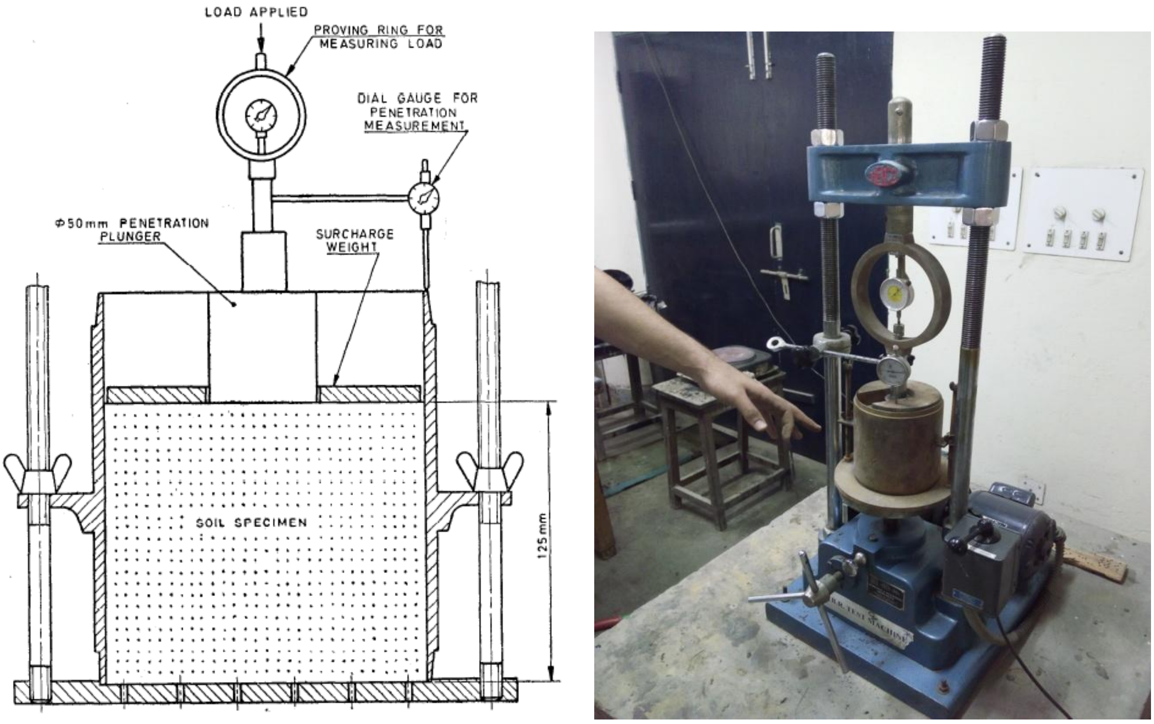


Fig.5.10 CBR test line diagram and set-up in laboratory

CHAPTER – 6
RESULTS & DISCUSSION

6.1 SCANNING ELECTRON MICROSCOPE (SEM)

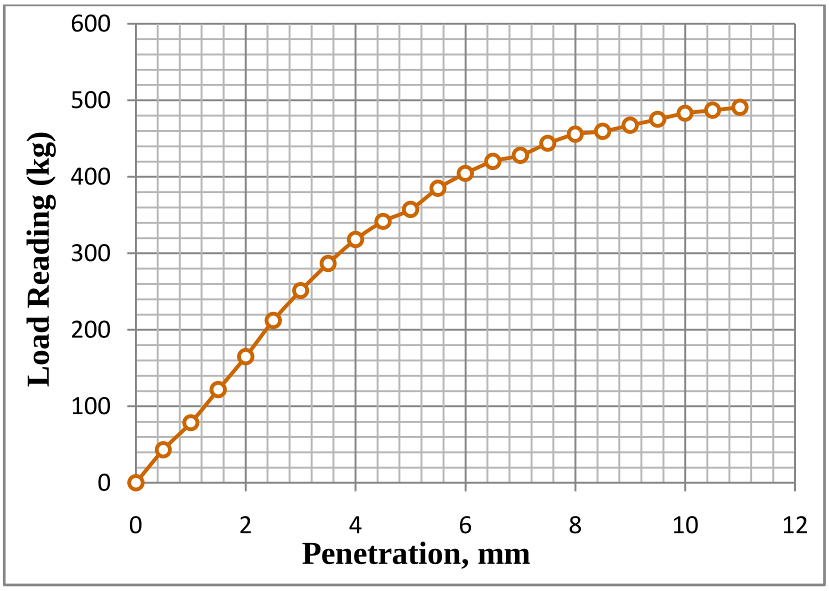
The images obtained from scanning electron microscopy, shown in Fig. 3.0 and 3.1, describes the morphology of the pond ash and sand crystals. Fig.3.0 (a), 3.0(b), 3.0(c) ware taken at 40µm, 100µm, 200µm scale respectively, shows the particles of pond ash sample. It shows the crystals of pond ash sample separated by voids. The pond ash image shows the agglomeration texture of Pond ash. After observing the SEM images of the pond ash samples, it can be concluded that the ash particles were mainly made up of irregular spherical, semi-spherical and sometimes irregular grains and fibrous matrix. Fig.3.1 (a), 3.1(b), 3.1(c) ware taken at 40µm, 100µm, 200µm scale respectively, shows the particles of sand sample. It shows the crystals of sand sample separated by voids.

6.2 RESULTS OF CBR TESTS ON POND ASH BEDS

6.2.1 Effects of reinforcement position on CBR value of Reinforced Pond Ash Beds

At different depths reinforcement are being placed and California bearing ratio test conducted and the variation of the CBR value is noted.

(a) Without reinforcement



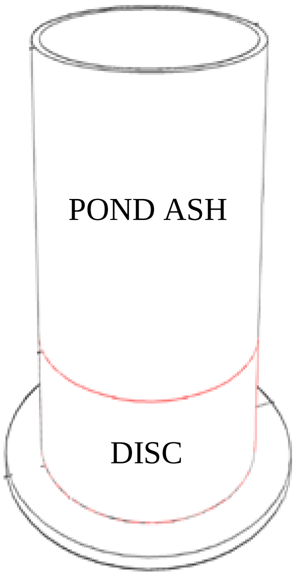


Fig.6.1 Load vs. Deformation curve of compacted pond ash beds without reinforcement

	2.5 mm Displacement	5.0 mm Displacement
CBR value (%)	15.48	17.38

(b)Reinforcement position: 2.0 cm from top

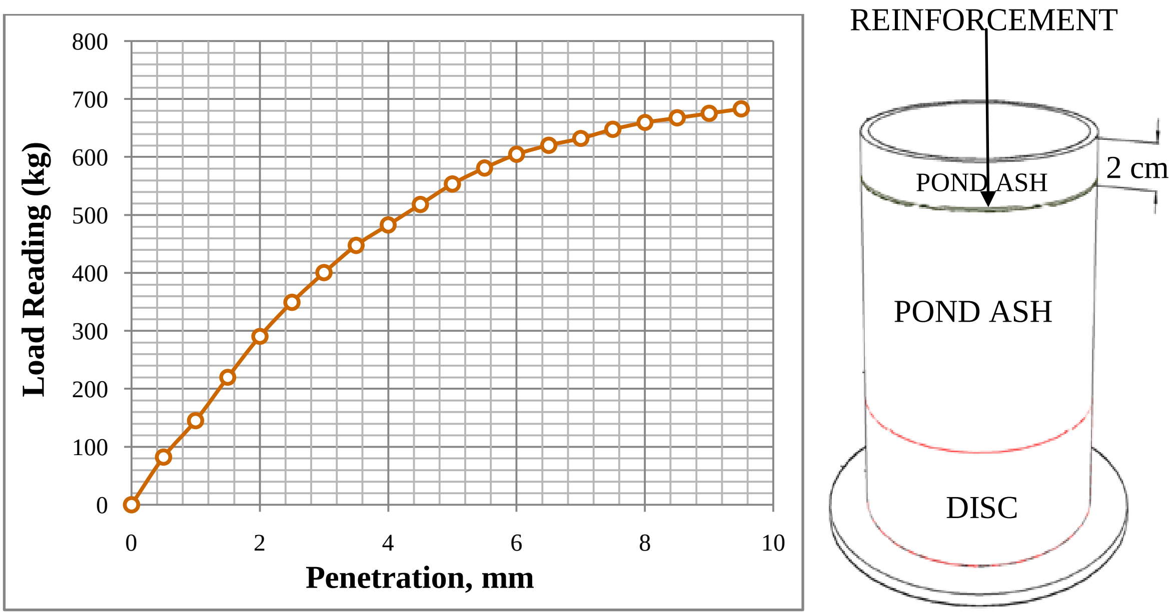


Fig.6.2 Load vs. Deformation curve of compacted pond ash beds when reinforcement is at 2.0 cm from top

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	23.5	25.61

(c) Reinforcement position: 4.5 cm from top

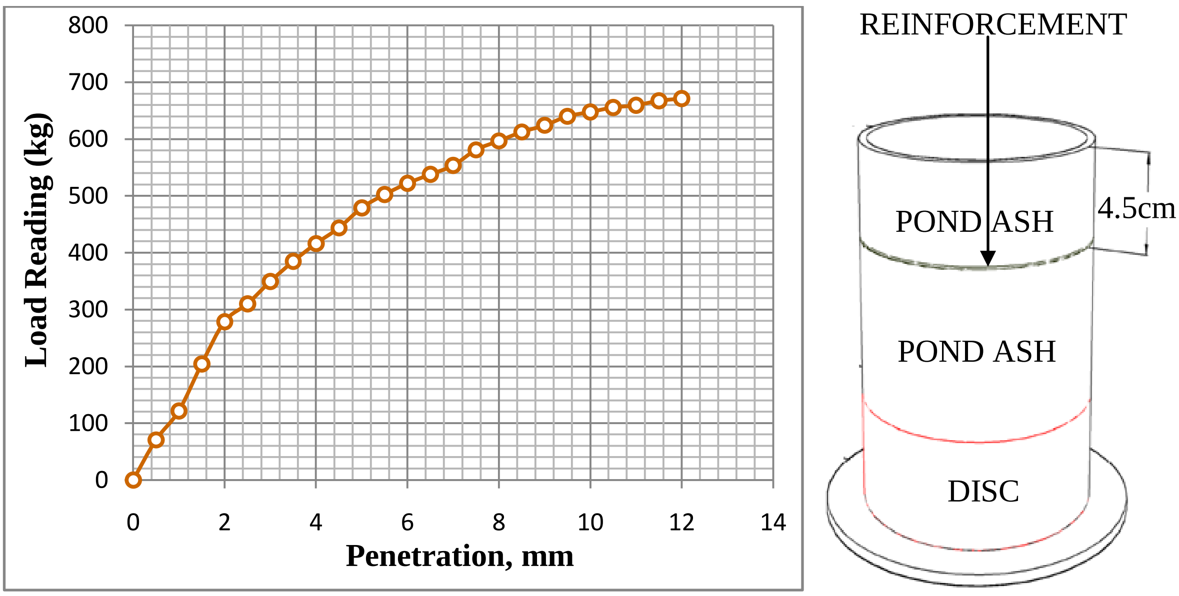


Fig.6.3 Load vs. Deformation curve of compacted pond ash beds when reinforcement is at 4.5 cm from top

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	22.64	23.31

(d) Reinforcement position: 7.0 cm from top

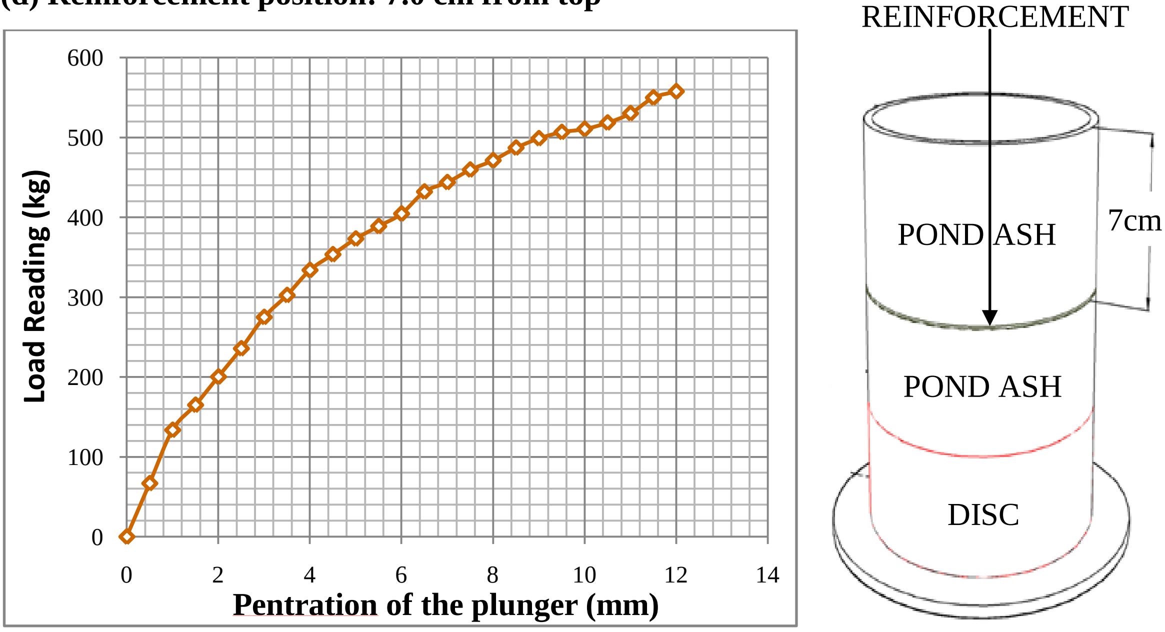


Fig.6.4 Load vs. Deformation curve of compacted pond ash beds when reinforcement is at 7.0 cm from top

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	17.15	18.15

(e) Reinforcement position: 10 cm from top

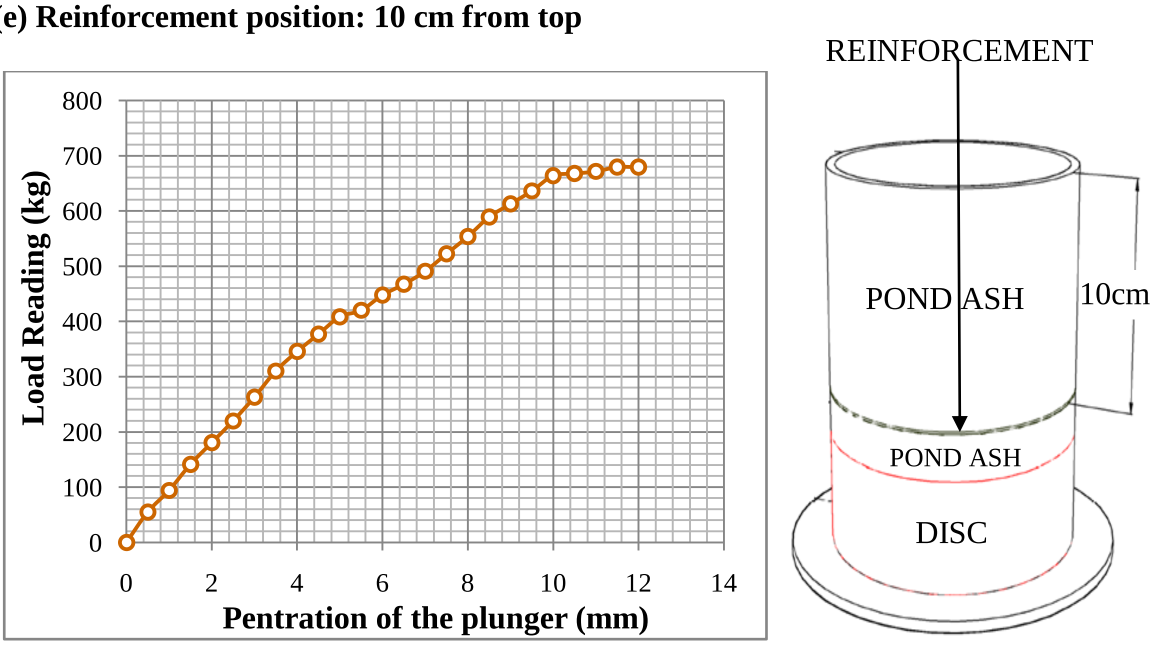


Fig.6.5 Load vs. Deformation curve of compacted pond ash beds when reinforcement is at 10.0 cm from top

CBR vale (%)	2.5 mm Displacement	5.0 mm Displacement
	16.05	17.95

6.2.1.1 Concluding Table and graph of Effects of reinforcement position on the CBR value

(a) For 2.5 mm displacement

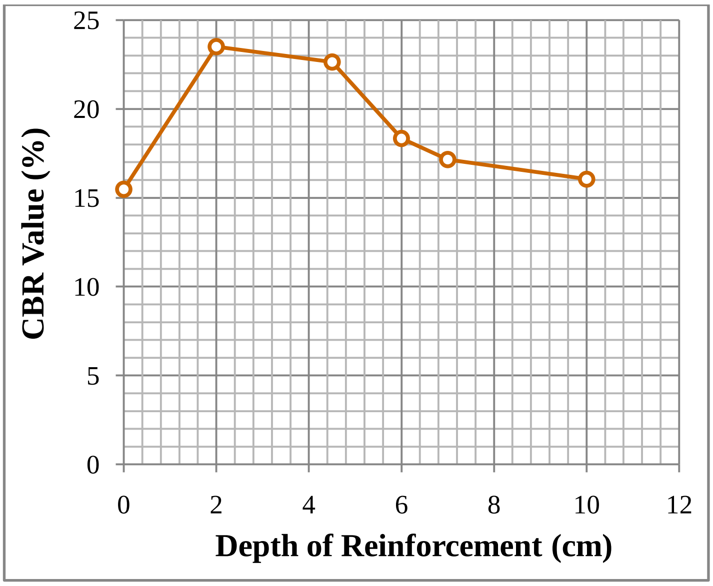


Table.6.1 CBR value at different depths of reinforcement for 2.5 mm displacement

Depth of Reinforcement (cm)	CBR Value (%) at 2.5 mm displacement
0	15.48
2	23.5
4.5	22.64
6	18.34
7	17.15
10	16.05

Fig.6.6 Depth of Reinforcement (cm) vs. CBR Value (%) curve of compacted pond ash beds at 2.5 mm displacement

(b) For 5.0 mm displacement

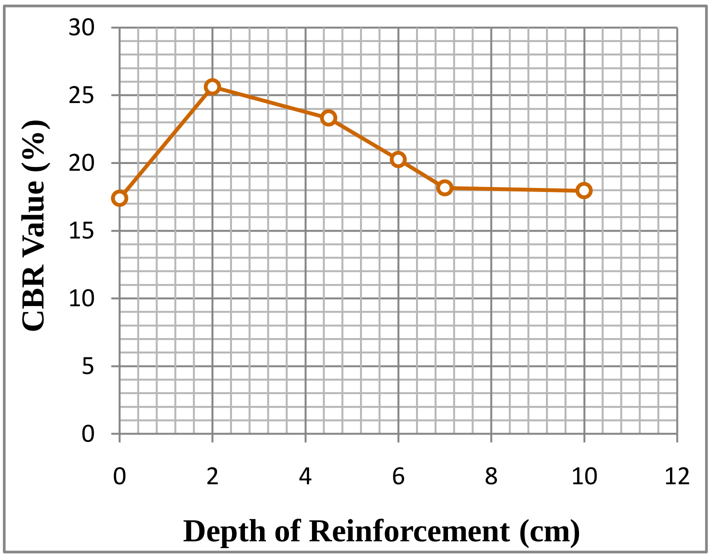


Table.6.2 CBR value at different depths of reinforcement for 5.0 mm displacement

Depth of Reinforcement (cm)	CBR Value (%) at 5 mm displacement
0	17.38
2	25.61
4.5	23.31
6	20.25
7	18.15
10	17.95

Fig.6.7 Depth of Reinforcement (cm) vs. CBR Value (%) curve of compacted pond ash beds at 5.0 mm displacement

CBR value decreases as the depth of reinforcement increases. When the depth of reinforcement is 2 times the diameter of the plunger, practically there is no improvement in the bearing capacity of reinforced pond ash.

6.2.2 Effects of Number of Layers of Reinforcement on the CBR value of Pond Ash Beds

(a) Reinforcement position: 6.0 cm from top (Single Layer)

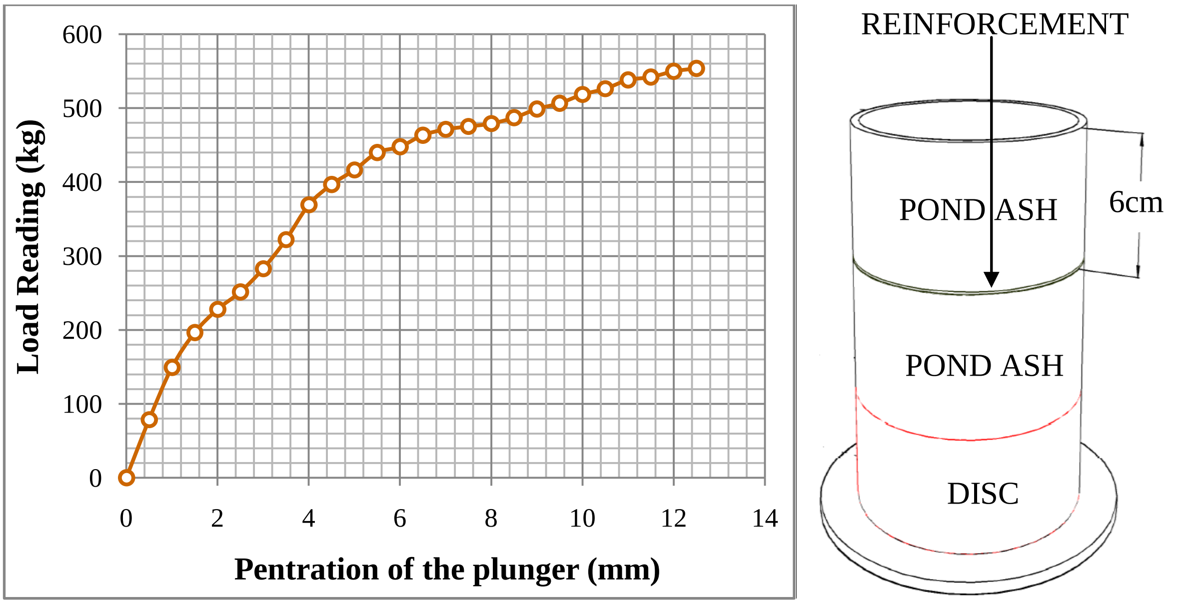


Fig.6.8 Load vs. Deformation curve of compacted pond ash beds when reinforcement is at 6.0 cm from top

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	18.34	20.25

(b) Reinforcement position: 4 cm and 8 cm from top (Double Layer)

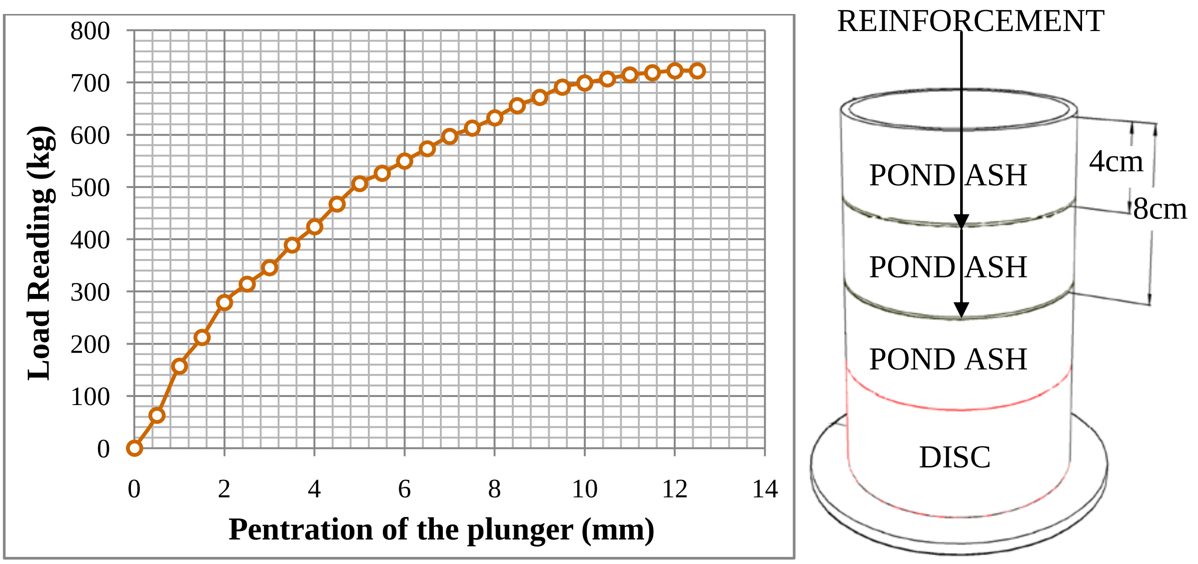


Fig.6.9 Load vs. Deformation curve of compacted pond ash beds when reinforcement is at 4.0 cm and 8.0 cm from top

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	22.93	24.64

(c) Reinforcement position: 3 cm, 6 cm and 9 cm from top (Triple Layer)

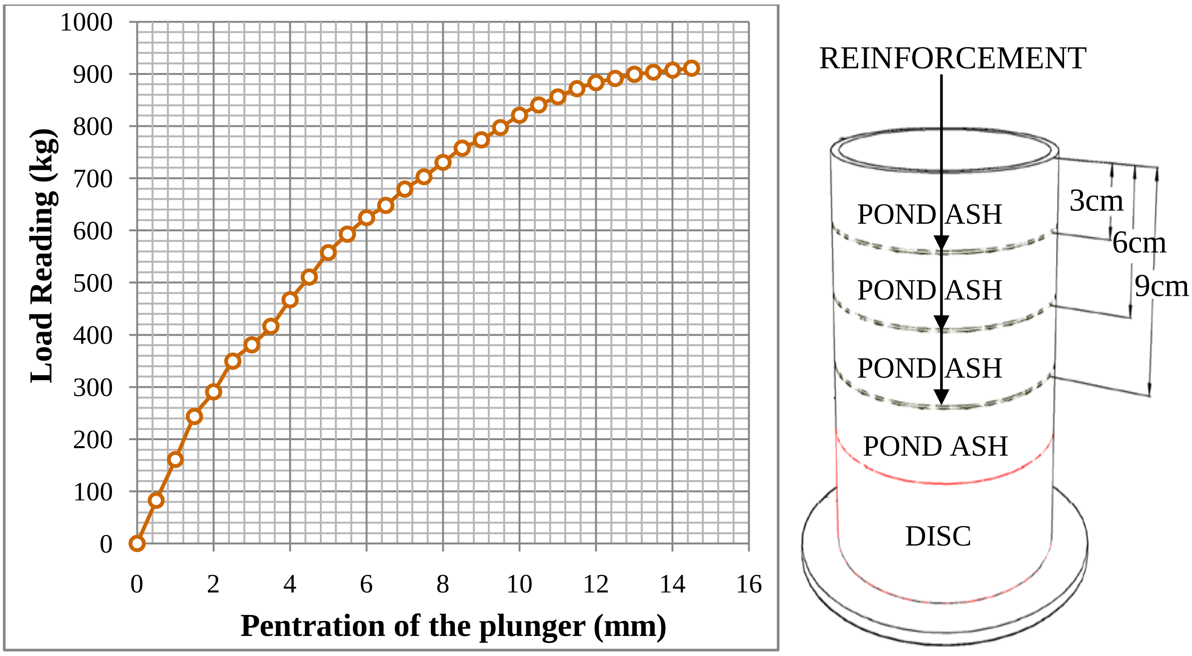


Fig.6.10 Load vs. Deformation curve of compacted pond ash beds when reinforcement is at 3.0 cm, 6.0 cm and 9.0 cm from top

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	25.51	27.13

6.2.2.1 Concluding Table and Graph of Effects of Number of Layers of reinforcement on the CBR value

Table.6.3 CBR value (%) at 2.5 mm and 5.0 mm displacement at varying number of layers of reinforcement

Number of Layers	**CBR value (%)**	
	2.5 mm Displacement	**5 mm Displacement**
0	15.48	17.38
1	18.34	20.25
2	22.93	24.64
3	25.51	27.13

(a) For 2.5 mm displacement

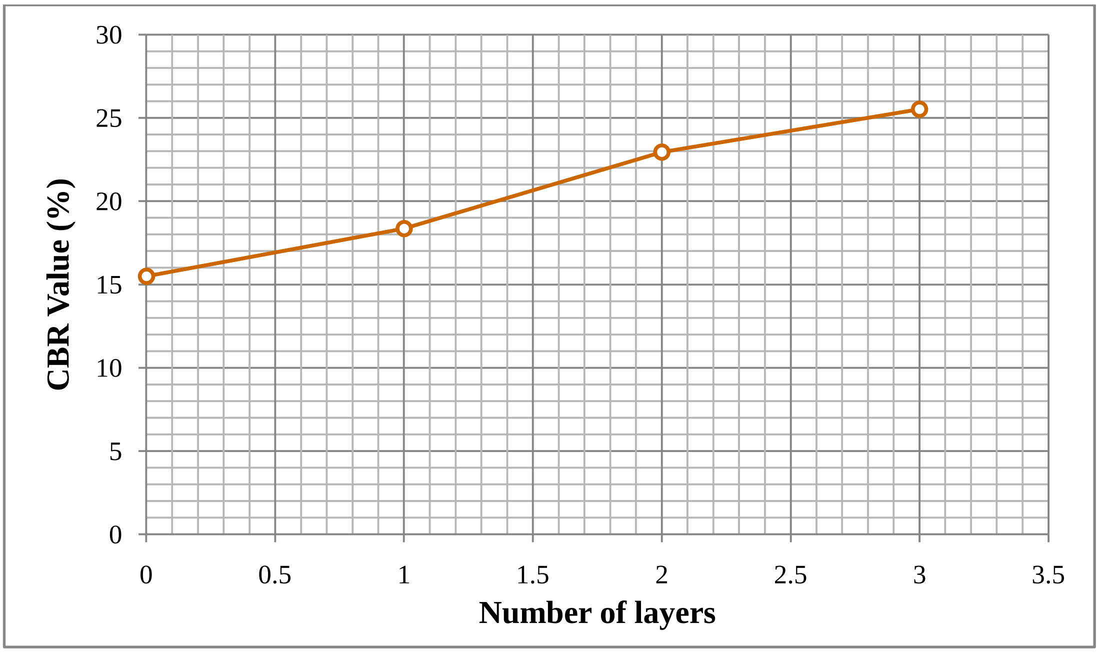


Fig.6.11 Number of layers vs. CBR Value (%) curve of compacted pond ash beds at 2.5 mm displacement

(b) For 5.0 mm displacement

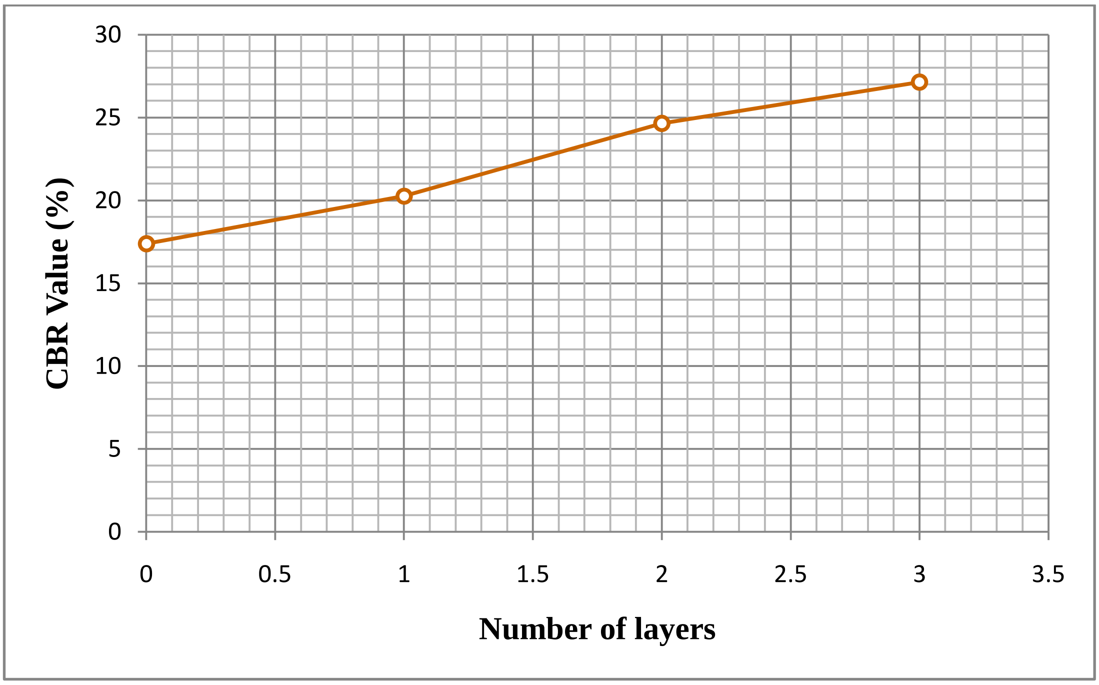


Fig.6.12 Number of layers vs. CBR Value (%) curve of compacted pond ash beds at 5.0 mm displacement

CBR value increases as the number of layers of reinforcement increases.

6.2.3 Effects of variation of Thickness of Sand Layer on the CBR value of Pond Ash Beds

(a) Sand layer thickness: 2.5 cm

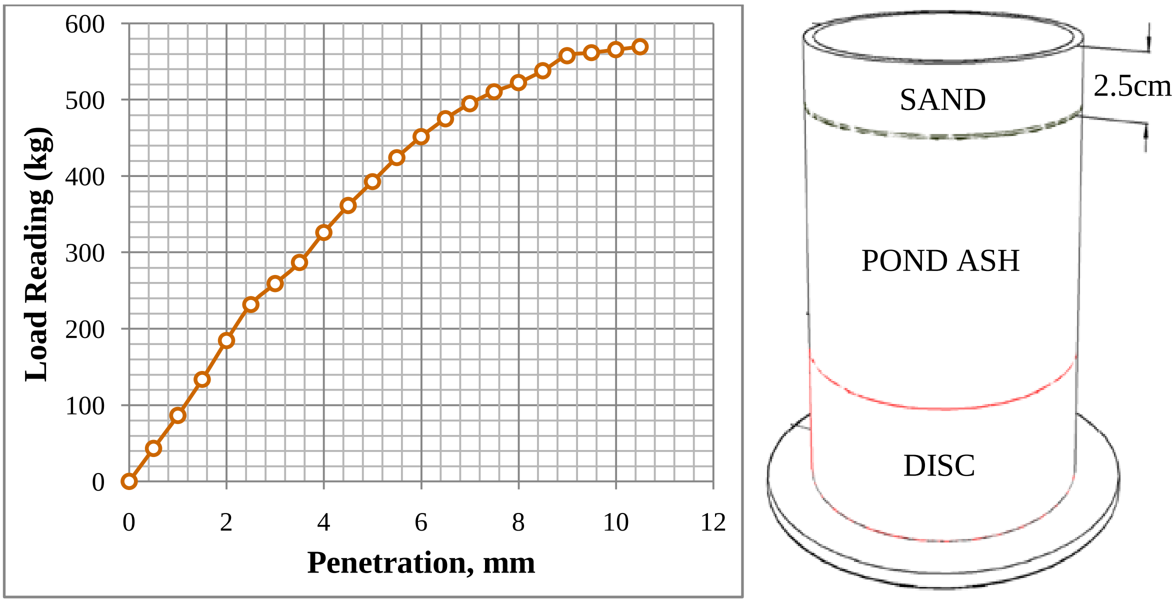


Fig.6.13 Load vs. Deformation curve of compacted pond ash beds overlain by 2.5 cm thick sand layer

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	16.90	19.11

(b) Sand layer thickness: 5.0 cm

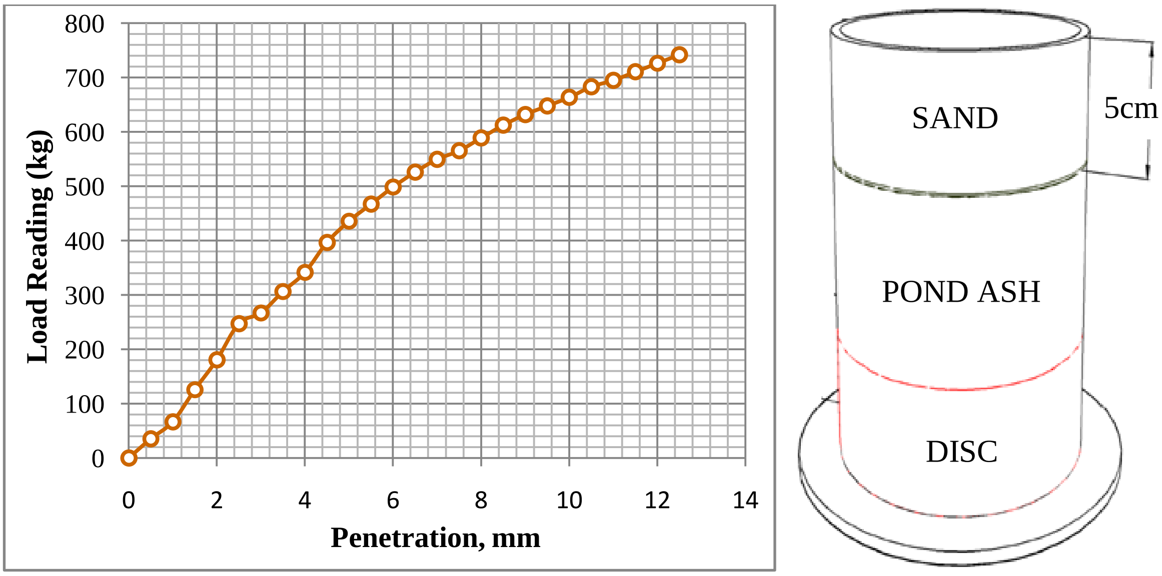


Fig.6.14 Load vs. Deformation curve of compacted pond ash beds overlain by 5.0 cm thick sand layer

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	18.05	21.21

(c) Sand layer thickness: 7.5 cm

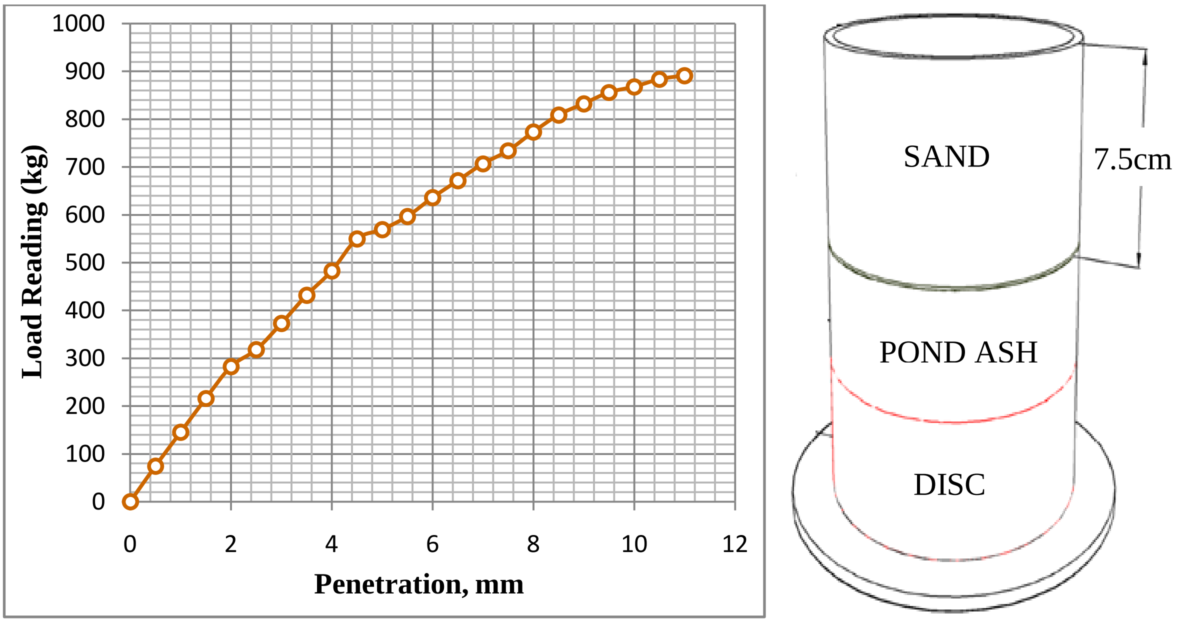


Fig.6.15 Load vs. Deformation curve of compacted pond ash beds overlain by 7.5 cm thick sand layer

CBR vale (%)	2.5 mm Displacement	5.0 mm Displacement
	23.20	27.71

(d) Sand layer thickness: 10 cm

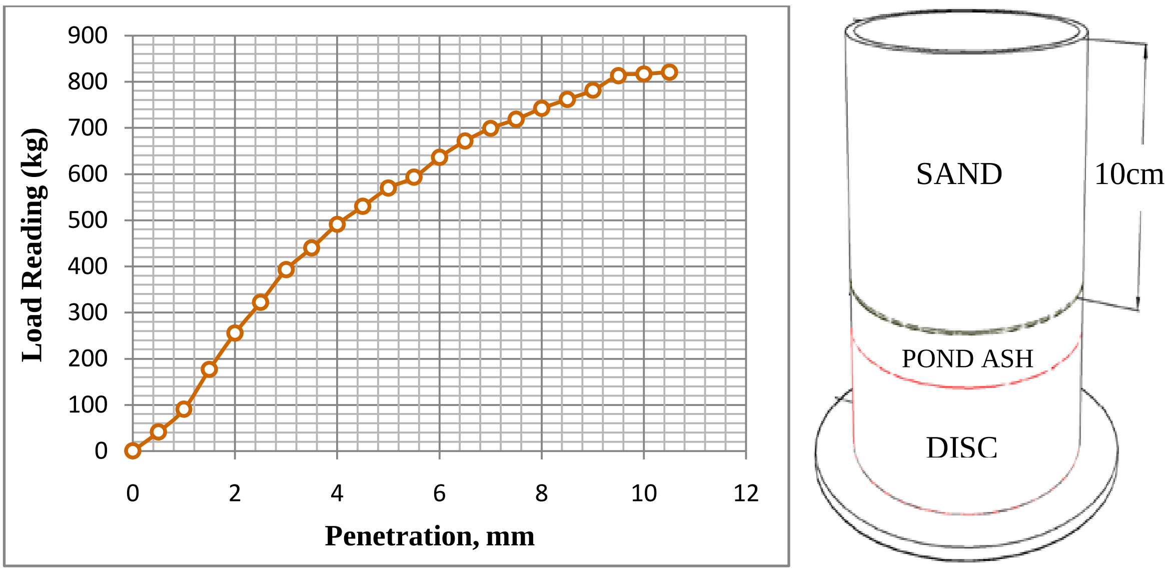


Fig.6.16 Load vs. Deformation curve of compacted pond ash beds overlain by 10.0 cm thick sand layer

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	23.50	27.71

6.2.3.1 Concluding Table and Graph of Effects of variation of Thickness of Sand Layer on the CBR value

Table.6.4 CBR value (%) at 2.5 mm and 5.0 mm displacement at varying thickness of sand layer

Thickness of Sand Layer (cm)	CBR value (%)	
	2.5 mm Displacement	5 mm Displacement
0	15.48	17.38
2.5	16.90	19.11
5	18.05	21.21
7.5	23.20	27.71
10	23.50	27.71

(a) For 2.5 mm displacement

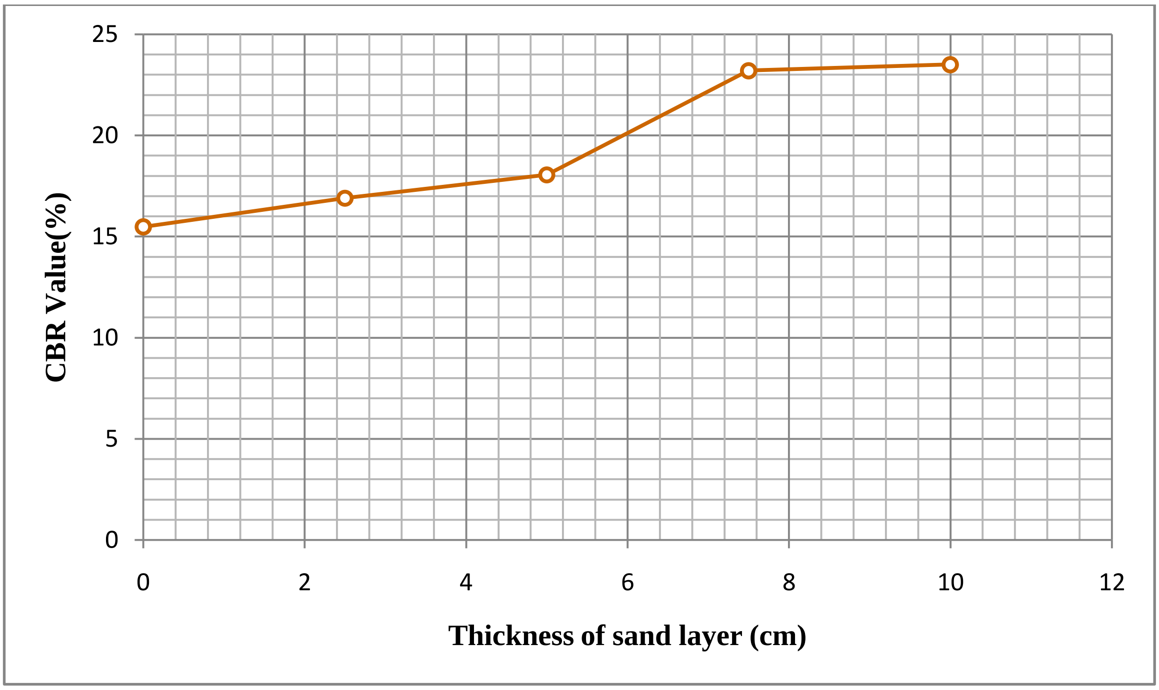


Fig.6.17 Thickness of sand layer (cm) vs. CBR Value (%) curve of compacted pond ash beds at 2.5 mm displacement

(b) For 5.0 mm displacement

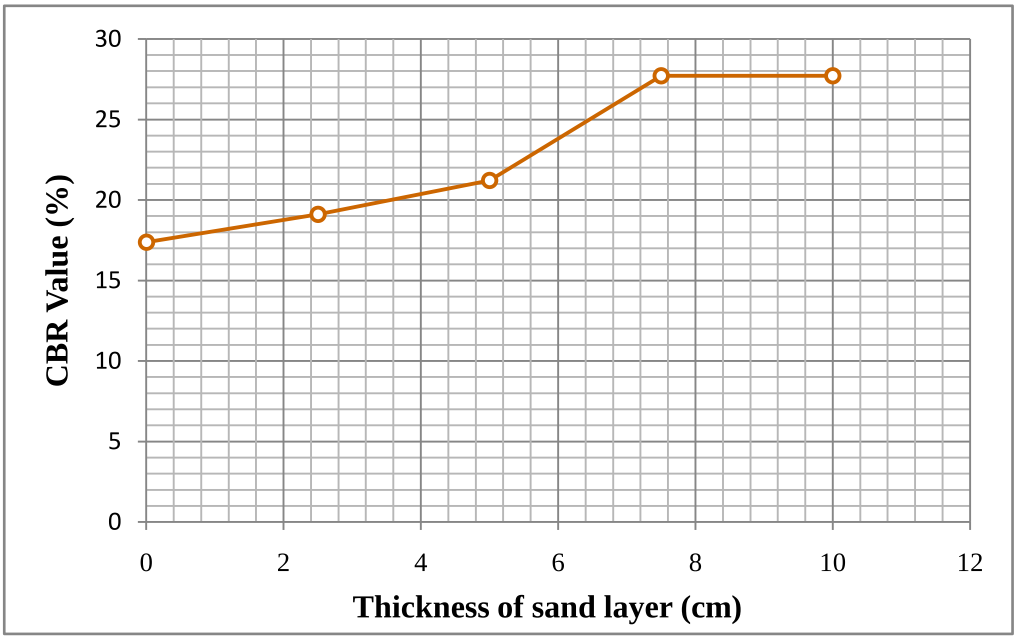


Fig.6.18 Thickness of sand layer (cm) vs. CBR Value (%) curve of compacted pond ash beds at 5.0 mm displacement

CBR value increases when the overlain sand layer thickness increases

6.2.4 Effects of variation of water content of sand on the CBR value of Pond Ash Beds

(a) Sand layer thickness: 5 cm with water content 4%

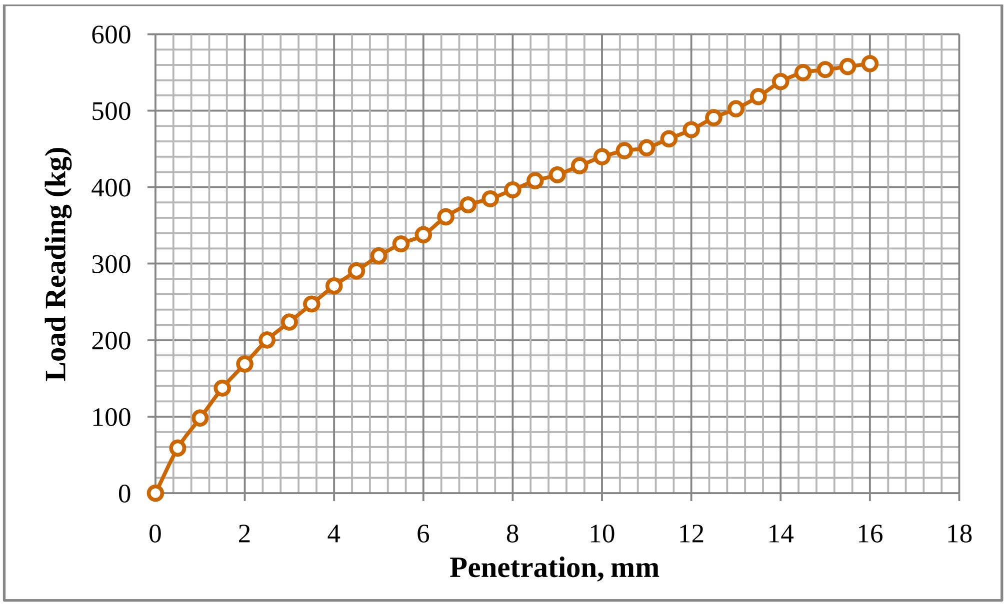


Fig.6.19 Load vs. Deformation curve of compacted pond ash beds overlain by 5.0 cm thick sand layer with water content 4%

	2.5 mm Displacement	5.0 mm Displacement
CBR value (%)	14.62	15.10

(b) Sand layer thickness: 5 cm with water content 7.0 %

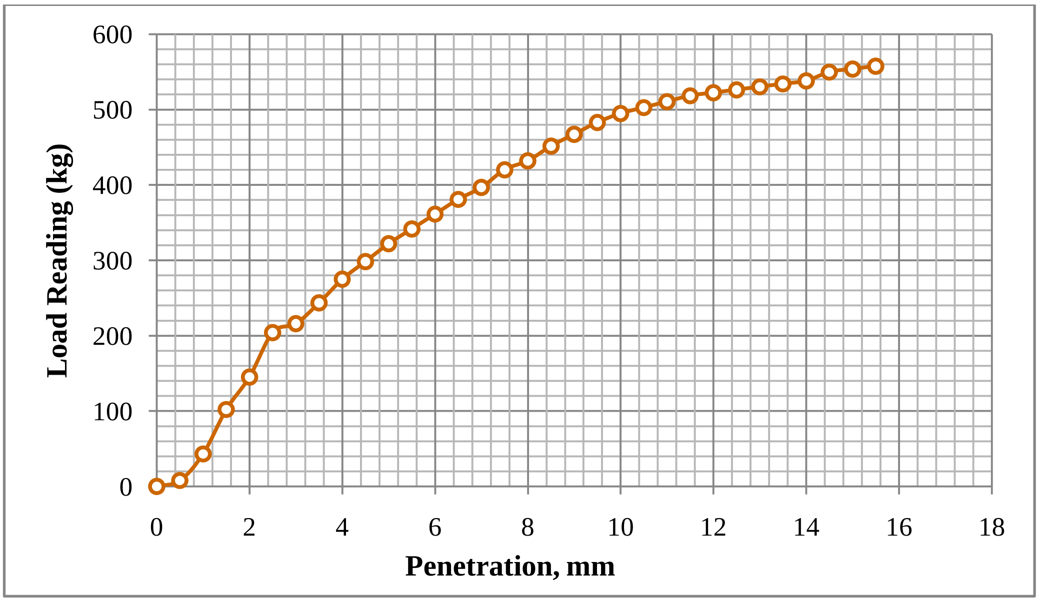


Fig.6.20 Load vs. Deformation curve of compacted pond ash beds overlain by 5.0 cm thick sand layer with water content 7.0 %

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	14.90	15.67

(c) Sand layer thickness: 5 cm with water content 10.0 %

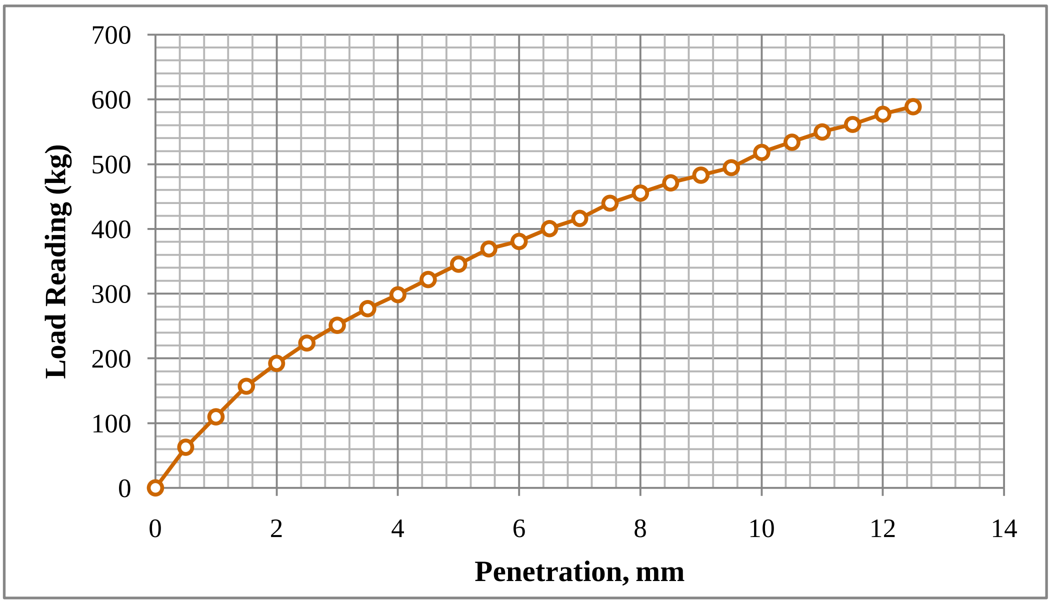


Fig.6.21 Load vs. Deformation curve of compacted pond ash beds overlain by 5.0 cm thick sand layer with water content 10.0 %

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	16.34	16.81

(d) Sand layer thickness: 5 cm with water content 13%

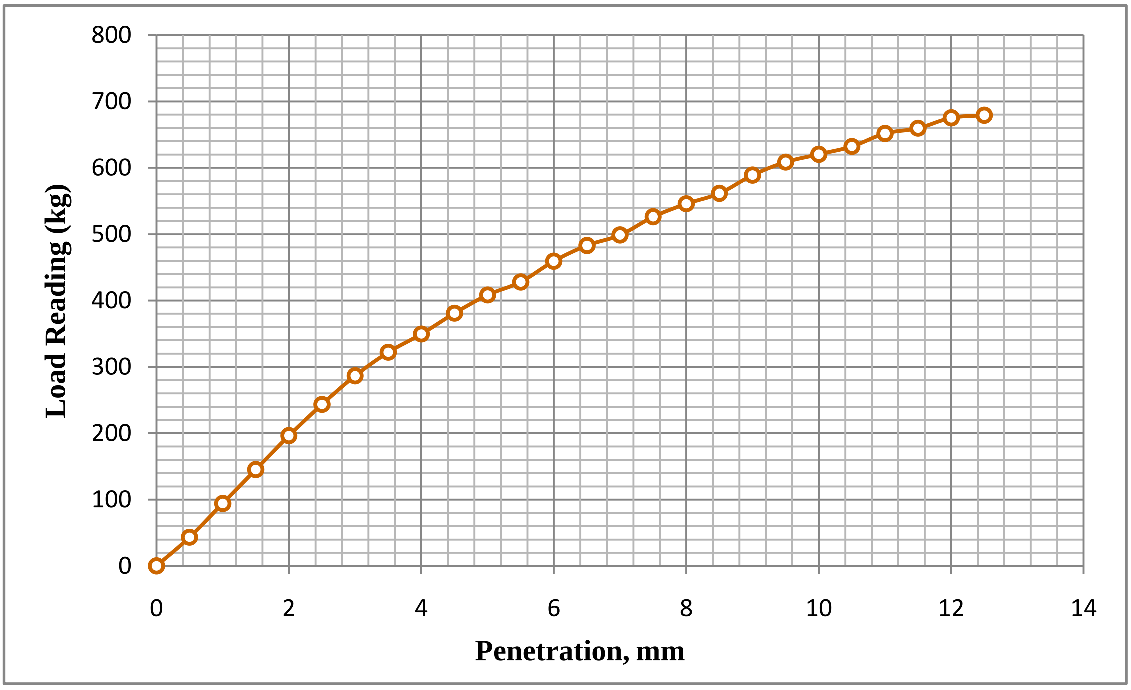


Fig.6.22 Load vs. Deformation curve of compacted pond ash beds overlain by 5.0 cm thick sand layer with water content 13.0 %

CBR value (%)	2.5 mm Displacement	5.0 mm Displacement
	17.77	19.87

6.2.4.1 Concluding Table and Graph of Effects of variation of water content of sand on the CBR value

Table.6.5 CBR value (%) at 2.5 mm and 5.0 mm displacement at varying water content of sand

Water content of Sand (%)	**CBR value (%)**	
	2.5 mm Displacement	**5 mm Displacement**
4	14.62	15.10
7	14.90	15.70
10	16.34	16.81
13	17.77	19.87

(a) For 2.5 mm displacement

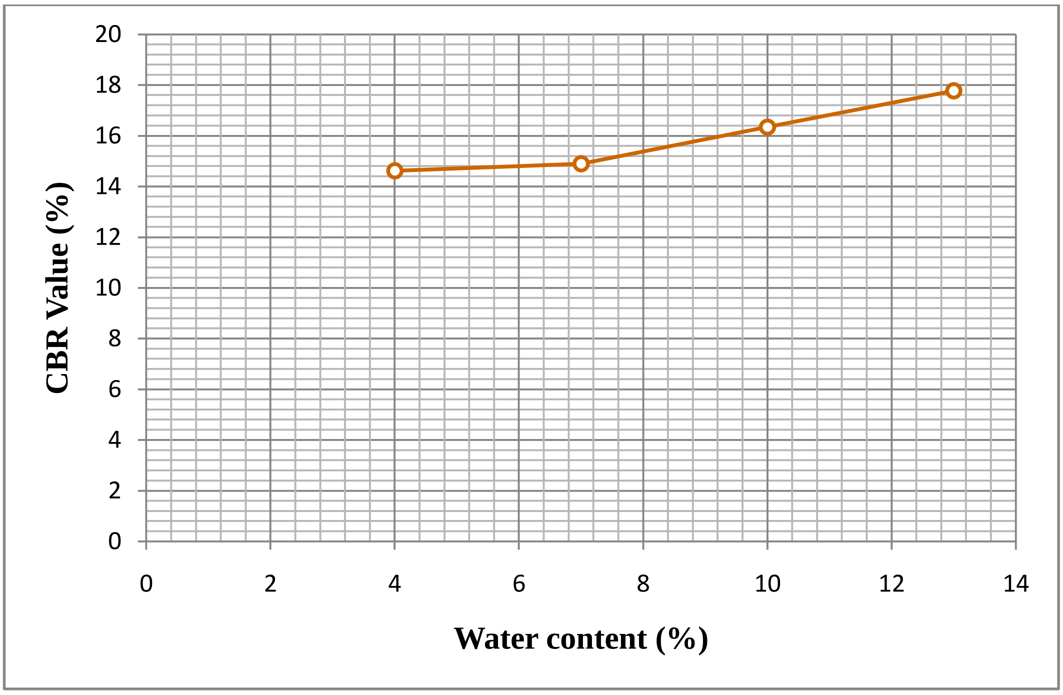


Fig.6.23 Water content (%) vs. CBR Value (%) curve at 2.5 mm displacement of compacted pond ash bed overlain by 5.0 cm thick sand layer

(b) For 5.0 mm displacement

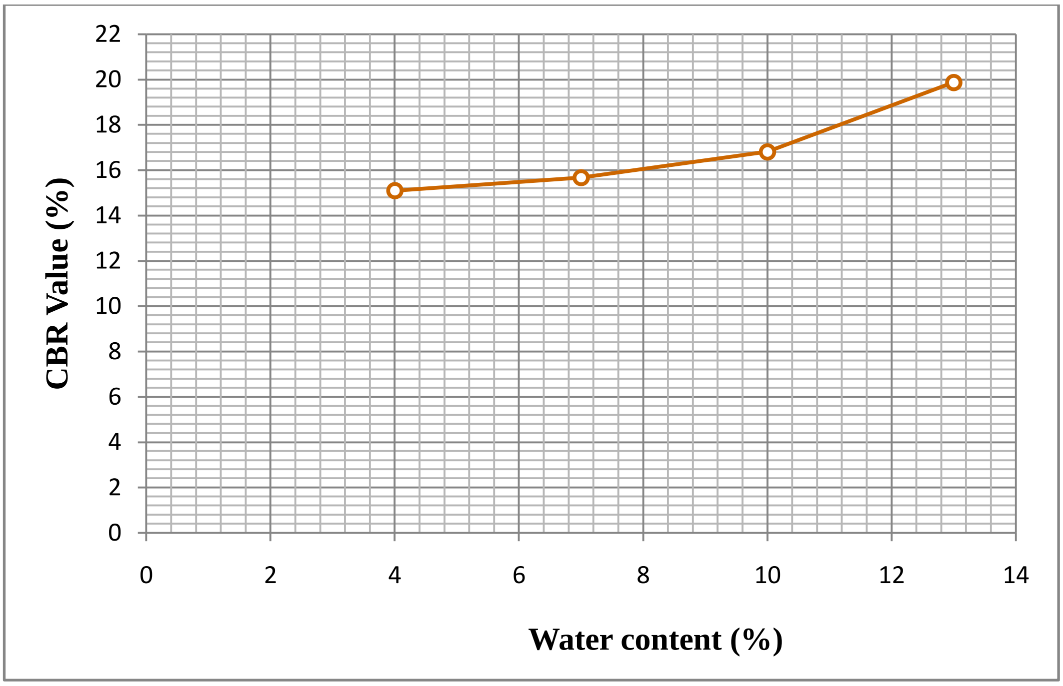


Fig.6.24 Water content (%) vs. CBR Value (%) curve at 5.0 mm displacement of compacted pond ash bed overlain by 5.0 cm thick sand layer

CHAPTER 7

CONCLUSION

1. After performing the various lab experiments on pond ash one can say that the pond ash has good capability for using in geotechnical applications. Its low specific gravity, ease of compaction, etc. can be widely used in the various construction works such as embankments construction, construction of road, filling of low-lying areas, structure fill, etc.

2. After observing the SEM images of the pond ash samples, it can be concluded that the pond ash particles shape may be irregular spherical, semi-spherical and sometimes irregular grains and presence of intra particle voids with irregular shapes can also be observed in these micrographs.

3. The grain sine analysis shows that the pond ash is mostly of medium to fine sand size of uniform gradation and with low specific gravity i.e. 1.85 whereas specific gravity of sand is 2.594.

4. With the increase in depth of reinforcement the CBR value decreases. However, when the depth of reinforcement is 2 times the diameter of the plunger, practically there is no improvement in the CBR value of reinforced pond ash.

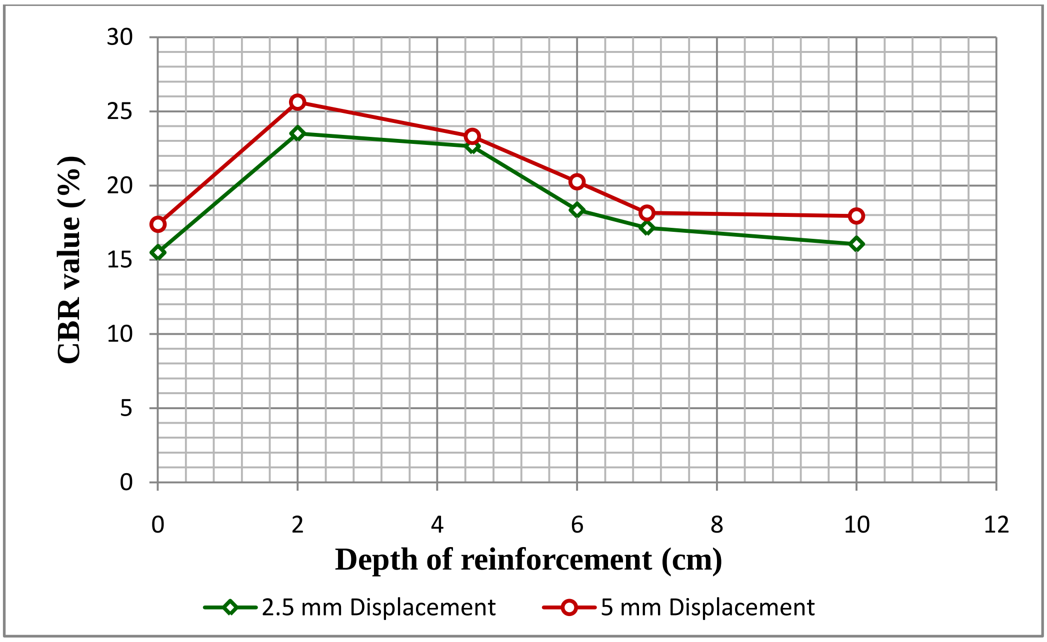


Fig.7.1 CBR value (%) vs. Depth of reinforcement for 2.5 mm, 5.0 mm displacement

5. With the increase in number of layers of reinforcement, the CBR value of reinforced pond ash beds increases.

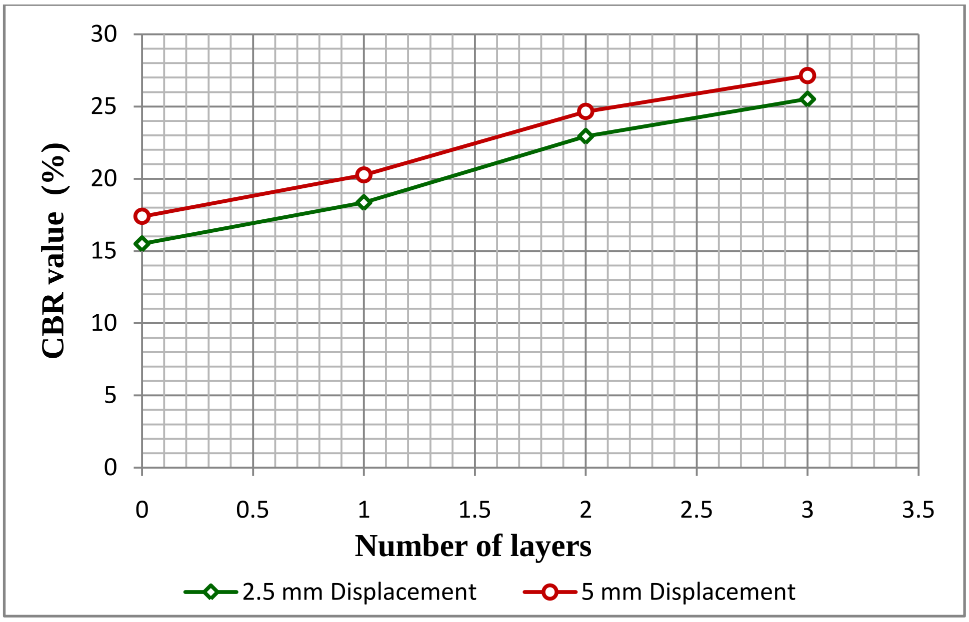


Fig.7.2 CBR value (%) vs. number of layers of reinforcement for 2.5 mm, 5.0 mm displacement

6. CBR value increases with the increase in thickness of overlain sand layer, so the CBR value of compacted pond ash can be improved by putting a layer of sand over it.

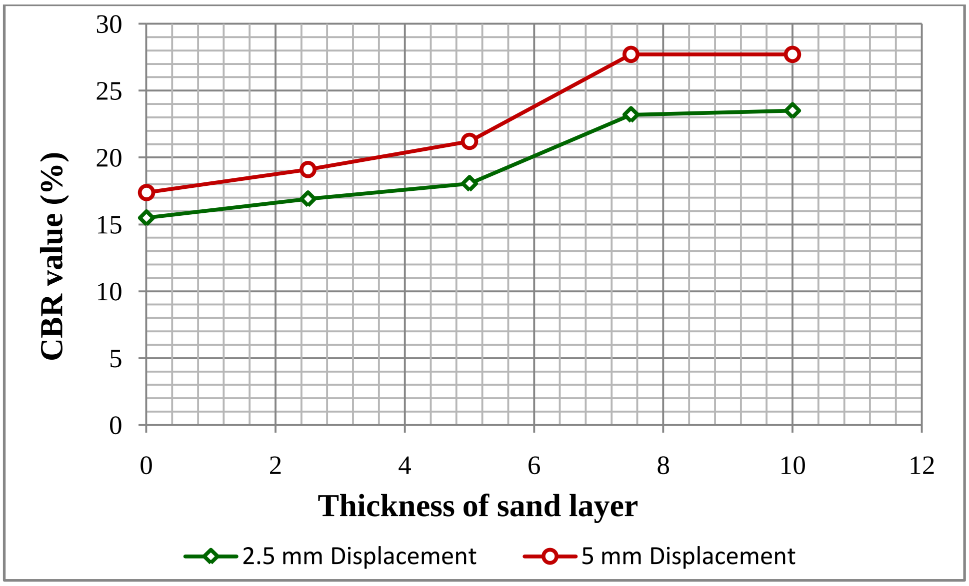


Fig.7.3 CBR value (%) vs. overlain thickness of sand layer for 2.5mm, 5.0 mm displacement

7. With the increase in water content of sand layer, the CBR value of reinforced pond ash beds increases.

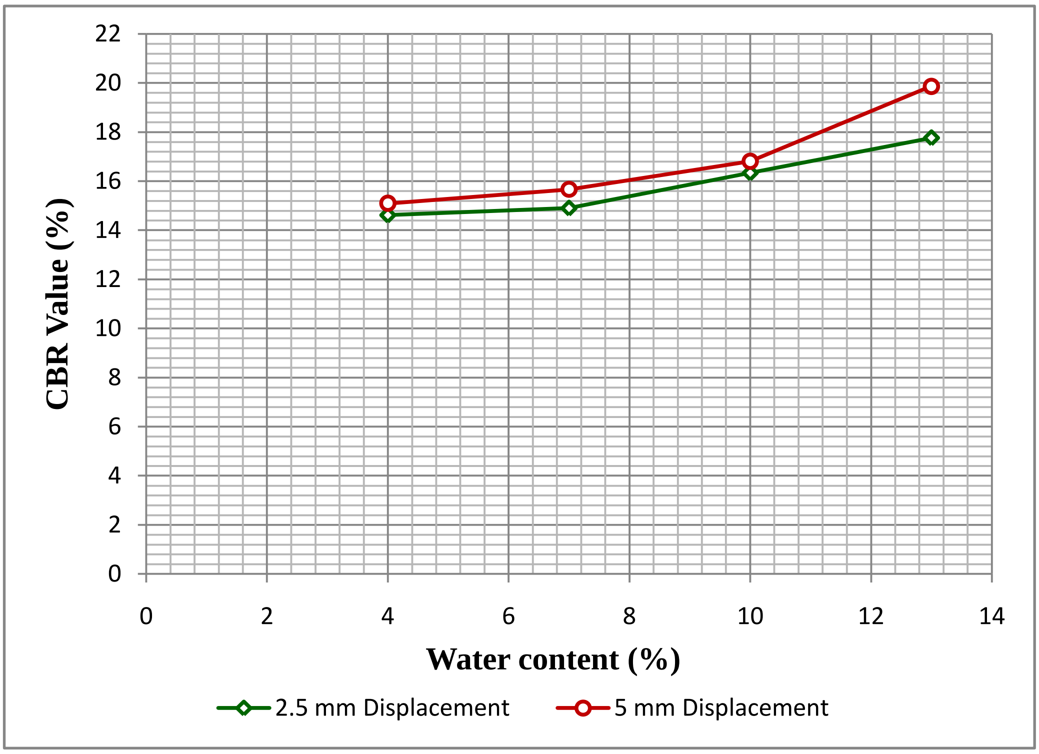


Fig.7.4 CBR value (%) vs. water content of sand layer for 2.5 mm, 5.0 mm displacement

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