COMPACTION CHARACTERISTICS OF

FLY ASH AND POND ASH

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Technology

In

Civil Engineering

(Geotechnical Engineering)

Ratnesh Kumar

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

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Under the guidance and supervision of

Prof. Chittaranjan Patra

Submitted by

Ratnesh Kumar

(ROLL NO. 215CE1264)

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Department of Civil Engineering

National Institute of Technology Rourkela

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CERTIFICATE

This is to certify that the project entitled "***Compaction Characteristics of Fly Ash and Pond Ash***" submitted by Mr. Ratnesh Kumar (Roll No. 215CE1264) in partial fulfilment of the requirements for the award of Master of Technology Degree in Civil Engineering at NIT Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this report has not been submitted to any other university/institute for the award of any degree or diploma.

Place: Rourkela

Date:

Prof. Chittaranjan Patra

Department of Civil Engineering

National Institute of Technology Rourkela

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(**Ratnesh Kumar**)

Abstract:

This study is based on compaction characteristics of Fly ash and pond ash. In thermal power plants, there are three kinds of ash formed named as (a) pond ash, (b) fly ash, and (c) bottom ash. Fly ash is one of the products of coal combustion, consisting of the fine particles that are determined out of the boiler with the flue gasses. The ash falls to the bottom of the boiler is called bottom ashes. In existing coal plants, generally,fly ash is captured by electrostatic precipitators and other clarified particles equipment before reaching the chimney. Pond ash is the by-product of thermoelectric power plants, which is recognized by means of an unused material and disposal is an important environmental issue and also needs a lot of removal regions. Several factors influence the dry density of Fly ash and Pond ash such as specific gravity, moisture content, compaction energy, layer thickness and mold area. The difference of the OMC and MDD of Fly Ash (collected from NTPC kanhia, Odisha) according to the standard proctor compaction energy is 0.90 – 1.59 gm/cc and 18 - 27%, respectively. This difference of the OMC and MDD of Pond ash as per standard proctor compaction energy at the level of 0.856 – 1.248 gm/cc and 33 - 46%, respectively. The study was that variation in these factors influencing the dry density of fly ash and ash pond significantly and to determine the Geotechnical properties of pond ash and fly ash.

KEYWORDS: Fly ash, Pond ash, MDD, OMC, Proctor test etc.

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List of Notations

NOTATION	DESCRIPTION
E	*Compaction Energy, kJ/m3*
OMC	*Optimum Moisture Content, %*
MDD	*Maximum Dry Density, kN/m3*
Cu	*Unit Cohesion, kN/m2*
Φ	*Angle of Internal Friction, Degrees*
M.C	*Moisture Content, %*
C‘‘/C	*Normalized Cohesion*
Cu	*Coefficient of Uniformity*
Cc	*Coefficient of Curvature*
G	*Specific Gravity*
LL	*Liquid Limit*
Dr	*Relative Density*
CBR	*California bearing ratio*
UCS	*unconfined compressive strengths*

CHAPTER-1

INTRODUCTION

1. Introduction:

Fly ash in with the products of coal burning, consisting of good particles that are excluded from the boiling with fumes. The ash falls bottommost of the boiler is named as bottom ashes. Depending on the source and the composition of burnt coal, volatile ash components vary significantly but all volatile ash contains significant quantities of silicon dioxide (SiO_2) (both uniformed and crystal-like), aluminum oxide (AL_2O_3) and calcium oxides. Flying ash component solidifies while deferred in use gasses and is possessed by electrostatic precipitators or refine baggage. Then fragments coagulate quickly though deferred now dissipate gasses, fly ash particles are normally rounded and vary from 0.5 to 300 microns. The main concern is that few hardening of the mineral has the time to crystallize and remain in the tempered amorphous glass. As a result, fly ash is a multifarious component.

For resolving fly ash compaction parameters the most normally used methods are Standard and Modified Proctor methods. One1of1the main compatibility tests, on1waste1from1a1power1industry1lagoon,1was achieved by Raymond and Smith, who indicated that1the1test1procedure1could influence compaction1parameters.1They observed, for the period of compaction through the Standard1Proctor1method, a dissimilarity among fly ash1compaction arch when1samples, saturated in the test, were1compacted regularly, or when without exception limit on1the arch was1obtained applying "pure" sampling. It was next established by Leonards & Bailey, who verified (by Modified Proctor) a bottom1ash and fly1ash mixture from the dry distribution place. They related to experimental consequence through particle degradation.

There are two classes of fly ash are defined by ASTM C618: F Class fly ash and C-Class fly ash. The main difference between these classes is the amount of calcium, silica, alumina and iron contained in the ash. Coal is used as the chief fuel in thermal power plant and in additional commerce. Good residues from the above-mentioned plants are assembled in a field recognized as fly ash and is measured as an unused component. Fly ash is available in a dry or varied form with liquid and fixed in places named pond ash. The quantity of powerful fly ash formed is enormous and increasing day by day. Four countries, specifically India, China, USA & Poland produce approximately 270 million tons of fly ash each year.

Pond Ash is the by-product of the thermoelectric power plants, which recognize an unused material and demolition is an important environmental issue and also requires a proportion of dumping areas. In fact, components are three kinds of ashes of the thermoelectric power plants i.e (i) fly ash, (ii) pond ash, (iii) bottom ash. Fly Ash is possessed by automatic or electrostatic fumes of central precipitators; the bottom ash is possessed from the lowermost of the boiler. When the above-mentioned two types of ash, varied simultaneously, are transferred in the form of sludge and reserved the gaps, the boiler is named ash pond or bottom ash and ashes are mixed with water to form slurry pumped ash zone. Ash is deposited in the ash and excess water is poured. This is called pond ash deposited ash. Ash pond is the outgrowth of the thermoelectric influence plants, that is studied an unused component and disposition is an important environmental issue and also needs an enough of clearance areas. In fact, three kinds of ashes of power plants, namely: (i) fly ash, (ii) bottom ash, and (iii) pond ash. Pond ash, which can be used to improve soil, has gained enormous momentum over the last two decades. The initial questions of the pond ash, become stable with lime, as a sub-grade of the road in the late 1950s and initial sixties (Davidson & manageable, 1960; Snyder & Nelson, 1962). In the seventies, the variation of fly ash functions expanded (Copp and Spencer 1970 Joshi et al 1975), and functions by swallowing cement-stabilized fly ash was introduced.

CHAPTER-2

LITERATURE REVIEW

2. 1 LITERATURE REVIEW:

2.1.1 Different studies on pond ash:

Bera et al. (2007) declared that the properties of changed compaction controlling parameters, i.e. mold area, layer width, moisture content, specific gravity, compaction energy and tank size on the dry density of pond ash are explained. The MDD and OMC of pond ash differ in reach the area of 0.856 – 1.248 gm/cc and 29–46%, correspondingly. The strength of concentration at an OMC of pond ash has been creating to differ in reach the area of 63 – 89%. An empirical model has been established to evaluation the dry density of pond ash, applying numerous regression studies, in terms of specific gravity, moisture content and compaction energy.

Jakka et al. (2010) declared that energy and alternative geotechnical features of pond ash specimen, possessed from invasion and streaming facts of two ponds ash in India, are related to sandy soils in many forms. Strength characteristics were examined by means of undrained (CU) and consolidated drained (CD) triaxial tests through compacted specimens of pond ash samples under different confining pressures, pore water pressure measurements and conducted on loose.

Ghosh (2010) declared that Class F pond ash only and become constant with changing % of lime (4, 6, and 10%) and phosphogypsum (0.5 & 1.0), to study the suitability of stabilized pond ash for sub-base and road base construction. Modified & standard proctor tests had been directed to disclose the compaction characteristics of the balanced pond ash. Equally the bearing ratio tests of soaked & unsoaked have been directed. The effect of PG content, curing period & lime on the bearing ratio of fixed pond ash. The empirical model has been established to estimate the bearing ratio for the stabilized mixes through numerous regression study.

Singh and Sharan (2014) declared that the degree of saturation on strength characteristics of compacted pond ash and properties of compaction energy. The MDD & OMC consistently to different compactive energies were resoluted by conventional compaction tests. The California bearing ratio (CBR), unconfined compressive strengths (UCS), shear strength parameters, and specimen's values of compressed to different moisture content and dry densities were evaluated and described. The degree of saturation of shear strength parameters and effects of compaction energy i.e. angle of internal friction (ϕ) values and unit cohesion (cu) and similarly the unconfined compressive strengths values are calculated and conferred.

N. S. Pandian (2004) studies carried out on a review of characterization of the fly ash with reference to geotechnical applications. He summarized that fly ash with some modifications/ additives, (if required) can be effectively utilized in geotechnical applications.

Bera et al. (2007) implemented on the effective utilization of pond ash, as foundation medium. A series of laboratory model tests have been carried out using square, rectangular and strip footings on pond ash. The effects of dry density, the degree of saturation of pond ash, size and shape of footing on the ultimate bearing capacity of shallow foundations are presented in this paper.Local shear failure of a square footing on pond ash at 37% moisture content (optimum moisture content) is observed up to the values of dry density 11.20 kN/m3 and general shear failure takes place at the values of dry density 11.48 kN/m3 and 11.70 kN/m^3. Effects of degree of saturation on ultimate bearing capacity were studied. Experimental results show that degree of saturation significantly affects the ultimate bearing capacity of strip footing. The effect of footing length to width ratio (L/B), on increase in ultimate bearing capacity of pond ash, is insignificant for L/B $\geq$ 10 in the case of rectangular footings. The effects of size of footing on the ultimate bearing capacity for all shapes of footings viz., square, Rectangular and strip footings are highlighted.

R. S. Jakka, G. V. Ramana, M. Datta (2010) gave a detailed experimental study carried on the strength and othe geotechnical characteristics of pond ash samples, collected from inflow and out flow points of two ash ponds. Strength characteristics were investigated using consolidated drained (CD) and undrained (CU) triaxial tests with pore water pressure measurements, conducted on loose and compacted specimens of pond ash samples under different confining pressures.

2.1.2 Different studies on fly ash:

Osman et al. (2008) considered a number of compaction test results on fine-grained (cohesive) soil, including those provided by Gurtug and Shridharan (2004). The following correlation was established on the basis of this study:

γd (max) (kN/m^3) = L-M w_{opt}

w_{opt} (%) = (1.99 – 0.165lnE) (PI)

where,

E = compaction energy (kN-m/m^3)

PI = Plasticity index (%)

M= -0.19 + 0.073ln E

L= 14.34 + 1.195ln E

Patra et al. (2010) directed modified and standard proctor tests (ASTM test designation D- 698 and D- 1557 appropriately) taking place 55 sand specimen to evaluated minimum and maximum void ratio (e_{min}, e_{max}) and the void ratios at the Optimum Moisture Content on or after modified and standard Proctor compaction tests (e_s and e_m). The median grain size (D_{50}) of soils have been correlated with the void ratios and hence, the relative density of compaction (D_r).

Modified proctor test:

$$D_r = .8321 D_{50}^{-.087}$$

Standard proctor test:

$$D_r = .5864 D_{50}^{-.107}$$

Patra et al. (2010), tests completed on 55 clean sand samples from modified (blows = 12, E= 1300 kN-m/m^3 approximately) and "reduced" standard (number of hammer blows per layer = 15 with E= 360 kN-m/m^3 approximately) proctor test and between D_r, D_{50} and the compaction energy (E), correlation developed.

$$D_r = AD_{50} – B \text{ (Modified Proctor test)}$$

Where,

A = 0.216ln E -0.850

And,

B = -0.03ln E +0.306

Lisa et al. (1998) defined a process for approximating optimum moisture content (w_{opt}) and maximum dry density ($\gamma_{d\ max}$) of soils (clayey) on any compaction energy E. One process was created on the compaction curve & liquid limit, while another created proceeding on

Liquid Limit merely. The Linear relationship among log E and $\gamma_{d\ max}$ & log E and W_{opt}, equally are a function of the liquid limit which used to generalize to different compaction energies.

If the LL and compaction curve known,

Then,

$$\gamma_{d\ max, E} = \gamma_{d\ max, k} + (2.27\ LL - 0.94) \log (E/E_K)$$

$$W_{opt, E} = w_{opt, k} + (12.39 - 12.21LL) \log (E/E_K)$$

And,

If only LL is known then,

$$\gamma_{d\ max, E} = (2.27 \log LL - 0.94) \log E - 0.16LL + 17.02$$

$$W_{opt, E} = (12.39 - 12.21 \log LL) \log E + 0.67LL + 9.21$$

Omar et al. (2003) studied modified proctor compaction test results of 311 soil samples, 45 were gravelly soils and 364 were sandy soils.The compaction test was done according to ASTM 1557 method C (modified proctor test) to avoid oversize correction. Based on result the following correlation was developed:

$$P_{d\ (max)}\ (kg/m^3) = [4,804,574\ G_s - 195.55(LL)^2 + 156,971(R\#4) - 9,527,830]^5$$

$$Ln\ (w_{opt}) = 1.195*10^{-4}\ (LL)^2 - 1.94\ G_s - 6.617*10^{-5}\ (R\#4) + 7.651$$

Where,

$pd_{(max)}$ = maximum dry density & W_{opt} = optimum water content (%)

G_S = specific gravity of soil solids & R#4 = percent retained on No. 4 sieve

Objective:

1. To check the effect of compaction on the geotechnical properties of fly ash and pond ash, such as permeability, shear strength, dry density with respect to moisture content.
2. To check the change in chemical and mineralogical composition with time delay due to compaction

CHAPTER-3

MATERIAL

AND

METHODOLOGY

3.1 MATERIAL AND METHODOLOGY:

This part defines the method and materials well-known reach the objectives. The important resources in this survey are fly ash and pond ash; experiential procedure for the characterization of these materials is discussed. The following section of this chapter is a brief introduction to materials and methodology.

3.1.1 Material:

(a) Fly ash (collected from NTPC Kanhia, Odisha)

(b) Pond ash (collected from NTPC Kanhia, Odisha)

(c) The samples were desiccated in an oven of 105 to 110º and sifted with a 4.75 mm Sieve.

(d) The compaction test, resistance and permeability parameters, and

(e) 2 mm IS sieve for per specific gravity.

Fly Ash

4.75 mm Sieve 2mm Sieve

Pond Ash

4.75 mm Sieve

2mm Sieve

3.1.2 Physical Properties of Fly Ash and Pond ash:

Fly ash particles are very fine, lightweight (density 1.97-2.89 g/cc) and spherical (specific surface area 4000-10,000 cm^2/g; diameter, 1-150μ), refractory and have the pozzolanic ability. Fly ash grey to blackish grey and is dependent on coal type and combustion process. Fly ash has dielectric property (dielectric constant, 104) and can be used in the electronic application.

Table 1: Physical properties of fly ash

PARAMETERS	RANGE
Colour	Grey
Shape	Rounded
Optimum Moisture Content (%)	18 - 27%
Maximum Dry Density (gm/cc)	0.90 – 1.59
Specific gravity	2.28
Plasticity Index, I_P	Non-plastic
Coefficient of curvature	1.29
Uniformity coefficient	5.58
Mean Diameter	0.05 mm

Table 2: Physical properties of pond ash

PARAMETERS1	1RANGE1
Colour	Light grey
Shape	Rounded / subrounded
Optimum Moisture Content (%)	33 - 46%
Maximum Dry Density (gm/cc)	0.856 – 1.248
Specific gravity	2.18
Plasticity Index, I_P	Non-plastic
Coefficient of curvature	1.27
Uniformity coefficient	5.69
Mean Diameter	0.3 mm

3.1.4 USES OF FLY ASH:

1. Waste stabilization and solidification.

2. Embankments and structural fill.

3. Portland cement.

4. Stabilization of soft soils.

5. Mine reclamation.

6. Raw feed for cement clinkers.

3.1.5 USES OF POND ASH:

1. In Landfill and dyke rising.

2. Manufacture of Portland cement.

3. Manufacture of Bricks.

4. Part replacement in mortar and concrete.

5. In Structural fill for reclaiming low areas.

6. Stowing materials for mines.

3.2 Test Procedures:

3.2.1 Specific gravity:

According to a unique load of fly ash and pond ash was expect as IS: 2720 (Part III, Section 1) 1980, which was used a sample of 50 g fly ash and pond ash oven at 105-110 degrees, passing through a sieve of 2 mm and the weight nearest to 0.001 g. Three density bottle (pyknometers) of 50 ml, a dryer, and boiler to heat the density bottle remove the air foams and refined water.

For describing exact pressure, three frequency bottles has been taken and weighing near to 0.001 gram. Next 50-gram oven dry bottom ash were taken passes through 2 mm IS sieve, weighing nearby to 0.001gram. At that moment sampling and pyknometers equally weighing collectively, then the mass of pycnometers and distilled water were taking. By this method presented in IS 2720 (Part-3, section-1)1980 specific gravity resolute.

To determine the specific weight, they were taken and the first three heavy bottles closer to the density of 0.001 g. Then 50 g of fly ash and pond ash dried in the oven by passing through a sieve of 2 mm, measured approximately of 0.001 g. Then the sampling and pyknometer are measuring simultaneously, then the mass of the pycnometer and refined water were taken. By this method presented in IS: 2720 (part 3, section-2), the specific weight of 1980 was defined.

3.2.2 Grain size analysis:

Grain size analysis was performed in keeping with IS code: 2720(part IV)-1985. For sieve analysis, 500-gram oven-dried specimen were taken and passing through sieve set which is: 75 μ, 150 μ, 212 μ, 300 μ, 425 μ, 600 μ, 1mm, 2mm, 4.75 mm. The mass of retained specimen was taken after that chart has been shown between passing percentage and width of the particle. Hydrometer analysis for the specimen which is passed through a sieve of 75 μ. Chart between the finest % and the diameter of the specimens was plotted. Both the chart was inserted and the ratio between the percentage passing and the width of the particle bending coefficient (Cc) and the coefficient of uniformity (Cu) was determined.

3.2.3 Permeability:

The permeability was resoluted according to fly ash and pond ash IS 2720 (part XVII) - 1986. Permeability is an influence by which water can flow through ash or soil due to consistent gaps. It is essential to estimate the amount of infiltration in different hydraulic conditions to investigate the stability analysis of ground and dam supporting structures that have undergone leakage. Hydraulic conductivity can be determined by two methods which are: Constant head test and Falling head test. According to current research, a constant1head test in which the head remained constant between the input and output of the control device were defined by hydraulic conductivity.

3.2.4 Compaction test:

The compaction of fly ash and pond ash has been done according to IS: 2720 (part 7)-1980 for light compaction and IS: 2720(part 8)-1983 for heavy compaction. Compaction is a process if densification of a granular material by applying mechanical energy. This process involves packing the granular material together with reducing the volume of air voids. Densification of granular material controls other engineering properties such as permeability, compression, and shear strength. The dry density of the compacted material is a measure of the degree of compaction achieved. This is the function of the quantity and application method of energy, the amount of water taken through compaction and the characteristics of materials such as specific gravity, particle shape, plasticity, grain size distribution, & gradation.

In the laboratory, the standard compaction test was performed using a molded diameter of 10 cm, 12.73 cm in height and 15 cm in diameter, 12.73 cm in height to give mold area variation. A 2.6 kg mass of hammer was used with a 310-millimeter drop to compact the ashes into the three-layer mold, each layer is subjected to 25 blows of the hammer drop mass providing 25 blows/layer. Modified compaction test uses the same mold in 5 layers of 4.9 kg of weight and a 450 mm drop mass providing 25 blows per layer.

3.2.4.1 Compaction test: Proctor mould

The impact of compaction controlling parameters testing on the dry density of variation of1these Parameters is Compaction energy variation (**up to eight energy levels**), specific gravity variation, layer thickness variation, compaction area variation.

3.2.5 Direct shear test:

Resistance parameters C & Φ are resoluted by the direct shear test according to IS: 2720 (part 13) 1986. Samples were collected by inserting a sample size of 0.06 m x 0.06 m x 0.025 m in the samples collected in the sampler. This test consists of a casing of dimensions 60 x 60 x 50 mm. A specimen obtained in MDD OMC and subsequently prepared deformation trimming to maintain normal variable strain content. A graph has been drawn in the middle of shear stress against normal stress and cohesion (c) and internal friction angle (Φ) shows the chart. C and Φ values were obtained with a light compacting energy and heavy compacting energy.

CHAPTER – 4

RESULT

AND

DISCUSSION

4.1 RESULTS AND DISCUSSION:

4.2 Index properties:

4.2.1 Specific gravity:

The specific gravity of coal ash mainly depends on its chemical composition. In specific gravity the value of coal ashes having a low when compared with those of soils that have specific gravity varying in a narrow range of 2.6-2.8.

In this study fly, ash and pond ash was collected and their specific gravity was found out as per IS: 2720 (Part-III, section-1)1980.

Table 3: Specific gravity of fly ash & pond ash collected from NTPC Kanhia, Odisha

Sl no.	Sample	Specific Gravity
1	Fly ash (NTPC Kanhia)	2.28
2	Pond ash (NTPC Kanhia)	2.18

4.2.2 Compaction test:

Two different molds were done in Compaction test to give the variation in compaction area as (a) Proctor mold, (b) CBR mold. Compaction energy variation has been given for each compaction mold.

4.2.2.1Compaction in Proctor mold:

Compaction test has been done in Proctor mold with variation in compaction energy. The Proctor mold which used has 10 cm width, and 12.7 cm length and which has a volume of 997.45 cm^3. The hammer weight for the standard was 2.6 kg and its fall height taken 31cm & the hammer weight for modified was 4.9 kg and its fall height is taken 45cm.

For fly ash:

Table 4: Maximum dry densities of samples, subjected to different compacting energies

Sl no.	No of blows/layer	Compaction energy (kN-m/m³)	Maximum Dry Density (kN/m³)	Optimum moisture content (%)
1	30	3244.6	13.83	18.25
2	25	2703.8	13.63	18.68
3	15	1622.3	13.43	19.34
4	12	1297.8	13.04	20.63
5	30	711.6	12.94	22.71
6	25	593.0	12.65	23.34
7	15	355.8	12.45	24.33
8	12	284.6	12.26	24.48

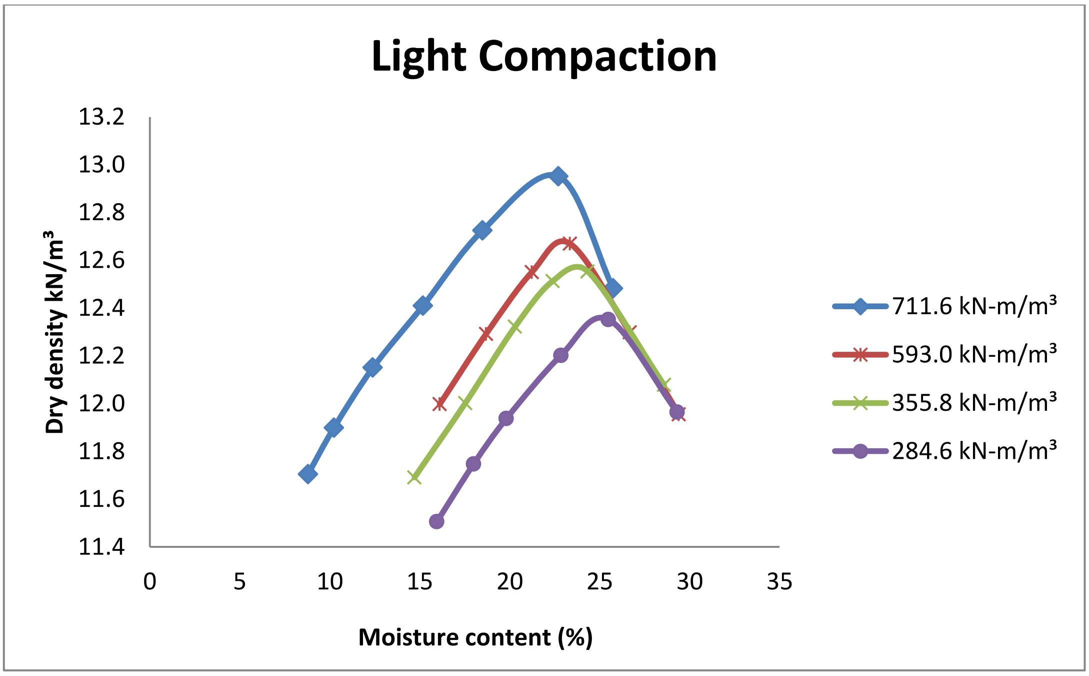

Figure 1: Variation in dry density with change in compaction energy (standard fly ash)

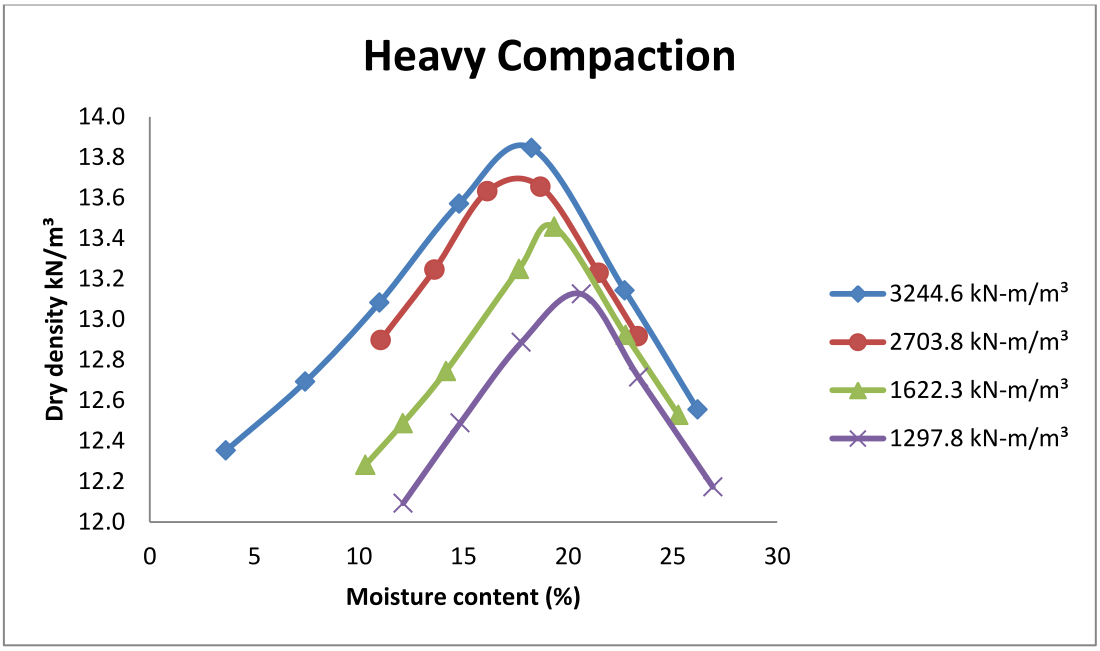

Figure 2: Variation in dry density with change in compaction energy (modified fly ash)

For pond ash:

Table 5: Maximum dry densities of samples subjected to different compacting energies.

Sl no.	No of blows/layer	Compaction energy (kN-m/m³)	Maximum Dry Density (kN-m³)	Optimum moisture content (%)
1	30	3244.6	10.59	34.24
2	25	2703.8	10.49	36.27
3	15	1622.3	10.30	37.90
4	12	1297.8	10.10	39.31
5	30	711.6	9.51	42.21
6	25	593.0	9.41	42.93
7	15	355.8	9.22	43.98
8	12	284.6	9.12	45.50

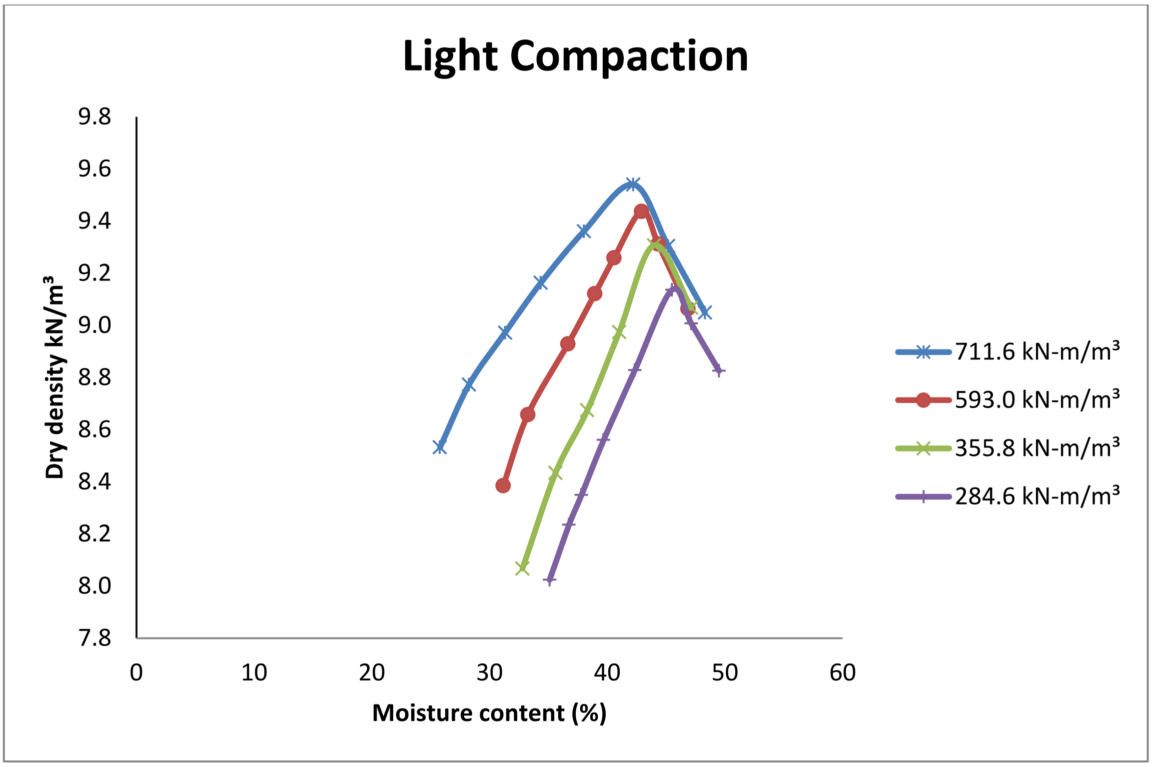

Figure 3: Variation in dry density with change in compaction energy (standard pond ash)

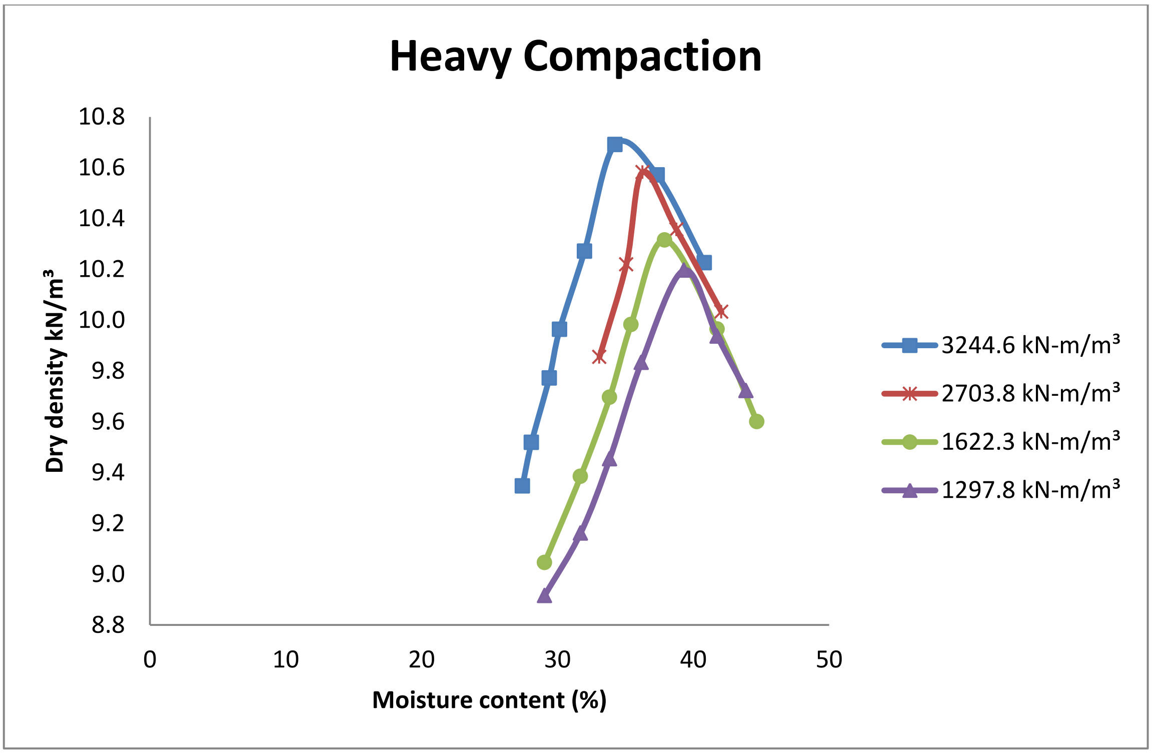

Figure 4: Variation in dry density with change in compaction energy (modified pond ash)

4.2.3 **The relationship between compaction energy vs dry density:**

The effect of compaction energy on dry density has been shown in the figure, from the curve of compaction energy vs dry density, it can be seen that as compaction energy increases, dry density increases until a critical point reached of dry density. The relationship between dry density and compaction energy is following:

For fly ash:

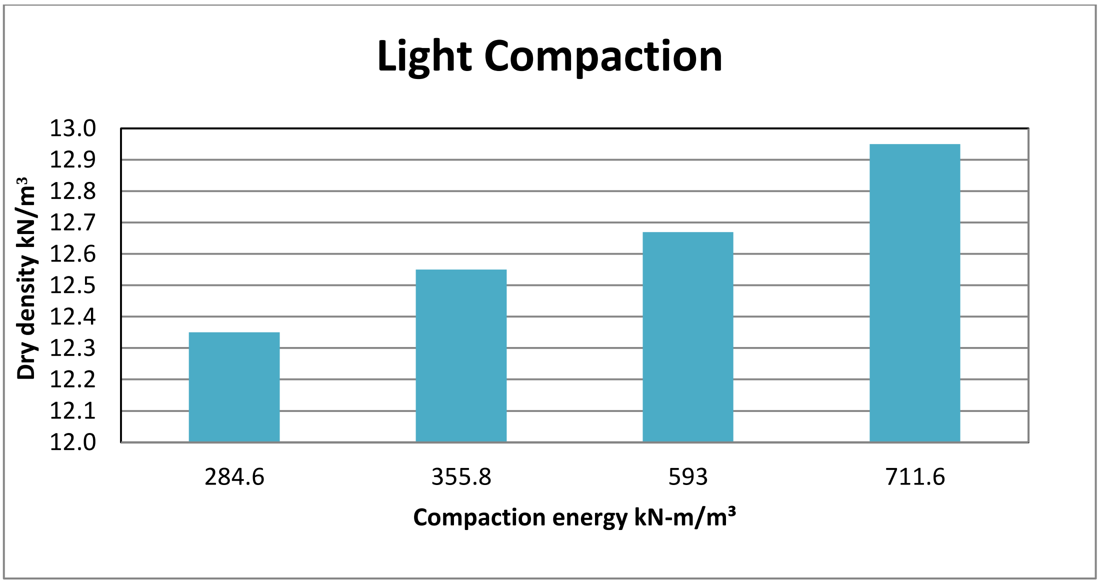

Figure 5: The relationship between compaction energy and dry density of standard fly ash collected from (NTPC Kanhia)

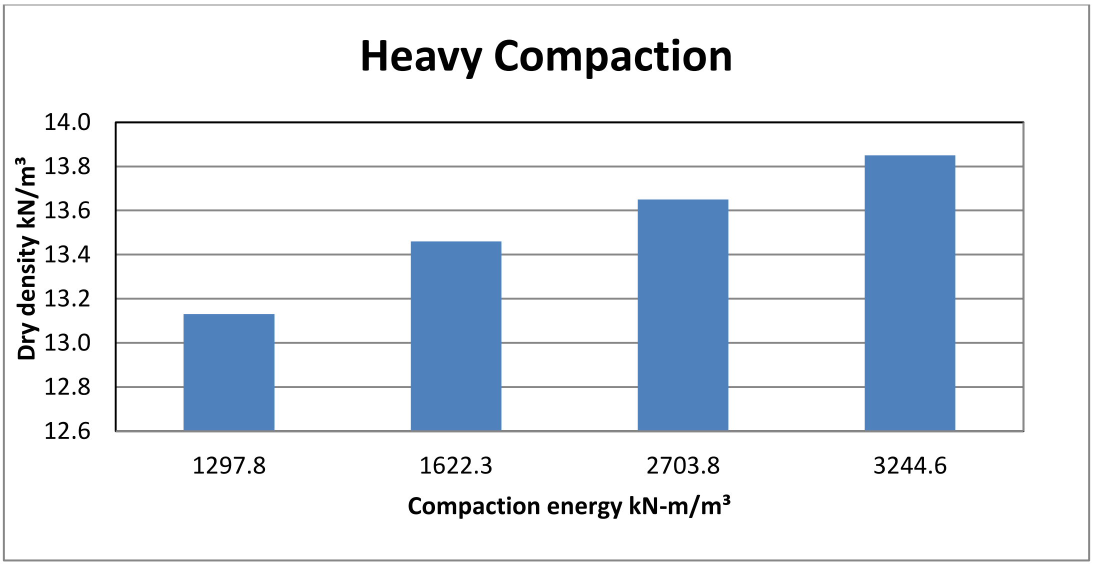

Figure 6: The relationship between compaction energy and dry density of modified fly ash collected from (NTPC Kanhia)

For pond ash:

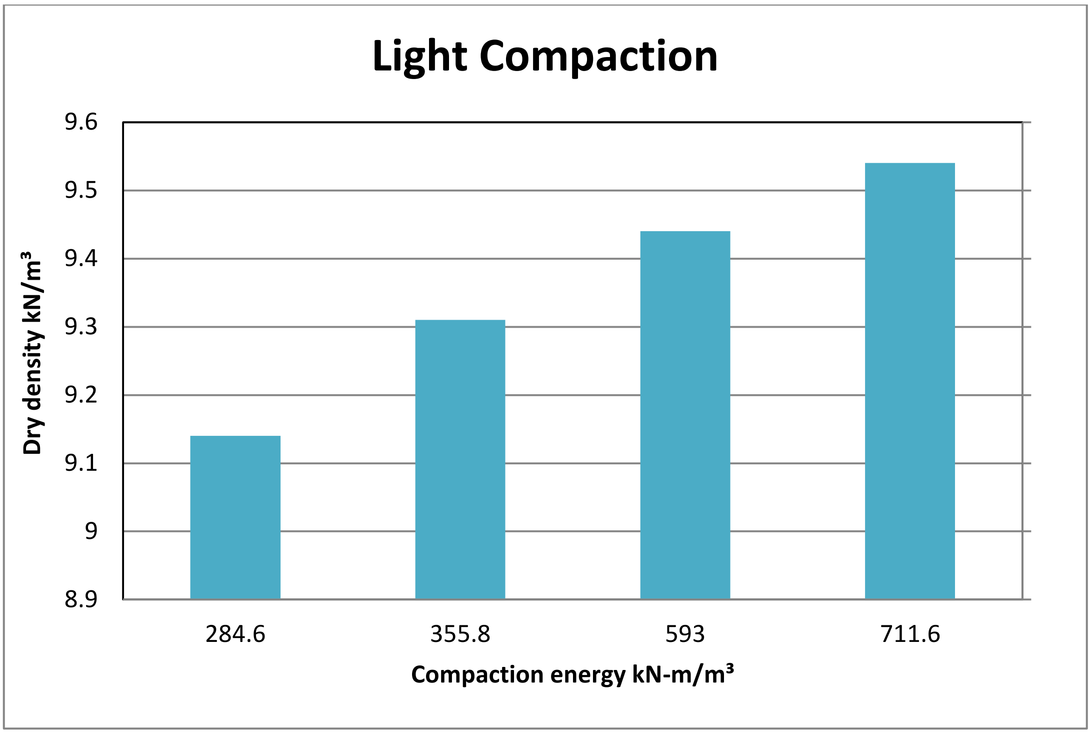

Figure 7: The relationship between compaction energy and dry density of standard pond ash collected from (NTPC Kanhia)

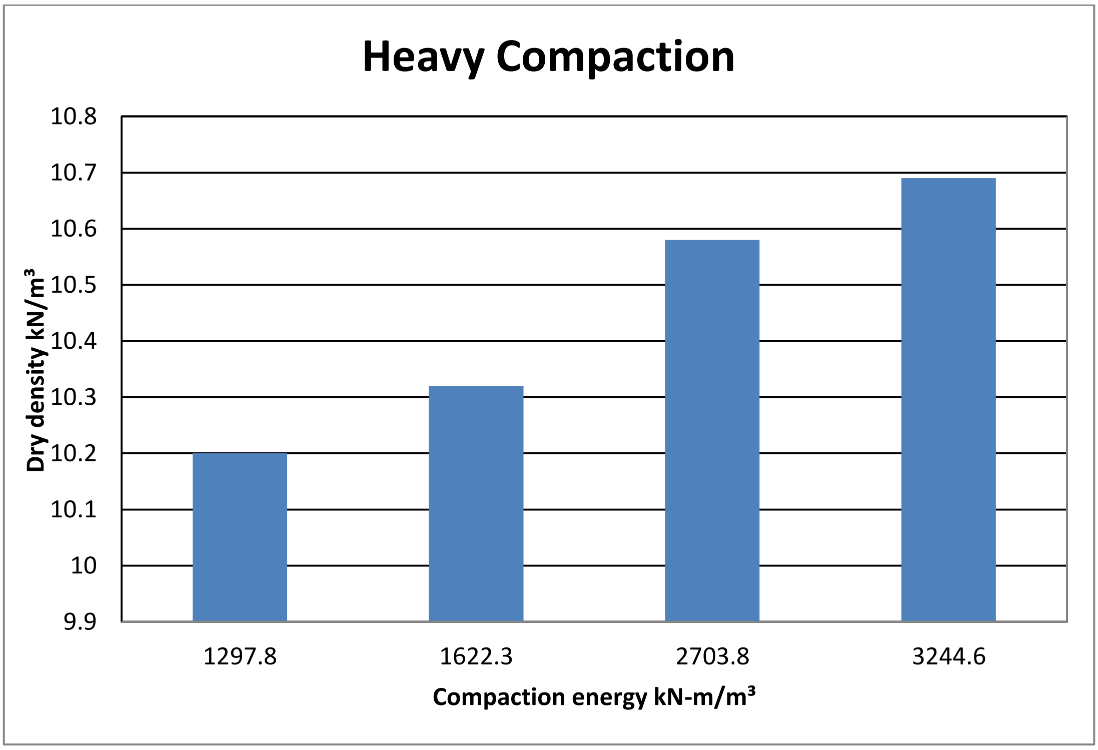

Figure 8: The relationship between compaction energy and dry density of modified pond ash collected from (NTPC Kanhia)

4.2.4 **The relationship between compaction energy vs moisture content:**

The curve has been plotted between compaction energy and moisture content. From the graph, it can be seen that as compaction energy increases, moisture content decreases.

For fly ash:

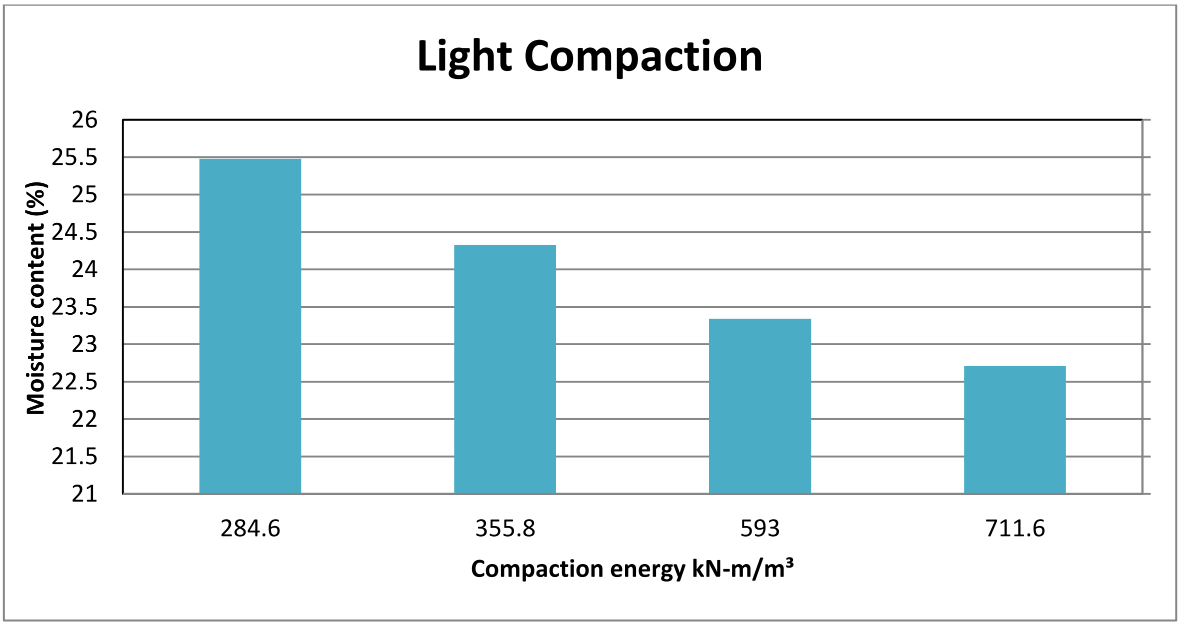

Figure 9: The relationship between compaction energy vs moisture content of standard fly ash collected from (NTPC Kanhia)

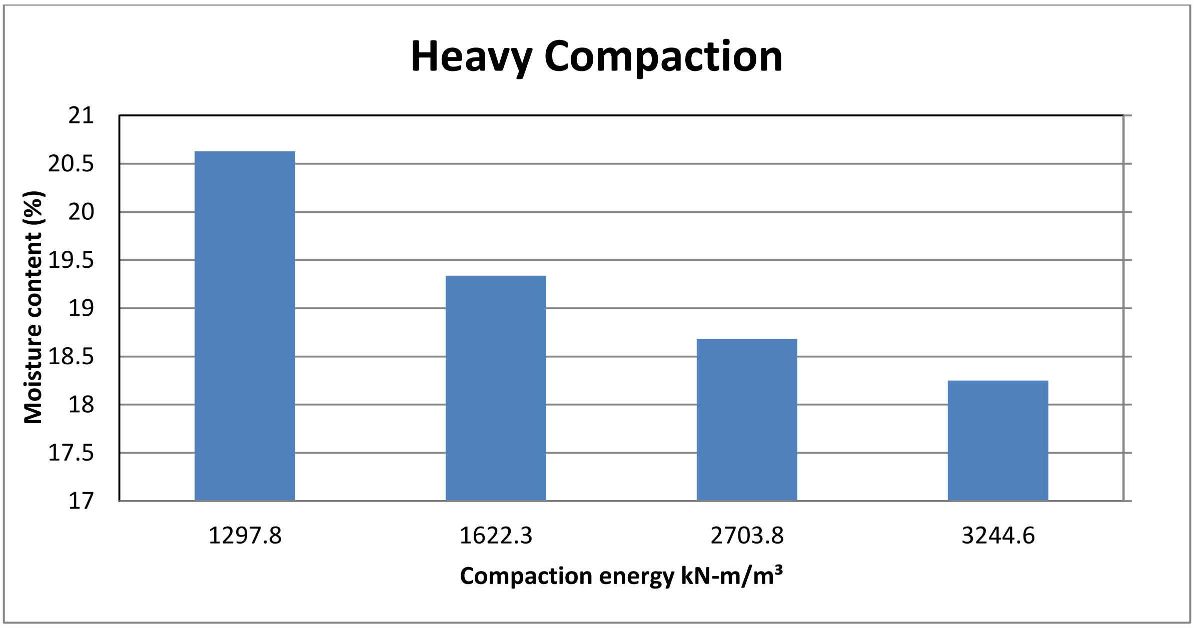

Figure 10: The relationship between compaction energy vs moisture content of modified fly ash collected from (NTPC Kanhia)

For pond ash:

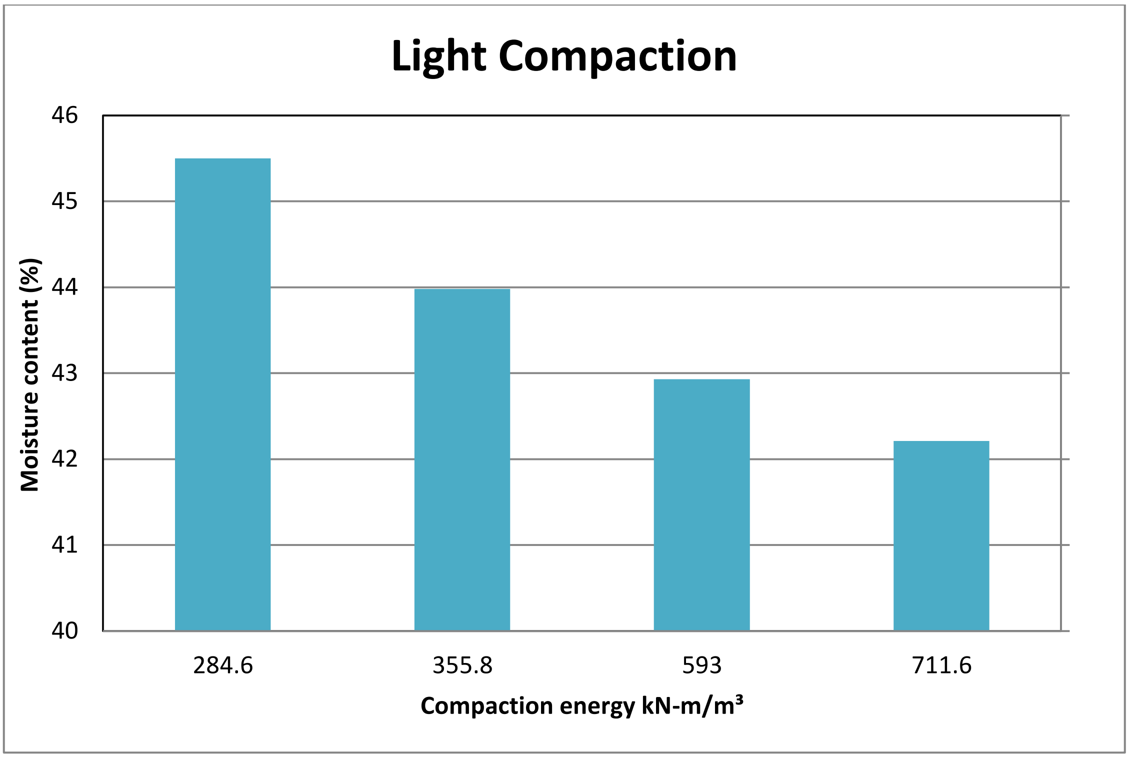

Figure 11: The relationship between compaction energy vs moisture content of standard pond ash collected from (NTPC Kanhia)

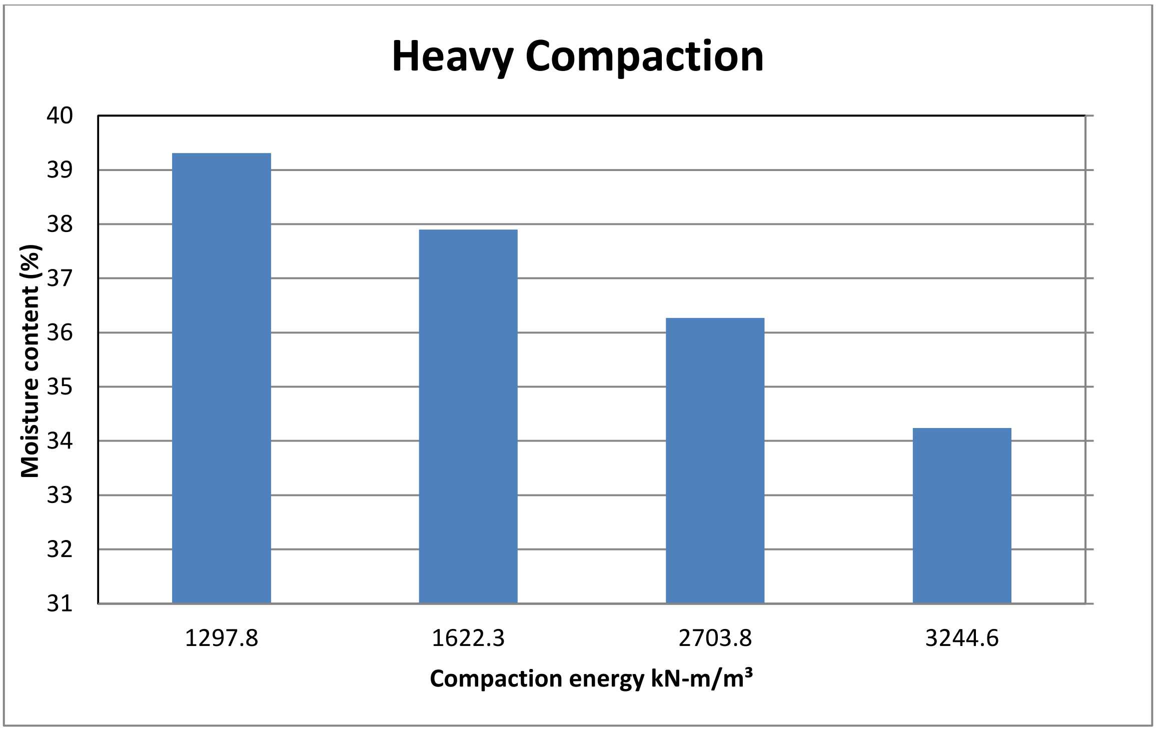

Figure 12: The relationship between compaction energy vs moisture content of modified pond ash collected from (NTPC Kanhia)

4.2.5 The relationship between dry density vs moisture content:

For fly ash:

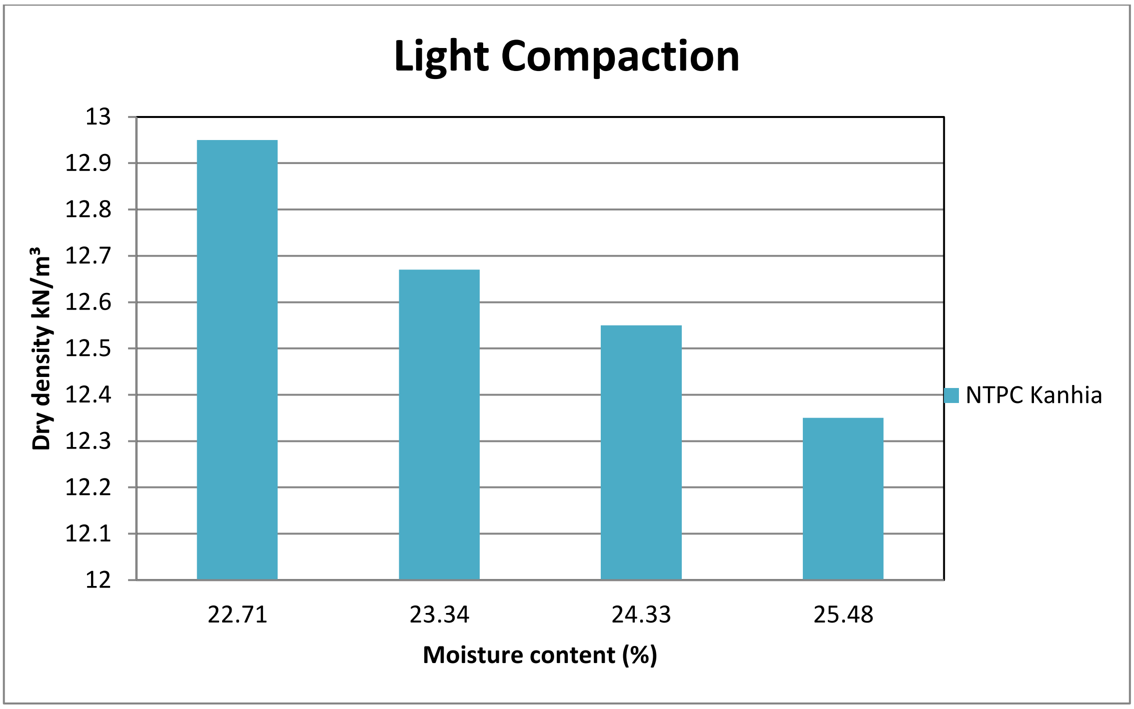

Figure 13: The relationship between dry density vs moisture content of standard fly ash collected from (NTPC Kanhia)

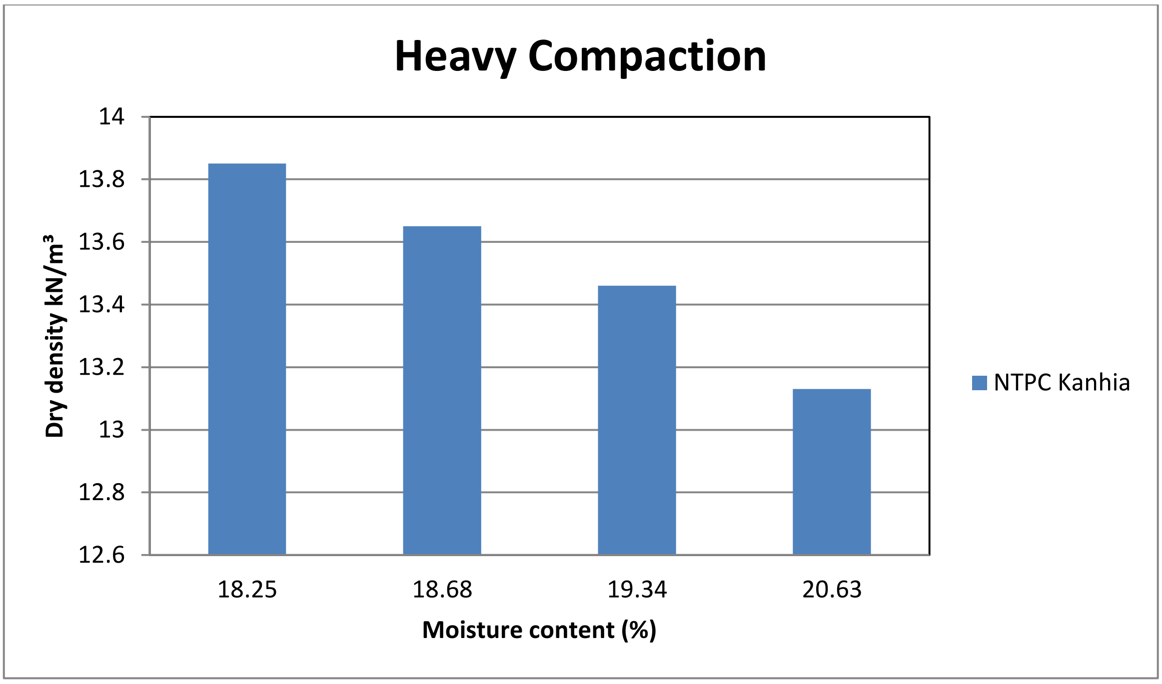

Figure 14: The relationship between dry density vs moisture content of modified fly ash collected from (NTPC Kanhia)

For pond ash:

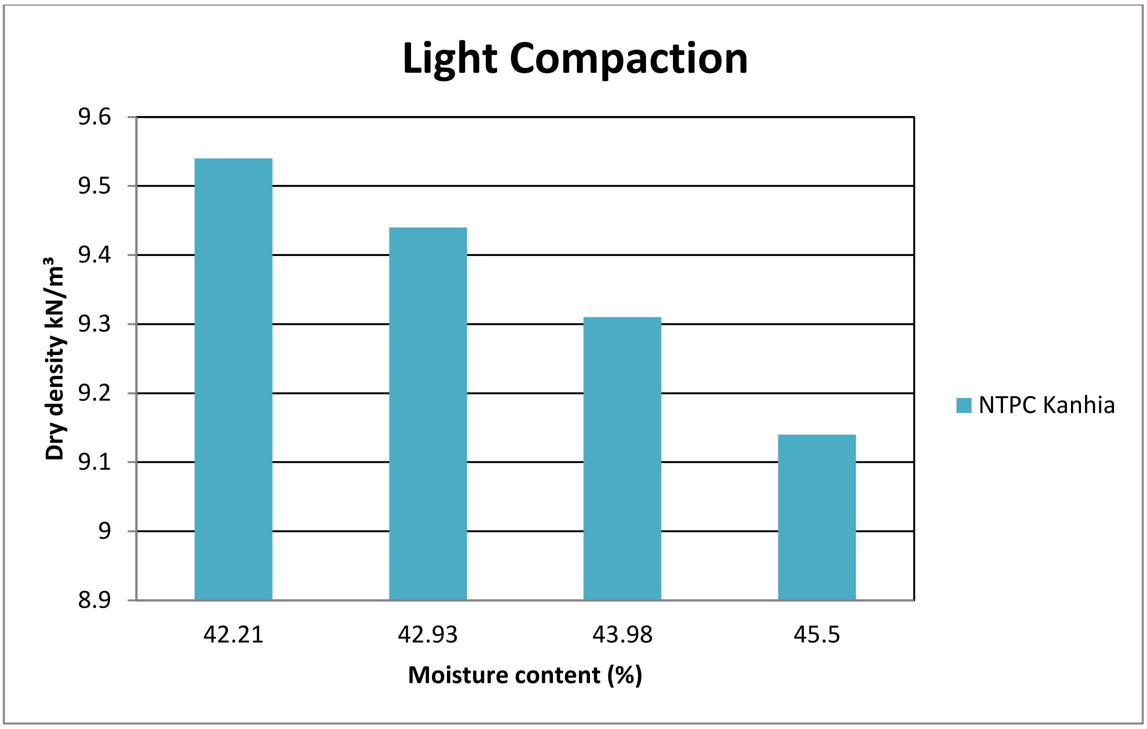

Figure 15: The relationship between dry density vs moisture content of standard pond ash collected from (NTPC Kanhia)

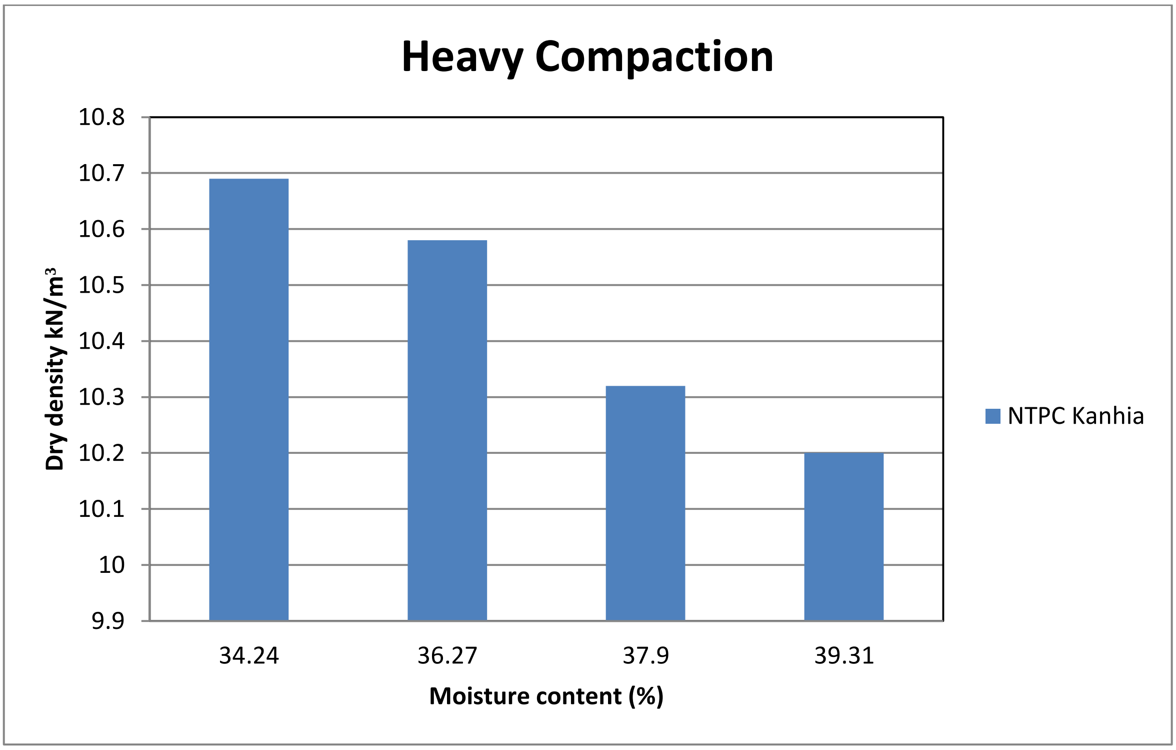

Figure 16: The relationship between dry density vs moisture content of modified pond ash collected from (NTPC Kanhia)

4.2.6 Grain size analysis:

For fly ash:

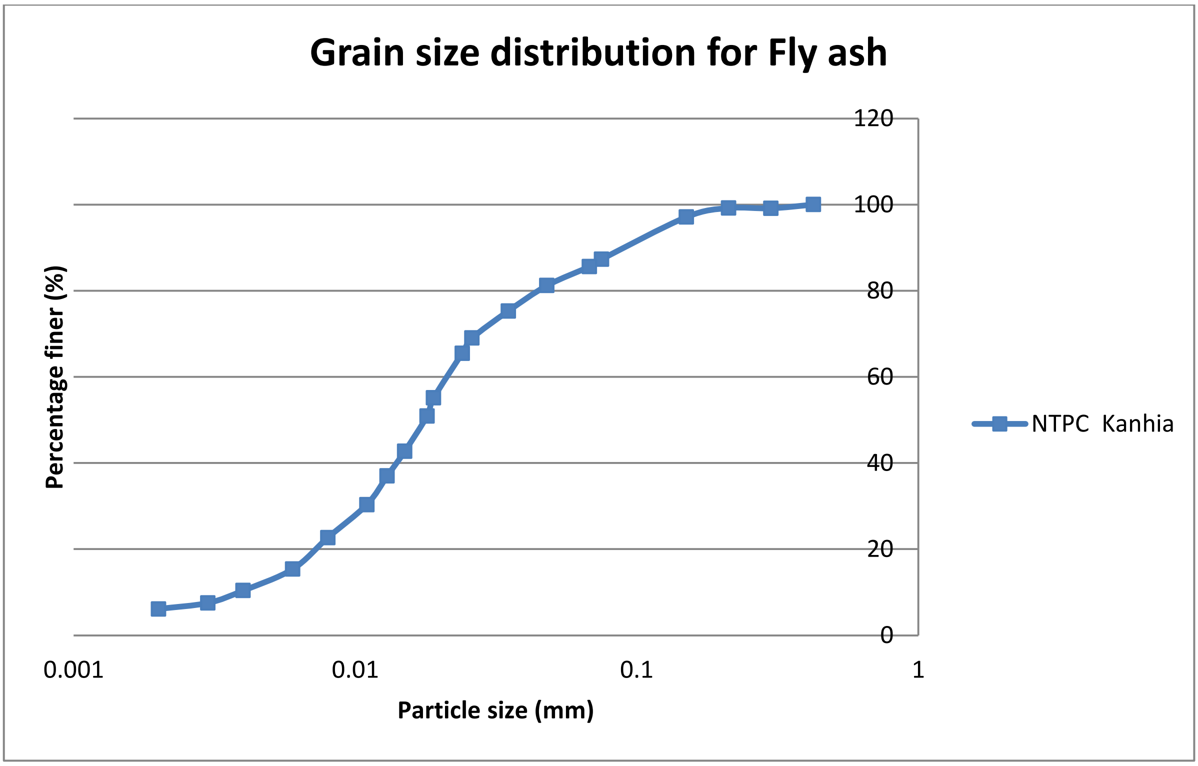

Figure 17: Grain size distribution curve of fly ash

Table 6: Uniformity coefficient and coefficient of gradation of fly ash

Parameters	Value
D_{10}	0.0038
D_{30}	0.0109
D_{60}	0.0212
Coefficient of uniformity, C_u	5.58
Coefficient of curvature, C_c	1.25

For pond ash:

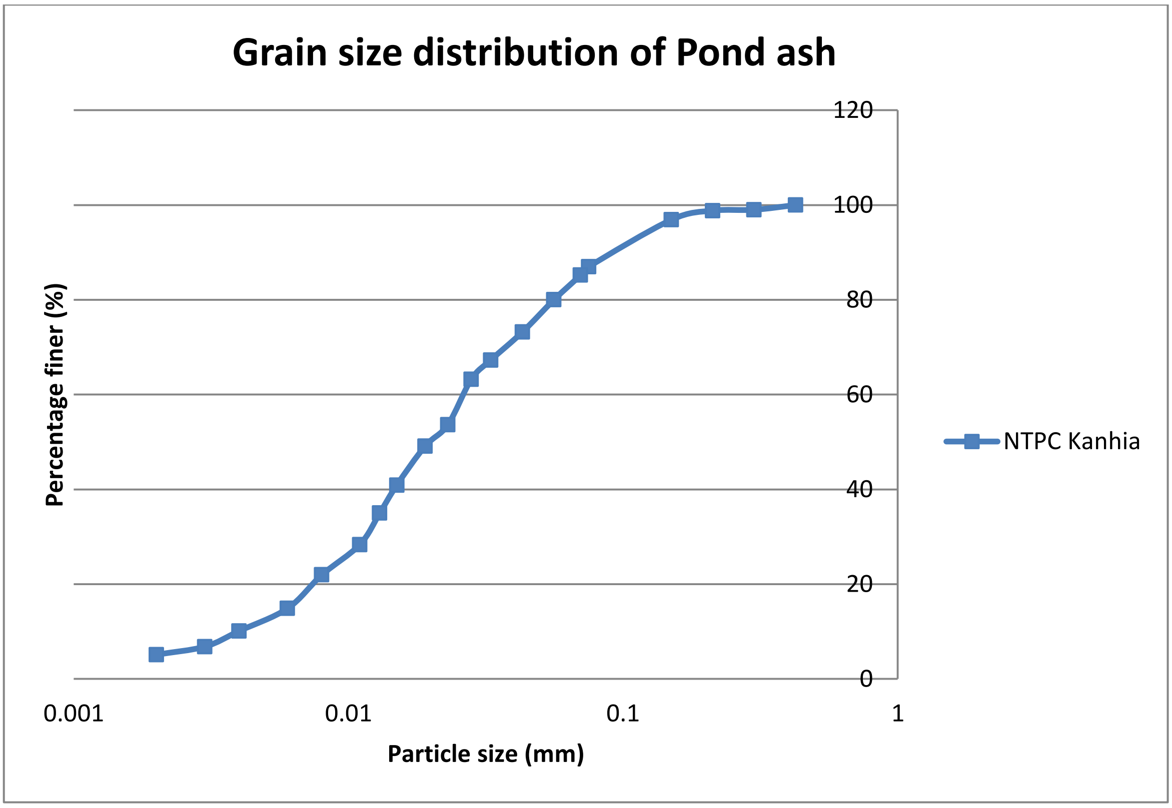

Figure 18: Grain size distribution curve of pond ash

Table 7: Uniformity coefficient and coefficient of gradation of pond ash

Parameters	Value
D_{10}	0.0039
D_{30}	0.0114
D_{60}	0.0261
Coefficient of uniformity, C_u	5.69
Coefficient of curvature, C_c	1.27

4.2.7 Permeability Test (Variable Head Method):

For fly ash:

Table 8: Hydraulic conductivity of Fly Ash

Sl no.	Compaction energy ($kN\text{-}m/m^3$)	Sample (Fly ash)
1	Increased modified 30 blows/layer ($3244.6\ kN\text{-}m/m^3$)	2.93×10^{-5}
2	Modified 25 blows/layer ($2703.8\ kN\text{-}m/m^3$)	3.23×10^{-5}
3	Reduced modified 15 blows/layer ($1622.3\ kN\text{-}m/m^3$)	3.71×10^{-5}
4	Reduced modified 12 blows/layer ($1297.8\ kN\text{-}m/m^3$)	3.98×10^{-5}
5	Increased standard 30 blows/layer ($711.6\ kN\text{-}m/m^3$)	4.57×10^{-5}
6	Standard 25 blows/layer ($593.0\ kN\text{-}m/m^3$)	3.82×10^{-5}
7	Reduced standard 15 blows/layer ($355.8\ kN\text{-}m/m^3$)	2.74×10^{-5}
8	Reduced standard 12 blows/layer ($284.6\ kN\text{-}m/m^3$)	2.53×10^{-5}

For pond ash:

Table 9: Hydraulic conductivity of pond Ash

Sl no.	Compaction energy ($kN\text{-}m/m^3$)	Sample (Pond ash)
1	Increased modified 30 blows/layer (3244.6 $kN\text{-}m/m^3$)	4.37×10^{-4}
2	Modified 25 blows/layer (2703.8 $kN\text{-}m/m^3$)	4.70×10^{-4}
3	Reduced modified 15 blows/layer (1622.3 $kN\text{-}m/m^3$)	5.11×10^{-4}
4	Reduced modified 12 blows/layer (1297.8 $kN\text{-}m/m^3$)	5.43×10^{-4}
5	Increased standard 30 blows/layer (711.6 $kN\text{-}m/m^3$)	5.61×10^{-4}
6	Standard 25 blows/layer (593.0 $kN\text{-}m/m^3$)	5.83×10^{-4}
7	Reduced standard 15 blows/layer (355.8 $kN\text{-}m/m^3$)	6.08×10^{-4}
8	Reduced standard 12 blows/layer (284.6 $kN\text{-}m/m^3$)	6.39×10^{-4}

4.2.8 Direct shear test:

For fly ash:

Table 10: Strength parameters of fly ash

Sl no.	Compaction energy ($kN\text{-}m/m^3$)	Sample	
		Fly ash (NTPC Kanhia)	
		Cohesion (Kpa)	Angle of internal friction (Φ)
1	Increased modified 30 blows/layer ($3244.6\ kN\text{-}m/m^3$)	11.83	38.55
2	Modified 25 blows/layer ($2703.8\ kN\text{-}m/m^3$)	11.23	37.91
3	Reduced modified 15 blows/layer ($1622.3\ kN\text{-}m/m^3$)	11.22	36.09
4	Reduced modified 12 blows/layer ($1297.8\ kN\text{-}m/m^3$)	10.16	35.33
5	Increased standard 30 blows/layer ($711.6\ kN\text{-}m/m^3$)	10.02	35.22
6	Standard 25 blows/layer ($593.0\ kN\text{-}m/m^3$)	9.49	34.64
7	Reduced standard 15 blows/layer ($355.8\ kN\text{-}m/m^3$)	9.03	33.22
8	Reduced standard 12 blows/layer ($284.6\ kN\text{-}m/m^3$)	8.71	32.94

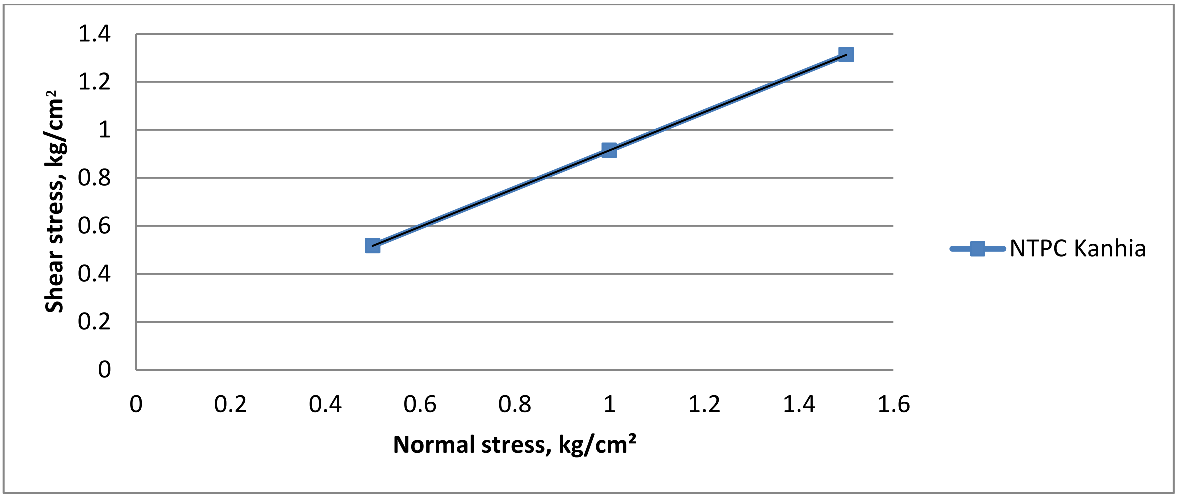

Figure 19: Compaction energy 3244.6 kN-m/m^3

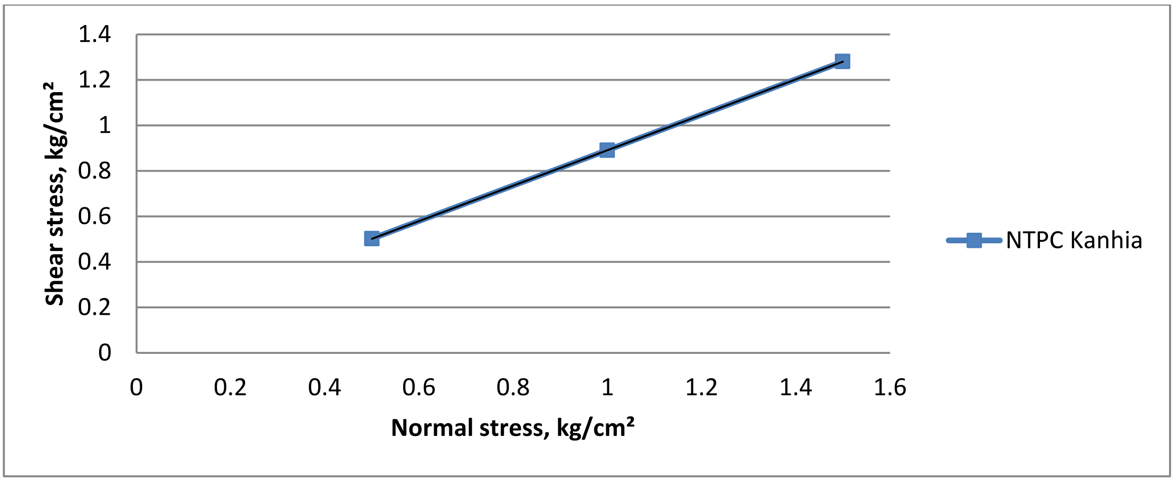

Figure 20: Compaction energy 2703.8 kN-m/m^3

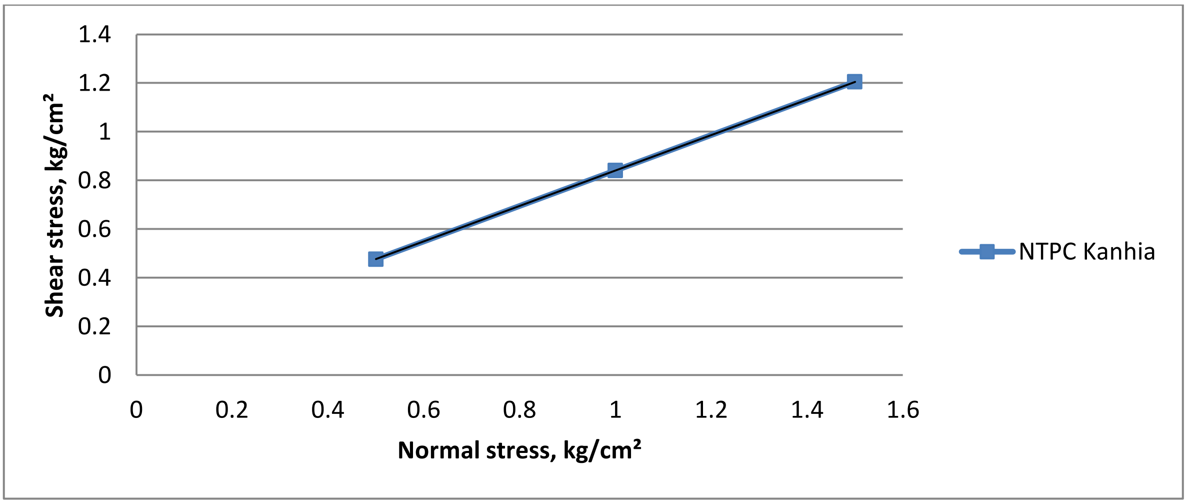

Figure 21: Compaction energy 1622.3 kN-m/m^3

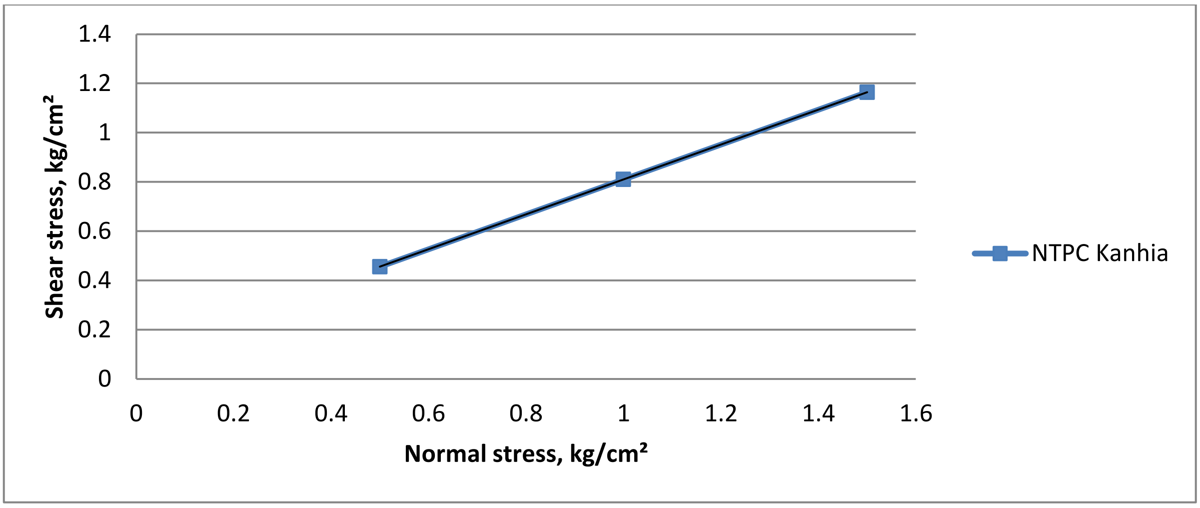

Figure 22: Compaction energy 1297.8 kN-m/m^3

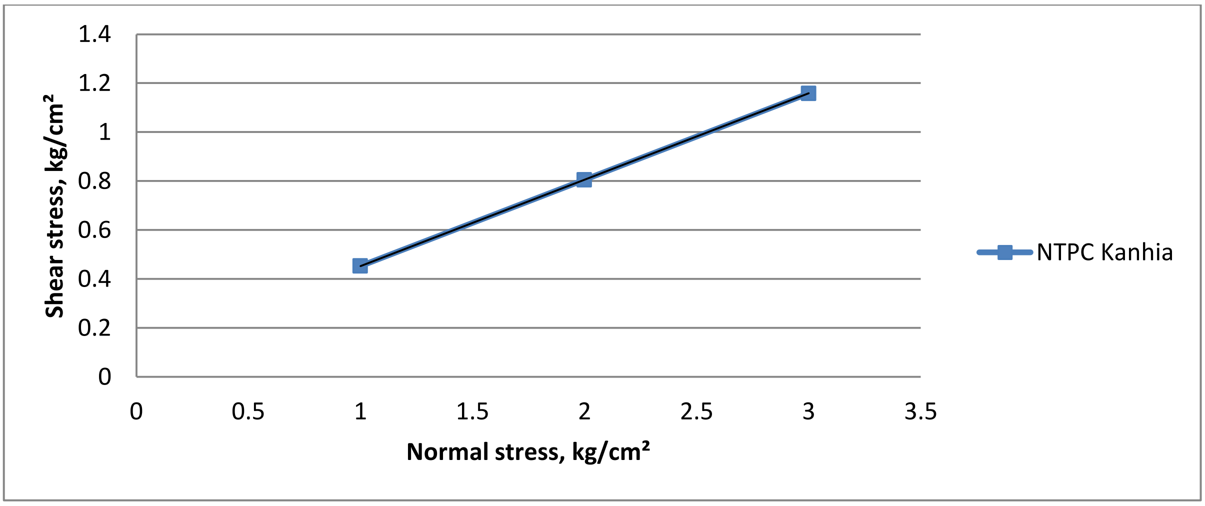

Figure 23: Compaction energy 711.6 kN-m/m^3

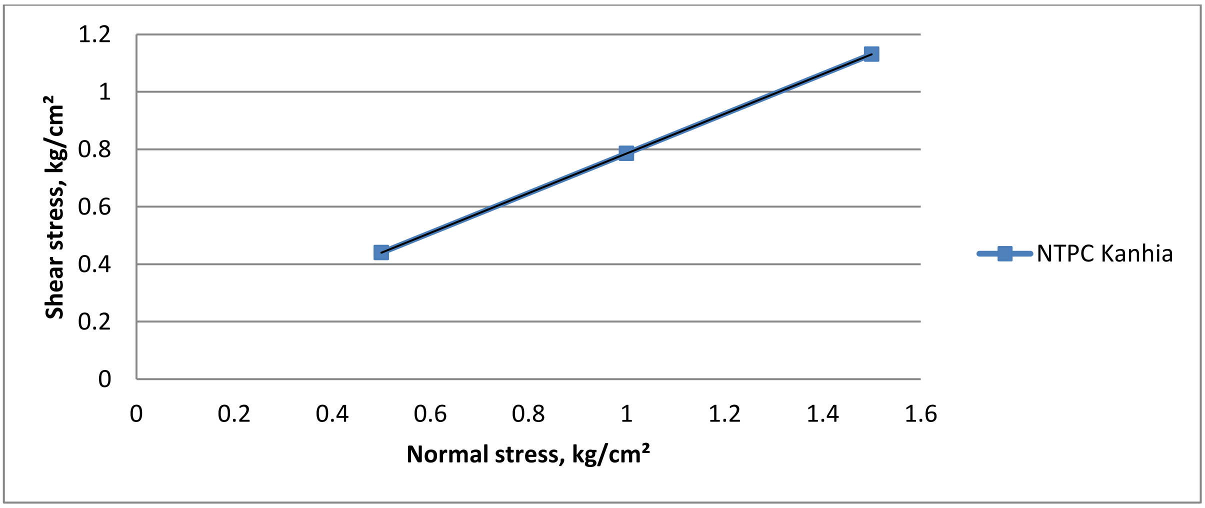

Figure 24: Compaction energy 593.0 kN-m/m^3

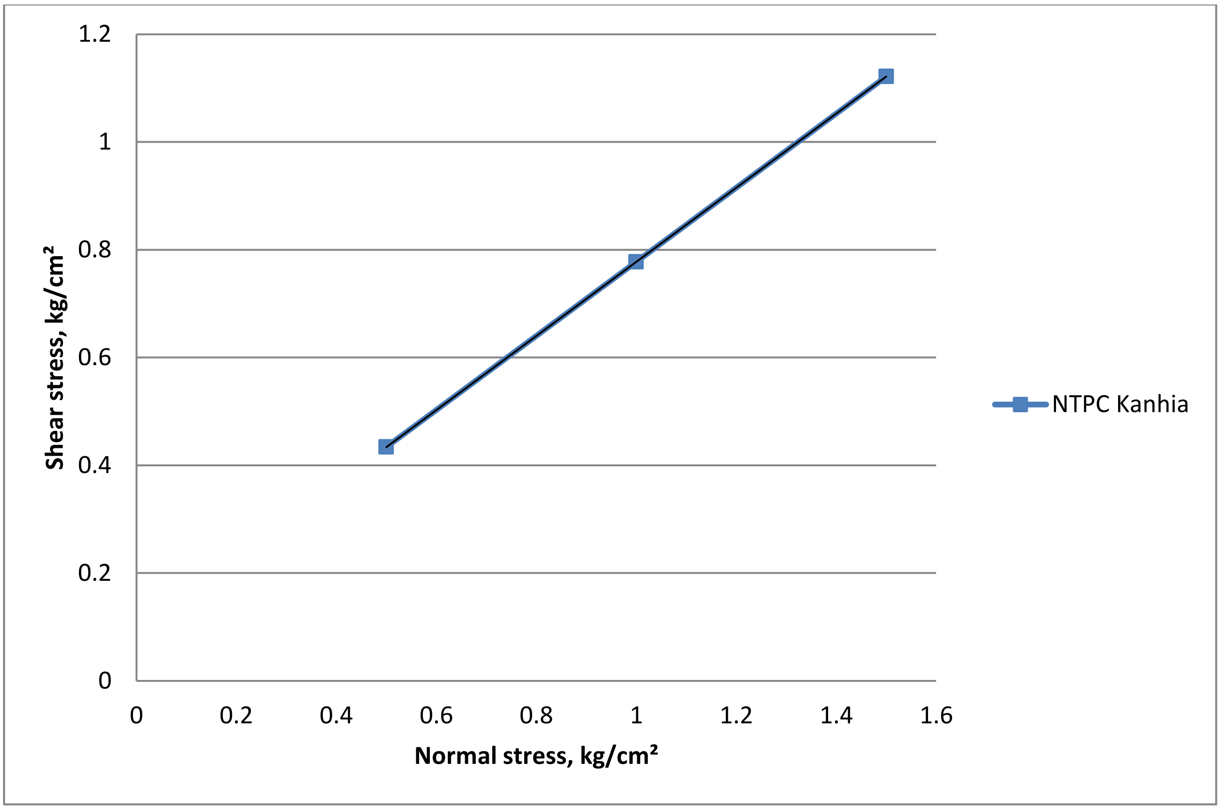

Figure 25: Compaction energy 355.8 kN-m/m^3

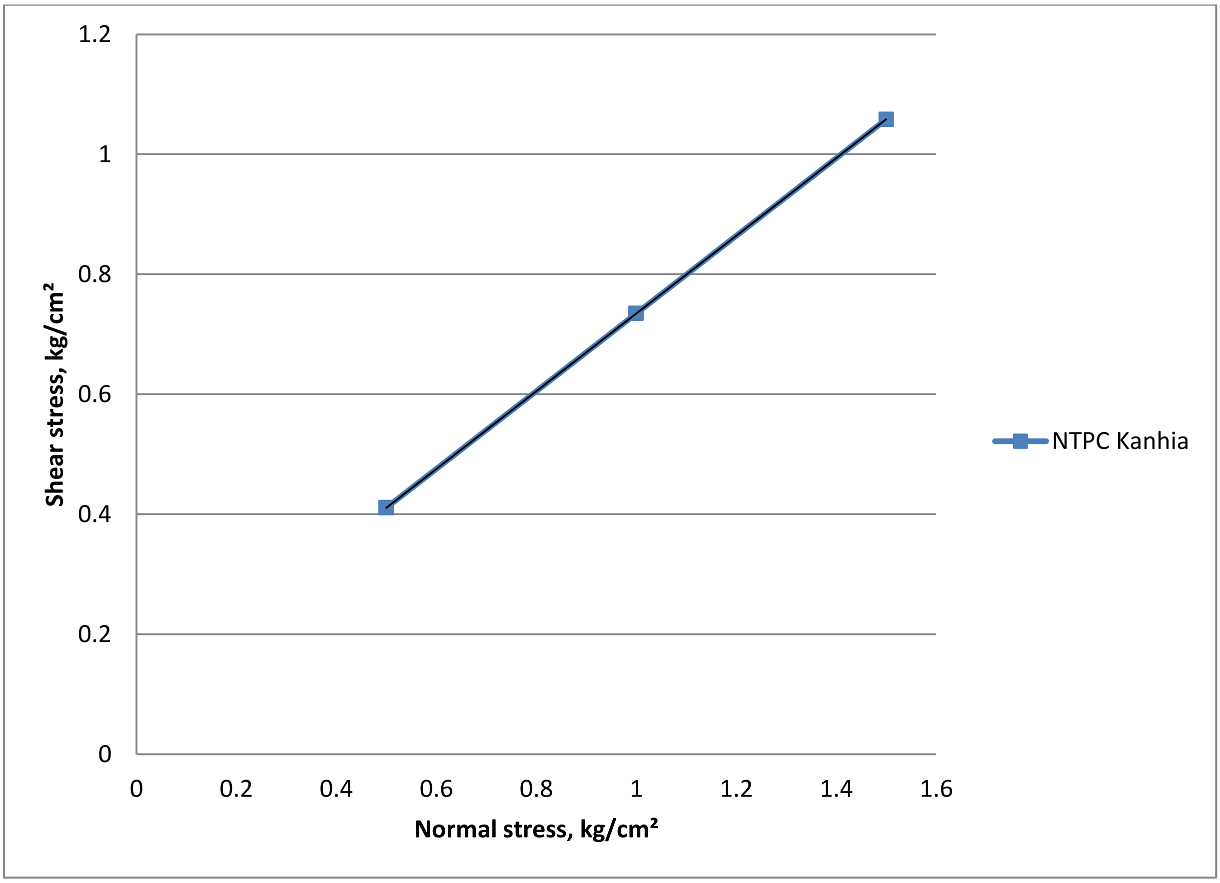

Figure 26: Compaction energy 284.6 kN-m/m^3

For pond ash:

Table 11: Strength parameters of pond ash

Sl no.	Compaction energy ($kN\text{-}m/m^3$)	Sample: Pond ash (NTPC Kanhia) Cohesion (kpa)	Sample: Pond ash (NTPC Kanhia) Angle of internal friction (Φ)
1	Increased modified 30 blows/layer (3244.6 kN-m/m3)	10.95	35.97
2	Modified 25 blows/layer (2703.8 $kN\text{-}m/m^3$)	10.82	35.49
3	Reduced modified 15 blows/layer (1622.3 $kN\text{-}m/m^3$)	10.28	33.86
4	Reduced modified 12 blows/layer (1297.8 $kN\text{-}m/m^3$)	10.11	33.36
5	Increased standard 30 blows/layer (711.6 $kN\text{-}m/m^3$)	9.6	32.24
6	Standard 25 blows/layer (593.0 $kN\text{-}m/m^3$)	9.49	31.99
7	Reduced standard 15 blows/layer (355.8 $kN\text{-}m/m^3$)	8.80	31.72
8	Reduced standard 12 blows/layer (284.6 $kN\text{-}m/m^3$)	8.59	31.63

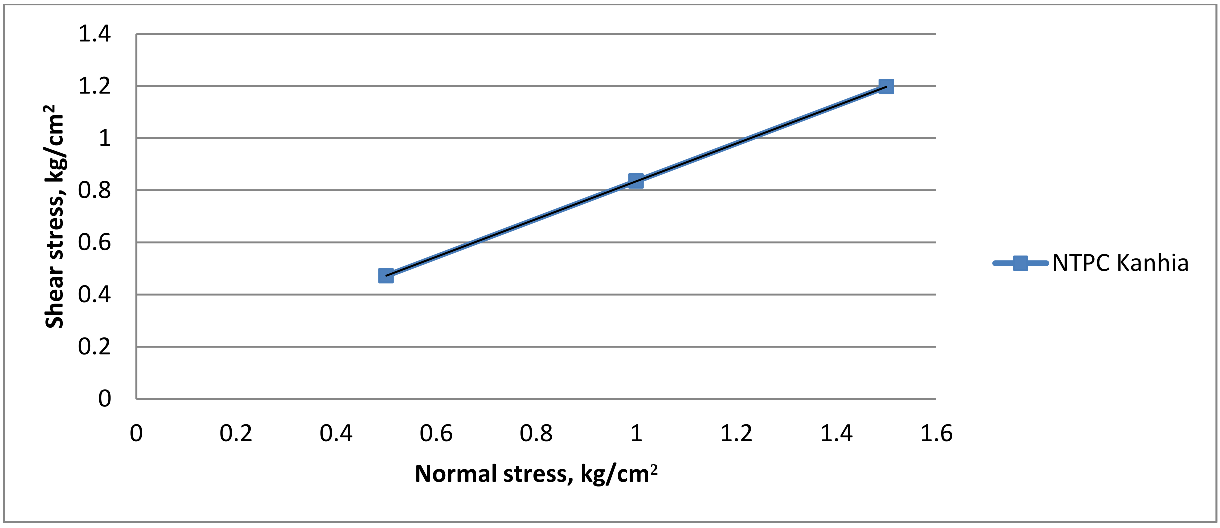

Figure 27: Compaction energy 3244.6 kN-m/m^3

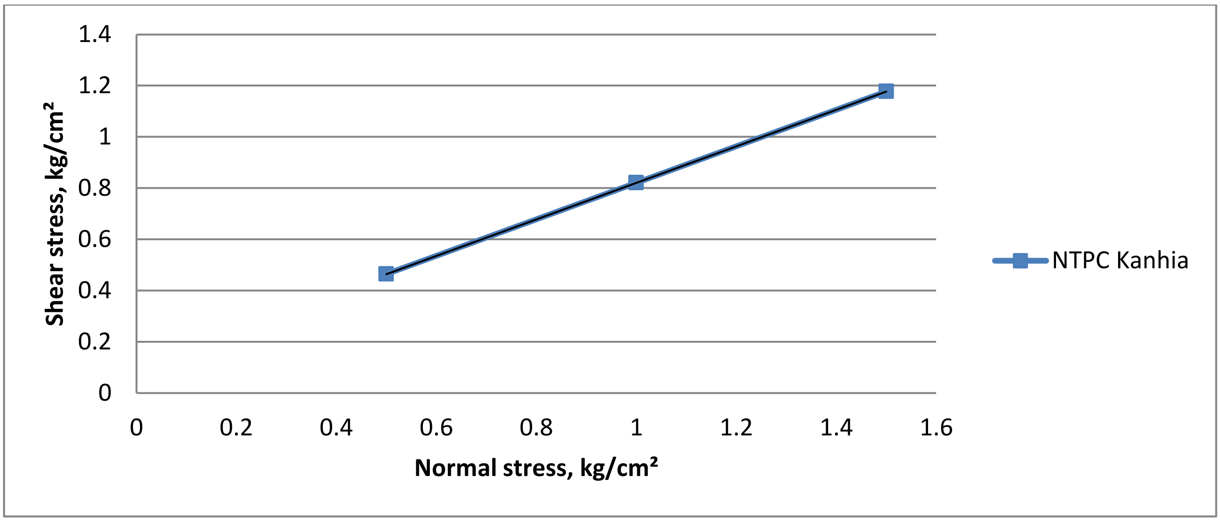

Figure 28: Compaction energy 2703.8 kN-m/m^3

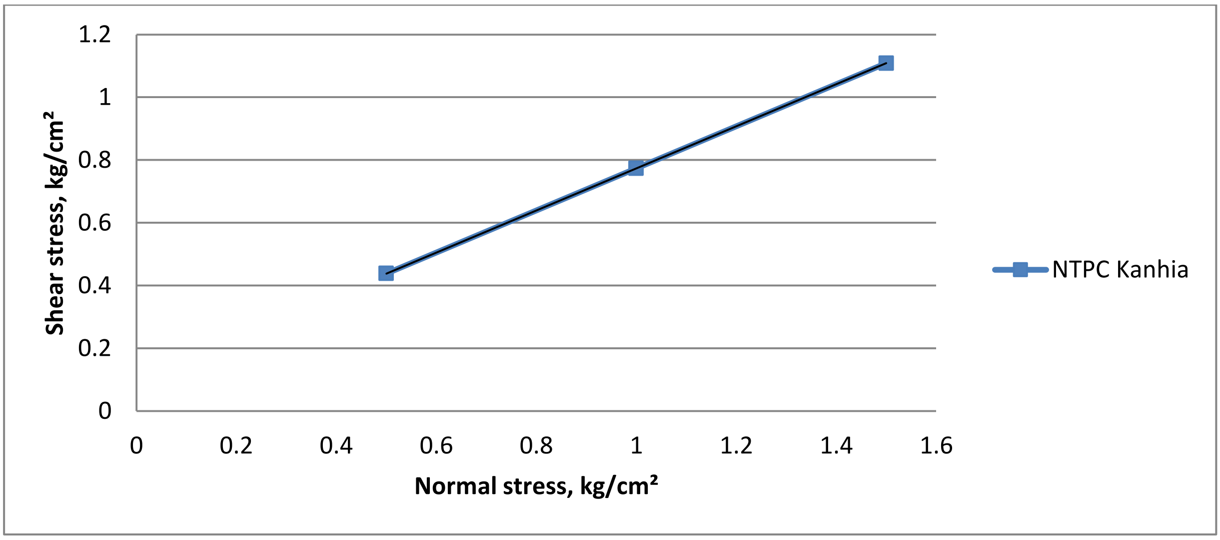

Figure 29: Compaction energy 1622.3 kN-m/m^3

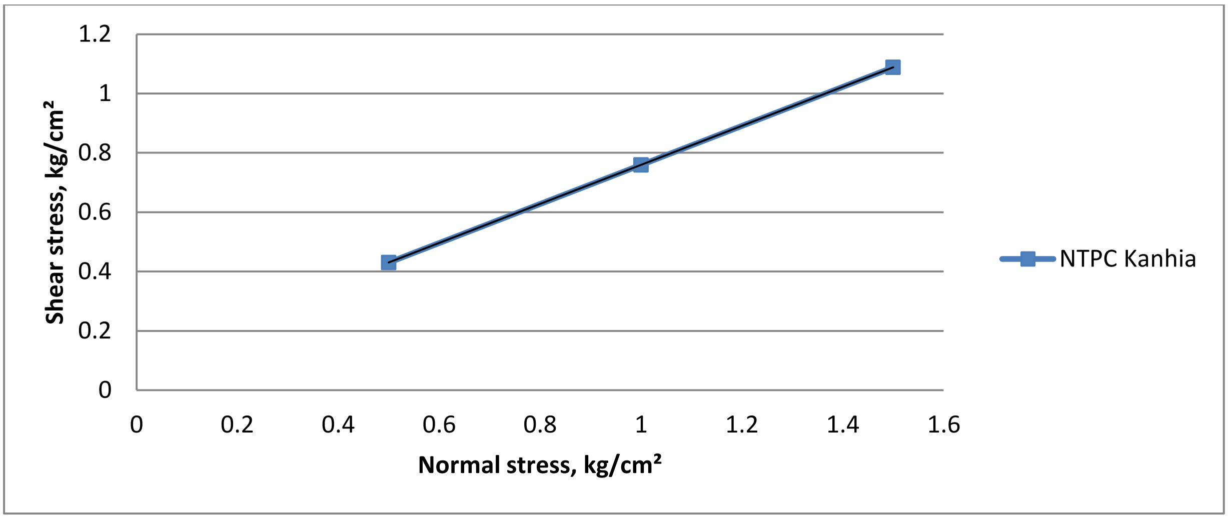

Figure 30: Compaction energy 1297.8 kN-m/m^3

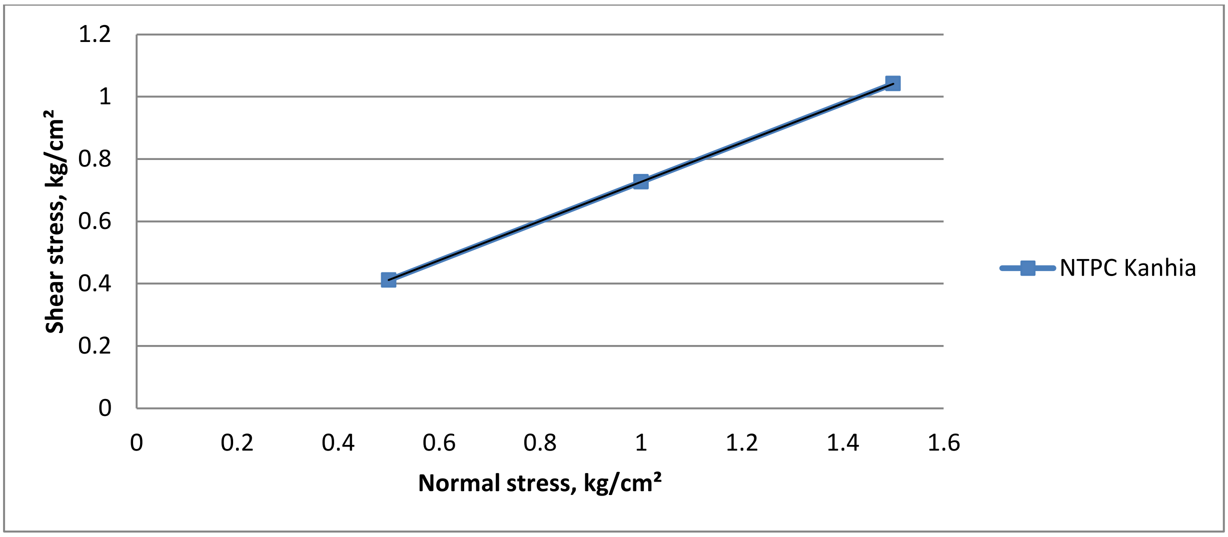

Figure 31: Compaction energy 711.6 kN-m/m^3

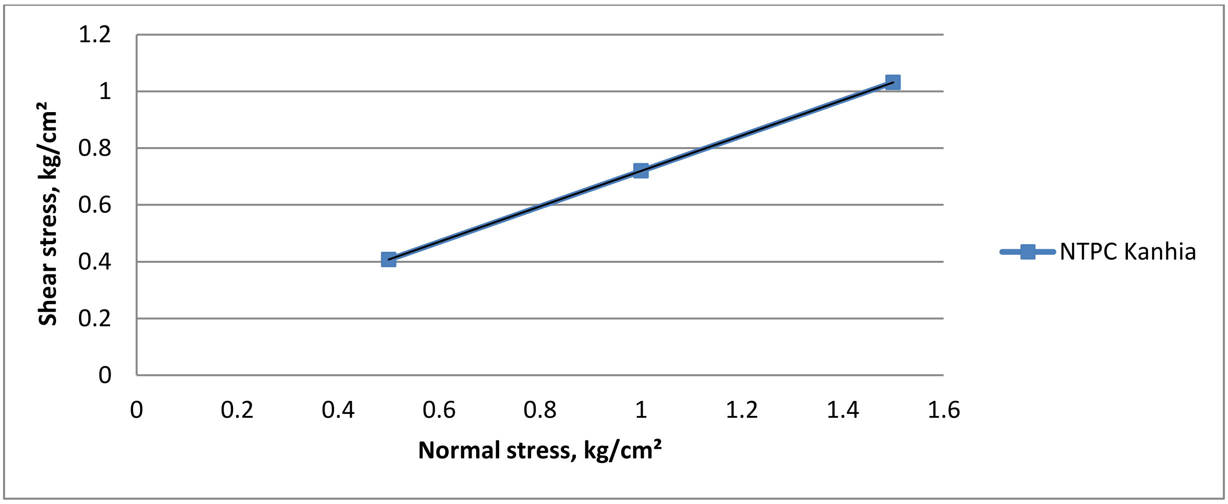

Figure 32: Compaction energy 593.0 kN-m/m^3

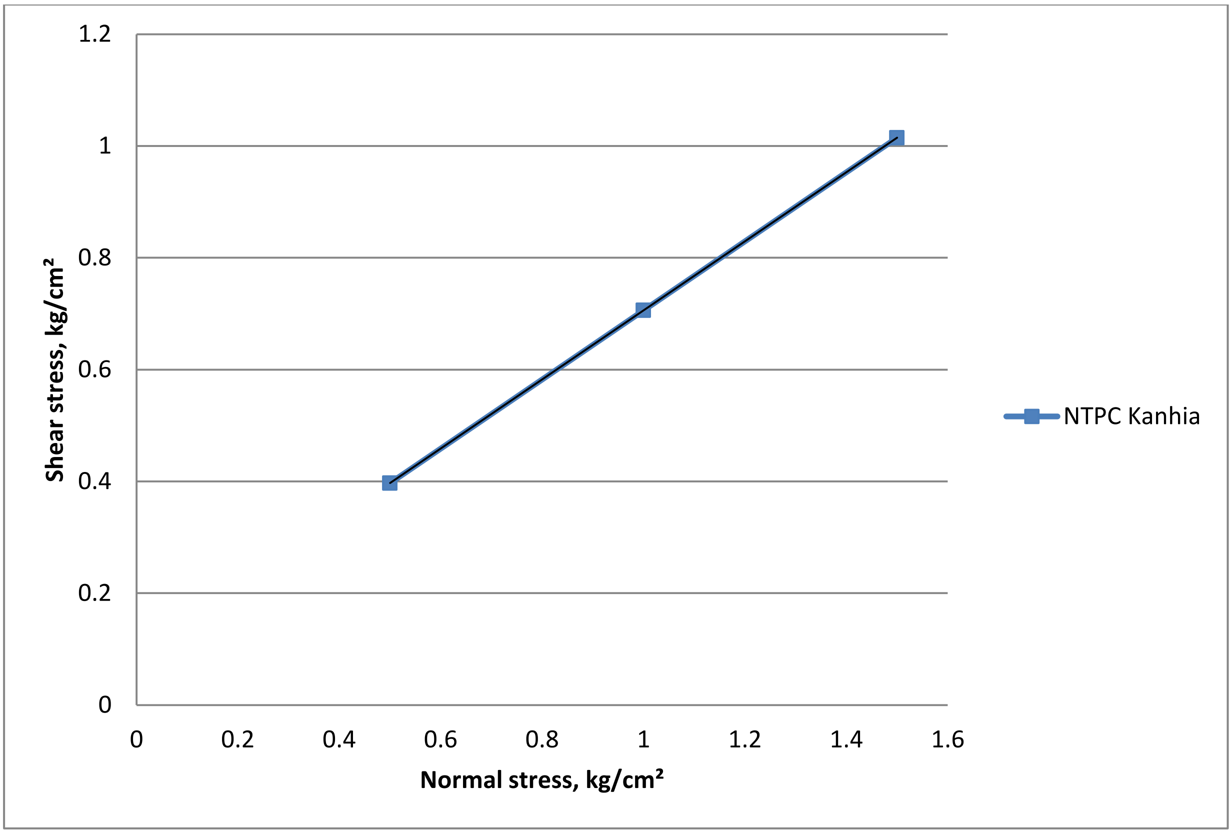

Figure 33: Compaction energy 355.8 kN-m/m^3

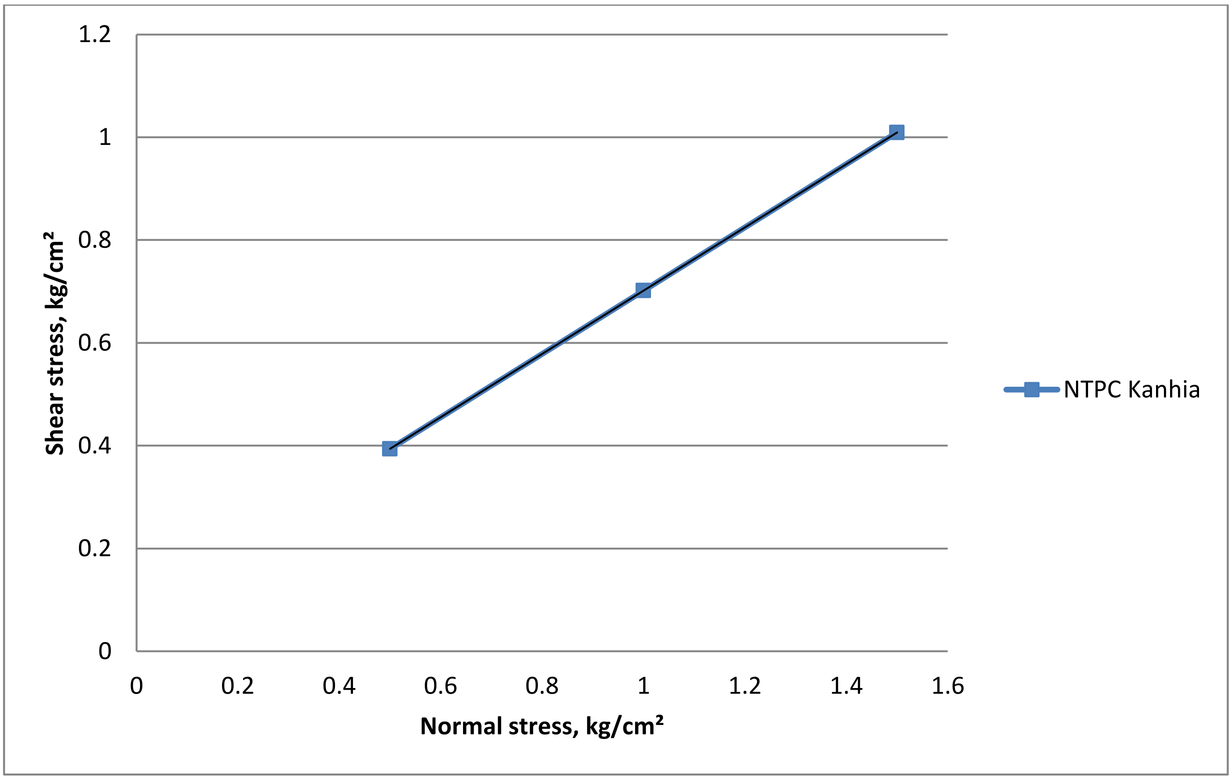

Figure 34: Compaction energy 284.6 kN-m/m^3

The relationship between compaction energy vs Cohesion:

For fly ash:

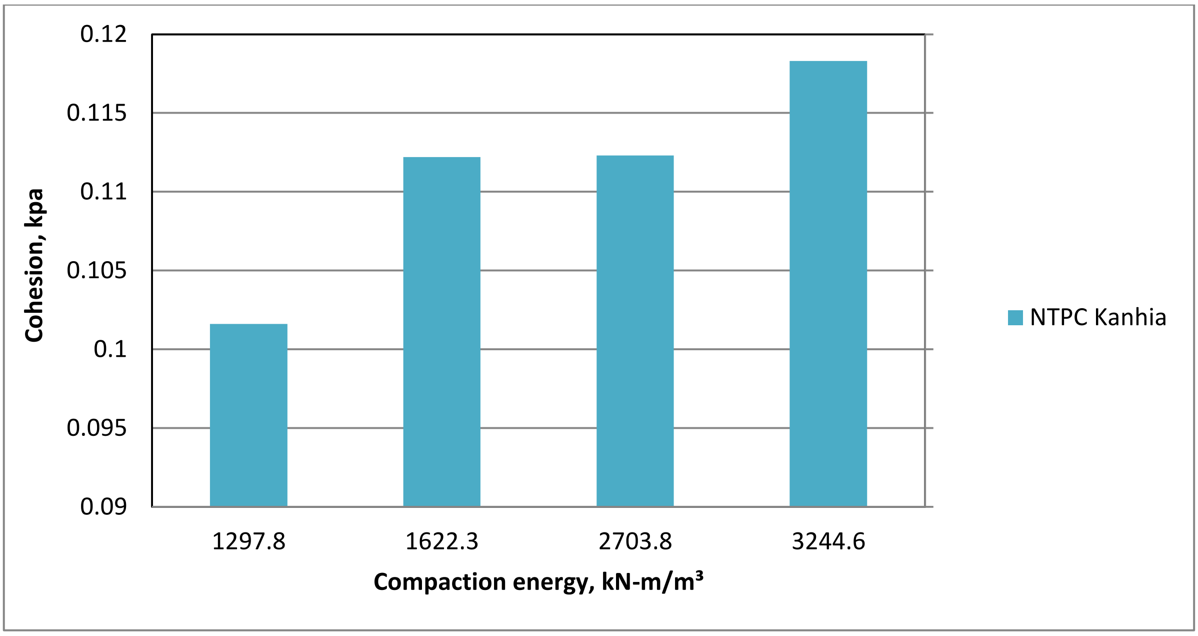

Figure 35(a): The relationship between compaction energy and cohesion of fly ash collected from (NTPC Kanhia)

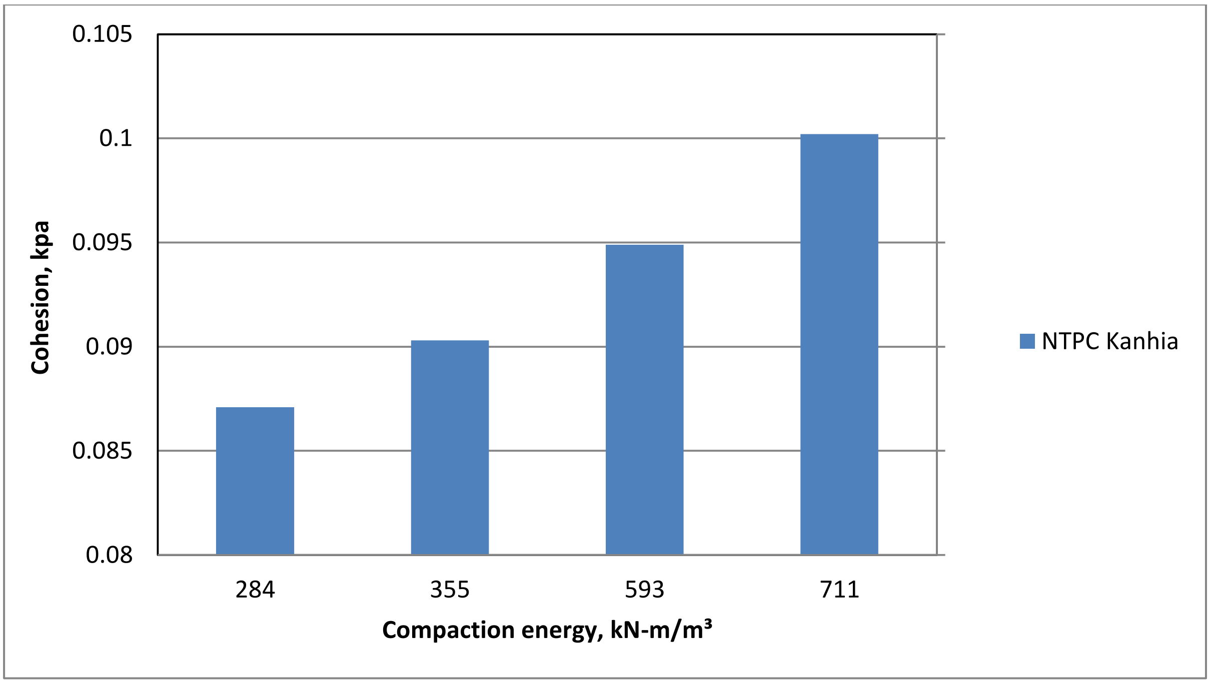

Figure 35(b): The relationship between compaction energy and cohesion of fly ash collected from (NTPC Kanhia)

For pond ash:

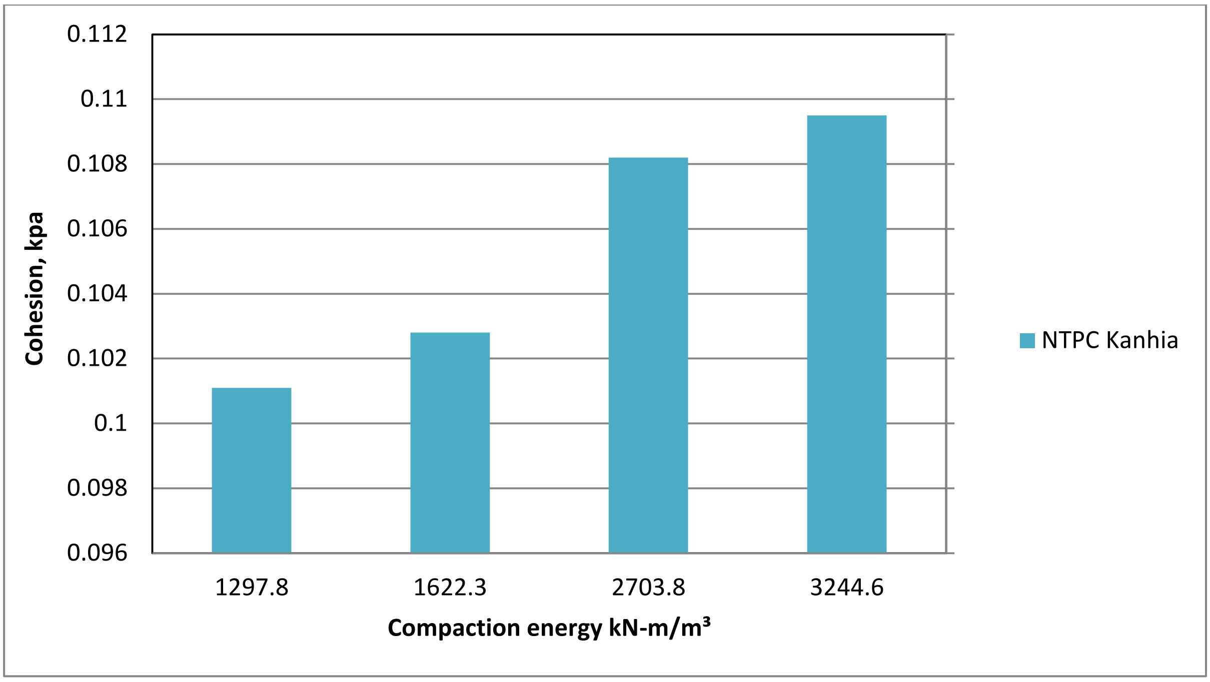

Figure 36(a): The relationship between compaction energy and cohesion of pond ash collected from (NTPC Kanhia)

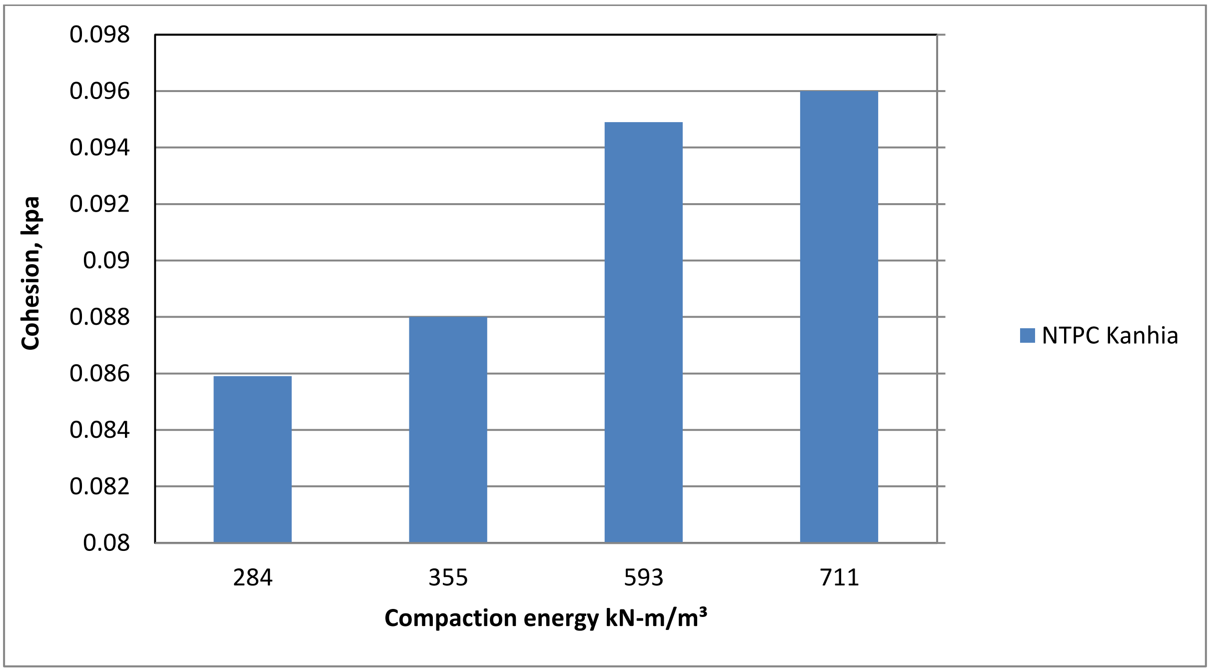

Figure 36(b): The relationship between compaction energy and cohesion of pond ash collected from (NTPC Kanhia)

The relationship between compaction energy vs Angle of internal friction (Φ):

For fly ash:

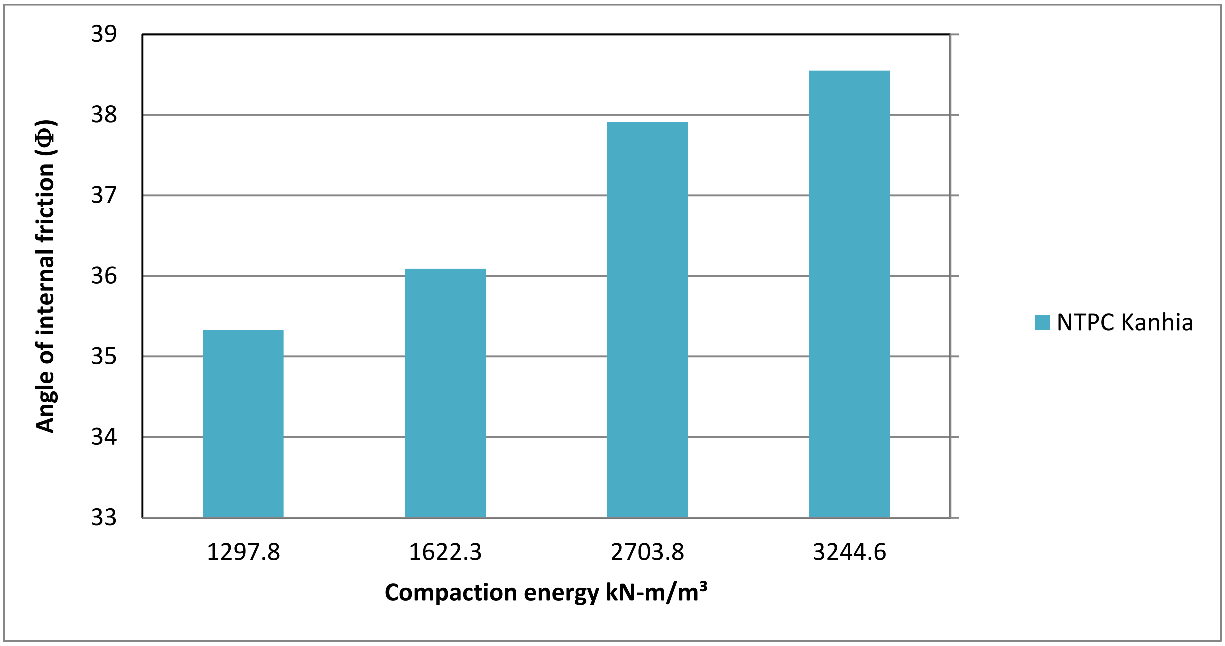

Figure 37(a): The relationship between compaction energy vs Angle of internal friction of fly ash collected from (NTPC Kanhia)

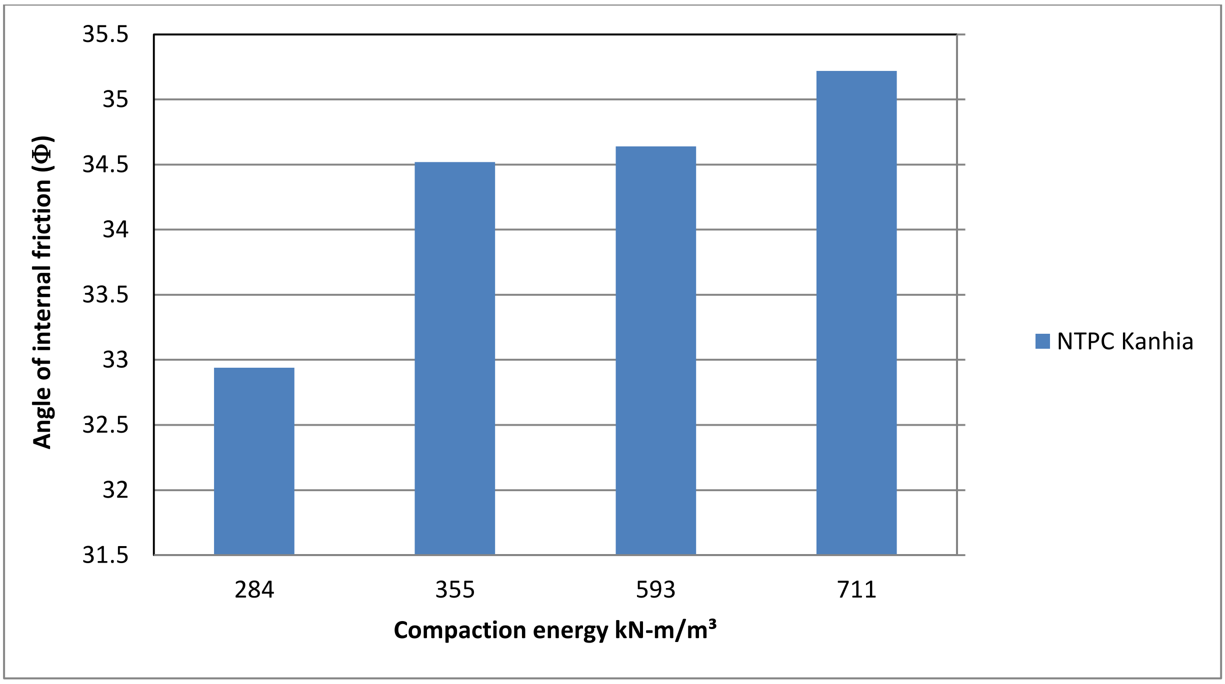

Figure 37(b): The relationship between compaction energy vs Angle of internal friction of fly ash collected from (NTPC Kanhia)

For pond ash:

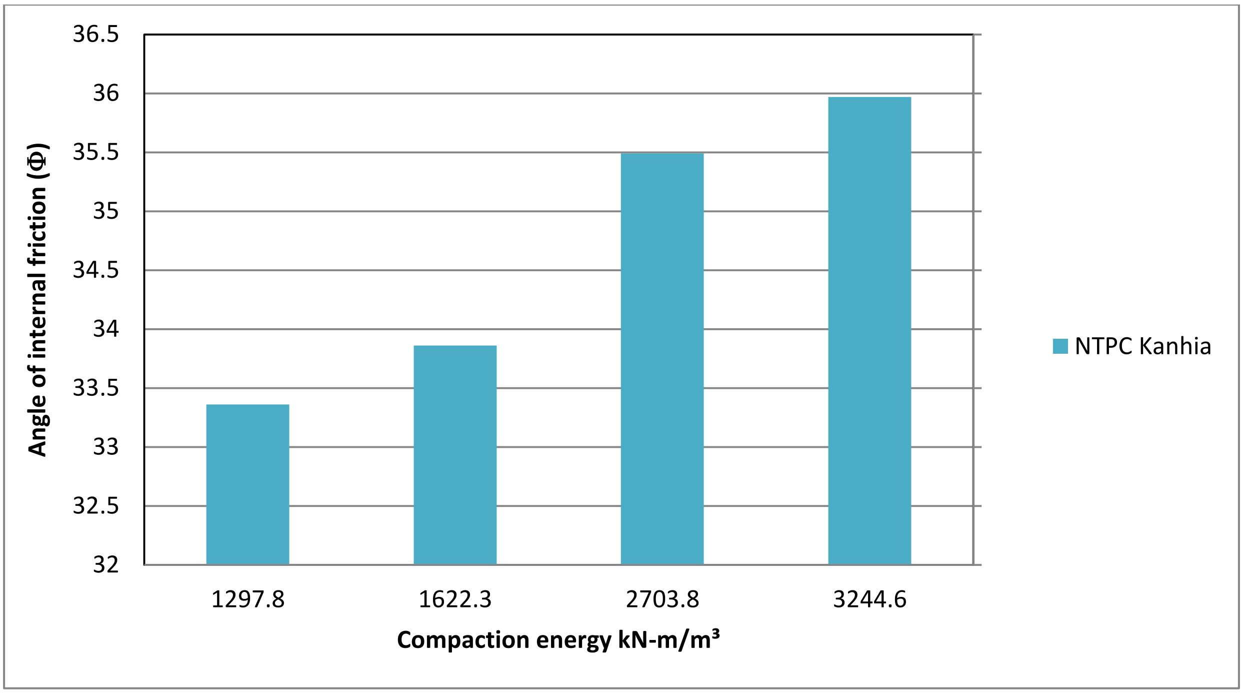

Figure 38(a): The relationship between compaction energy vs Angle of internal friction of pond ash collected from (NTPC Kanhia)

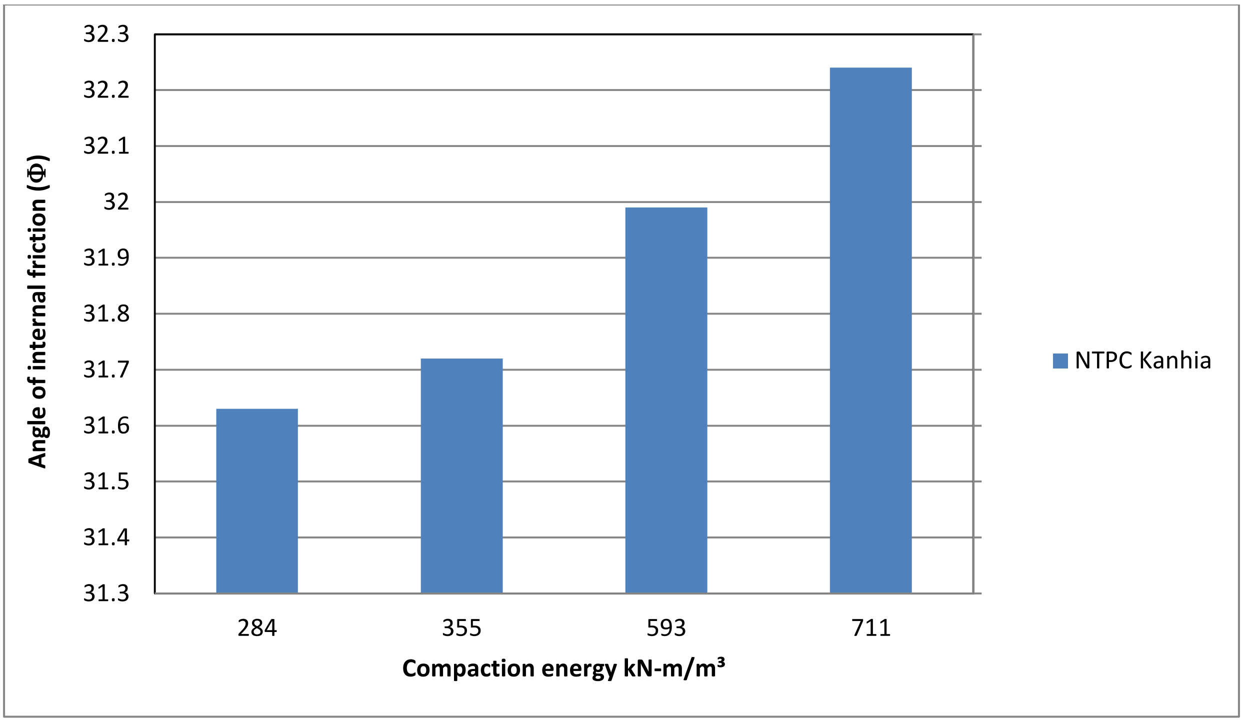

Figure 38(b): The relationship between compaction energy vs Angle of internal friction of pond ash collected from (NTPC Kanhia)

CHAPTER-5
CONCLUSION

5.1 Conclusion:

1. The variation in compaction energy significantly affects the dry density. With the increase in compaction energy from 284.65 to 3244.66 kN-m/m^3, maximum dry density (MDD) increases at the same time optimum moisture content (OMC) decreases.

2. The variation in the maximum dry density and optimum moisture content of Fly Ash (collected from NTPC Kanhia, Odisha) as per Standard Proctor compaction energy is 0.90 – 1.59 gm/cc and 18 - 27%, respectively.

3. The variation in the maximum dry density and optimum moisture content of Pond ash (collected from NTPC Kanhia, Odisha) as per Standard Proctor compaction energy is 0.856 – 1.248 gm/cc and 33 - 46%, respectively.

4. In hydrometer analysis the particle which is passed through 75 μ size sieve and graph was plotted among percentage finer and diameter of particles. Through hydrometer analysis, the coefficient of curvature and coefficient of uniformity were found to be 1.26 and 5.66 respectively.

Future Scope:

1. To determine the Geotechnical properties of pond ash and fly ash.
2. To determine the effect of energy change of Maximum Dry Density and Optimum Moisture Content.
3. To determine the effect of energy change of Permeability.
4. To determine the effect of energy change of Direct Shear Test.
5. To determine the effect of energy change of unconfined compressive strength.

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