CHAPTER-1

INTRODUCTION

1.1 Introduction

Because of population growth, rapid urban and industrial growth, more land is required for further development. In order to meet this demand, utilization of land has been taking place. At that land, Soil may have less load carrying capacity or may subjected to more settlement, For this purpose various ground improvement techniques, ground reinforcement techniques, and ground treatment techniques are used. For our project, Yamuna sand is collected from Yamuna bank, Delhi. Yamuna sand is located on the bank of Yamuna which is located at Indo-gangetic plain. Yamuna sand in Delhi is in seismic active zone, which is located in zone 4.Yamuna sand has low bearing capacity, and susceptible to erosion. We use Pond ash mixed with lime for improvement of its bearing capacity and shear behavior.

1.2 Scope of the study-

In India, Thermal power plants are the main source for production of energy. We use 70-75% of total coal production in thermal power plants. Study shows, 30% of residue is generated from coal combustion. In 2010-12, about 408 Million tons/year was used by 88 thermal plants in India (Ghosh and Goyal 2014), Presently 116 thermal plants are running across the India, and approx 90,000 acres of valuable land is used to collect this ash.This residue includes Fly ash, Bottom ash and Pond ash and also called as Coal Combustion Residue or CCR.We are recycling about 28-30% of total CCR produced (Saxena and Asolekar 2014). Fly ash is collected by mechanical or electrostatic precipitators, Bottom ash is collected from the bottom of boilers.When this Bottom ash mixed with dry Fly ash are transported in the form of slurry and disposed off in the ash pond located few kilometers distance from thermal plant, this ash is called Pond ash.

This large volume of Pond ash causes various environmental and significant economical problems.To solve this problem, Pond ash uses in various applications

- Pond ash can be used as fine aggregate in concrete works.

- It is suitable for backfilling of low lying areas.
- It is suitable for saline land reclamation.
- Appropriate quantity of Pond ash can increase the production of agriculture, horticulture and forestry.
- It is suitable for filling as Reinforced Earth, Wall pavements and Flyover construction.
- It can be used for stabilization of soil with appropriate amount of lime or cement and decrease the cost of pavement and foundations.
- Pond ash mixed with residue of integrated steel plants can be used for brick manufacturing.
- It can also be used as a stowing material in underground mines.(Kumar 2003;Mishra 2007 and Das 2010)

There should be more study or research should be done to make more utilization of Pond ash and to reduce consumption of natural resources.

In my study, Pond ash is collected from Badarpur thermal power station, Delhi. In this study Pond ash is mixed with Yamuna sand and their shear strength parameter variation by increasing Pond ash content is carried out.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction-

A brief review of literature is presented in this chapter. The available literature is itemised into two groups namely study of Pond ash as a mix; Study of behaviour of Yamuna sand and Yamuna sand stabilisation, Study of behaviour of Pond ash when it is mixed with lime and study of literature work related with this work.

2.2 Study of Pond ash material as a mix-

1. **Bera et al (2007)-** Three different types of pond ash have been used in this study and compaction characteristics of pond ash are find out. The effects of different compaction controlling parameters, viz. compaction energy, moisture content, layer thickness, mould area, tank size, and specific gravity on dry density of pond ash are highlighted herein. The maximum dry density and optimum moisture content of pond ash vary within the range of 8.40–12.25kN/m38.40–12.25kN⁄m3 and 29–46%, respectively. In the present investigation, the degree of saturation at optimum moisture content of pond ash has been found to vary within the range of 63–89%. An empirical model has been developed to estimate dry density of pond ash, using multiple regression analyses, in terms of compaction energy, moisture content, and specific gravity. Linear empirical models have also been developed to estimate maximum dry density and optimum moisture content in the field at any compaction energy. These empirical models may be helpful for the practicing engineers in the field for planning the field compaction control and for preliminary estimation of maximum dry density and optimum moisture content of pond ash.
2. **Ghosh et al(2009)-** This study represents the laboratory test results of a Class F pond ash alone and stabilized with varying percentages of lime (4, 6, and 10%) and PG (0.5, and 1.0), to study the suitability of stabilized pond ash for road base

and sub-base construction. Standard and modified Proctor compaction tests have been conducted to reveal the compaction characteristics of the stabilized pond ash. Bearing ratio tests have been conducted on specimens, compacted at maximum dry density and optimum moisture content obtained from standard Proctor compaction tests, cured for 7, 28, and 45 days. Both unsoaked and soaked bearing ratio tests have been conducted. This paper highlights the influence of lime content, PG content, and curing period on the bearing ratio of stabilized pond ash. The empirical model has been developed to estimate the bearing ratio for the stabilized mixes through multiple regression analysis. Linear empirical relationship has been presented herein to estimate soaked bearing ratio from unsoaked bearing ratio of stabilized pond ash. The experimental results indicate that pond ash-lime-Phosphogypsum mixes have potential for applications as road base and subbase materials

3. **Singh et al(2013)**- This paper focuses on the effects of compaction energy and degree of saturation on strength characteristics of compacted pond ash. The pond ash sample subjected to compactive energies varying from 357 kJ/m^3 to 3488 kJ/m^3. This study indicates that the dry density and strength of the compacted pond ash can be suitably modified by controlling the compactive energy and moulding moisture content. The strength achieved in the present study is comparable to the good quality, similar graded conventional earth materials. Hence, it may be safely concluded that pond ash can replace the natural earth materials in geotechnical constructions.
4. **Das et al(2005)-** This studyreports the findings of experimental studies with regard to some common engineering properties (e.g., grain size, specific gravity, compaction characteristics, and unconfined compression strength) of both low and high calcium fly ashes, to evaluate their suitability as embankment materials and reclamation fills. In high calcium fly ash, mineralogical and chemical differences are observed for particles, >75 μm and the particles of <45 μm size. The mode and duration of curing significantly affect the strength and stress–strain behavior of fly ashes. The geotechnical properties of fly ash are governed by factors like lime content (CaO), iron content (Fe_2O_3) and loss on ignition. The distinct difference between self-hardening and pozzolanic reactivity has been emphasized.

5. **Suthar et al (2016)-** Study shows Shear behavior of Loose and Compacted Pond Ash. This paper presents a detailed characterization study on the physico-chemical, mineralogical and morphological properties of pond ash samples. Results reveal that all inflow and outflow pond ashes have low specific gravity (2.03–2.27) as compared to soil (2.6–2.7), i.e. natural fill material, low amount of unburned carbon content (1.79–3.49 %) and the values of maximum dry density and optimum moisture content are within the permissible limits as per design standards of embankment construction. It can be effectively used as construction fill materials for low-lying areas and as embankment materials etc., with caution to protect ground water from contamination due to the high concentration of lead (Pb) and chromium (Cr).
6. **Subbarao et al (2007)-** Study shows In-Place Stabilization of Pond Ash Deposits by Hydrated Lime Columns. In This study shows a technique of in-place stabilization by hydrated lime columns was applied to large-scale laboratory models of ash ponds. samples were tested to study the improvements in the water content, dry density, particle size distribution, unconfined compressive strength, pH, hydraulic conductivity, and leachate characteristics over a period of one year. The in-place stabilization by lime column technique has been found effective in increasing the unconfined compressive strength and reducing hydraulic conductivity of pond ash deposits in addition to modifying other geotechnical parameters. The method has also proved to be useful in reducing the contamination potential of the ash leachates, thus mitigating the adverse environmental effects of ash deposits.
7. **Jakka et al (2010)-** A detailed experimental study carried on the strength and other geotechnical characteristics of pond ash samples, collected from inflow and outflow points of two ash ponds in India. 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. Ash samples from inflow point exhibited behaviour similar to sandy soils in many respects. They exhibited higher strengths than reference material (Yamuna sand), though their specific gravity and compacted maximum dry densities are significantly

lower than sands. Ash samples from outflow point exhibited significant differences in their properties and values, compared to samples from inflow point. Shear strength of the ash samples from outflow point are observed to be low, particularly in loose state where static liquefaction is observed

8. **Chand et al(2007)**- Study shows Pond ash, after adequate stabilization, may be suitable for various engineering applications. The effects of lime stabilization on the strength and durability aspects of a class F pond ash, with a lime constituent as low as 1.12%, are reported. Lime contents of 10 and 14% were used, and the samples were cured at ambient temperature of around30°C30°C for curing periods of 28, 45, 90, and 180days180days. Unconfined compressive strength (UCS) values of 4.8 and 5.8MPa5.8MPa and slake durability indices of 98 and 99% were achieved after 180days180days of curing for samples stabilized with 10 and 14% lime, respectively. Good correlations, that are particularly suitable for stabilized materials of low density and low strength, have been derived for strength parameters obtained from UCS tests, point load strength tests, and Schmidt rebound hammer tests, and also between UCS and slake durability index.

2.3 Study on Yamuna Sand as a mix or Yamuna sand stabilisation-

1. **Trivedi et al (2013**)- Study shows Shear Strength Parameters for Silty Sand Using Relative Compaction. As a result of his work, the dilatancy of silty sand based on relative compaction is evaluated. The values of shear strength parameters of silty sand calculated based on the concept of relative compaction is more appropriate as compared to that based on relative density due to the inherent limitation associated with the correct determination of relative density for silty soils. The values thus obtained for and are comparable with that calculated by Bolton. The outcome of present study indicates that the values of are sensitive to the mean sizes, relative compaction and extent of confinement. Such a sensitivity of shear strength parameters significantly contributes to the evaluation of strength behaviour of silty sand obtained from the catchment of river Yamuna.
2. **Saurav de et al(2010)-** Work shows Steady State Strength Behavior of Yamuna Sand. the ultimate steady state is generally achieved irrespective of the initial state

of

the soils sample and whether the response is contractive or dilative. But due to errors arising from change, trend is not observed.

2.4 **Study on Pond Ash and lime-**

1. **Raju et al (2012)-** study shows Geotechnical Behavior of Lime Stabilized Pond Ashes from Delhi Region. Experimental studies were conducted to characterize Badarpur, Dadri and Rajghat Pond ashes**.**
    - All the pond ash samples collected from Badarpur, Dadri and Rajghat were predominantly sand with nearly 72%, 56% and 66% sand size particles and 22%, 34% and 31% of silt size particles**.**
    - The ratio of light (standard Proctor) compaction characteristics and heavy (modified Proctor) compaction characteristics of Badarpur, Dadri and Rajghat pond ashes were different. As shown in Table IX, Badarpur pond ash could be compacted to a somewhat greater dry density values as compared to the other two pond ashes. The ratios of MDD values of the two Proctor tests were found to be 75%, 80% and 83%, respectively for Badarpur, Dadri and Rajghat pond ashes.
    - In the consolidated undrained triaxial shear tests of Badarpur, Dadri and Rajghat pond ash specimens compacted at MDD, deviator stress attained peak value at axial strains in the range of 1.5-3.0% for all the specimens and thereafter remained almost constant.The drained cohesion and angle of shearing resistance were 0 kPa and 30.4o; 0 kPa and 32.0o and 0 kPa and 28.9o respectively. The cohesion intercept values for all the pond ashes mixed with lime were found to be zero.
    - In the California Bearing Ratio tests, the value of CBR increases with the increase of the lime percentage in the pond ash lime specimens upto 8% and decreases thereafter.
2. **Gupta et al (2013)-** Study shows Geotechnical Behaviour of Fine Sand Mixed with Pond Ash and Lime. SEM results shows better interlocking between fine

sand, pond ash particles and lime. Hence mixing of pond ash and lime in fine sand can result in enhanced strength of fine sand. The results from the grain size analysis reveal that fine sand is uniformly graded and pond ash is not well graded, though in particle size distribution they were very much parallel. The standard proctor test indicates that MDD of fine sand increases with lime percentage. It can be due to interlocking of lime particles in voids of fine sand. Also, MDD of fine sand increases with pond ash percentage up to 8% after that it decreases. The CBR test reveals that CBR value increases every time when lime percentage is increased. This can be due to the interlocking of lime particles in fine sand. Also, lime provides strength on hydration and acts as a binder between particles. CBR value increases with increases in pond ash percentage due to cementitious material formed by pond ash and lime.The triaxial test reveals that cohesion and angle of internal friction of fine sand increases with lime % up to 9% after that they decreases. This can be because of increase in slippage between fine sand particles due to extra lime. Addition of pond ash with 9% lime in fine ash shows the cohesion and internal friction increases with pond ash percentage up to 16% pond ash. Cohesion and angle of internal friction of fine sand maximizes at 16% pond ash and 9% lime.

3. **Negi et al (2013)-** Study shows Effect of Curing on Compaction Behavior of Pond Ash Mixed with Marble Dust and Lime. Pond ash and marble dust are predominantly sand with 60% of particles of sand size. X-ray diffraction of the samples shows the presence of quartz, hematite, corundum, and lime in pond ash and dolomite in marble slurry dust. SEM pictures of cured samples clearly shows coarser bonded particles of pond ash and marble dust.Maximum dry density increases in a linear fashion with increase in percentage of marble dust.

CHAPTER-3

SAMPLE DETAILS

3.1 Yamuna sand

Yamuna sand was brought from dealer in rohini delhi. The sand is cohesionless with fine grain particles and is dark grey in colour.

Figure3.1: Yamuna Sand

3.2 Pond Ash

for our project Pond ash is collected from Badarpur Thermal Power Plant, NTPC Badarpur. Chemical properties of badarpur pond ash are-

S.No.	Constituent in Pond Ash	Content in %
1.	SiO_2	49.5
2.	Al_2O_3	25.01
3.	MgO	1.21
4.	Fe_2O_3	9.81
5.	CaO	4.48
6..	Loss of Ignition	9.79
7.	Others	0.08

Table 3.1: Chemical properties of pond ash

3.3 Lime

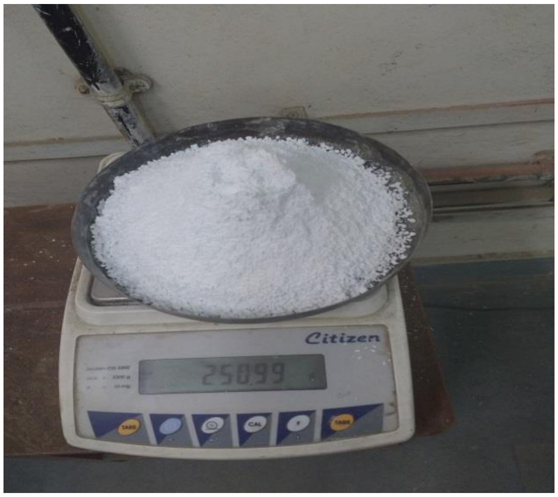

Figure3.2: Lime Sample

Lime was purchased from the market. Chemical composition of lime is following- (Raju et al, GEOMATE, Sept. 2012)

Chemical Composition	**Content (in %)**
Minimum array (Acidimetric)	95.00
Chloride(Cl)	.10
Sulphate(S)	.50
Iron (Fe)	.10
Lead (Pb)	.02
Loss on Ignition	10

Table 3.2: Chemical properties of Lime

CHAPTER-4

EXPERIMENTAL WORK

4.1 XRD Test-

X-Ray diffraction is used for phase identification of unknown crystalline materials (mineral and inorganic compounds), It distinguishes between amorphous and crystalline material.Its application includes-

- Characterization of crystalline material.
- Identification of fine grained minerals such as clays and mix layer clays which can not be identified by naked eyes.
- For measurement of purity of sample.

According to A.W.Hull "Every crystalline substance gives a pattern; and same substance provides same pattern; and in case of mixture of substances, each produce independent pattern."

The atoms of crystalline solids are arranged in a regular pattern and obtain smallest volume element.About 95% of all solids can be described as crystalline.

An electron in an alternative electromagnetic field oscillates with same frequency as the field.When an X-Ray beam hits this atom, electron around this atom oscillates with the same frequency as that of incoming beam.We have destructive interface almost in all the directions, this lead to combining waves out of phase and there is no resultant energy leaving the solid sample.Since atoms arranged in a regular manner in the crystal, So in a few direction, There may be chance of constructive interface.X-rays are generated by cathode ray tube filtered to produce monochromatic radiation, collimated to concentrate and directed towards the sample.Intaction of the incident rays with sample produce constructive interface when satisfy Bragg's law condition

$$n\lambda=2d \sin \theta$$

Figure 4.1: XRD Machine

All diffractions method are based on generation of X-rays in X-ray tube.These rays are directed at the sample and diffracted rays are collected.These diffracted rays are then processed and counted.

4.2 Scanning Electron Microscope (SEM) Test-

SEM uses a finely focused beam of electrons in order to produce high resolution images of the sample.SEM image have a 3D appearance, which is very useful when examining the surface structure of the sample.

The SEM uses Energy Dispersive X-ray Spectroscopy(EDS) in the production of elemental maps, Which accurately represents the distribution of elements within sample.SEM most commonly used in elemental analysis, mineral orientation, morphology and contrast study.

Principal- Accelerated electrons in SEM carries significant amount of kinetic energy and this energy is dissipated by variety of signals produce by electron sample interactions, when the incident electrons are decelerated in the solid sample.These signals contains

- Secondary Electrons (which produce SEM images).
- Backscattered electrons
- Diffracted backscattered electrons.(useful for determination of crystal structure and mineral orientation)
- Photons.(Used for elemental analysis and continuum X-ray)
- Heat.

Secondary electrons and backscattered electrons are commonly used for imaging of samples, they are important for morphology and show topography on samples and Backscattered electrons are valuable for illustrating contrasts in composition in multiphase samples.X-ray generation is produced by inelastic collisions of the incident electrons with electron in discrete shells of atoms in the sample.

SEM analysis is considered to be 'Non destructive'; that is X-rays generated by electron interactions do not lead to volume loss of sample and that can be analyze repeatedly.

Figure 4.2 SEM Machine

-4.3 Grain Size Analysis-[IS : 2720 (part 4)-1985]

In this quantitative determination of grain size distribution of soil is done.There are 2 methods.

1. Dry analysis.(Particle size greater than 75µ,otherwise wet analysis)

Wet analysis.-soils having appropriate amount of clay and not applicable if less than 10% material passes through 75µ.

Wet analysis includes two methods-

1. Pipette method.(standard method)
2. Hydrometer method.

For Yamuna sand particle size analysis is done with grain size distribution curve and for pond ash hydrometer analysis is done.

hydrometer method-

Fgure 4.3: Hydrometer Analysis.

Part-I: Calibration of hydrometer

Take about 800ml of water in one measuring cylinder. Place the cylinder on a table and observe the initial reading.

Immerse the hydrometer in the cylinder. Take the reading after the immersion.

Determine the volume of the hydrometer (V_H) which is equal to the difference between the final and initial readings. Alternatively weigh the hydrometer to the nearest 0.1g. The volume of the hydrometer in ml is approximately equal to its mass in grams.

Determine the area of cross section (A) of the cylinder. It is equal to the volume indicated between any two graduations divided by the distance between them. The distance is measured with an accurate scale.

$$H_e = H + \frac{1}{2}\left(h - \frac{V_H}{A}\right)$$

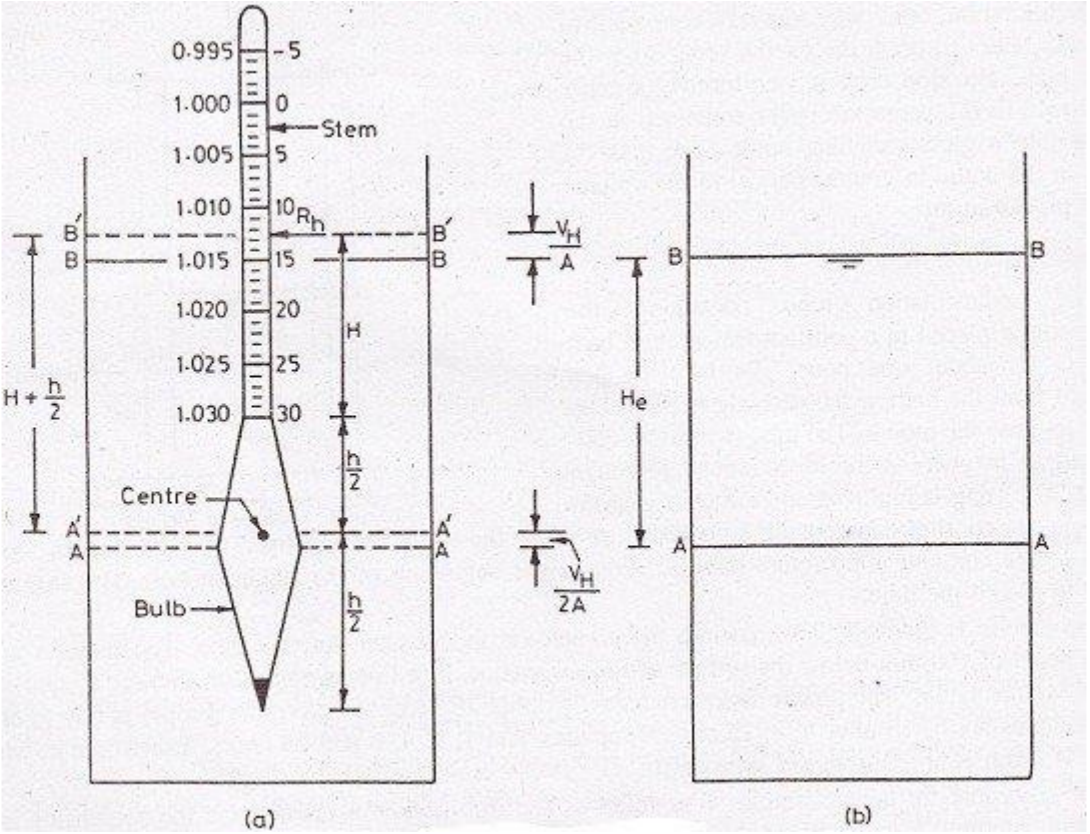

Fig:4.4 Hydrometer Method

<u>Part-II: Meniscus Correction</u>

1. Insert the hydrometer in the measuring cylinder containing about 700ml of water.
2. Take the readings of the hydrometer at the top and at the bottom of the meniscus.
3. Determine the meniscus correction, which is equal to the difference between the two readings.
4. The meniscus correction C_m is positive and is constant for the hydrometer.
5. The observed hydrometer reading R_h' is corrected to obtain the corrected hydrometer.

Part-III: Pretreatment and Dispersion

1. Weigh accurately, to the nearest 0.01g about 50g air-dried soil sample passing 2mm IS sieve, obtained by riffling from the air-dried sample passing 4.75mm IS sieve. Place the sample in a wide mouthed conical flask.
2. Add about 150ml of hydrogen peroxide to the soil sample in the flask. Stir it gently with a glass rod for a few minutes.
3. Cover the flask with a glass plate and leave it to stand overnight.
4. Heat the mixture in the conical flask gently after keeping it in an evaporating dish. Stir the contents periodically. When vigorous frothing subsides, the reaction is complete. Reduce the volume to 50ml by boiling. Stop heating and cool the contents.
5. If the soil contains insoluble calcium compounds, add about 50ml of hydrochloric acid to the cooled mixture. Stir the solution with a glass rod for a few minutes. Allow it to stand for one hour or so. The solution would have an acid reaction to litmus when the treatment is complete.
6. Filter the mixture and wash it with warm water until the filtrate shows no acid reaction.

4.4 Specific Gravity Test-[IS : 2720 (part 3-Section 1)]

Significance- Specific gravity is used to find out degree of saturation and unit weight of moist soil.This unit weight is used in various applications of Geotechnical engineering like pressure calculation, settlement, strength and various stability problems.

Specific gravity gives us phase relationship between air, water and solid particles for the given volume.

Equipments used -Pycnometer, Balance, Vacuum desiccator, Vacuum pump, Oven etc.

4.5 Standard Proctor Test-[IS : 2720 (part 7)-1980]

Significance- In this relation between optimum moisture content and Maximum dry density is found out for given soil using light compaction.Purpose of test is to find out proper amount of mixing water to be use, when compacting the soil in the field and resulting degree of denseness which can be expected from compaction at optimum moisture content.Due to this we can achieve better field compaction..

Object- To determine relation between OMC and MDD of soil and soil mix.

Equipments used-

1. Cylindrical metal mould (Capacity-1000 c.c., Internal dia-100mm, Effective Height-127.3 mm),
2. Rammer for light compaction (having 2.6 kg mass and falling through 310mm height).
3. Other mould accessories like detachable base plate and removable collar.
4. Oven,
5. Container,
6. Balance,
7. IS Sieve (4.75mm)
8. Mixing tool,

Theory-

Compaction of soil is a process of increasing the unit weight of soil by forcing the soil solids into dense state and reducing its air voids. It leads to increase its shear strength and helps improve the stability and bearing capacity of soil. This is achieved by static or dynamic application of loads on soil. If large air voids left, may lead to compaction under working load causing settlements during service life of the structure and increase in water content is also accompanied by swelling and loss of shear strength with time, to recover this compaction is important. Various advantages of compaction are-

- Reduction in settlement.
- Increase in soil strength and stability.
- Load carrying capacity of pavement subgrade can be improved.
- Undesirable volume changes by frost action, swelling shrinkage may be controlled.

In field, we can attain 90-95% of maximum dry unit weight of laboratory.

Figure 4.5: Standard Proctor Test

Application-

We can achieve γ_d at two moisture contents and it is easier to compact with wet side of optimum but this result in lower shear strength than compacting the soil on dry side of optimum moisture content. Based on this-

- Core of an earthen dam is compacted wet side of optimum, this causes reduce in permeability and prevent cracking in core.
- Homogenous embankments are compacted on dry side of optimum, this causes stronger soil and to prevent building up high pore water pressure.

- Subgrade of pavement is compacted on wet side of optimum; this limits volume change in subgrade.

Figure 4.6 Automatic Compaction Machine

4.6 Direct Shear Test-

Significance-

Shear strength of soil is given by-

$$\tau = C + \bar{\sigma} tan Ø$$

Here C and Ø are parameters related to type of test and condition under which these are measured. Normally for clayey soil Ø=0, and for granular soil C=0.

Direct shear test is performed to find out C and Ø. In this test drainage condition cannot be controlled so rate of loading should be such that pore water pressure does not develop. This test is good for free draining soil like sand and gravel.

Sample Preparation- sample is prepared at OMC and MDD. Sample weight is obtained by multiplying MDD with volume of the sample that is 60×60×26 mm^3.

Advantages-

- Test is quick, inexpensive and simple.
- Sample preparation is easy.

Disadvantages-

- As drainage condition cannot be controlled, We cannot measure pore water pressure.
- Failure plane is always horizontal and pre-determined which may not be weakest plane.
- Non uniform distribution on shear plane. Failure starts at edge and progresses towards Centre.
- Direction of principal planes is not known at every stage of test, in this test only Mohr failure envelope is known that direction of principal stresses will be known. In fact there is rotation of principal plane between the start of test and failure of soil.

Figure 4.7: Direct Shear Test

4.7 Triaxial Test-

Significance-

- This is most widely shear strength test and is suitable for all type of soil.
- Drainage can be controlled, whatever be the soil, can be tested by controlling drainage condition as present in the field.
- Pore water pressure, Volume changes can be measured.
- Failure plane is not predetermined, and there is no rotation of principal stresses during test. Stress distribution on failure plane is uniform.
- Confining pressure is given by filling the triaxial cell with water and specimen is sealed inside with rubber membrane.

Triaxial test is performed in 2 stages.

1^{st} stage (Confining Stage)	**2^{nd} stage (Shear stage)**
Drainage allowed (consolidated)	Volume change allowed (Drained)
Drainage not allowed (unconsolidated)	No volume change (Undrained)

Accordingly type of tests are-

i. Consolidated Drained test (CD Test).
ii. Consolidated Undrained test (CU Test).
iii. Unconsolidated Undrained test (UU Test).

Consolidated Drained test (CD Test)

- Drainage is allowed in both stages.
- Loading rate is slow so there is no pore water pressure develops. So we get effective stress parameter in this case.
- CD test is used in analysis of gradual loading condition. And also to check long term stability of embankment which has been in existence since long ago.

$$\tau_f = C'_{CD} + \bar{\sigma}\tan\emptyset'_{CD}$$

Where $\bar{\sigma}$ - Effective vertical stress in field.

Consolidated Undrained test (CU Test)

- In 1^{st} stage-Drainage allowed.

  In 2^{nd} stage-Drainage not allowed, volume change not allowed, Pore water pressure develops.
- This gives total stress parameters. Effective stress parameters can be calculated if pore water pressure is measured.
- This test is use to check stability under sudden unloading such as dewatering or drawdown condition and to check stability of an embankment that has lived some of its life and now being unloaded.

$$\tau_f = C'_{Cu} + \bar{\sigma}\tan\O'_{Cu}$$

Unconsolidated Undrained test (UU Test).

- In 1^{st} stage-Drainage not allowed.

  In 2^{nd} stage-Drainage not allowed. (Initially sample is saturated)

  If sample is saturated diameter of the Mohr’s circle is same, which implies same increment of deviator stress with respect to any confining pressure.in this case

$$\tau_{f} = \frac{(\sigma_1 - \sigma_3)}{2}$$

- In our case sample is not saturated.
- It is a quick test. Time taken is approx. 20 minutes.
- This test is suitable for soil of low permeability or when loading is very fast. As in rapid construction.
- UU test is used where short term stability under construction pore water pressure i.e. during construction only.

Figure 4.8 Triaxial Testing machine

CHAPTER-5

ANALYSIS OF RESULTS

5.1 Sem (Scanning Electron Microscope) Test-

Test was conducted on all three materials at various scales 5µm, 10µm & 20µm.

1. <u>Yamuna Sand-</u>

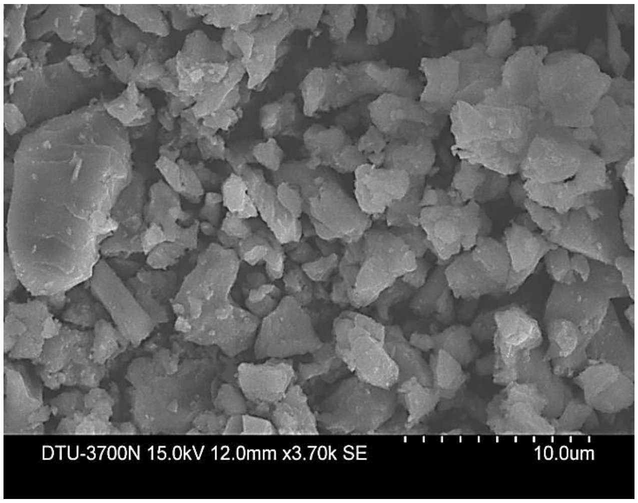

Figure 5.1 SEM test on Yamuna sand at 10µm

As shown in previous images, Yamuna sand is fine sand and particles are little bit angular and rounded both, Sand particles can be seen with sharp edges. particles are formed by weathering of rocks and showing silica content.

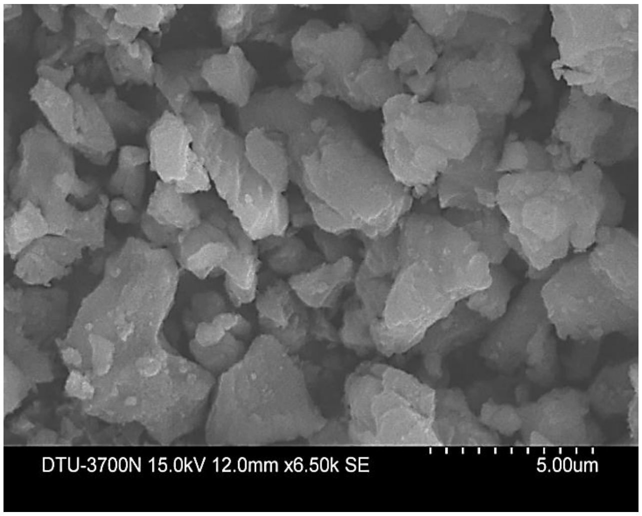

Figure 5.2 SEM test on Yamuna sand at 5µm

B)Pond Ash-

The SEM of pond ash shows the spherules of alumina silicates. Dark matter present shows magnetite. SEM test of Pond ash at 5, 10 and 15µm showing morphology of it when PA is alone. When PA reacts with lime and water, it forms cementious compounds

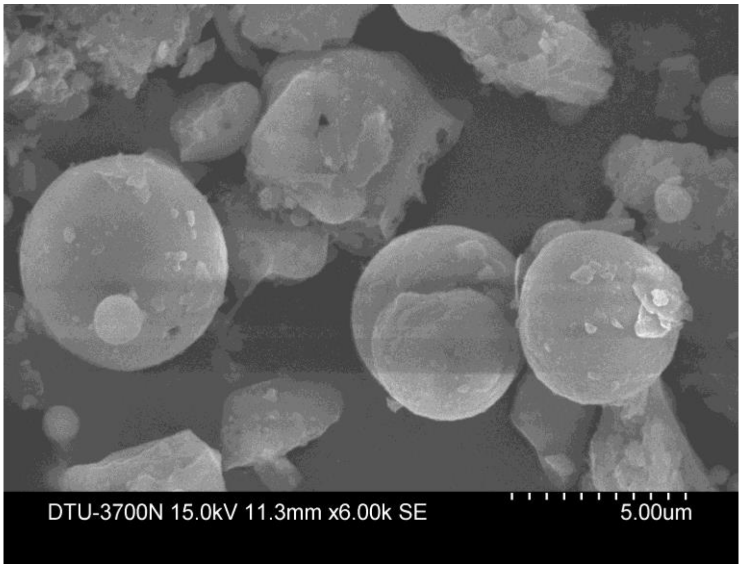

Figure 5.3 SEM test on Pond ash at 5 µm

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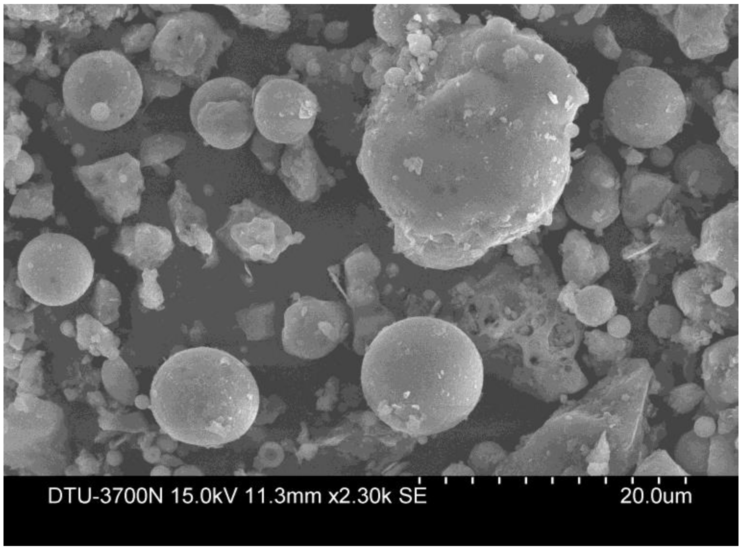

Figure 5.4 SEM test on Pond ash at 20µm

2. Lime-

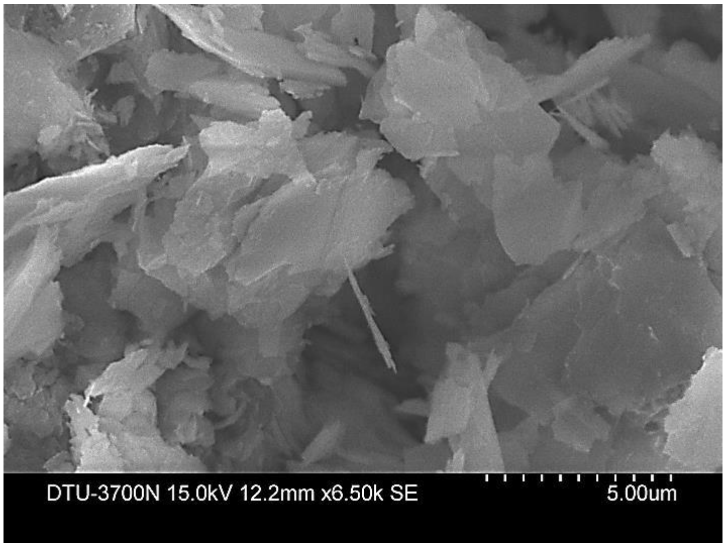

Figure 5.5 SEM test on Lime at 5μm

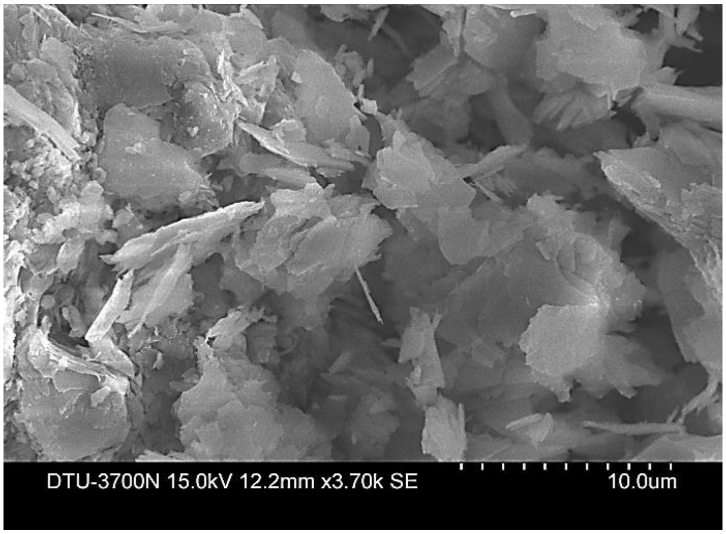

Figure 5.6 SEM test on Lime at 5μm

SEM results shows better interlocking between fine sand, pond ash particles and lime. Hence mixing of pond ash and lime in fine sand can result in enhanced strength of fine sand.

5. 2. XRD Test-

Test was done on Yamuna Sand and Pond Ash.

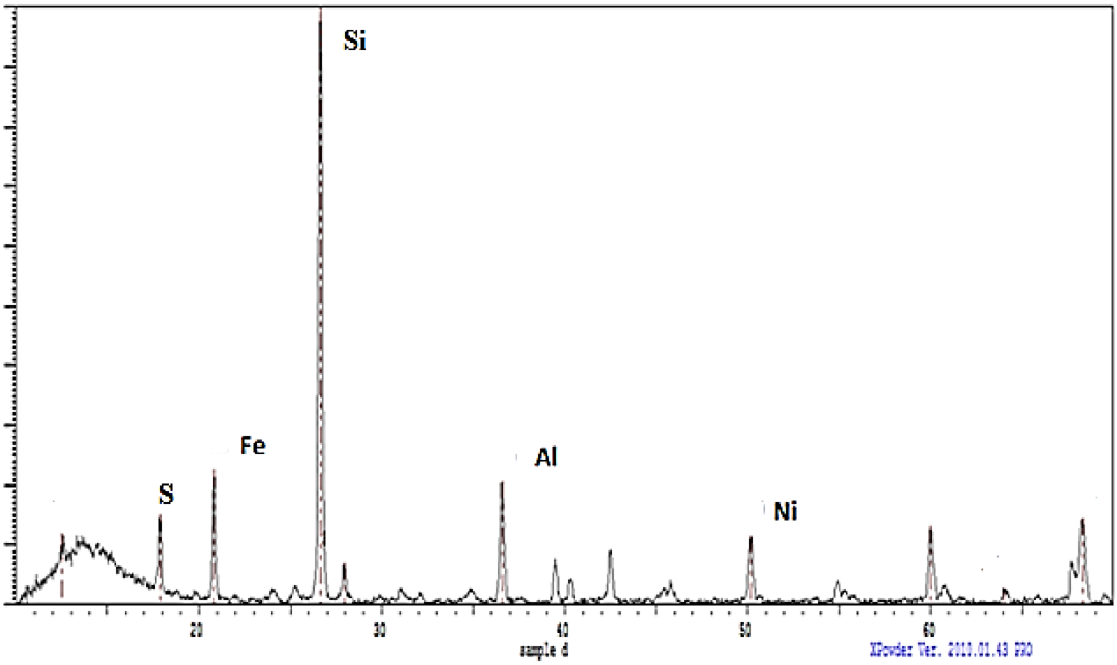

Figure: 5.7 XRD analysis of Yamuna sann

XRD test on Yamuna Sand shows that presence of mainly Silica, Hematite, Corundum, Nickel etc. From this we can get mineral composition of sand and particle size using Scherrer's Equation:

$$t = \frac{0.9\lambda}{\beta \cos\theta}$$

Where,

t-mean particle size or grain size,

λ- X ray wavelength at which XRD takes place (=1.540A°),

β-Full width at mid heights (=0.02 cm)

θ-Bragg angle (=13.325 radian)

putting these values we get grain size of sand = 72µm.

XRD analysis of PA shows mainly presence of quartz, hematite, corundum, lime and MgO etc.

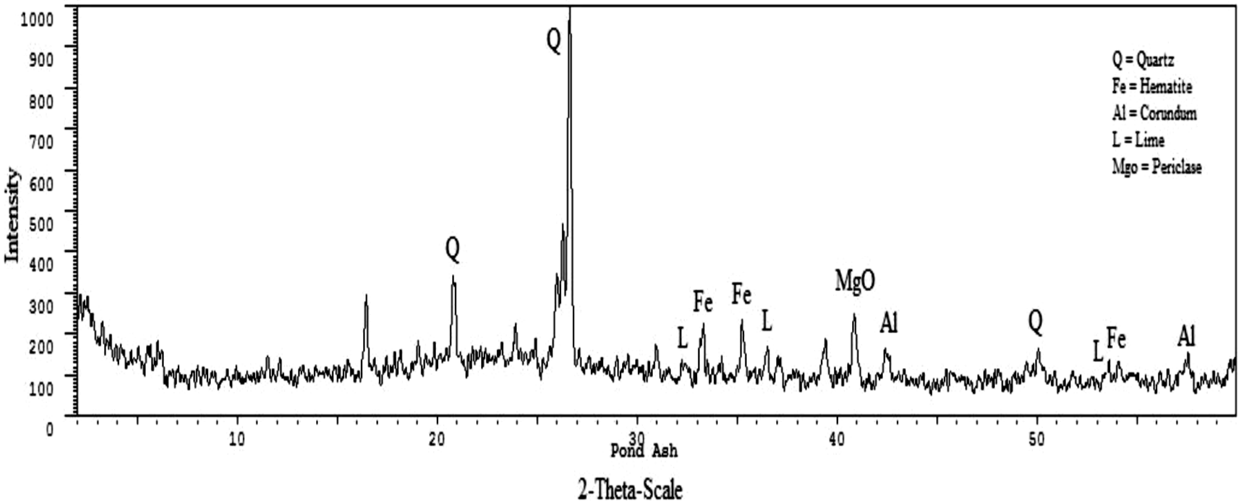

figure5.8: XRD analysis for Pond ash

3) PARTICLE SIZE DISTRIBUTION-

For particle size distribution Sieve analysis has been done.

Sieve size	**Weight retained (gm.)**	**% wt. retained**	**% cumulative wt. retained**	**% finer**
4.75 mm	0.41	0.08	0.08	99.92
2.36 mm	0.27	0.05	0.13	99.87
1.18 mm	1.35	0.27	0.40	99.60
600 micron	0.89	0.18	0.58	99.42
300 micron	74.6	14.92	15.50	84.50
150 micron	290.83	58.17	73.67	26.33
75 micron	93.63	18.73	92.40	7.60

Table 5.1:-Particle size analysis of Yamuna sand.

Behavior of %finer with particle size is as follows-

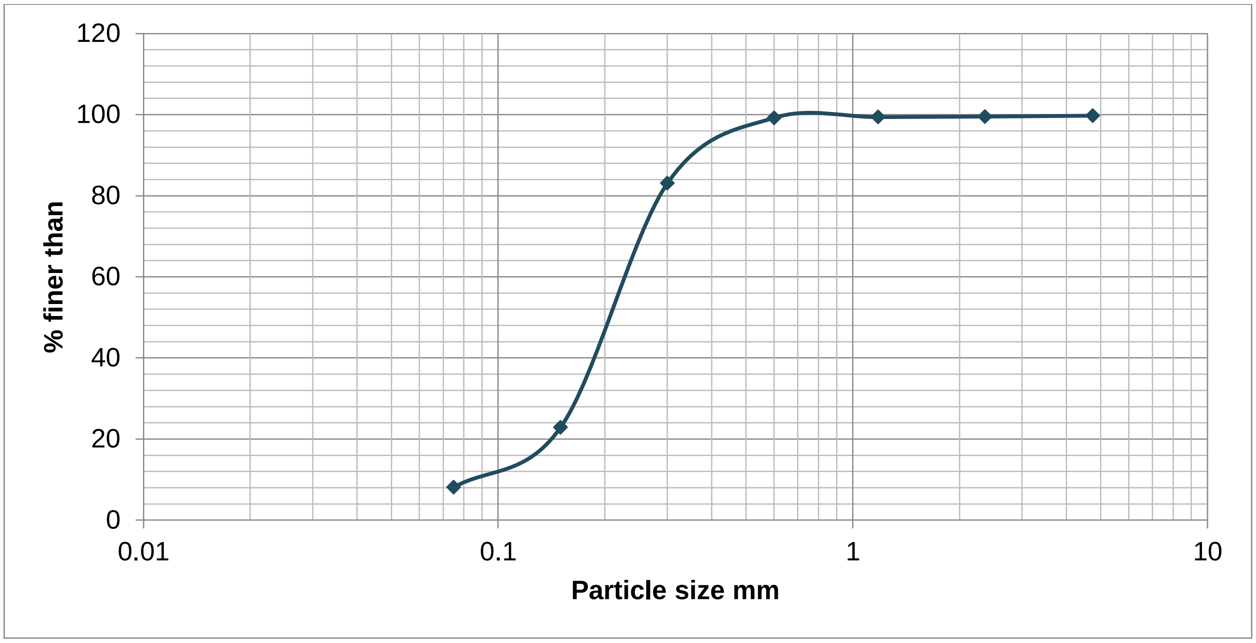

Figure5.9: particle size analysis for Yamuna sand

From the graph D_{10},D_{30} and D_{60} value is calculated, that is

D_{10}=0.0845

D_{30}=0.1677

D_{60}=0.2426

C_u=1.36

C_c=2.88

Here fine soil fraction (<75µ) is 7.58%, which is less than 10% so no need of hydrometer analysis.

For PA hydrometer analysis is done.

Remaining Silt content after 24 hour oven drying = 24 gms

For Pond ash particle size analysis is following-

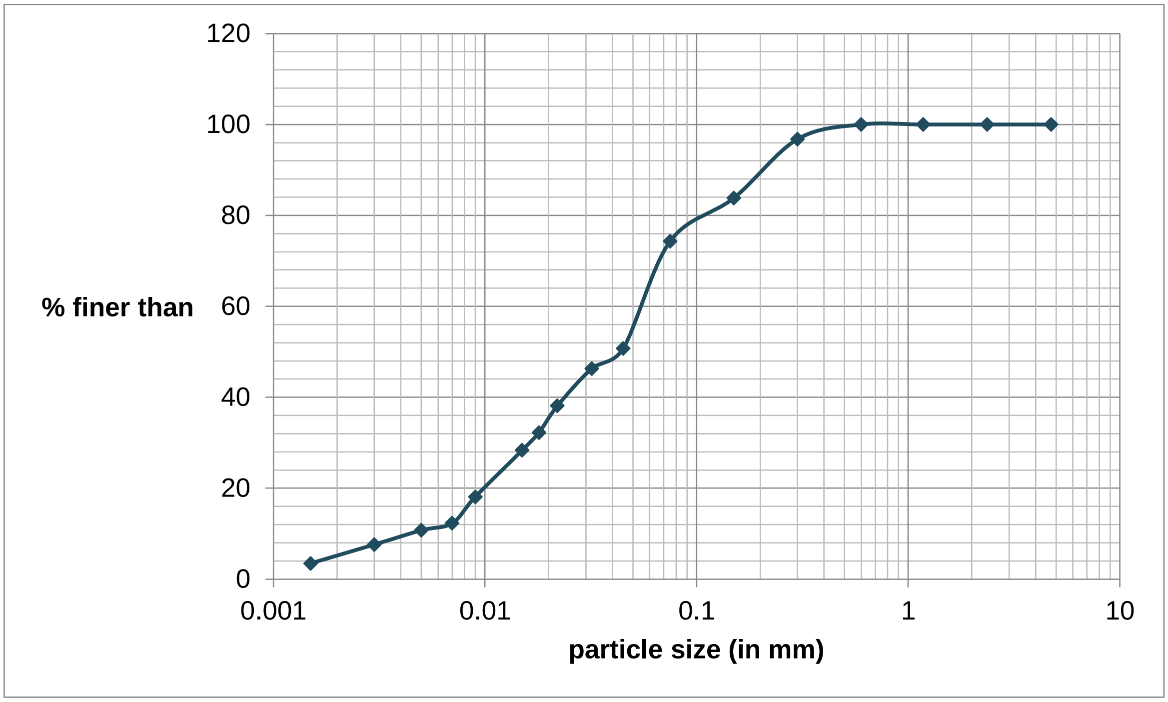

Figure5.10: particle size analysis for Pond ash

5.4 SPECIFIC GRAVITY TEST-

Specific gravity of Pond ash is obtained by Pycnometer method)

The specific gravity G of the fly ash was tested in a non-aqueous medium (kerosene) as per International Union of Laboratories and Experts in Construction Materials, Systems, and Structures recommendations.

Material	Specific gravity (G)
Yamuna Sand	2.65
Pond ash	2.15
Lime (Quick lime)	3.3
Lime (Hydrated lime)	2.2

Table 5.2- Specific gravity

5.5 Liquid Limit and Plastic Limit Determination

Liquid limit and Plastic limit determination is not possible for Yamuna sand as it is classified as coarse grained soil and liquid limit and plastic limit are associated with fine grained soil specially clayey soil**.**

5.5.1 Liquid Limit and Plastic Limit Test on Pond ash-

Pond ash shows non plastic behavior.

5.6 Standard Proctor Test-

Standard proctor test is performed on virgin sand and Pond ash, Results are following-

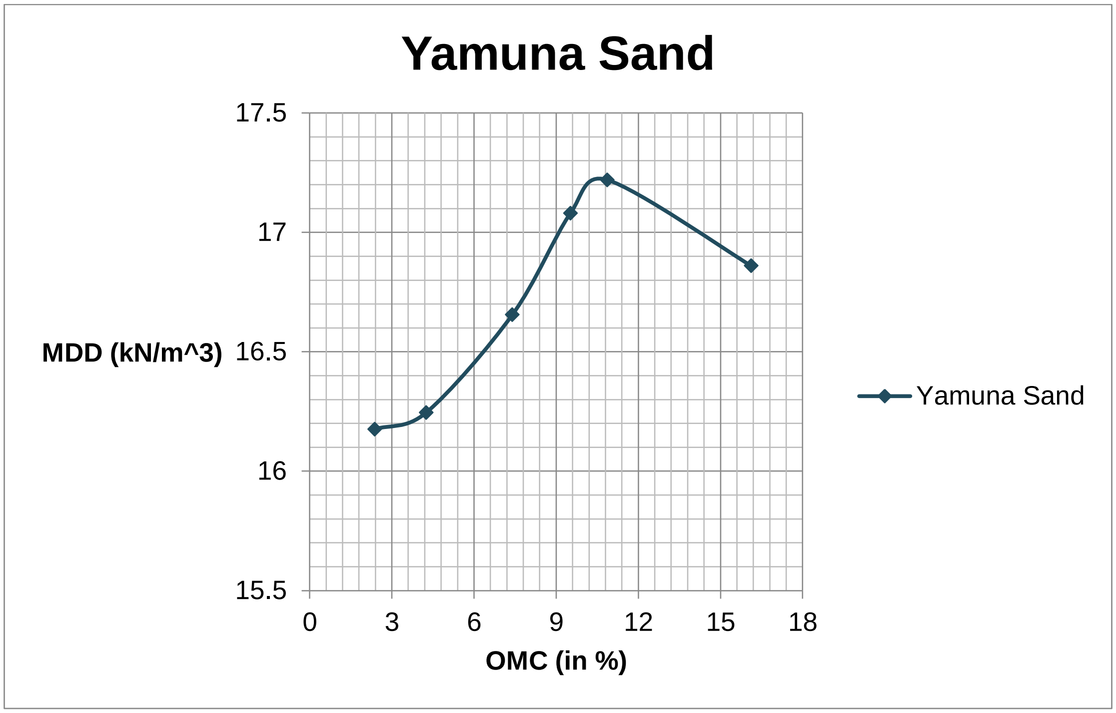

Figure5.11: Compaction curve for Yamuna sand

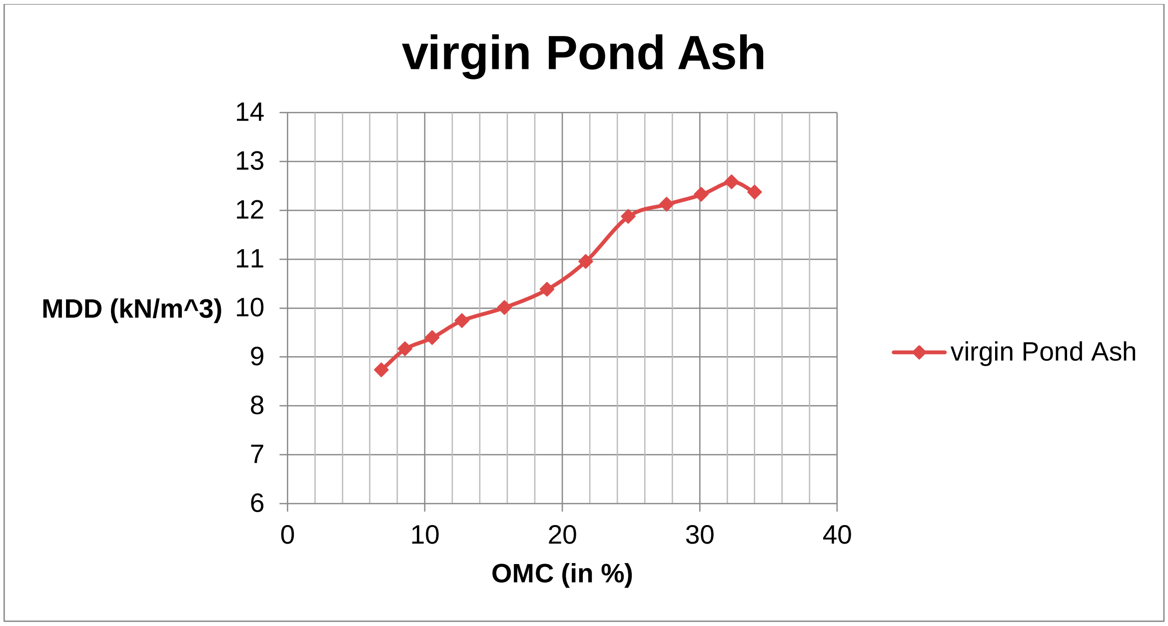

Figure5.12: Compaction curve for virgin Pond Ash

For lime content determination in mix standard proctor and direct shear test has performed.

A) When lime mixed with YS at various %-

For lime content determination lime is taken at 3%, 5%, 8% and 10% respectively. Their MDD & OMC variation are as follows.

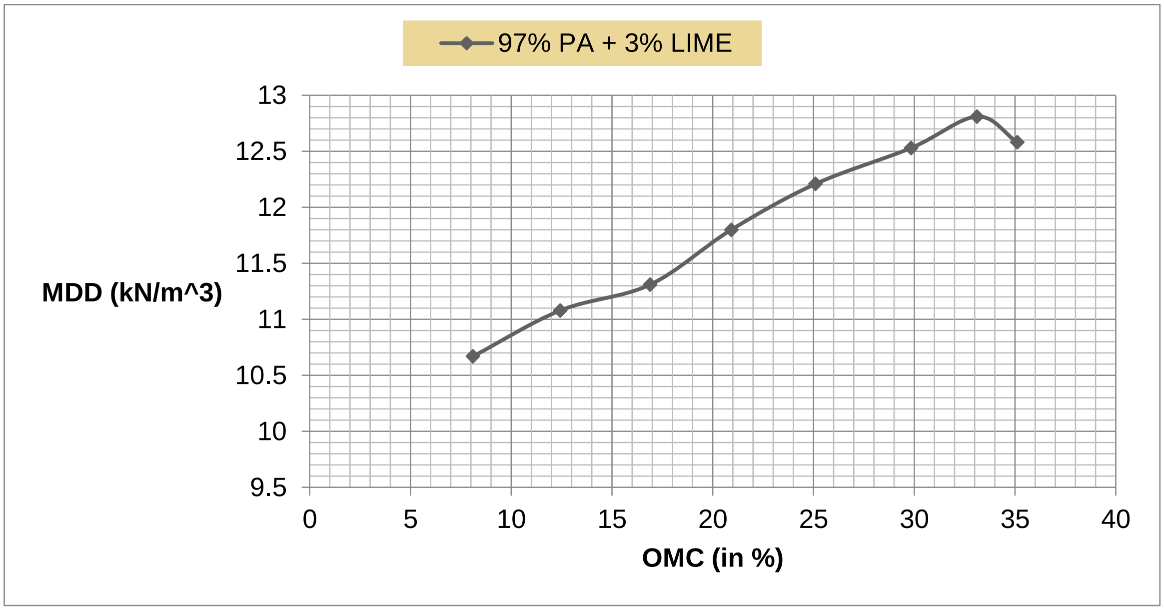

Figure5.13: Compaction curve for 97% Sand + 3 % lime

335

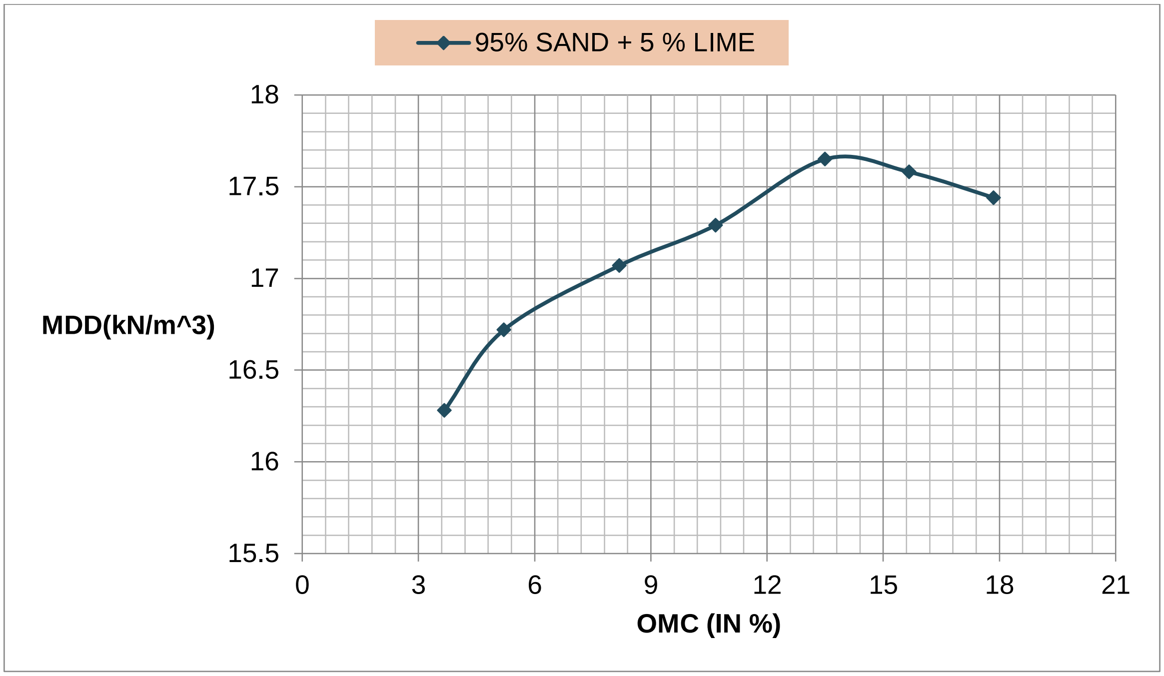

Figure5.14: Compaction curve for 95% Sand + 5 % lime

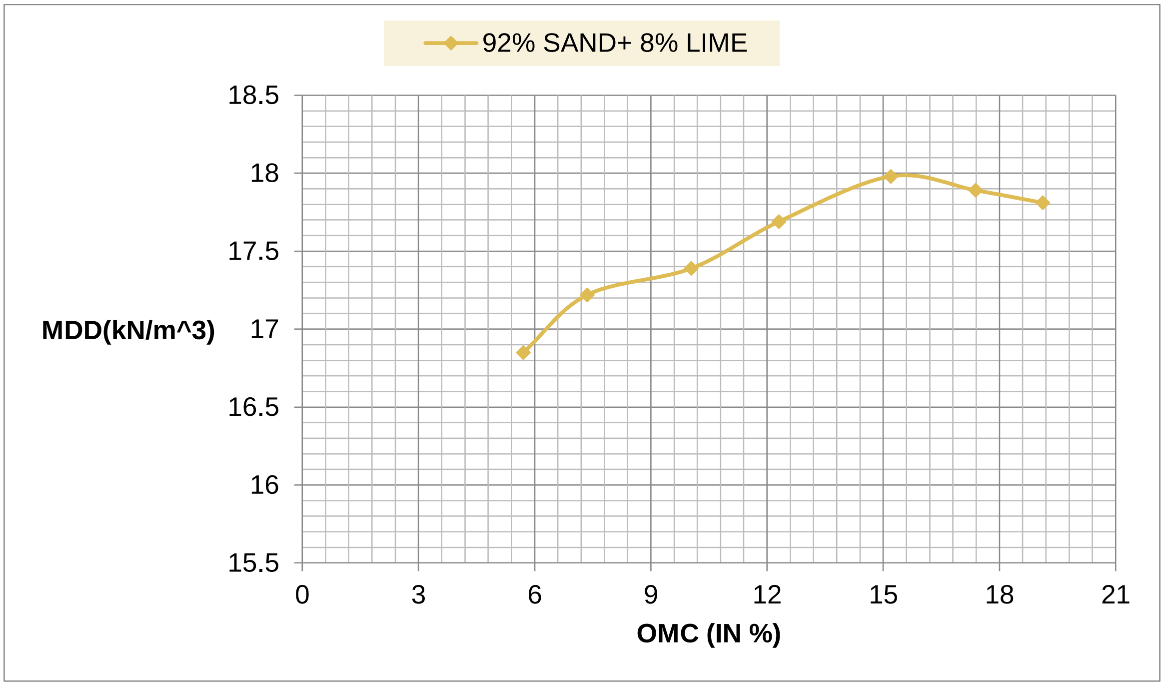

Figure5.15: Compaction curve for 92% Sand + 8 % lime

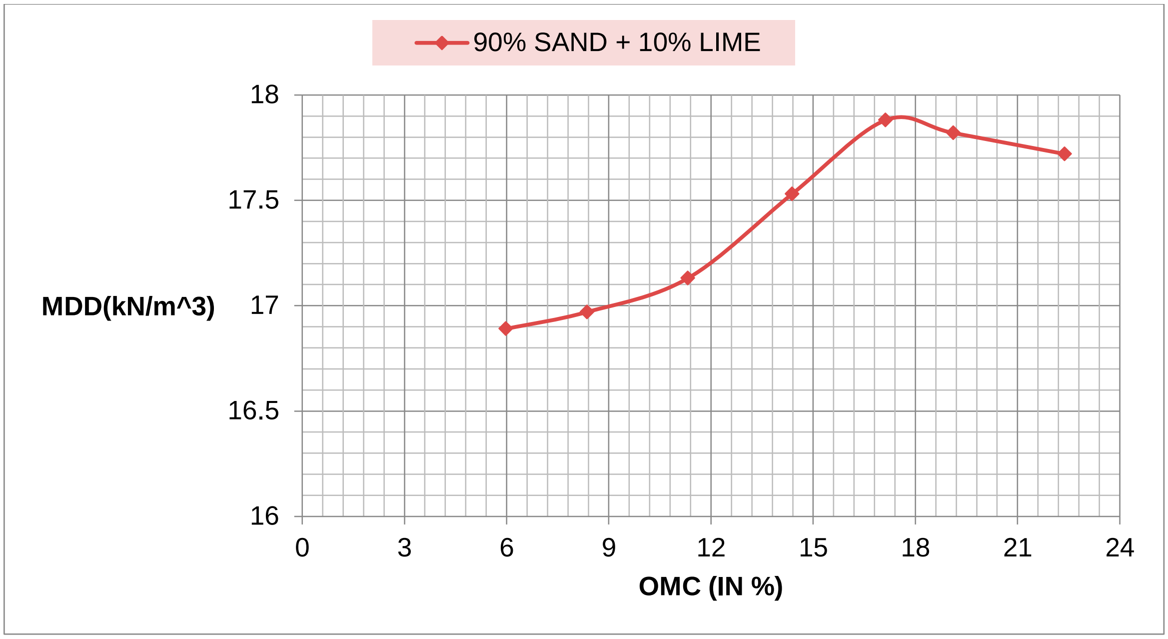

Figure5.16: Compaction curve for 90% Sand + 10 % lime

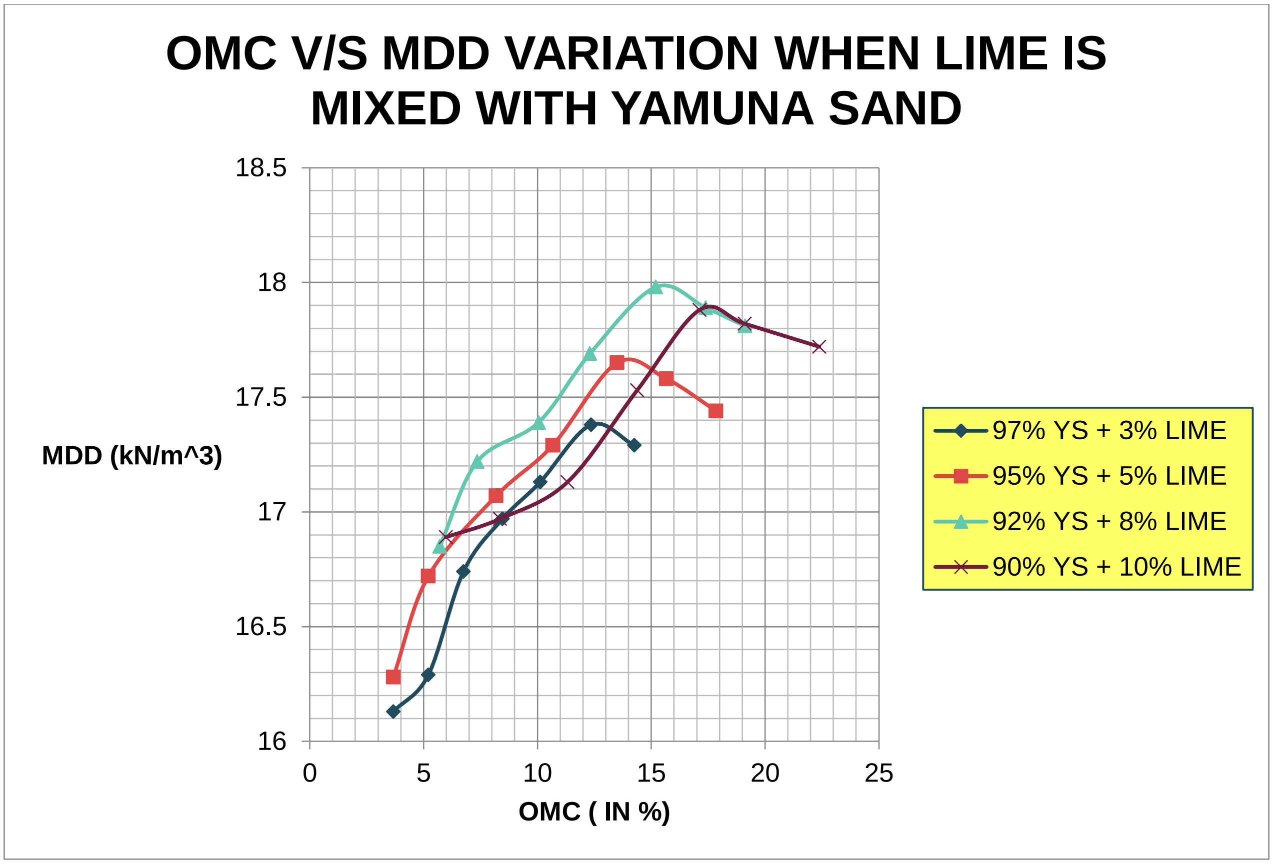

Figure5.17: Compaction curve showing variation in MDD when lime is mixed with pond ash

SAMPLE MIX	MDD (kN/m^3)	OMC (in %)
97% YS + 3% LIME	17.38	12.36
95% YS + 5% LIME	17.65	13.5
92% YS + 8% LIME	17.98	15.2
90% YS + 10% LIME	17.89	16.7

Table 5.3 Compaction behavior when lime is mixed with Yamuna sand.

Above results shows that MDD is increasing when lime content is upto 8% in YS , and above 8% MDD is not showing significant change.

Again lime content is determined, when lime is mixed with same content 3, 5, 8, 10% with Pond ash, again MDD v/s OMC study is carried out, which are following-

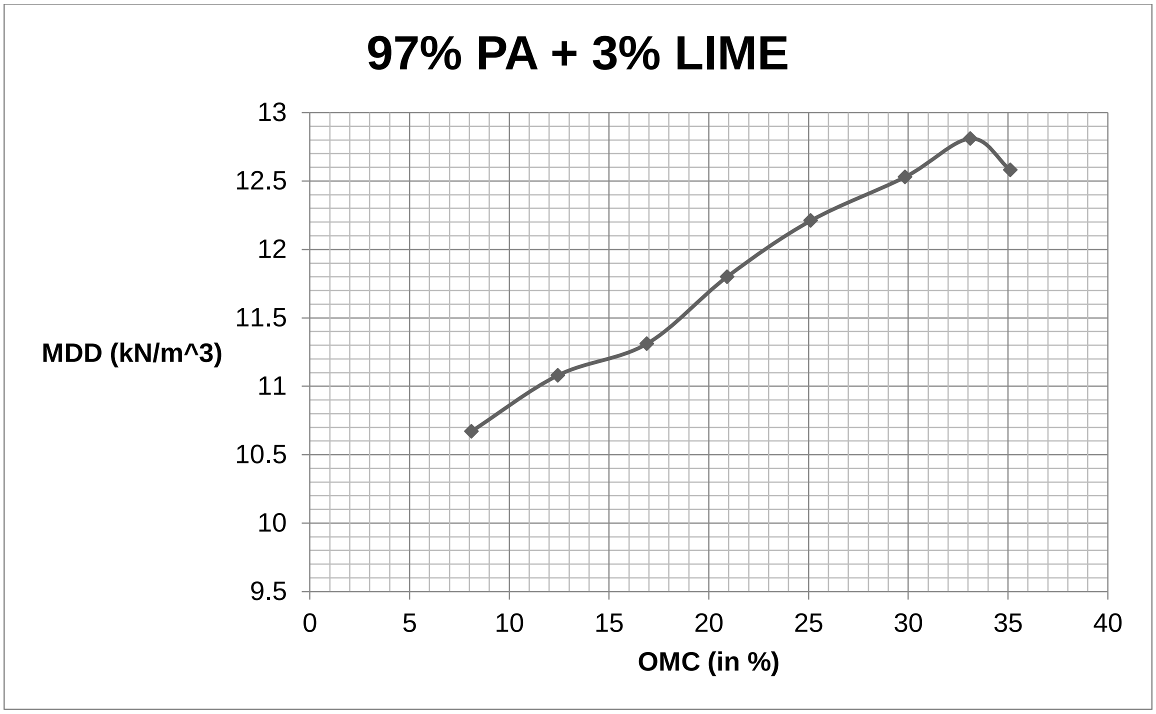

Figure5.18: Compaction curve for 97% PA + 3 % lime

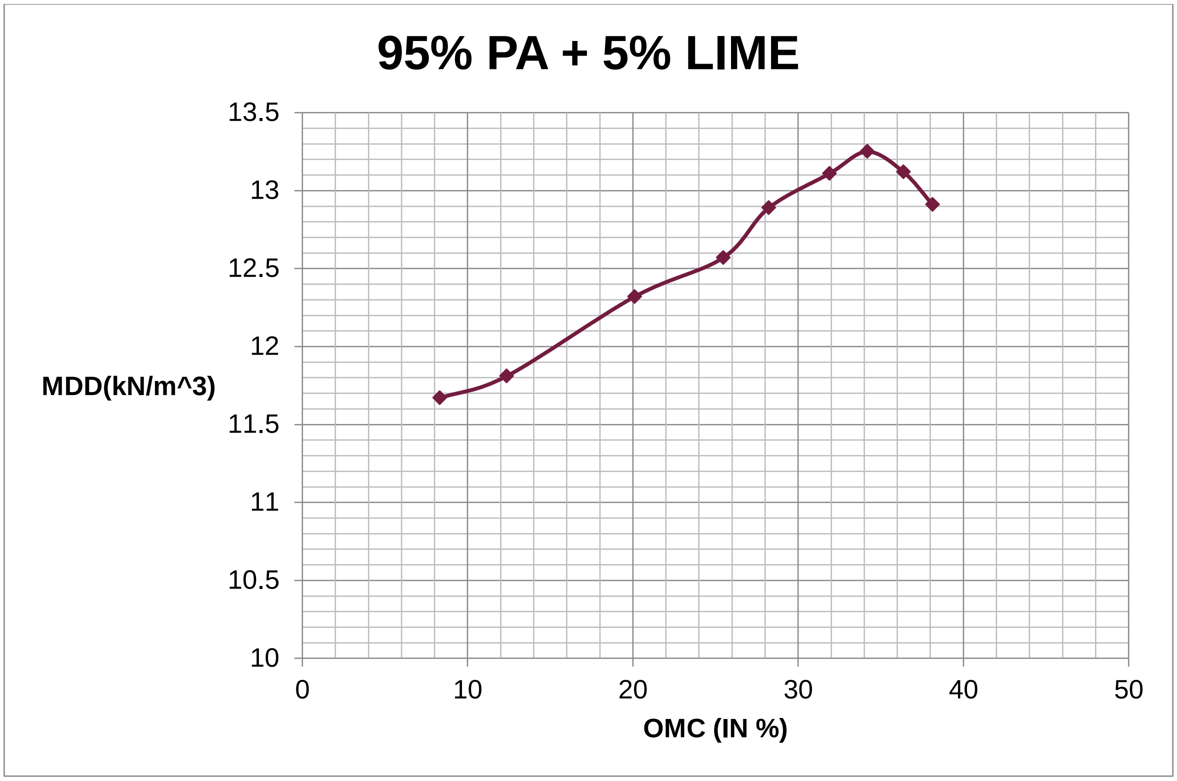

Figure:5.19 Compaction curve for 97% PA + 3 % lime

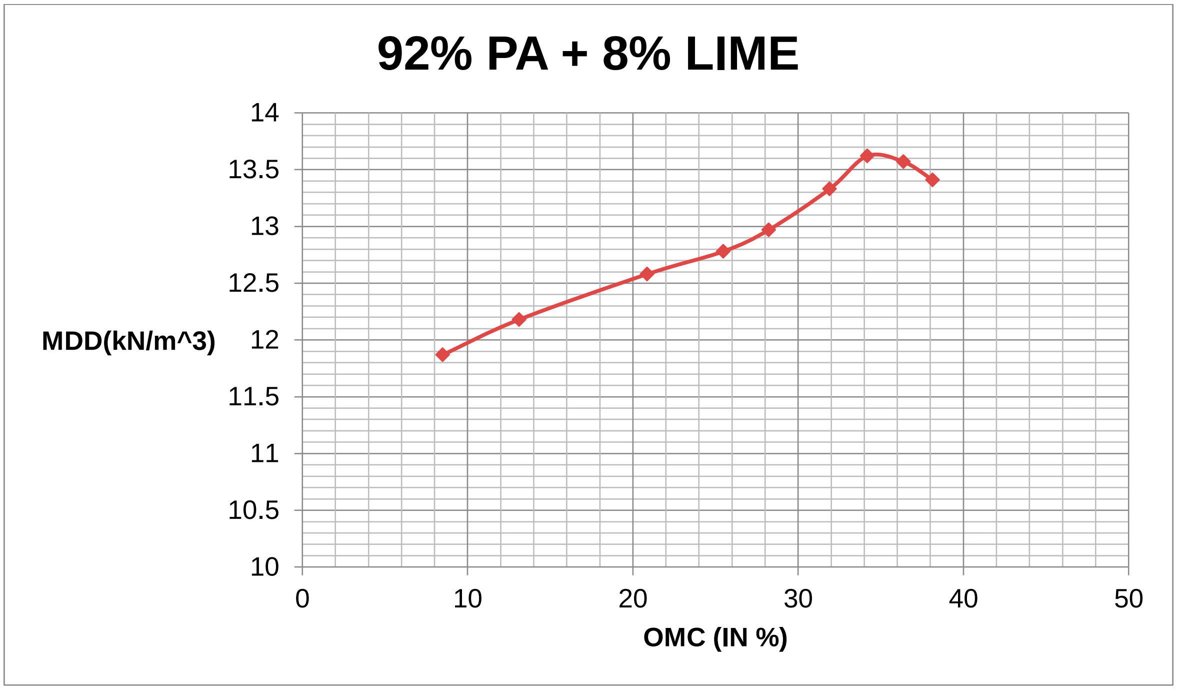

Figure5.20: Compaction curve for 92% PA + 8 % lime

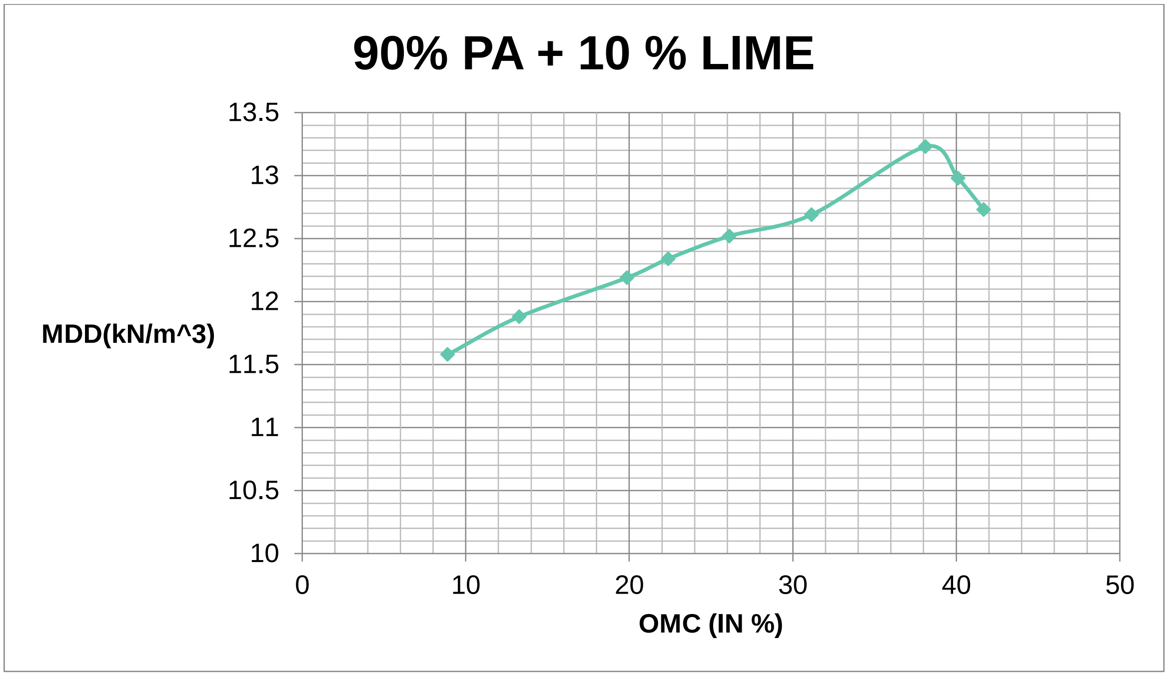

Figure5.21: Compaction curve for 92% PA + 8 % lime

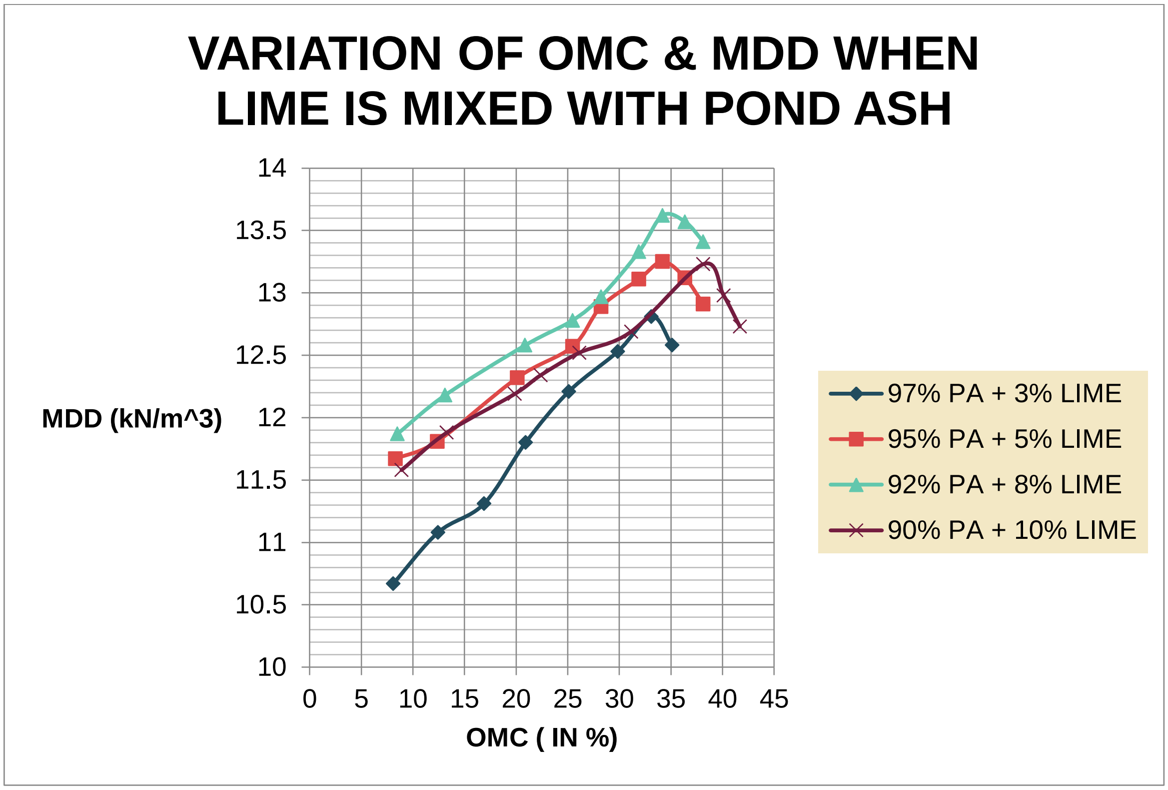

Figure5.22: Compaction curve showing variation of MDD when lime is mixed with Pond ash

SAMPLE MIX	OMC (in %)	MDD (kN/m^3)
97 % PA + 3 % LIME	33	12.7
95 % PA + 5 % LIME	34	12.9
92 % PA + 8 % LIME	36	13.3
90 % PA + 10 % LIME	38	13.05

Table 5.4 Compaction behavior when lime is mixed with PA.

From above it is clear that when lime is mixed with PA at various content, MDD increases upto 8% lime content, beyond that there is no significant change in MDD.

For our Project, keeping lime content fixed at 8%, at various contents of PA like 5%, 10%, 15% and 20% taken for study of shear behavior of that mixes and for that MDD v/s OMC study is carried out.

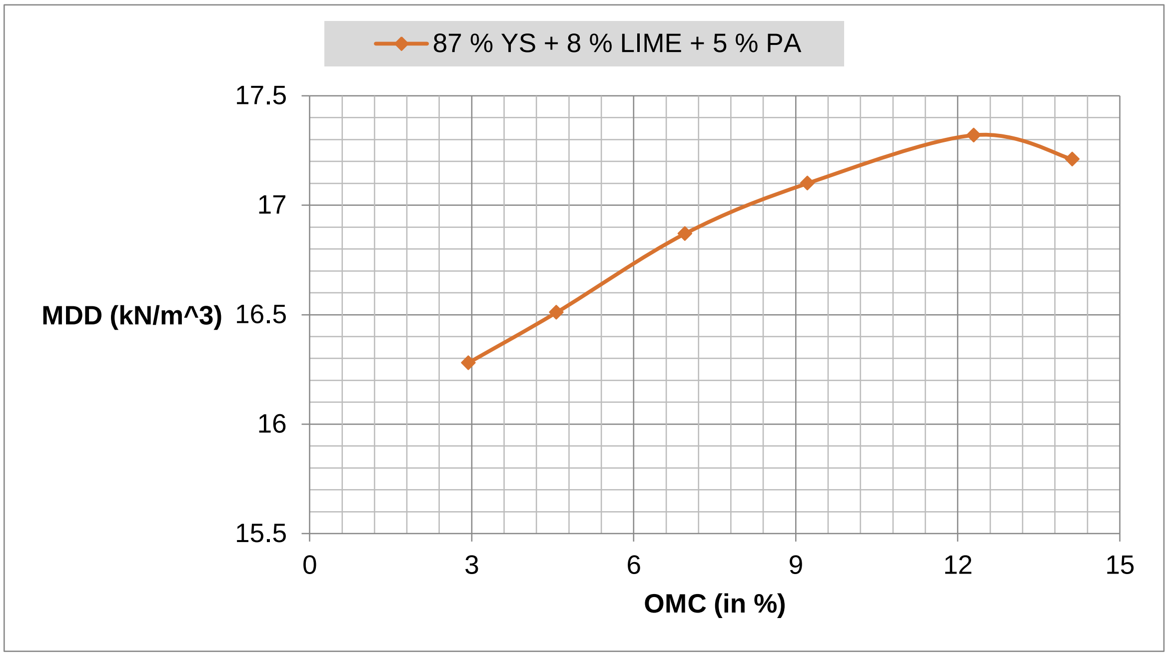

Figure5.23: Compaction curve for 5% mix (87% YS+ 5% PA + 8 % lime)

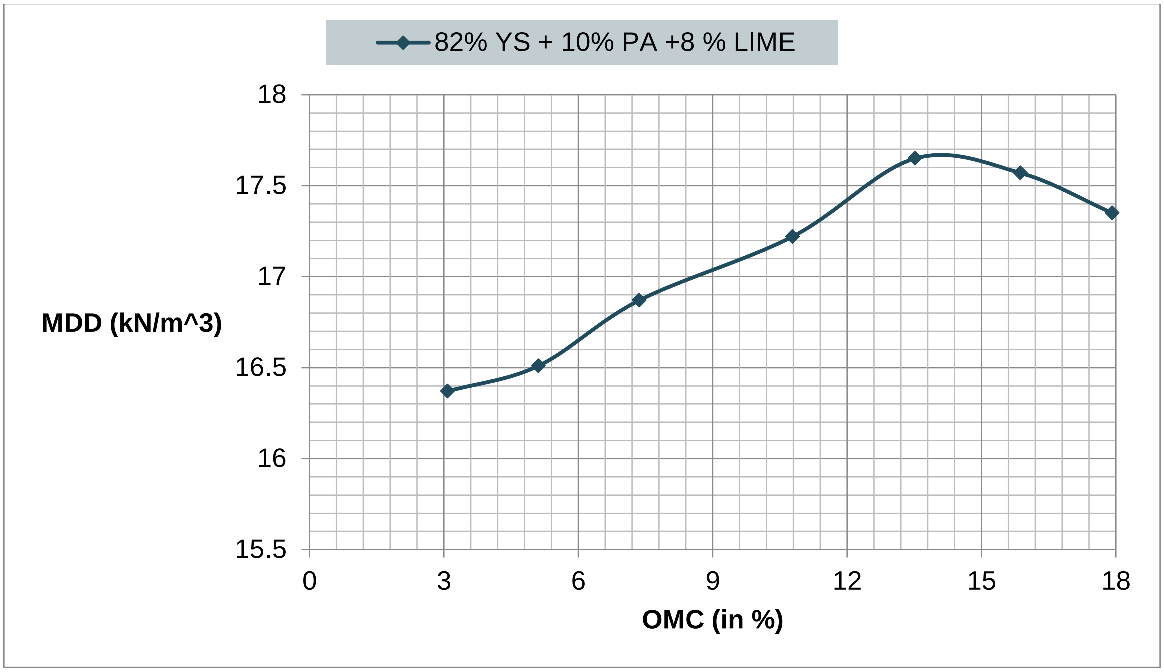

Figure5.24: Compaction curve for 10% mix (82% YS+ 10% PA + 8 % lime)

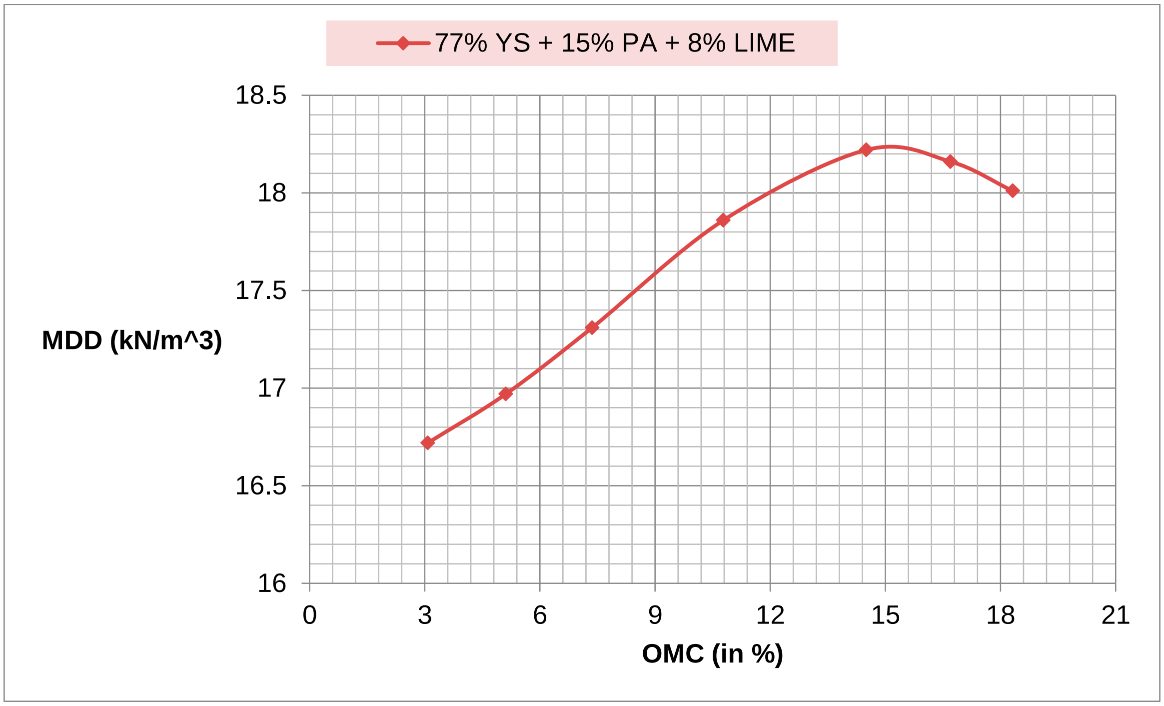

Figure5.25: Compaction curve for 15% mix (77% YS+ 15% PA + 8 % lime)

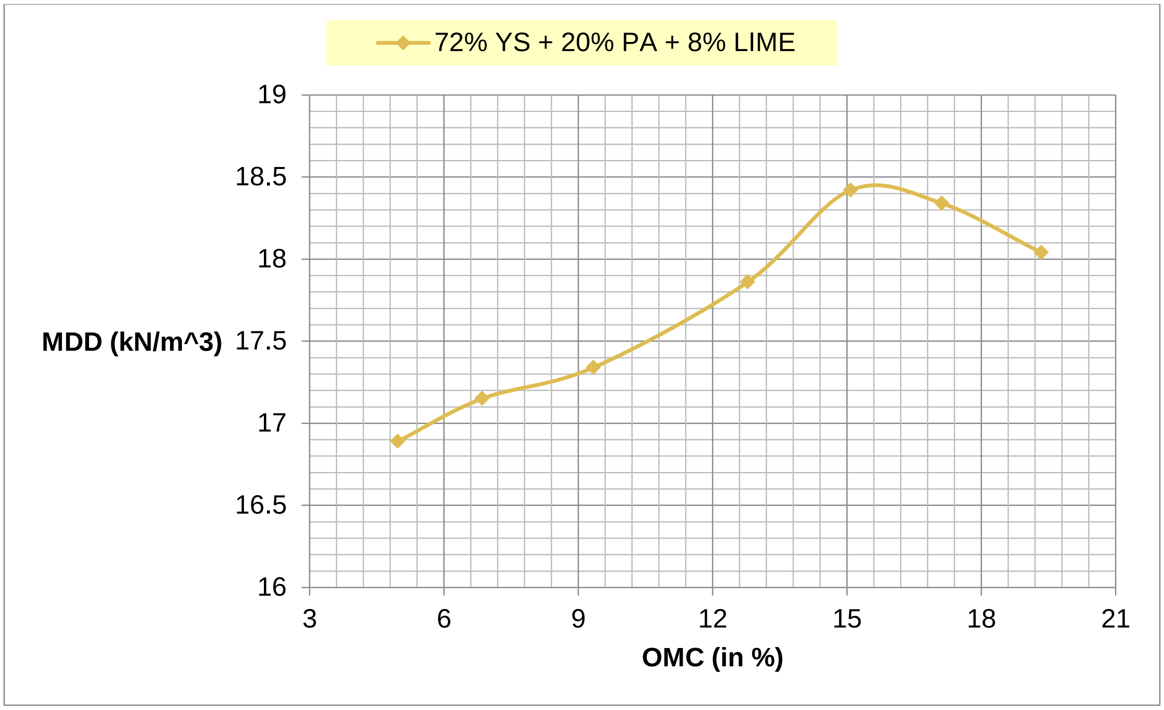

Figure5.26: Compaction curve for 20% mix (72% YS+ 20% PA + 8 % lime)

From above graphs we can conclude MDD and OMC of mix, that is-

MIX	**MDD** **(kN/m^3)**	**OMC** **(in %)**
87% YS+ 5% PA +8%LIME	17.32	12.38
82% YS+ 10% PA +8%LIME	17.65	13.6
77% YS+ 15% PA +8%LIME	18.24	14.5
77% YS+ 20% PA +8%LIME	18.42	15.1

Table 5.5- Compaction behavior of mix when Pond ash content increased

Results shows that MDD increase up to 15% mixing of Pond ash and OMC increases continuously up to 20 %. Mixing of finer particles into coarser particle leads to increase in OMC. Increasing MDD showing here, improvement in the stability of Yamuna sand, this also gives the idea that we can replace our waste material Pond ash into Yamuna sand while keeping lime content constant. Obtained OMC and MDD values are used for preparation of sample.

5.5) DIRECT SHEAR TEST-

Direct test is performed on virgin Yamuna sand and Pond ash. Their results are following-

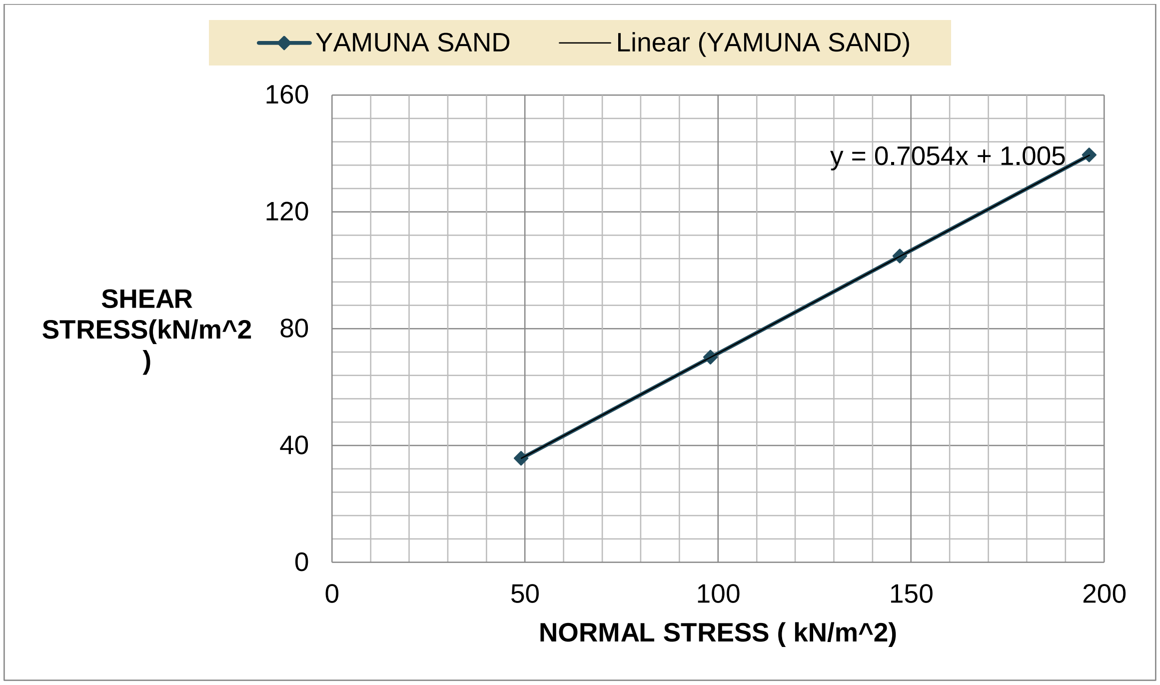

Figure5..27: Direct Shear Test for Yamuna Sand

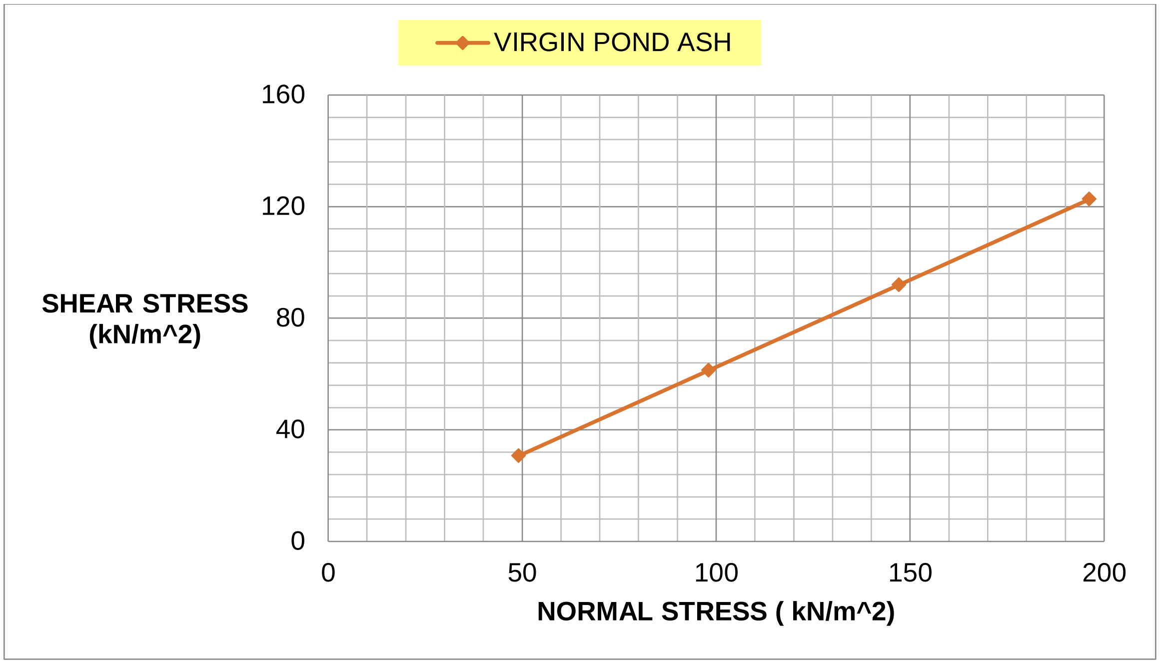

Figure5.28: Direct Shear Test for Pond ash

Direct shear box test is performed here for all samples and specimen of mix. For determination of lime content and its amount in mix, shear behavior of mix when lime is mixed with pond ash and Yamuna sand has studied, their results are following-

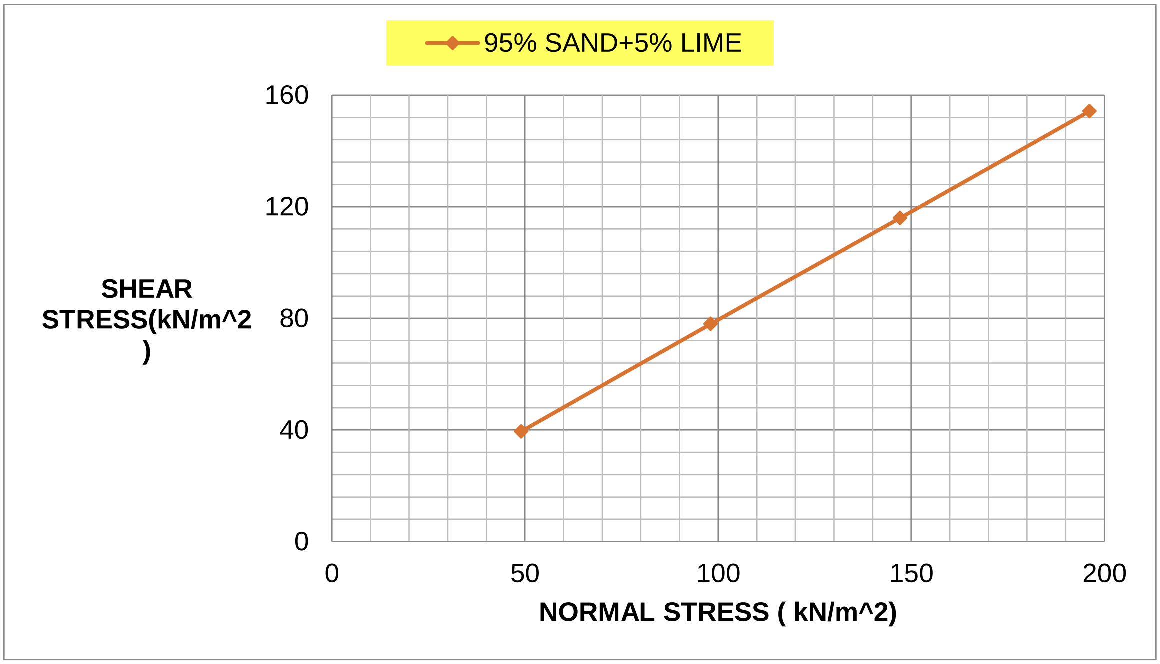

Figure5.29: Direct Shear Test for (97% YS + 3% LIME)

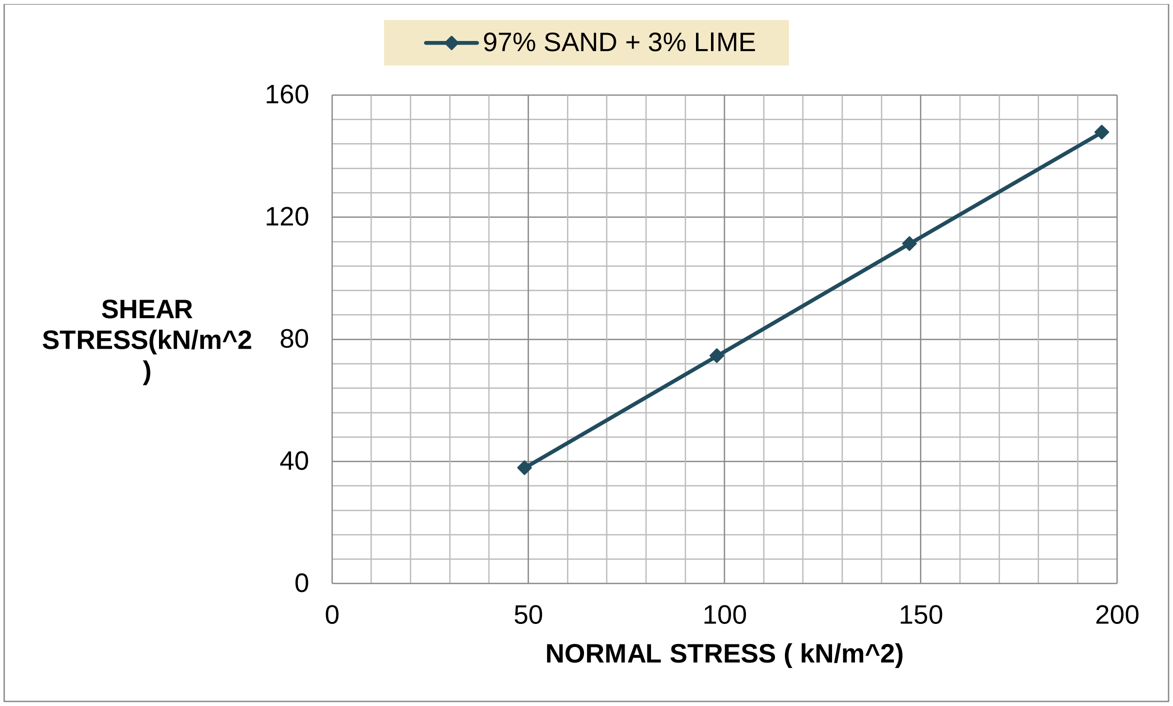

Figure5.30: Direct Shear Test for (95% YS + 5% LIME)

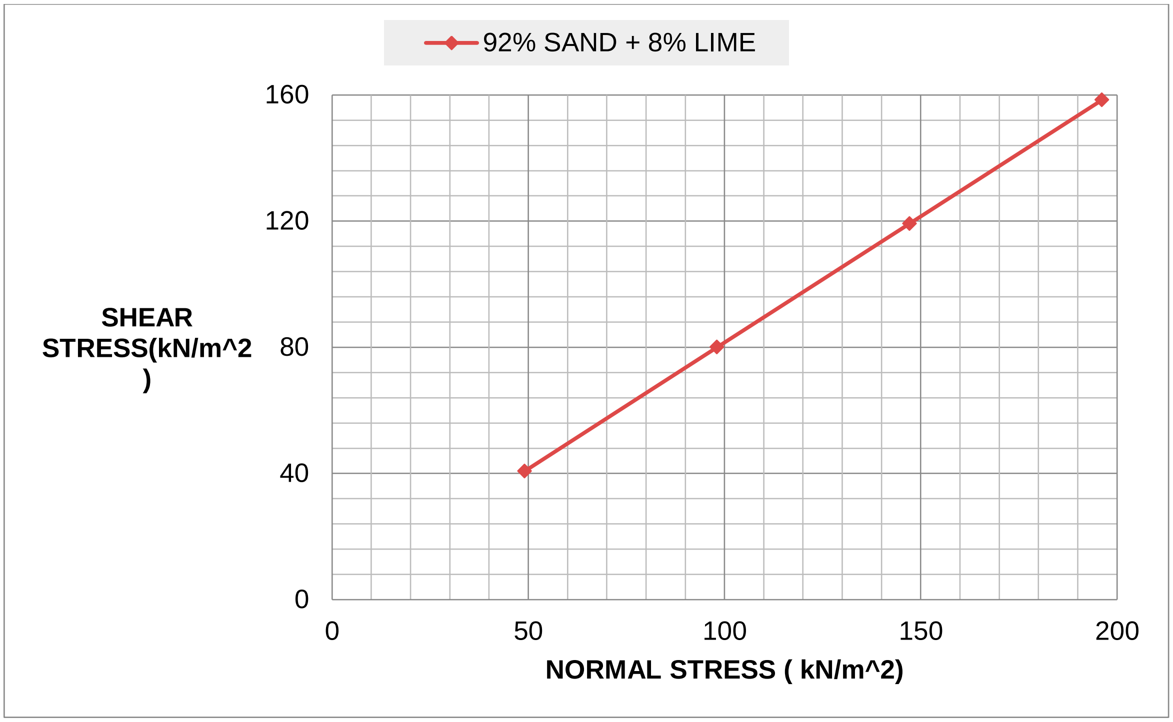

Figure5.31: Direct Shear Test for (92% YS + 8% LIME)

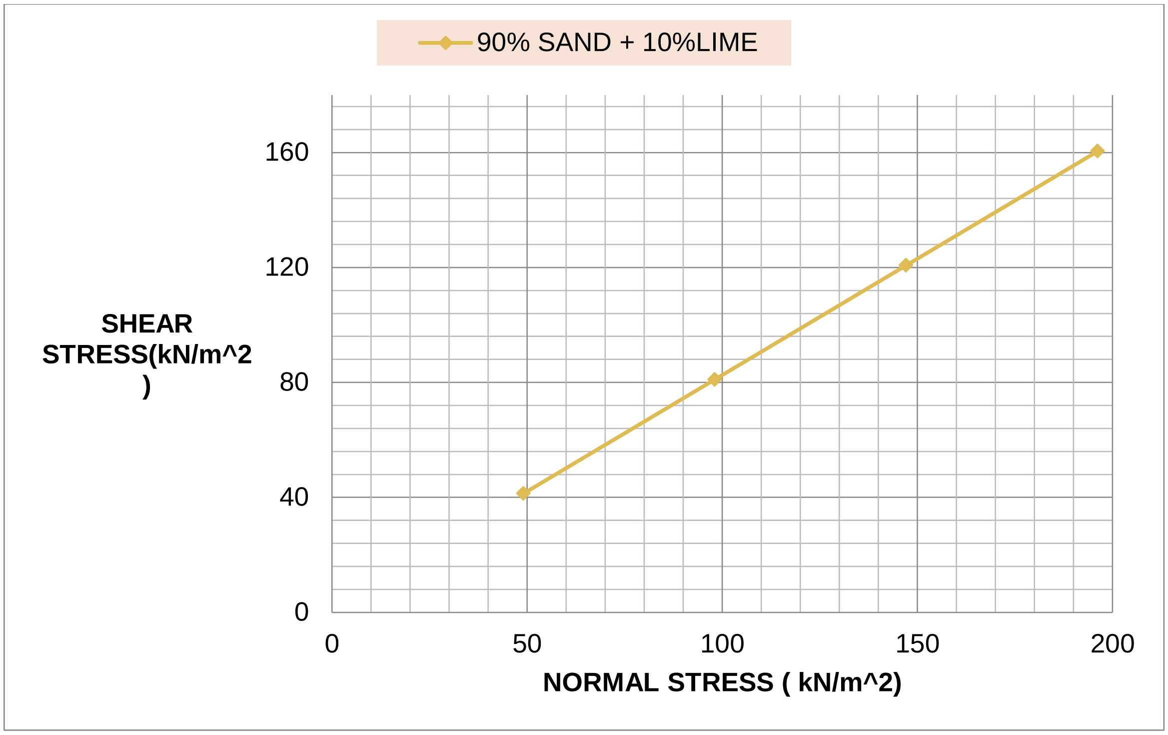

Figure5.32: Direct Shear Test for (90% YS + 10% LIME)

Variation in Shear parameters are shown as following-

Sample	**C(kN/m^2)**	**Ø**
97%YS+3% LIME	1.22	36.76
95%YS+5% LIME	1.35	37.93
92%YS+8% LIME	1.49	38.62
90%YS+10% LIME	1.59	39

Table 5.6 Direct shear results when lime is mixed with Yamuna Sand

Similarly Direct shear test is performed over Pond Ash and lime. Line content is taken as 3%, 5%, 8% and 10 %.Results are following

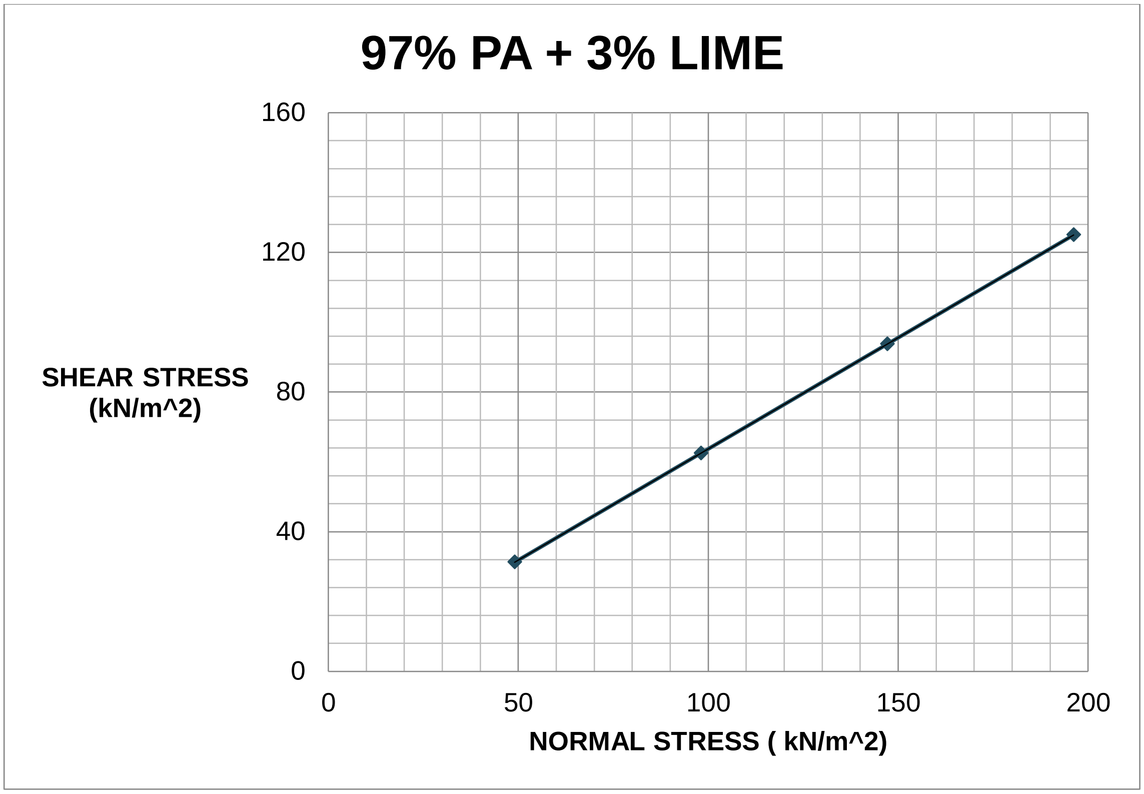

Figure5.33: Direct Shear Test for (97% PA + 3% LIME)

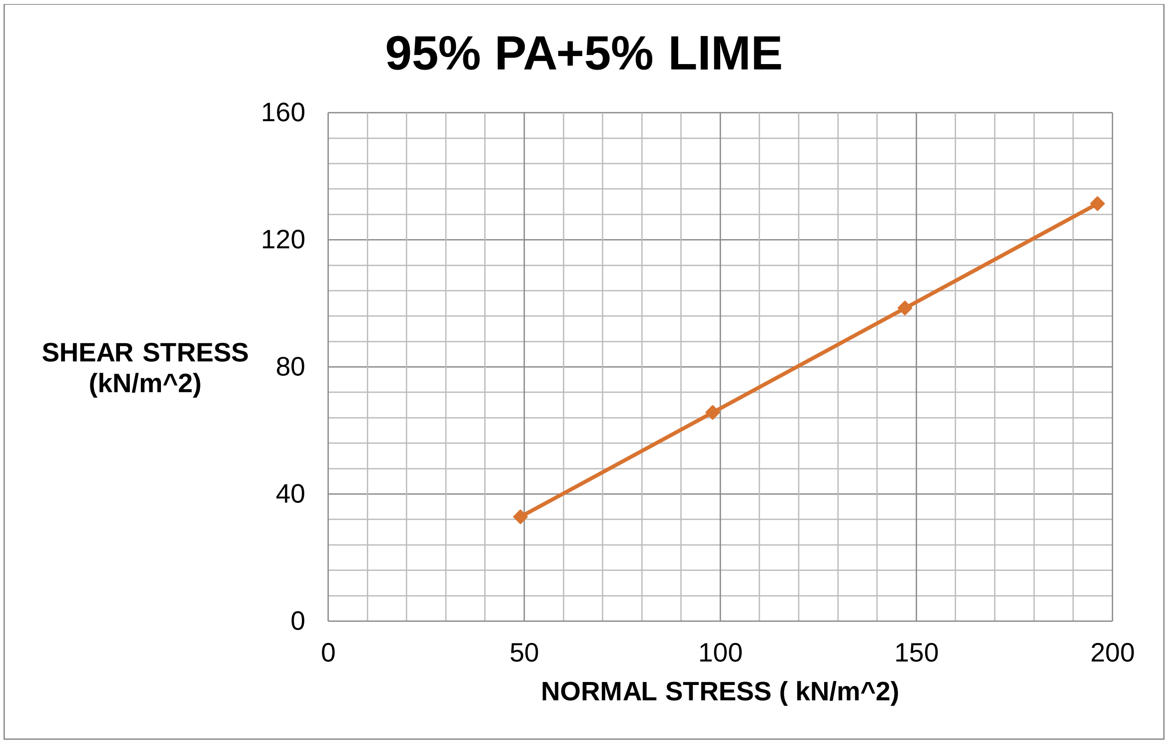

Figure5.34: Direct Shear Test for (95% PA + 5% LIME)

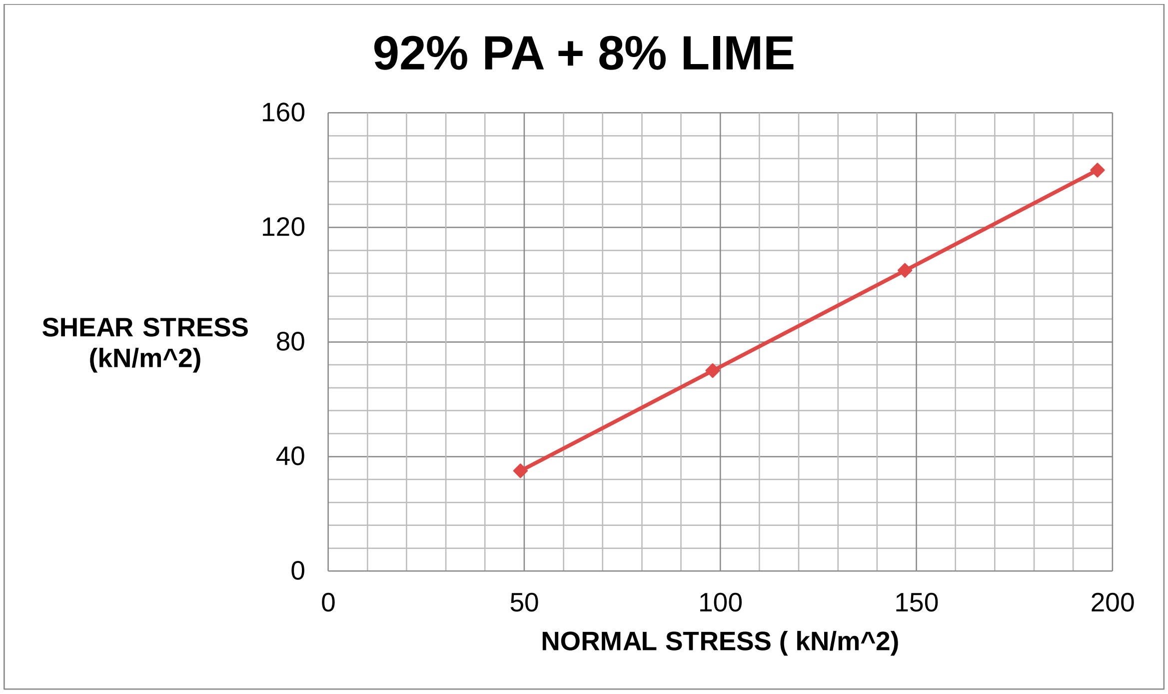

Figure5.35: Direct Shear Test for (92% PA + 8% LIME)

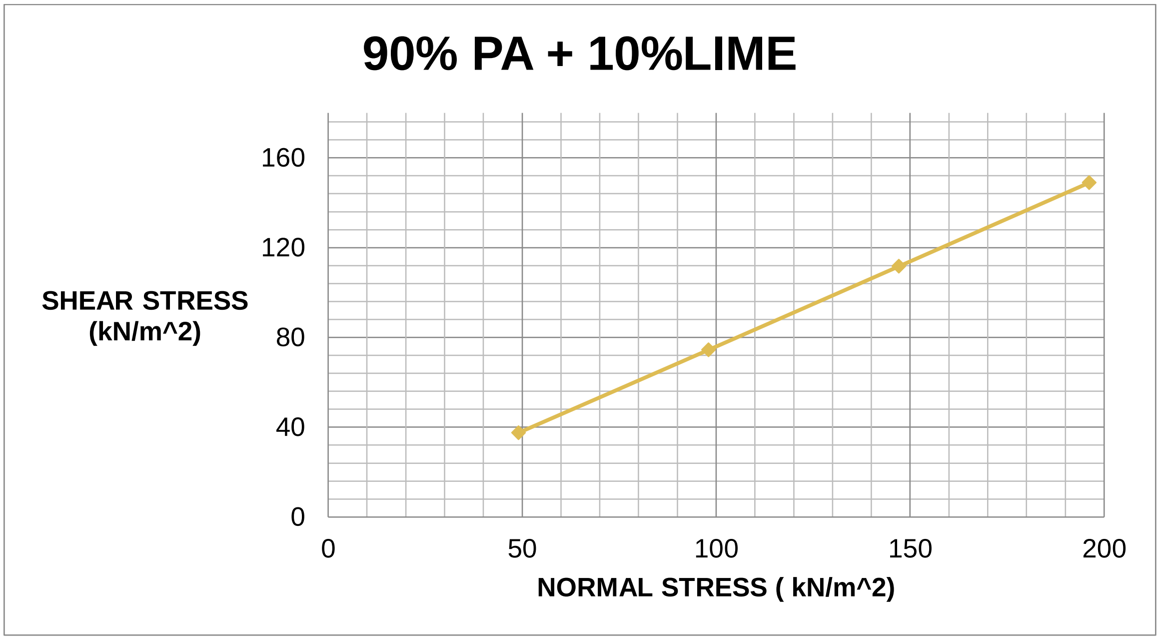

Figure5.36: Direct Shear Test for (90% PA + 10% LIME)

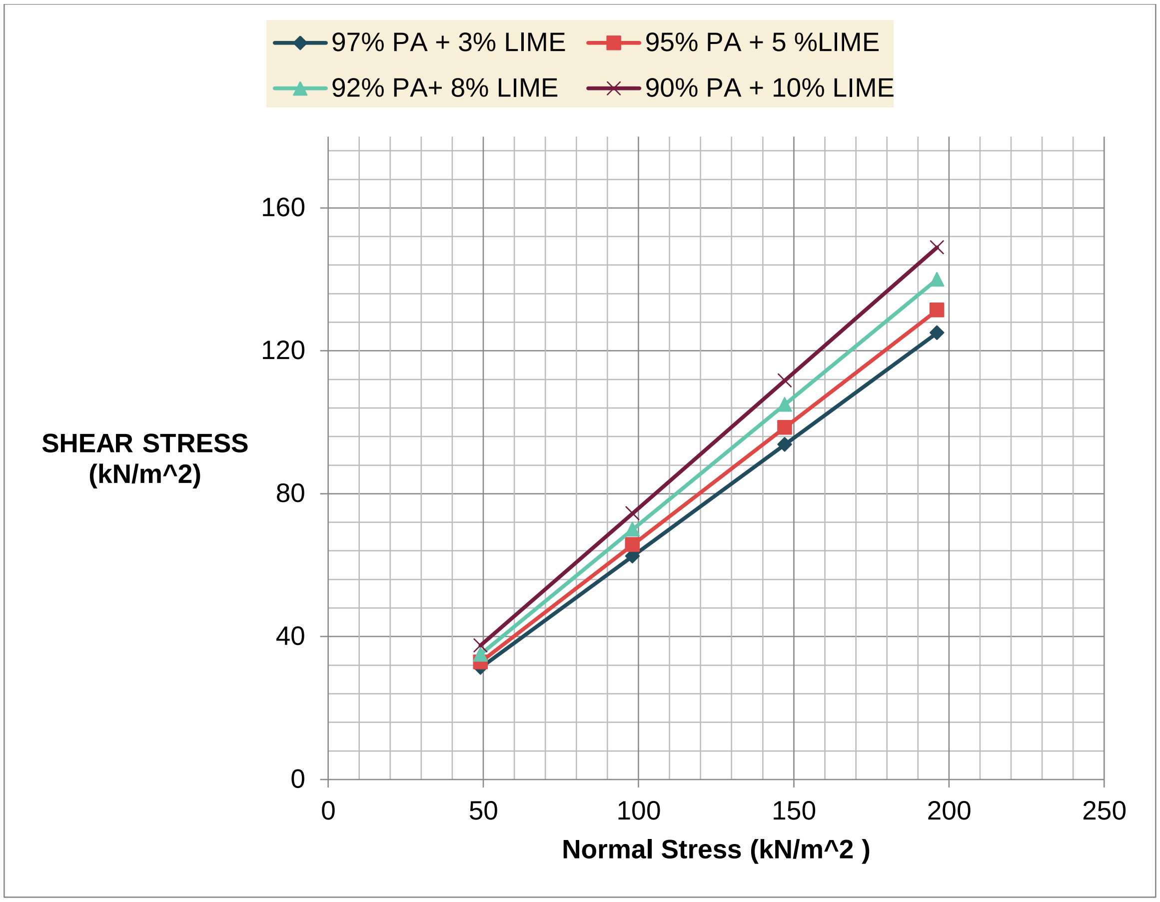

Figure5.37:Direct shear Test reults when lime content is increased with Pond ash

Similarly direct shear test has performed when lime is mixed with pond ash. Results are shown as following-

SAMPLE MIX	C	Ø
97 % PA + 3 % LIME	0.	32.5
95 % PA + 5 % LIME	0.	33.8
92 % PA + 8 % LIME	0	35.5
90 % PA + 10 % LIME	0	38.3

Table 5.7 Direct shear results when lime is mixed with Pond ash.

As results are showing when lime is mixed with Pond ash, its shear parameters C doesn’t influence much but Ø parameter increases as lime content increases, but after 8% lime addition Ø parameter does not increase much. As lime is also a costly material or not a waste material so we can fix its content in the mix. As MDD & OMC variation and Direct shear results are showing, beyond 8 % lime is not showing significant changes in MDD and shear behavior above 8 % shows not much variation in shear parameters. So from these results keeping lime content fixed as 8% in the mix.

Direct shear test are performed on the mix keeping lime fixed as 8 % and pond ash variation as 5%, 10%, 15% and 20%. The results are following.

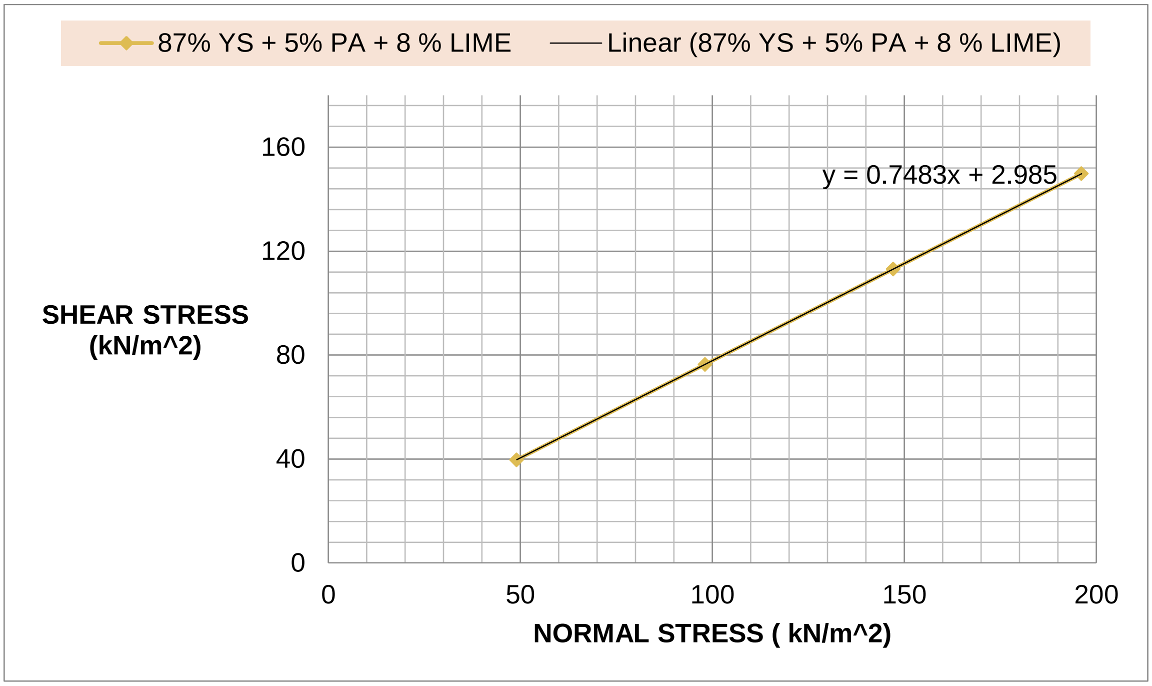

Figure5.38: Direct Shear Test for 5% Pond ash mix (87% YS + 5% PA+ 8% LIME)

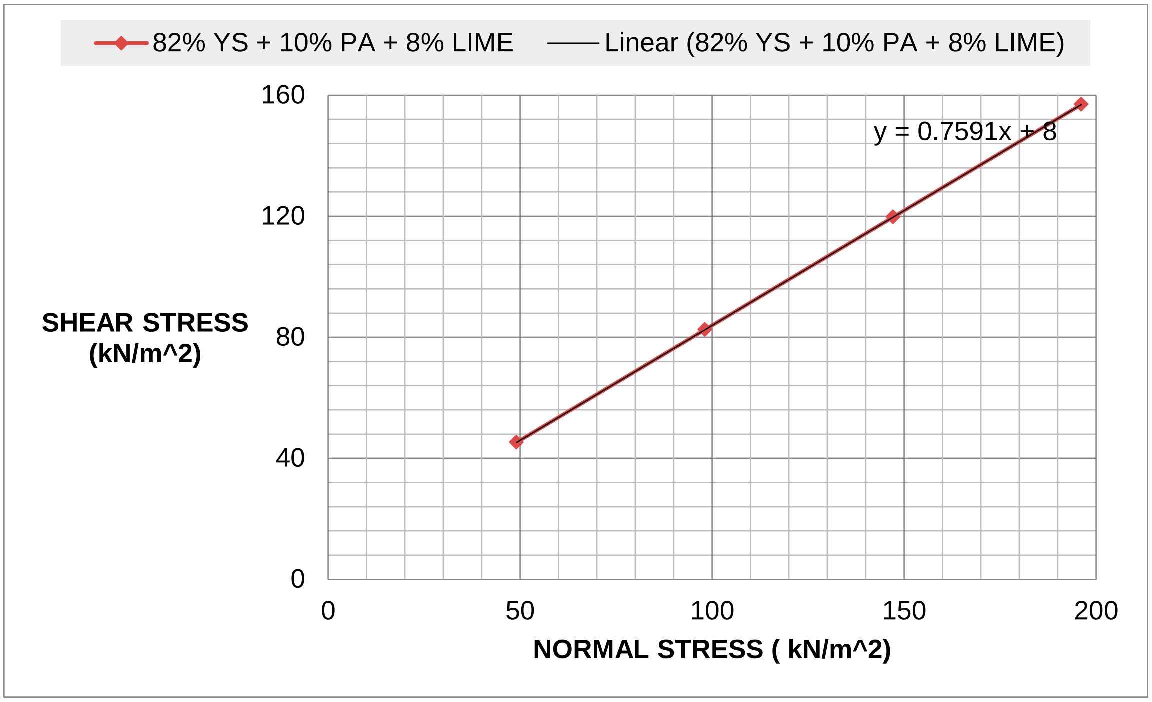

Figure5.39: Direct Shear Test for 10% Pond ash mix (83% YS + 10% PA+ 8% LIME)

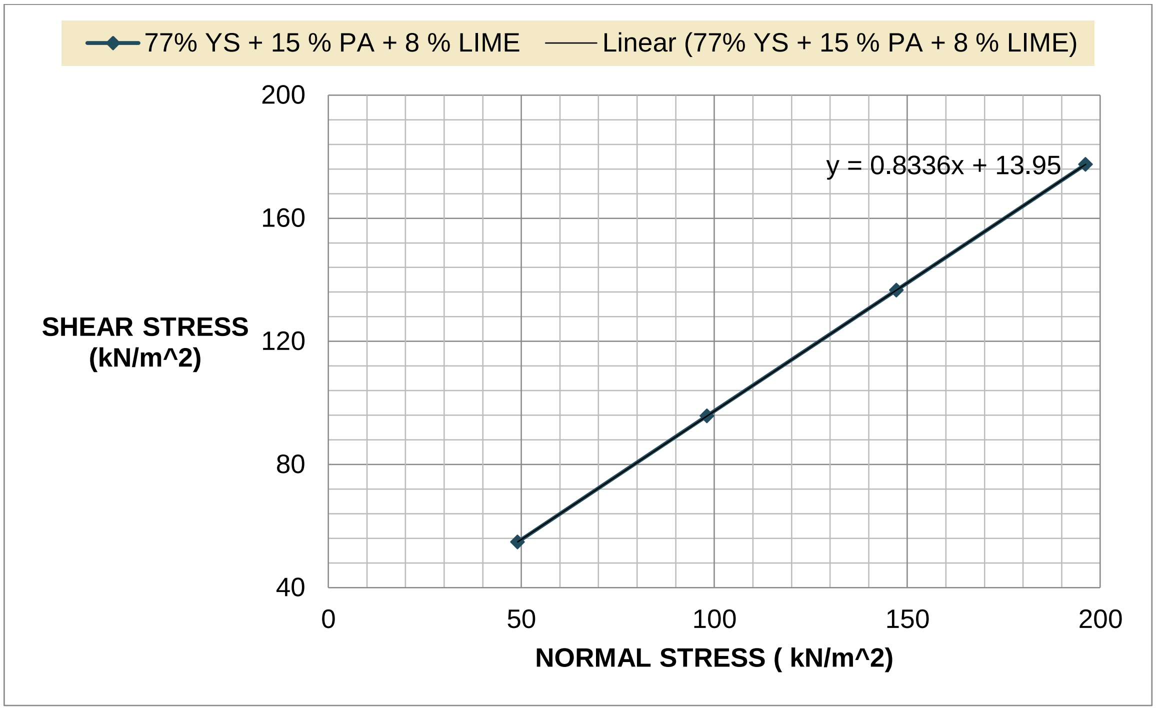

Figure5.40: Direct Shear Test for 15% Pond ash mix (77% YS +1 5% PA+ 8% LIME)

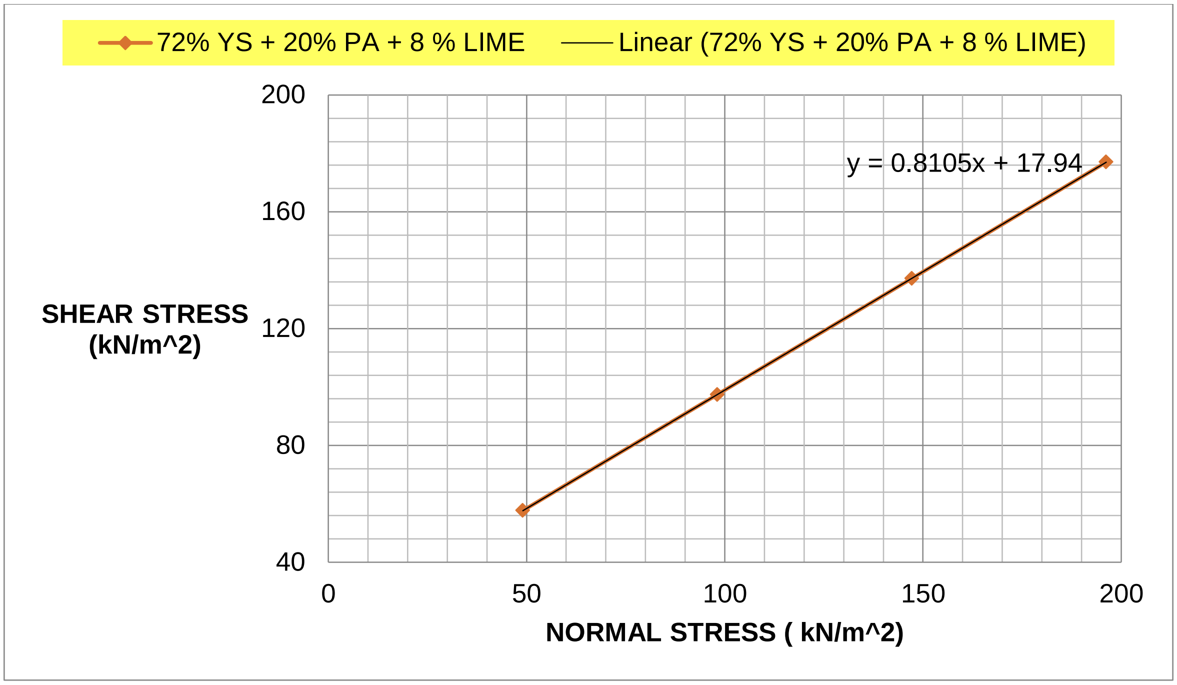

Figure5.41: Direct Shear Test for 20% Pond ash mix (72% YS + 20% PA+ 8% LIME)

SAMPLE MIX	**C (kN/m^2)**	**Ø**
87 % YS + 3 % PA+8% LIME	3	36.8
87 % YS + 3 % PA+8% LIME	8	37.2
87 % YS + 3 % PA+8% LIME	14	39.8
87 % YS + 3 % PA+8% LIME	18	39

Table 5.7 Direct shear results when mix (Pond ash) content is varied .keeping lime content fixed

6) TRI-AXIAL TEST-

Tri-axial test has performed on virgin Yamuna sand and sample mix at UU condition, Size of mould was used as 38mm diameter and 76 mm height. The applied cell pressures were 100, 200 and 300 kPa respectively. Results show here deviator stress v/s axial strain variation, P-Q plot, shear stress v/s normal stress variation using Mohr’s circle method.

Triaxial test results for Yamuna sand is given below-

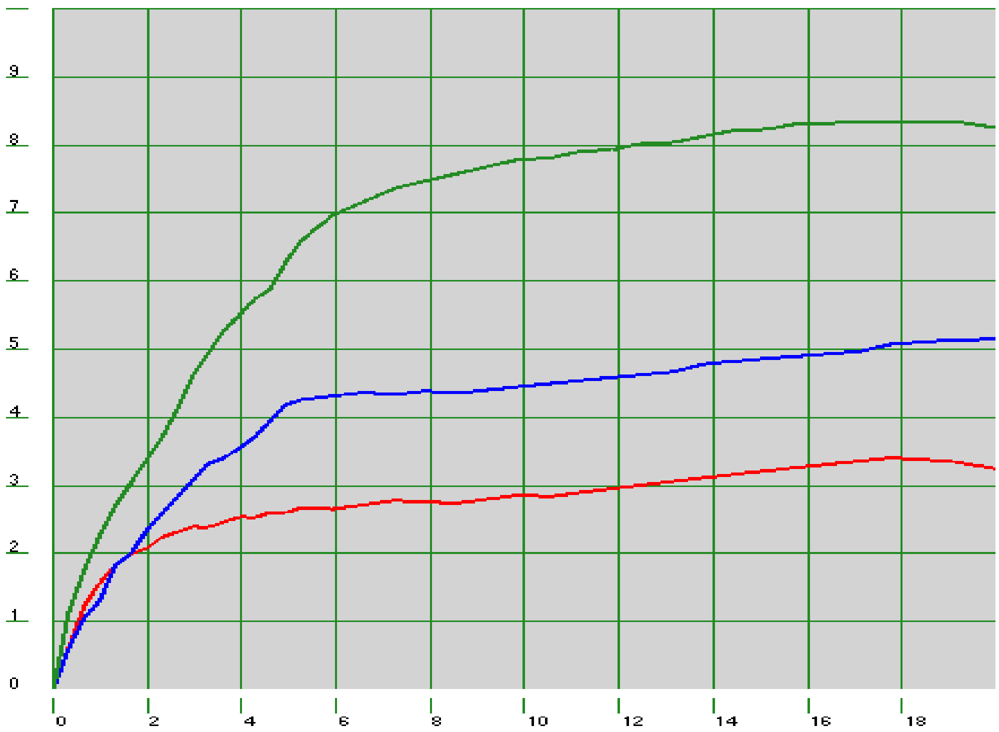

Figure5.41: Deviatric Stress(kg/sq.cm) vs Axial Strain(%)

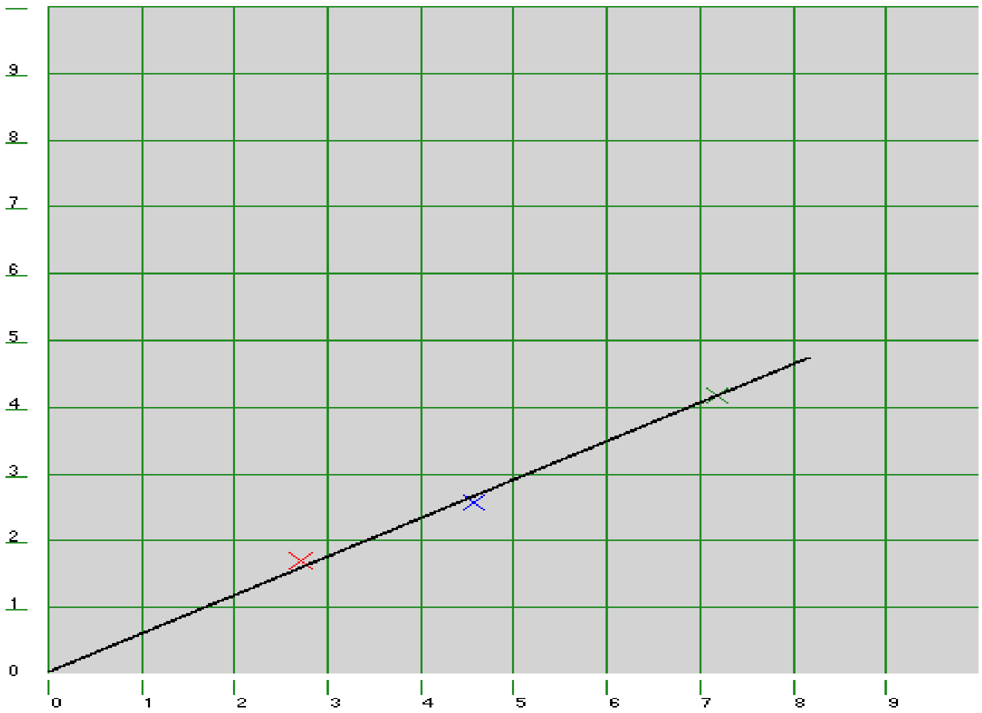

Figure5.42: Mean stress vs Shear stress [a=0.04kg/sq.cm ,alpha=30.0deg]

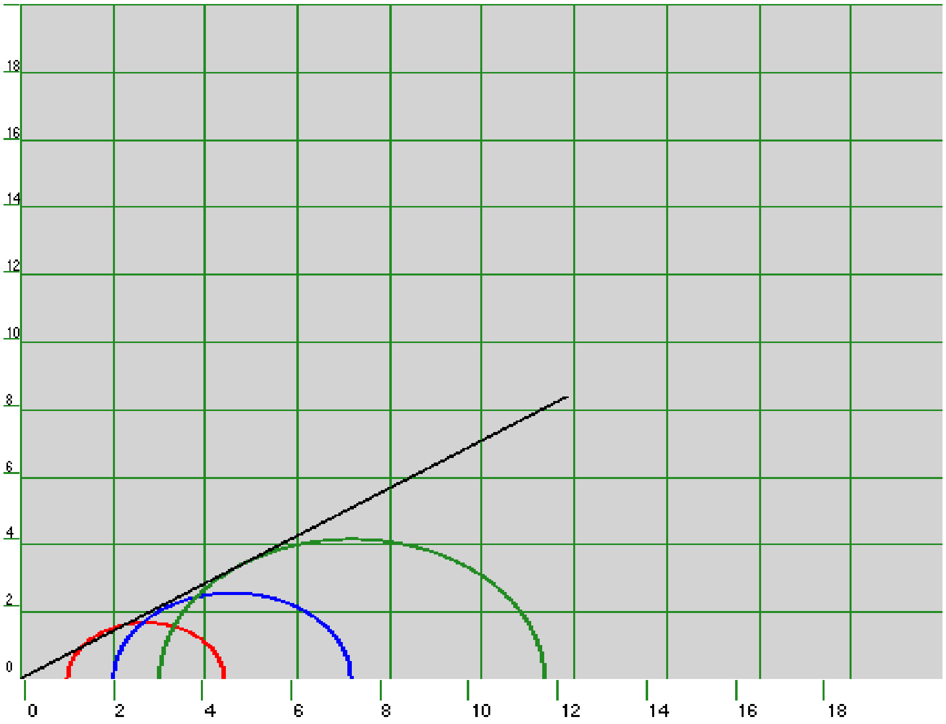

Figure5.43: Mohr-Coulomb Plot [c=0.01kg/cm^2 Phi=35.2deg]
Shear Stress (kg/cm^2) vs Normal Stress (kg/cm^2)

Tri-axial tests are performed for various sample mix, in which lime content has fixed at 8% and Pond ash varies with 5%, 10%, 15% and 20% with remaining Yamuna sand to study shear strength parameters variation. Their results are-

1 .87%YS+ 5/% POND ASH + 8% LIME-

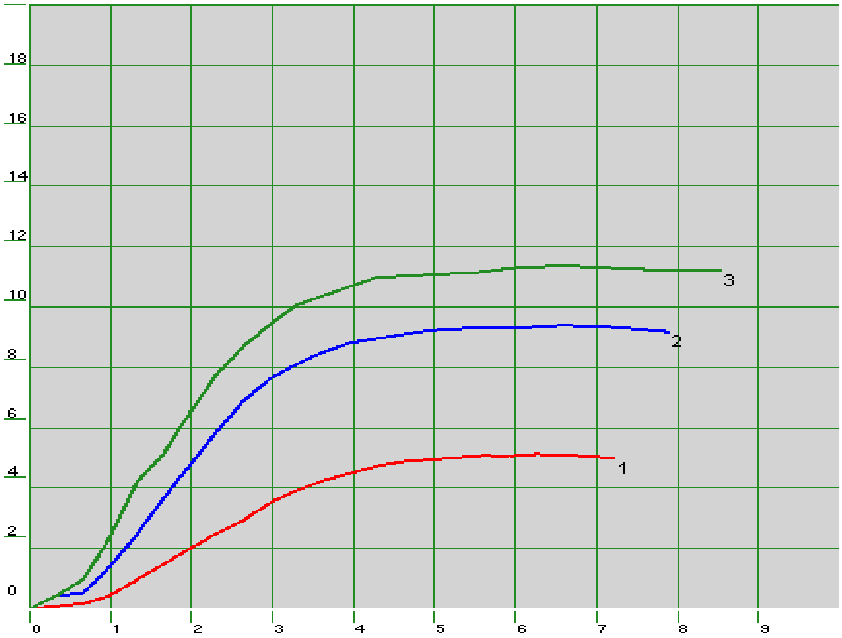

Figure5.44: Deviatric Stress(kg/sq.cm) vs Axial Strain(%)

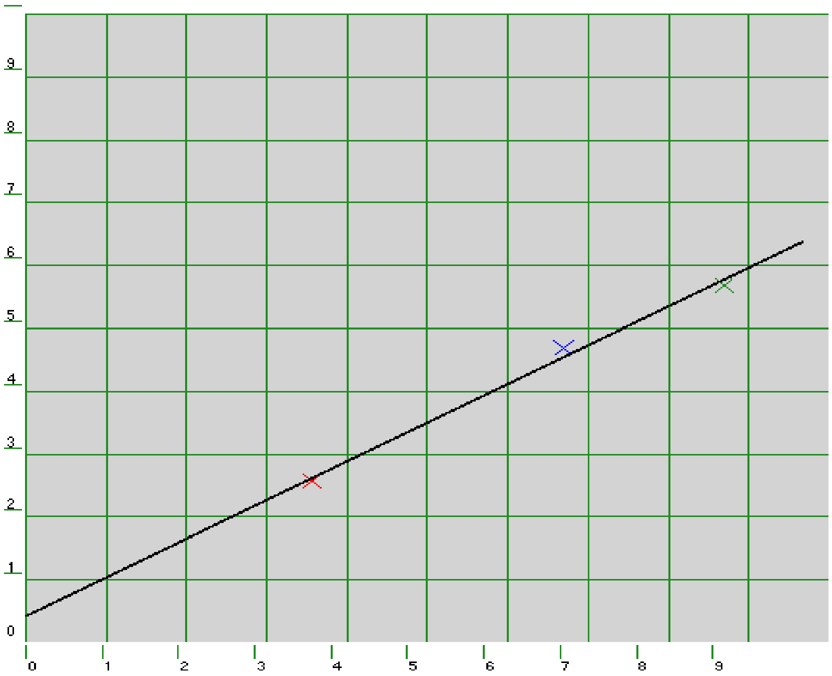

Figure5.45: Mean stress vs Shear stress [a=0.43kg/sq.cm ,alpha=31.6deg]

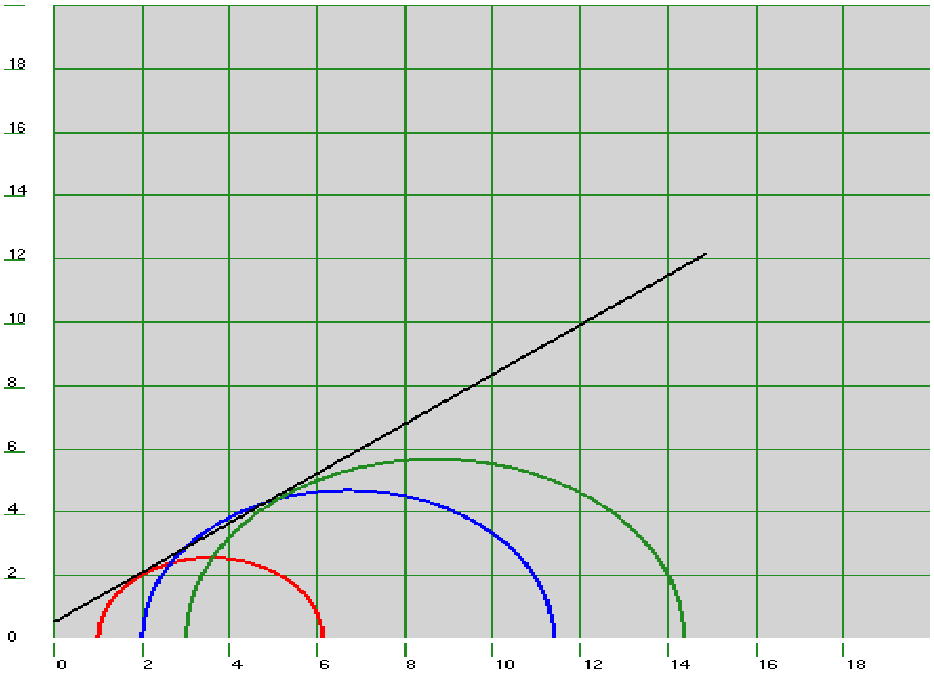

Figure46: Mohr-Coulomb Plot [c=0.09 Phi=37.1deg]

Shear Stress (kg/cm^2) vs Normal Stress (kg/cm^2)

2.**82% YS+ 10 % PA + 8% LIME-**

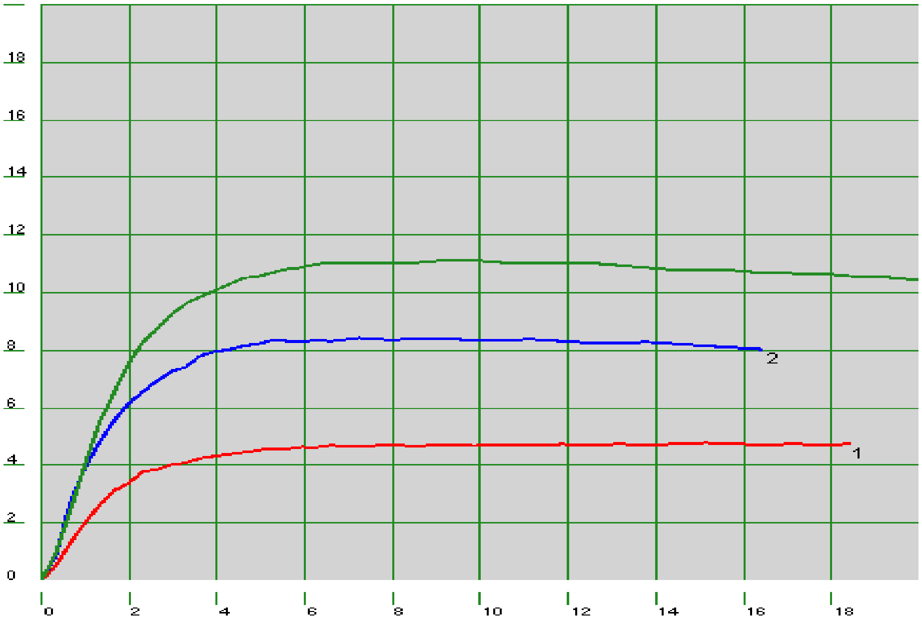

Figure47: Deviatric Stress(kg/sq.cm) vs Axial Strain(%)

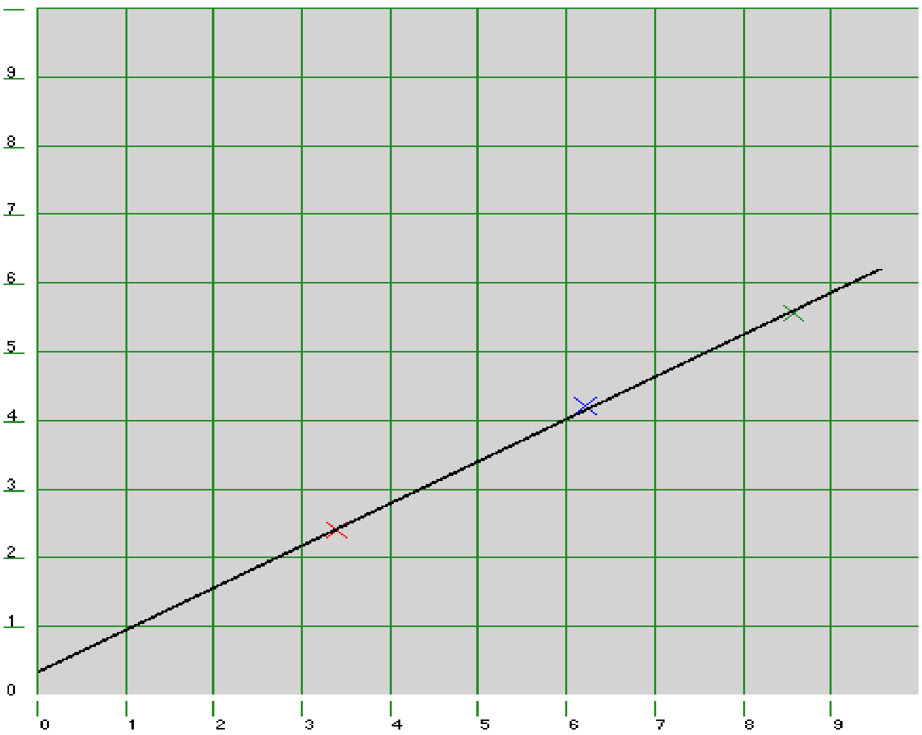

Figure5.48: Mean stress vs Shear stress [a=0.34kg/sq.cm ,alpha=31.6deg]

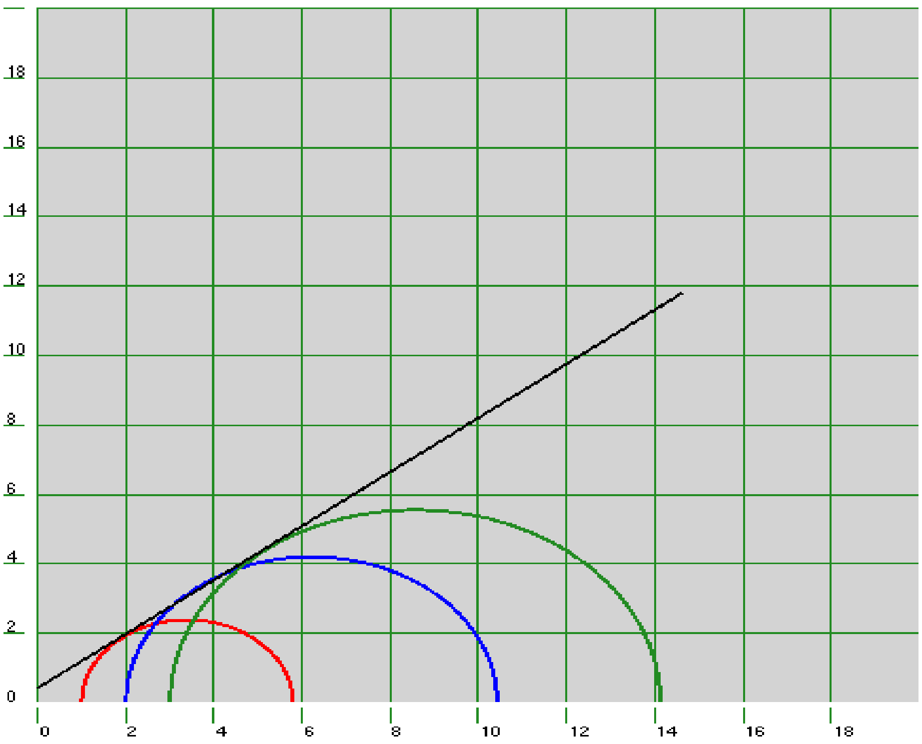

Figure5.49: Mohr-Coulomb Plot [c=0.14kg/sq.cm Phi=37.9deg]
Shear Stress(kg/Sq.cm) vs Normal Stress(kg/Sq.cm)

3) 77% YS + 15% PA + 8 % LIME-

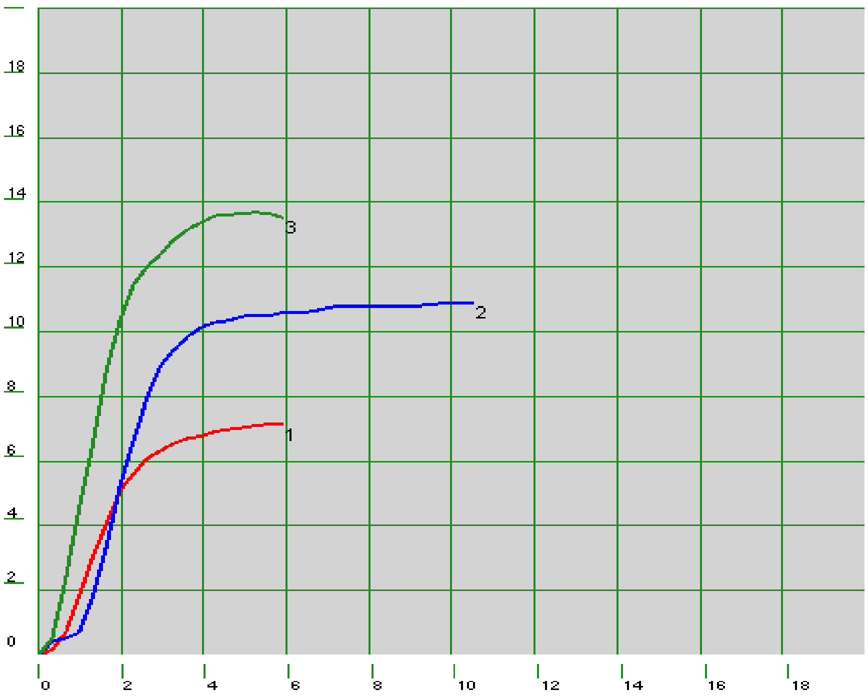

Figure5.50: Deviatric Stress(kg/sq.cm) vs Axial Strain(%)

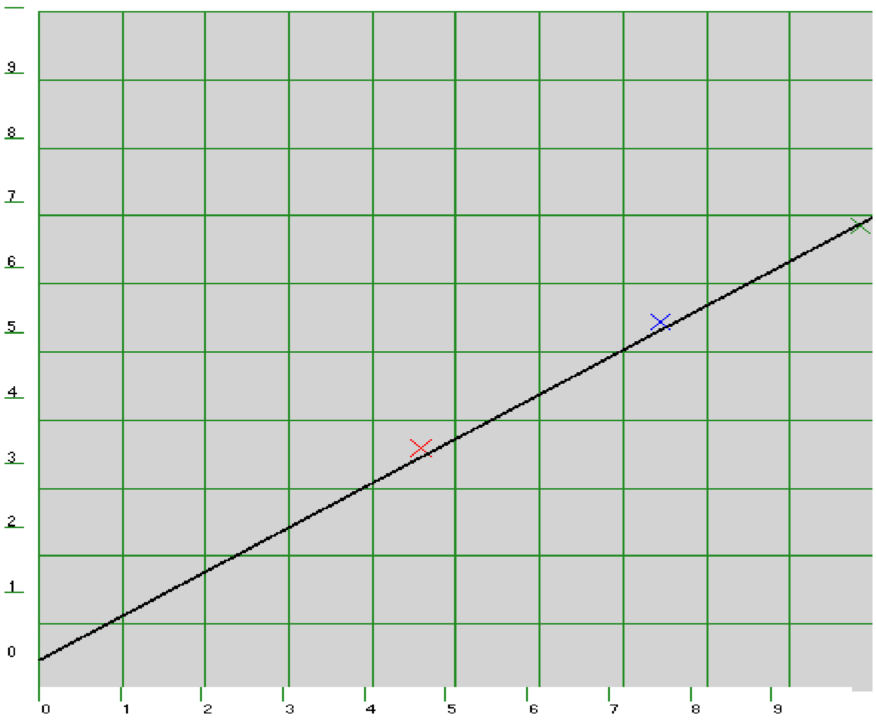

Figure5.51 :Mean stress vs Shear stress [a=0.47kg/sq.cm ,alpha=33.1deg]

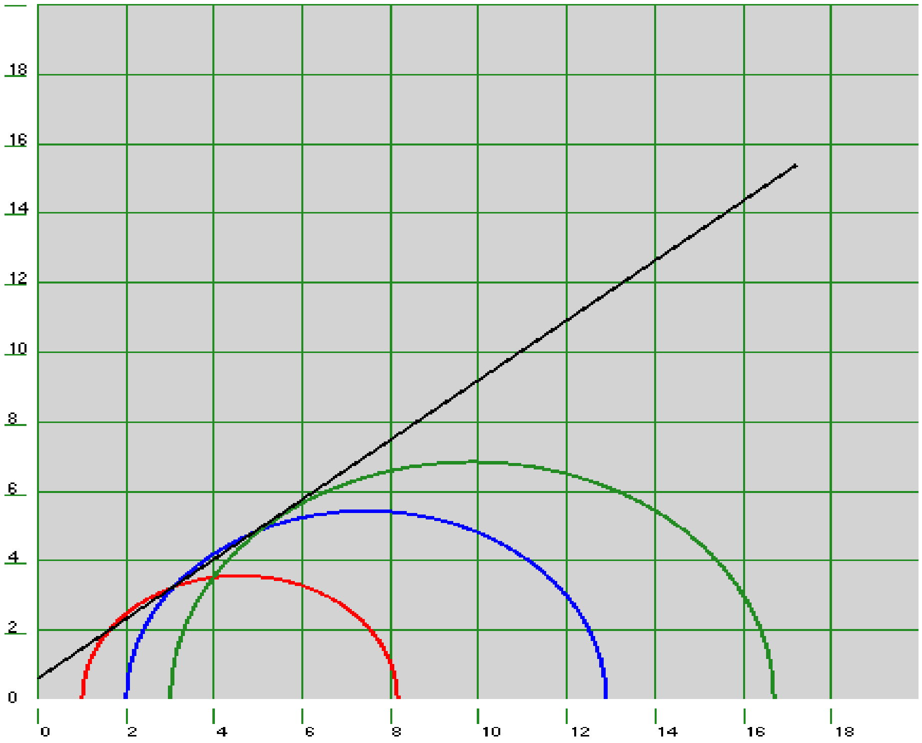

Figure5.52: Mohr-Coulomb Plot [c=0.17kg/sq.cm Phi=40.7deg]
Shear Stress (kg/cm^2) vs Norma lStress (kg/cm^2)

4) 72% YS+ 20% PA +8 % LIME

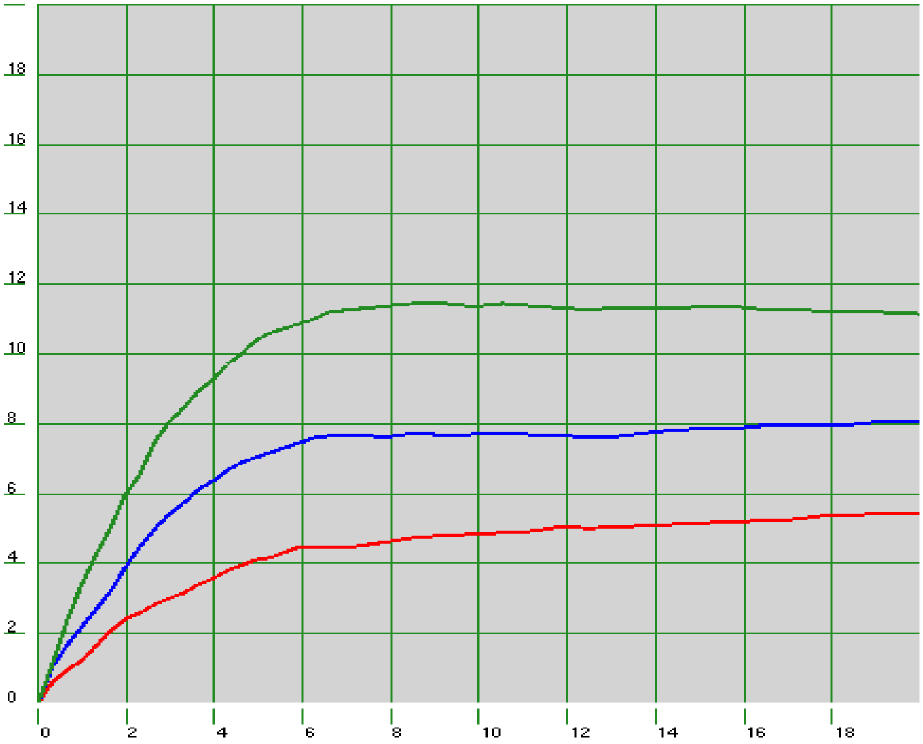

Figure5.53: Deviatric Stress(kg/sq.cm) vs Axial Strain(%)

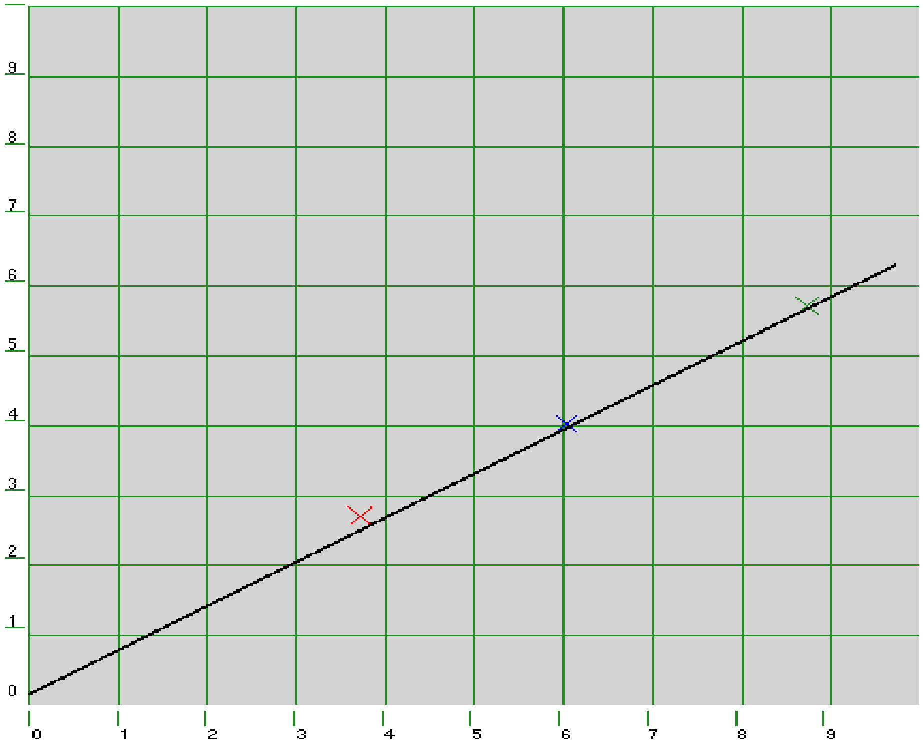

Figure5.54: Mean stress vs Shear stress [a=0.16kg/sq.cm ,alpha=32.3deg]

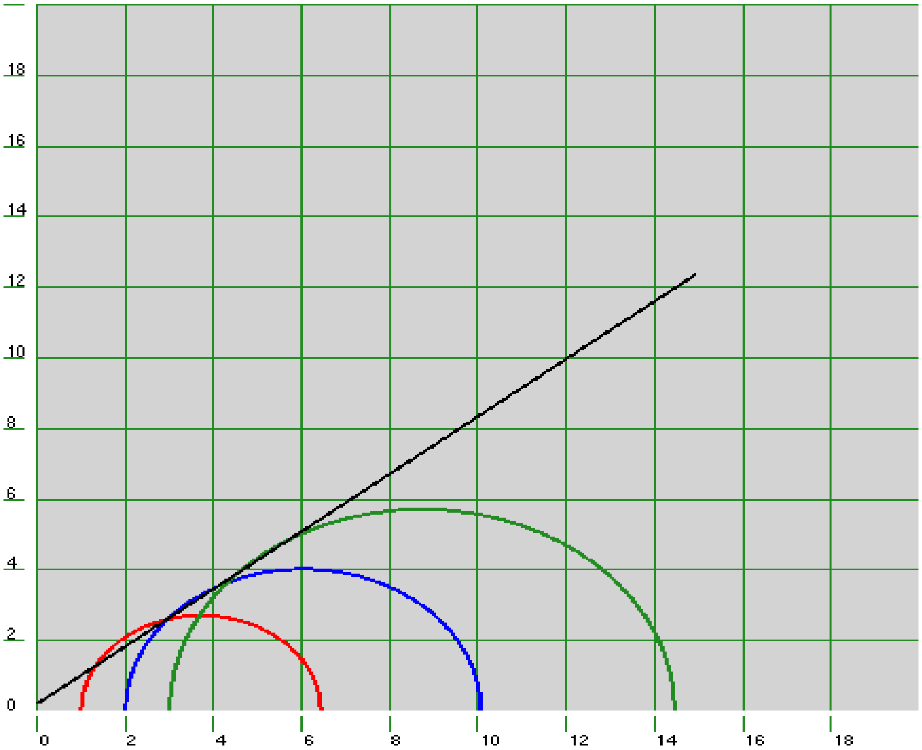

Figure5.55: Mohr-Coulomb Plot [c=0.21kg/sq.cm Phi=39.2deg]
ShearStress(kg/Sq.cm) vs NormalStress(kg/Sq.cm)

CHAPTER 6

DISCUSSIONS ON RESULT

6.1 Lime content determination-

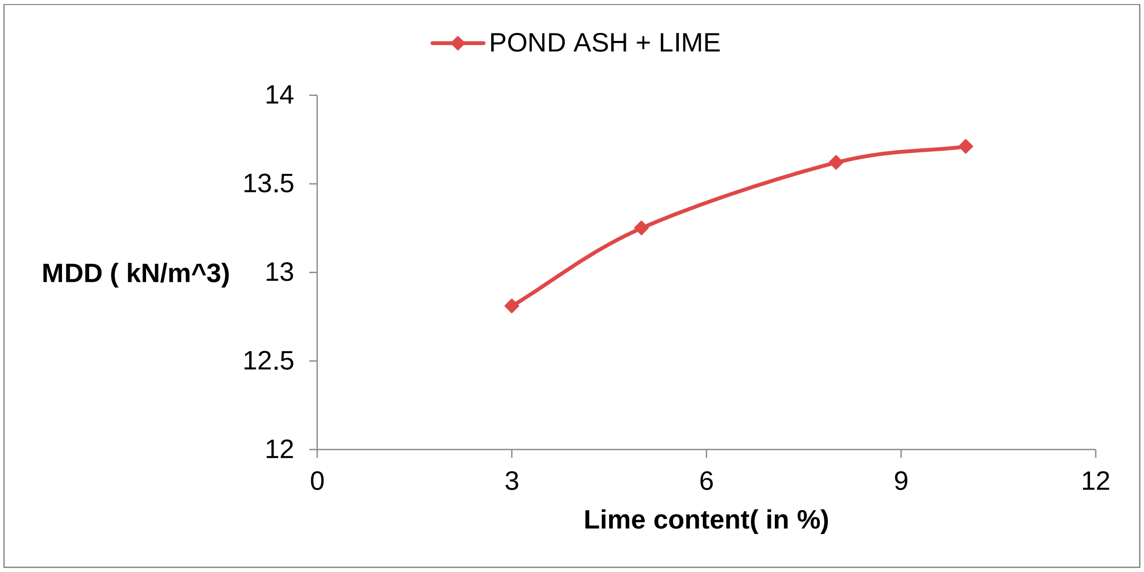

Figure 6.1: MDD variation of Pond ash with lime content.

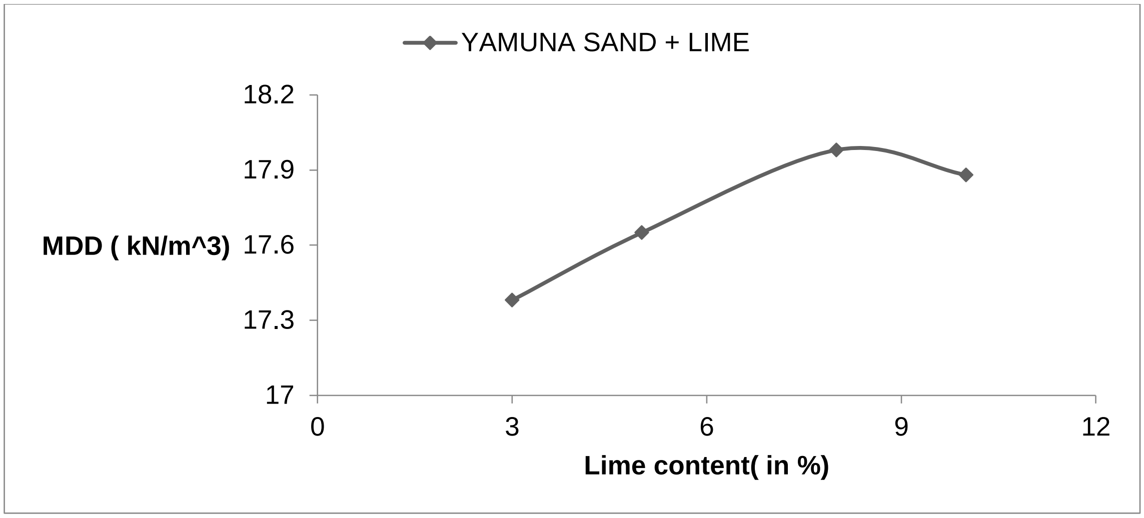

Figure 6.2: MDD variation of Yamuna sand with lime content.

Lime when reacts with Pond ash in presence of moisture form cementious compounds and Lime mixed with sand increases its stability and also it is not a waste material, So it is important to decide its optimum content. For lime content determination, lime is taken as 3%, 5%, 8% and 10% with Yamuna sand and similarly with pond ash. As results showing here MDD increased with lime up to 8% and after that there is less decrease in value of MDD and similarly for Pond ash MDD gets increase with addition of lime content but after 8 % it is not showing significant increment.

Direct shear results also show that as lime content is increasing, there is negligible change on ‘C’ parameter and ‘Ø’ parameter increasing with lime content.

Taking lime content fixed as 8 % for our study.

6.2 MDD Variation-

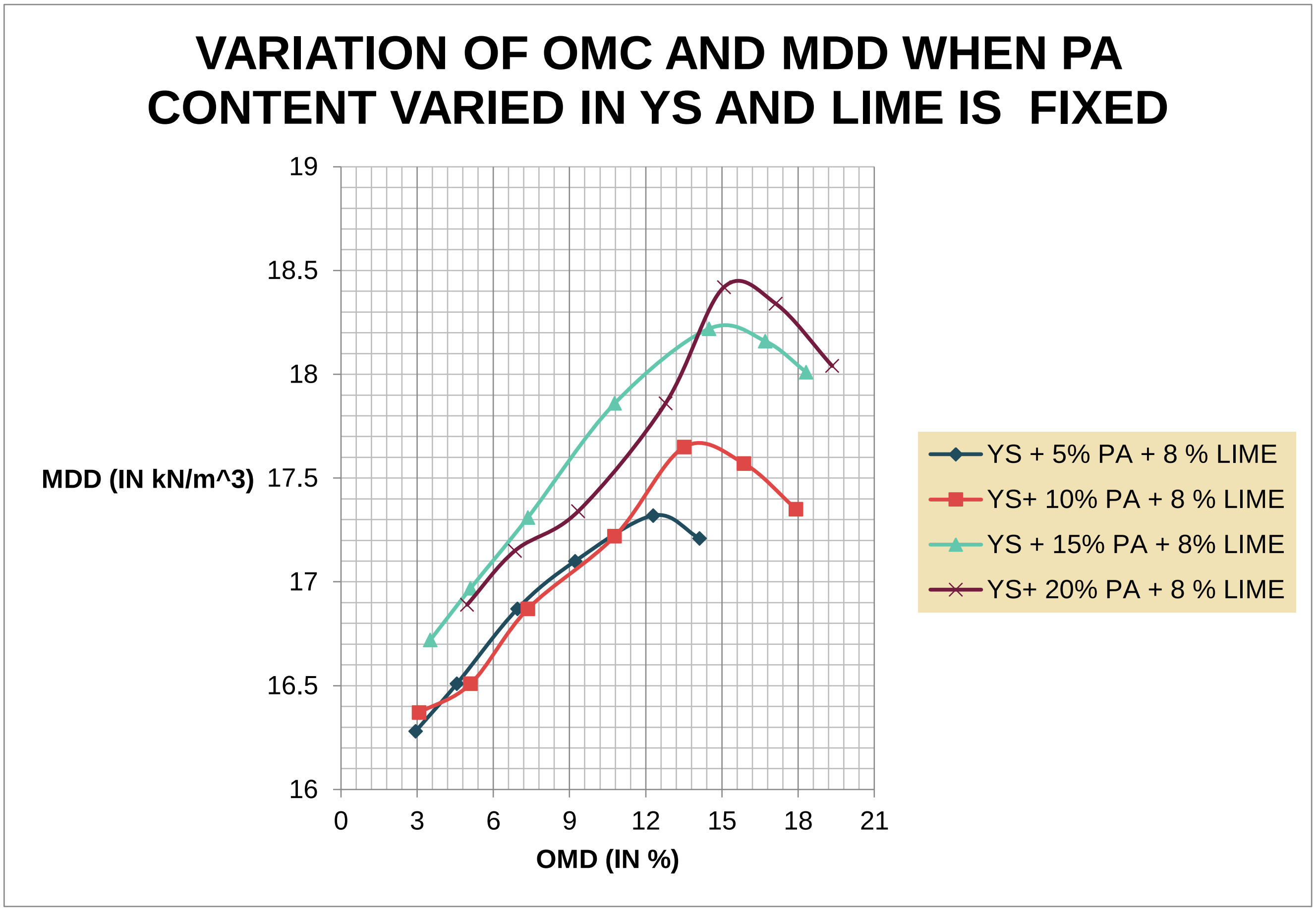

Figure6.3: MDD variation of Pond ash with Yamuna sand when lime content is fixed.

As results are showing MDD and OMC increase with increase in Pond ash content .but after 15% addition of Pond ash increasing rate of MDD is not same as before. Increase in the OMC shows that presence of finer particles into Yamuna sand.

6.3 Direct shear test- Direct shear results on mix shows increase in the shear strength as increase in the shear strength parameter Ø, it also leads to increase in the bearing capacity of the mix.

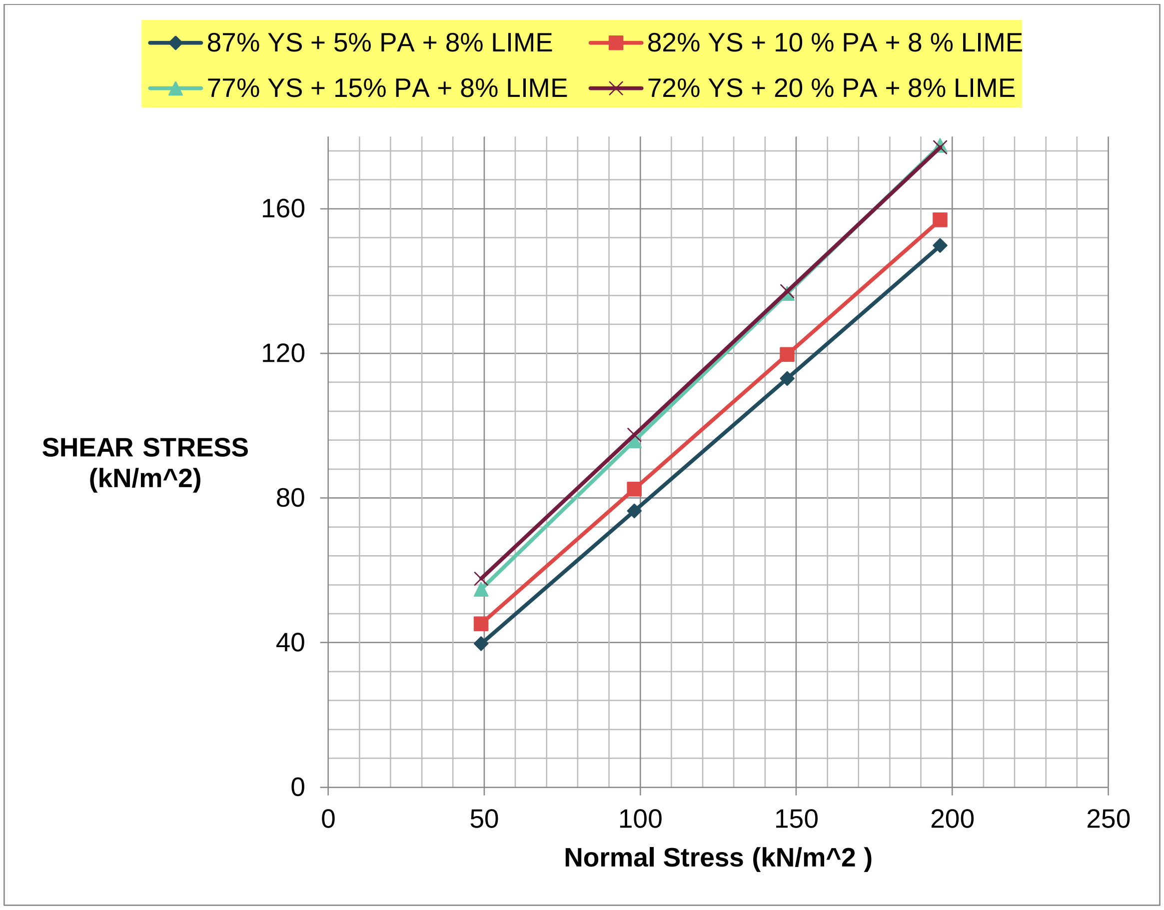

Figure6.4: Direct shear resuts showing variation at different Pond ash content while lime is keeping fixed.

6.4 **Triaxial test-** Triaxial results show better representation of shear behavior. And failure of plane As from the above results, deviator stress increasing continuously as increasing the Pond ash content up to 15%


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Figur6.5 Failure of Triaxial sample showing bulging

As avobe figure shows sample after failure gives bulging failure

5) Deviator stress v/s axial strain curve at various confining pressure shows with increase Pond ash content, there is increase in deviator stress up to 15 % lime content, after that deviator stress decreases.

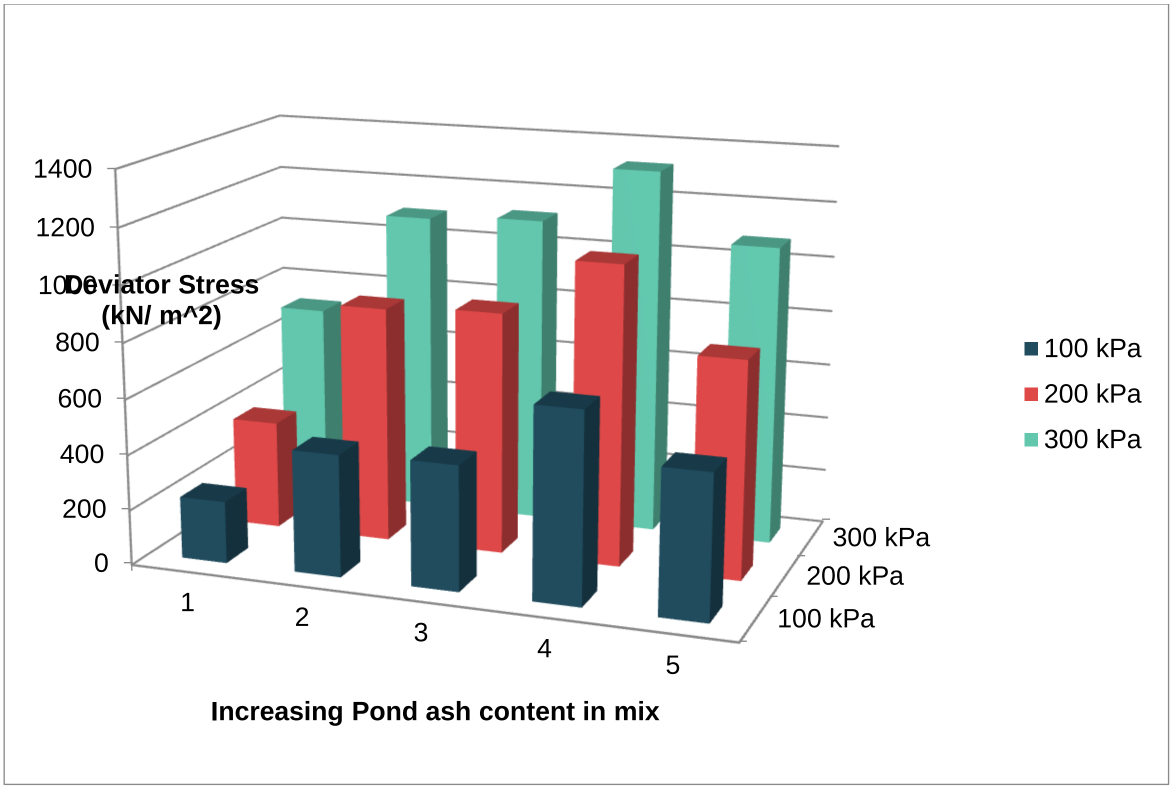

Figure6.6: Deviatric Stress v/s Axial strain variation when Pond ash is added on different proportions

Here,

1) Yamuna Sand.
2) 87% Yamuna Sand + 5% Pond ash + 8% Lime
3) 82% Yamuna Sand + 10% Pond ash + 8% Lime
4) 77% Yamuna Sand + 15% Pond ash + 8% Lime
5) 72% Yamuna Sand + 20% Pond ash + 8% Lime.

CHAPTER 7

CONCLUSION

As a result of present work Pond Ash and lime is used to stabilize Yamuna sand, Geotechnical properties mainly shear behaviour and compaction behaviour of the individual and mix have found out. Following conclusions are drawn from this work

- Since Pond ash is a waste material obtained from thermal power station, which is present on large amount, is a major constituent in mix, In mix its finer size leads to larger surface area than Yamuna sand leads to increase the MDD of mix as Pond ash increase.
- Pond ash alone does not provide binding or stabilizing action, since it does not provide cohesion, so we need such a material which forms some binding action in the mix. In our study lime is taken.
- Lime is not a waste material or freely available, so it is important to determine lime content. In our case direct shear test and standard proctor test has performed when lime mixed with pond ash and when lime mixed with Yamuna sand. Results show optimum lime content taken for mix is 8%.
- Pond ash content is taken 5%, 10%, 15% and 20% of sample mix; keeping lime fixed as 8 % and remaining content is Yamuna sand. Compaction result shows, As Pond ash content is increasing, OMC & MDD both are increasing.
- Shear behaviour study is done by both Direct shear test and Triaxial test. Shear strength tests on virgin Yamuna sand and fresh pond ash compacted on OMC and MDD show that shear strength is mainly due to internal friction.
- Shear strength tests on mix show that increase in the ‘C’ parameters is little, ‘Ø’ parameter mobilized more and up to Pond ash content 15% and after that internal friction decreases.
- Deviator stress v/s axial strain behavior also show that deviator stress increases up to 15% Pond ash content for same confining pressure and for 20 % Pond ash deviator stress decreases suddenly.

- Hence by studying shear behavior and compaction behavior, Optimum replaceable amount of Pond ash should be 15%.
- This work shows by utilizing Pond ash, We not only use this waste material and can reduce the load of environment as well.

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