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COMPARATIVE STUDY OF HAIR REINFORCED POND ASH WITH LIME AND SILTY SOIL

Submitted in Partial Fulfilment for the Award of the Degree of

MASTERS OF TECHNOLOGY
IN
CIVIL ENGINEERING

With Specialization in

GEO-TECHNICAL ENGINEERING

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CERTIFICATE

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This is to certify that the project report entitled "***COMPARATIVE STUDY OF HAIR REINFORCED POND ASH WITH LIME AND SILTY SOIL***" is a bona fide record of work carried out by SHIVENDRA S. KUSHWAH under my guidance and supervision, during the session 2013 in partial fulfilment of the requirement for the degree of Master of Technology (Geotechnical Engineering) from Delhi Technological University, Delhi.

The work embodied in this project has not been submitted for the award of any other degree to the best of our knowledge..

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ABSTRACT

Production of solid waste is another challenging problem confronted by the world for which vast area of land is required for its disposal. Alternatively, engineers attempting to employ these solid waste materials in the civil engineering construction based on their suitability & workability on their performances. The main goal of this study is to investigate the feasibility of huge industrial waste material Pond ash by another solid waste materials such as human hair fibre for its stabilization as a reinforcement with the use of lime and soil as additive which not only save tons of fertile soil for different purposes but also can replace conventional commercial fibre materials.

The effect of its reinforcement over Pond ash composite observed through a series of laboratory tests such as Index property tests, compaction tests ,unconfined compression tests, Indirect tensile strength .i.e. Brazilian test, Unconfined untrained triaxial tests ,CBR tests ,X ray diffraction and Scanning Electron Microscope.

The test result shows that the inclusion of randomly distributed fibre (Human hairs) in Pond ash composite mixtures substantially improves the engineering properties of Pond ash.

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LIST OF ABBREVIATION & SYMBOL

The principal symbols used in this thesis are presented for easy reference. A symbol is used for different meaning depending on the context and defined in the text as they occur.

NOTATION	DISCRIPTION
LL	Liquid Limit
PL	Plastic Limit
G	Specific gravity
Cu	coefficient of uniformity
Cc	coefficient of curvature
OMC	Optimum Moisture Content,%
MDD	Maximum Dry Density, kN/m^3
UCS	Unconfined Compressive Strength, kN/m^2
DST	Direct shear test
CBR	California Bearing Ratio%
Φ	Angle of Internal Friction,degrees
C	Unit Cohesion, kN/m^2
A R	Aspect Ratio
PA	Pond Ash
S	Soil
L	Lime
α	Slope of modified failure envelope
a	Intercept of modified failure envelope

CHAPTER-1

INTRODUCTION

The greatest challenge for the Growing & developing countries is the disposal of the residual waste products for their processing and manufacturing industries. Waste products that are generally toxic, ignitable, corrosive or reactive have detrimental environmental consequences. So disposal of industrial wastes is a big issue for the present generation. This big issue needs an economic, effective and environment friendly method to tackle with the disposal of the residual industrial waste products. One of the common and feasible ways to utilize these waste products is to go for construction of roads, highways and embankments and by this suitable amount of soil which to be used in the construction of highways& roads large amount of trees are being cut which cause deforestation, soil erosion and loss of fertile soil which also hampers in the agricultural productivity. Also, cost of extracting good quality of natural material is increasing. So effective uses of these industrial wastes which are used as a substitute for natural soil in the construction not only solve the problems of disposal and environmental pollution but also help to preserve the natural soil. This will provide a number of significant benefits to the constructing industry as well as to the country as a whole by conservation of natural resources, by reduction of volume of waste to landfills, by lowering the cost of construction materials, and by lowering waste disposal costs.

One of the waste product which is hugely produced in world’s second largest populated country of world is “HAIRS”, while the second is industrial waste used as a construction material is “FLY ASH”. In many countries including ours, coal is the primary fuel in thermal power stations and other industries. The fine residue from the burnt coal is carried in the flue gas, separated by electrostatic precipitators, and collected in a field of hoppers. This residue called fly ash is considered to be an industrial waste. The fly ash is disposed of either in the dry form or mixed with water and discharged as slurry into locations called POND ASH (wet method). The quantity of fly ash produced worldwide is huge and keeps increasing from year to year. Four countries, namely, China, India, Poland, and the United States, alone produce more than 270 million tons of fly ash every year while less than half of this is used. The potential impacts on the environment suggest the need for proper disposal of fly ash and justify maximum utilization of fly ash when viable.

For increasing use of Pond ash as a construction material, it is required to enhance some properties by stabilizing raw pond ash with suitable stabilizers or additives. The present project work aims at evaluating the feasibility of huge industrial waste material Pond ash by another solid waste material such as human hair fibre for its stabilization as reinforcement with the use of lime and soil as additive.

Pond ash use in this project was collected from Rajghat's Pond of NTPC plant at New Delhi.

Fig 1.Rajghat Pond Ash Site

1.2 POND ASH

The combustion of pulverized coal at high temperatures and pressures in power stations produces different types of ash at different levels. The 'fine' ash fraction is carried upwards with the flue gases and captured before reaching the atmosphere by highly efficient electro static precipitators. This material is known as Pulverized Fuel Ash (PFA) or 'fly ash'. It is composed mainly of extremely fine, glassy spheres and looks similar to cement. The 'coarse' ash fraction falls into the grates below the boilers, where it is mixed with water and pumped to lagoons. This material known as Furnace Bottom Ash (FBA) has a gritty, sand-like texture. Fly ash closely resembles volcanic ashes used in production of the earliest known hydraulic cements about 2,300 years ago. Those cements were made near the small Italian town of Pozzuoli - which later gave its name to the term "pozzolan." A pozzolan is a siliceous or siliceous / aluminous material that, when mixed with lime and water, forms a cementing compound. Fly ash is the best known, and one of the most commonly used, pozzolan in the world. Instead of volcanoes, today's fly ash comes primarily from coal-fired electricity generating power plants. These power plants grind coal to powder fineness before it is burned.

Fly ash - the mineral residue produced by burning coal - is captured from the power plant's exhaust gases and collected for use. Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. The difference between fly ash and Portland cement becomes apparent under a microscope. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That capability is one of the properties making fly ash a desirable admixture for concrete.

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, whereas bottom ash is removed from the bottom of the furnace. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO).

Dry fly ash – It is collected from different rows of electrostatic precipitators in dry form. The fly ash is produced from the burning of pulverized coal in a coal-fired boiler. It is a fine grained, powdery particulate material in nature. It is carried through the flue gas and collected from the flue gas by means of electrostatic precipitators, bag-houses, or mechanical collection devices such as cyclones. Fly ash is the finest of coal ash particles. It is transported from the combustion chamber by exhaust gases. Fly ash is the fine powder produced from the mineral matter present in coal, plus a small amount of carbon that remains due to incomplete combustion. Fly ash is generally light tan in colour and consists mostly of clay-sized and silt-sized glassy spheres. This gives fly ash to a consistency somewhat like talcum powder

Properties of of fly ash vary with coal composition and plant operating conditions. Fly ash can be referred as either pozzolanic or cementitious. A cementitious material is one that hardens when mixed with water. A pozzolanic material also hardens when mixed with water but only after activation with an alkaline substance such as lime. Due to cementitious and pozzolanic properties of fly ashes they are used for replacement of cement in concrete and many other building applications.

Bottom ash –It is collected at the bottom of the boiler furnace and is characterized by better geotechnical properties. Coal bottom ash and fly ash are different physically, minerologically and chemically. Bottom ash is a coarse, granular, incombustible by-product that is collected from the bottom of the furnaces that burn coal for the generation of steam, the production of electric power or both. Bottom ash is coarser than fly ash, and grain sizes varying from fine sand to fine gravel. The type of by-product produced depends on the type of furnace used to burn the coal.

Pond ash – Bottom ashes and Fly ash are mixed together with water to form slurry which is pumped to the ash pond area. In the ash pond the ash gets settled and excess water is poured out. This deposited ash is called pond ash.

1.3 LIME:

Lime i.e. CaO or $Ca(OH)_2$, the burned by product of lime stone ($CaCO_3$), is one of the oldest developed construction materials. It has been used by man more than 2000 years ago.

Today, lime stabilization of soils is being widely used in several constructions such as, highways, railways, airports, embankments, foundation base, slope protection, canal lining etc. This is primarily due to the overall economy, ease of construction, coupled with simplicity of this technology that provides an added attraction for the engineers. Several research works have been reported highlighting the beneficial effect of lime in improving the performance of soils.

Quicklime commonly known as Calcium oxide (CaO), is a widely used chemical compound. It is a white, caustic and alkaline crystalline solid at room temperature. As a commercial product, lime often also contains magnesium oxide, silicon oxide and smaller amounts of Aluminium oxide and Iron oxide. Lime is produced by calcinations of limestone in a lime kiln at temperatures above 1,000° C. Calcium carbonate ($CaCO_3$) is converted into calcium oxide (CaO) and carbon dioxide (CO_2). Active calcium oxide is highly reactive. In finely ground burnt lime a high level (80-90%) of calcium oxide guarantees good stabilization reaction in the soil, favourable water reduction in the soil and a temperature increase upon slaking. Lime in the form of quicklime (calcium oxide–CaO), hydrated lime (calcium hydroxide –Ca $(OH)_2$, or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – $CaCO_3$) into calcium oxide.

Hydrated lime is created when quicklime chemically reacts with water. Hydrated lime reacts with clay Particles and permanently transforms them into a strong cementitious matrix. Most lime used for soil treatment is “high calcium” lime, which contains no more than 5 percent magnesium oxide or hydroxide. Lime stabilization occurs over a longer time period of “curing.” The effects of lime stabilization are typically measured after 28 days or longer, but can be accelerated by increasing the soil temperature during the curing period. Stabilization differs from modification in a way that a significant level of long-term strength gain is developed through a long-term pozzolanic reaction. This pozzolanic reaction is the formation of calcium silicate hydrates and calcium aluminate hydrates as the calcium from the lime reacts with the aluminates and silicates solubilized from the clay mineral surface. This reaction can begin quickly and is responsible for some of the effects of modification. However, research has shown that the full term pozzolanic reaction can continue for a very long period of time - even many years – as long as enough lime is present and the pH remains high (above about 10). As a result of this long-term pozzolanic reaction, some soils can produce very high strength gains when lime treated. very substantial improvements in shear strength (by a factor of 20 or more in some cases), continued strength gain with time even after periods of environmental or load damage(autogenously healing) and long-term durability over decades of service even under severeenvironmental conditions.

1.4 HAIRS:

Long Hairs of 50% population i.e. of women are very demanding & can’t categorised to waste product as it is a billion crores turnover business in which main exporter of the world is INDIA. While remaining 50% population i.e. of men’s short hairs got from saloons can be categorised as Waste and is more useful for us like propylene fibres, which still not properly disposed & dumped due to its lack of waste management.

The lightweight, strength and deformation properties of fibers make them effective materials in various foundation-engineering applications. Scanning Electron Microscope analysis was conducted to obtain the average diameter of human fibre. A single hair fiber consists of three morphological regions; a medulla, cortex, and cuticle from inside to outside, respectively. Its diameter usually varies from 50 to 90 μm. The hair is primarily composed of a fibrous structural protein a called keratin. This keratin is a same type of a protein that makes up nails and an outer layer of skin. Like other proteins in a body, the keratin protein is a large molecule of amino acids or an amino-acid residue. The amino-acid residues are periodically held together with a molecular spacing of 1.5 A by the chemical bonds such as hydrogen bonds, cystine or sulphur bonds, salt bonds, and sugar bonds to form a polypeptide chain. This chain of human hair is known as an alpha helix or alpha keratin.

1.5 ENVIRONMENTAL IMPACTS OF FLY ASH

The World Bank has cautioned India that by 2015, disposal of coal ash would require 1000 sq. km. of land. Since coal currently accounts for 72% of power generation in the country, there is a need of new and innovative methods for reducing impacts on the environment. The problem with fly ash lies in the fact that not only does its disposal require large quantities of land, water and energy, its fine particles, if not managed well, can become airborne. Currently more than 120 million tonnes of fly ash are being generated annually in India, with 65000 acres of land being occupied by ash ponds. Such a huge quantity does pose challenging problems, in the form of land use, health hazards and environmental damages.

Hazards

Due to physical characteristics and large volumes generated, fly ashes pose problems like:

1. It is very difficult to handle the material in dry state because it is very fine and readily air borne even in mild wind.

2. It disturbs the ecology of that region, becomes source of soil, air and water pollution.

3. Long inhalation of fly ash causes fibrosis of lungs, silicosis, pneumonitis bronchitis etc.

4. Flying fine particles of ash poses problems for living near power stations, corrode structural surfaces and affect horticulture.

5. Ultimate settlement of fly ash particles over many hectares of land in the vicinity of power station brings about perceptible degeneration in soil characteristics.

1.6 NEED FOR THE RESEARCH

Substitution of natural soils, aggregates, and cement with the effective use of industrial or natural wastes is highly desirable. The lower cost of these materials makes an attractive alternative if adequate performance can be obtained. Although the concept of randomly reinforced Pond ash with Hair fibre is relatively new in geotechnical engineering but the reinforcement of clay soils with natural fibres has been practiced from the ancient time. Recently soil or Fly ash or Pond ash reinforcement with short, discrete, randomly oriented fibres is getting more attention from many researchers around the world. Extensive studies were carried out on the stabilization using various additives such as lime, cement, synthetic and natural fibres.

1.7 OBJECTIVES:

The above goal was achieved with the following specific objectives.

1. Investigating the engineering properties and characteristics of the Pond ash samples collected.

2. Investigating the strength gain of composite material aspects associated with the Pond ash specimen collected.

3. Establishment of better suitable combinations of Pond ash-lime and Pond ash-local available soil reinforced with the hair fibre for optimum effectiveness.

CHAPTER-2

LITERATURE REVIEW

2.1 INTRODUCTION

India has a total installed capacity of 115,000 MW of electricity generation. Seventy-two percent of this is based on thermal power generation. The coal reserves of India are estimated around 220 billion metric tons. Because of this, 85% of the Indian thermal power stations are coal based. There are 85 coal based thermal power stations and other power stations in the country. The Indian coal has a low calorific value and a high ash content of 35–50%. To achieve the required energy production, a high coal fired rate is required, generating greater ash residue. The most common method adopted in India for the disposal of coal ashes is the wet method. This method requires, apart from a large capital investment, about 1 acre of land for every 1 MW of installed capacity. Thus, ash ponds occupy nearly 26,300 ha of land in India. The utilization of fly ash was just 3% in 1994, but there is a growing realization about the need for conservation of the environment in India. In 1994, the Government of India commissioned a **Fly Ash Mission**(**FAM**) with the broad objective of building confidence among the producer and consumer agencies in the safe disposal and utilization of fly ash, through technology demonstration projects. The FAM has chosen 10 major areas and so far has undertaken 55 technology demonstration projects at 21 locations across India. The fly ash utilization has increased from 3% in 1994 to 19% in 2012

Recently, the Indian Road Congress has also published guidelines for the use of fly ash in road embankments (IRC 2001).Fly ash became an attractive construction material because of its self-hardening characteristics for which available free lime is responsible. The variation of its properties depends upon the nature of coal, fineness of pulverization, type of furnace and firing temperature.

2.2 POND ASH STABILIZATION

Pond ash is defined as the mineral matter extracted from the flue gases of a furnace fired with coal. Pond ash consists of often hollow spheres of silicon, aluminium and iron oxides, and unburned carbon. Fly ash can be regarded as non plastic fine silt and sand by the Unified Soil Classification System. The composition of Pond ash varies considerably depending on the nature of the coal burned and the power plant operational characteristics. Pond ash is a pozzolanic material, which is defined as siliceous or siliceous and aluminous and, therefore, its engineering behaviour can be improved by the addition of lime or other admixtures.

Pond ash can provide an adequate array of divalent and trivalentcationsCa^{2+}, Al^{3+}, Fe^{3+}, etc. under ionized conditions that can promote flocculation of dispersed clay particles. Thus, soils can also be potentially stabilized by cat ion exchange.

2.3 LIME STABLISATION

The use of lime for stabilizing soils & even Fly ash or pond ash increasing in favour during the last few decades because it lowers volume change characteristics . Generally the amount of lime required to stabilize expansive soils ranges from 2 to 9% by weight (**Chen -1975**).

The addition of lime to pond ash provides an abundance of calcium ions $Ca^{2+}$and magnesium ions $Mg2^{+}$. These ions tend to displace other common cati ons such as sodium $Na^{+}$and potassium K^{+}, in a process known as cat ion exchange. A change of pond ash texture takes place when lime is mixed with it. With the increase in lime content, there is an apparent reduction in fine particles and a corresponding increase in percentage of coarse particles (**Chen 1975)**.

2.4 FIBRE-REINFORCED POND ASH /SOIL

Fibre inclusions cause significant modification and improvement in the engineering behavior of soils. A number of research studies on fiber-reinforced soils have recently been carried out throughtriaxial tests, unconfined compression tests, CBR tests, directshear tests, and tensile and flexural strength testsThe literature cites various studies conducted to understand the behavior of Pond ash with lime andsoils, modified by the addition of fibers(Hairs).Lima -1996 observed a large increase in compressive strength with the addition of lime and cement to fiberreinforced soils.

Kumar-2005 found that unconfined compressive strength of highly compressible clay increases with the addition of fiber sand it further increases when fibers are mixed in clay sand mixtures.

Numerous research papers were studied for the literature review. In which reinforcement using waste product i.e HAIR is totally and while work over XRD and SEM analysis is just recently started for testing the mixed specimen. Very less data was available on the mixture of Hair reinforced Pond Ash mixed with lime & soil differently at variable proportions. Although, numerous tests were performed on Pond Ash and Fly Ash.

Table 1 Prominent Scholars Contributed Work Used

Scholars	Contribution
Marco Del Monte and Cristina Sabbioni (1984)	Mineralogical compositions of coal and fly ash
Bell (1996)	Soil-lime stabilization
Kumar (1999)	Laboratory investigations conducted on silty sand and pond ash the inclusion of fibres
N Pandian (2004)	Investigations on Indian coal ash and Characterises
Arvind kumar-Baljit Walia (2007)	Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil
Dr Praveen Kumar (2008)	Various tests on fly ash in roorkee campus
S.K Das (2010)	Talcher coal fly ash physico-chemical and mineralogical analysis
Ghosh (2010)	Class F pond ash with varying percentages of lime (4, 6, and 10%) and PG (0.5, and 1.0)
Dr. Raju Sarkar (2011)	Detailed analysis of Pond Ash samples collected around Delhi from NTPC's three Power Plants.
Phannee Saengkaew(2011)	A Preliminary X-Ray Study on Human-Hair Microstructures for a Health-State Indicator.

Marco Del Monte and Cristina Sabbioni et al. (1984) compared the mineralogical compositions of coal and fly ash outlines a simpler scheme as far as single particle formation is concerned.. It is however important to outline that the bulk composition and the relative ratio of the different typologies (with particular regard to the glassy, carbonaceous and metallic fractions) constituting the fly ash are strictly dependent on the furnace design and generating conditions as well as on the coal composition, while the diverse morphological classes of particles forming during combustion processes seem to constitute quite a general scheme. The classification proposed by this paper is closely comparable to that presented by **Ramsden and Schibaoka**.

Bell et al. (1996) indicates that with Increase in liquid limit and plasticity index lime has increased the plasticity of the soils treated with. This is suggested due to the action of hydroxyl ions modifying the water affinity of the soil particles. Besides, increase in lime content, beyond a certain limit, is found to have reduced the strength. It is postulated that since lime itself has neither appreciable friction nor cohesion, excess of lime reduces the strength. But soil-lime stabilization being dependent on several factors such as, soil type, its mineralogy, lime content, curing period etc.

Kumar et al. (1999) gives the results of laboratory investigations conducted on silty sand and pond ash specimens reinforced with randomly distributed polyester fibres. The test results reveal that the inclusion of fibres in soils increases the peak compressive strength, CBR value, peak friction angle, and ductility of the specimens. It is concluded that the optimum fibre content for both silty sand and pond ash is approximately 0.3 to 0.4% of the dry unit weight

N Pandian (2004) carried out investigations on Indian coal ash and Characterises it by taking sample from Badarpur ,Raichur, Vijyavada, Neyveli,Korba & Ramagundam by performing series of laboratory tests on Fly-ash,Pond-ash & Bottom-ash individually. He characterises their Physical & Chemical properties, Compaction, Consolidation, Strength, CBR & Permeability behaviourand showed how that Fly ash has good potential for use in geotechnical applications. Its low specific gravity, freely draining nature, ease of compaction, insensitiveness to changes in moisture content, good frictional properties, etc. can be gainfully exploited in the construction of embankments, roads, reclamation of low-lying areas, fill behind retaining structures, etc. It can be also used in reinforced concrete construction since the alkaline nature will not corrode steel. This not only solves the problems associated with the disposal of fly ash (like requirement of precious land, environmental pollution, etc.) but also helps in conserving the precious top soil required for growing food.

Arvind kumar-Baljit Walia (2007) have studied Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil and performed series of tests effects of polyester fiber inclusions and lime stabilization on the geotechnical characteristics of fly ash-soil mixtures. An Indian fly ash was mixed with expansive soil in different proportions. The geotechnical characteristics of fly ash-soil specimens, lime-soil specimens and lime-fly ash-soil specimens mixed with different proportions of randomly oriented fibers were investigated. Lime and fly ash were added to an expansive soil at ranges of 1–10% and 1–20%, respectively. Test specimens were subjected to compaction tests, unconfined compression tests and split tensile strength tests. Specimens were cured for 7, 14, and 28 days after which they were tested for unconfined compression tests and split tensile tests. Based on optimum values obtained for lime and fly ash, tests were conducted on test specimens prepared from fly ash-expansive soil- lime-fiber mixture after 28 days of curing. Samples were tested with 0, 0.5, 1.0, 1.5, and 2% plain and crimped polyester fibers by dry weight. Based on the favorable results obtained, it can be concluded that the expansive soil can be successfully stabilized by the combined action of fibers, lime, and fly ash.

Dr Praveen Kumar et al. (2008) Performed various tests on fly ash in roorkee campus and concluded following:

1. In the modified proctor compaction test, the optimum moisture content for flyash decreases with increase in fibre content and maximum dry density increases with increase in fibre content. For Roorkee soil the maximum dry density as well as optimum moisture content decrease with increase in fibre content.

2. Lab CBR value of flyash at 5.0 mm penetration is more compared to 2.5 mm penetration.

3. CBR value of flyash increases with increase in fibre content for both soaked and unsoaked conditions. But the rate of increase is more upto 1.0% fibre content and thereafter the rate of increase is very less. For flyash with 1.5% and 2.0% fibre content, the CBR values are same in soaked condition.

4. The angle of internal friction increases with the addition of fibre content. The maximum percentage increase in angle of internal friction is at 0.5% fibre content, there after percentage increase is less.

5. The increase in shear strength of flyash is very high at high confining pressures compared to at low confining pressure..

6. The field CBR value at 2.5 mm penetration is more compared to 5.0 mm penetration. CBR value for flyash is 18.28% and with 0.5% fibre content it is 25.71%. The percentage increase in CBR is 40.64.

S.K Das (2010) examines the suitability of Talcher coal fly ash for stowing in the nearby underground coal mines based on their physico-chemical and mineralogical analysis. The physical properties such as bulk density, specific gravity, particle size distribution, porosity, permeability and water holding capacity etc. have been determined. From the chemical characterization it is found that the ash samples are enriched predominantly in silica (SiO2), alumina (Al2O3) and iron oxides (Fe2O3), along with a little amount of CaO, and fall under the Class F fly ash category. In addition, the mineral phases identified in the ash samples are quartz, mullite, magnetite, and hematite. The particle morphological analysis revealed that the ash particles are almost spherical in shape and the bulk ash porous in nature. From the particle size and permeability point of view, pond ash may be considered a better stowing material than fly ash.

Ghosh et al. (2010) presents 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 un-soaked 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 un-soaked bearing ratio of stabilized pond ash. The experimental results indicate that pond ash-lime-PG mixes have potential for applications as road base and sub base materials.

RajuSarkar et al. (2011) have studied detailed analysis of Pond Ash samples collected around Delhi from NTPC's three Power Plants – Badarpur,Dadri,Rajghat and carried series of laboratory tests with various Admixtures like Bentonite,Polypropylene Fibre(1,2,&3%), Lime, Marble dust &Gelatin Starch(1:2) and Characterise them by determining their Physical properties& Geotechnical characteristics with the conclusion that all the pond ash particles collected from Badarpur, Dadri and Rajghat are predominantly sand. The ratio of light (standard Proctor) compaction characteristics and heavy (Modified Proctor) compaction characteristics of Badarpur, Dadri and Rajghat pond ashes were different. The Badarpur pond ash could be compacted to a somewhat greater dry unit weight than the other two pond ashes. The ratio of MDD and OMC of the two Proctor tests were found for these three pond ashes as 75% and 133%; 77% and 126% and 86% and 125% respectively. In the consolidated untrained triaxial shear tests of the Badarpur, Dadri and the Rajghat pond ash specimens (MDD-OMC state), the deviator stress attained peak value at axial strains in the range of 1.5-3.0% for all the samples and thereafter remained almost constant. The drained cohesion and angle of shearing resistance were 0 kPa and 30.4°, 0 kPa and 32.0° and 0 kPa and 28.9° respectively.

Also the optimum percentage of lime used to stabilize Pond ash found by him during experiment is 8% and as I use the same Rajghat's pond ash, thus I refer & execute my analysis by taking same Optimum percentage value i.e. 8% for lime.

Phannee Saengkaew et al. (2011) Performed A Preliminary X-Ray Study on Human-Hair Microstructures for a Health-State Indicator and describe its basic structure and morphology through Scanning Electron Microscope & XRD tests.

CHAPTER-3

EXPERIMENTAL INVESTIGATION

3.1 Sample Preparation

Different values of fiber content adopted for present study were 0.5%, 1.0%, 1.5%, and 2.0% by weight of pond ash. The mixing of hair was felt very difficult beyond 2.0%, as the same stick together to form lumps. This also caused pockets of low density. So, it was decided to stop with 2.0% fiber content. Fibers were added to the moist mixture composite sample at different percentages and were tested as per IS specifications. All mixing was done manually and proper care and time were spent for preparing homogenous mixture at each stage of mixing. It was found that the fibers could be mixed with pond ash more effectively in the moist state than in dry state.

Fig.2 Sample Preparation

3.2 DETERMINATION OF INDEX PROPERTIES

3.2.1 Specific Gravity, IS: 2720 (Part 3) (1985)

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask in a very simple experimental setup where the volume of the soil is found out and its weight is divided by the weight of equal volume of water.

Specific Gravity G = (W2−W1)/(W4−W1 − W3−W2)

W1- Weight of bottle in gms

W2- Weight of bottle + Dry soil in gms

W3- Weight of bottle + Soil + Water

W4- Weight of bottle + Water

Specific gravity is always measured in room temperature and reported to the nearest 0.1 decimal.

3.2.2 Liquid Limit , IS: 2720 (Part 5) (1985)

The Casagrande tool cuts a groove of size 2mm wide at the bottom and 11 mm wide at the top and 8 mm high. The number of blows used for the two soil samples to come in contact is noted down. Graph is plotted taking number of blows on a logarithmic scale on the abscissa and water content on the ordinate. Liquid limit corresponds to 25 blows from the graph.

3.2.3 Plastic Limit , IS: 2720 (Part 5) (1985)

This is determined by rolling out soil till its diameter reaches approximately 3 mm and measuring water content for the soil which crumbles on reaching this diameter.

Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

$I_p = W_L – W_P$

W_L - Liquid limit & W_P - Plastic limit

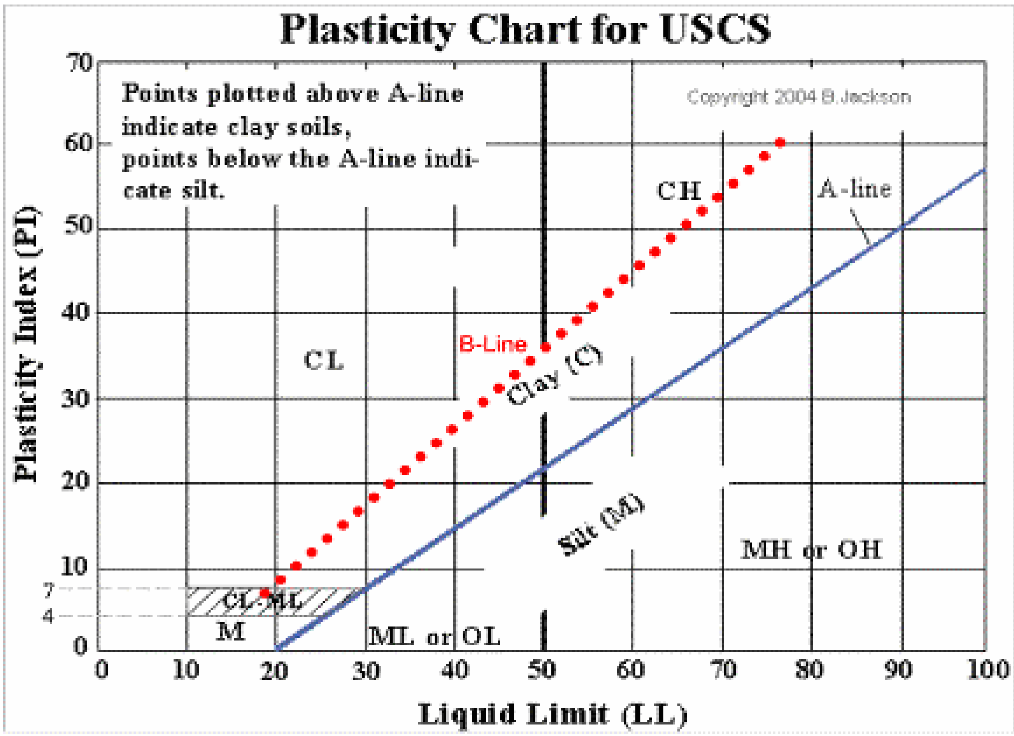

Fig 3 Plasticity Chart (From Jackson)

Table 2 Symbol Representaion of Plasticity chart

SYMBOL				
G	Gravel		P	Poorly Graded
S	Sand		W	Well Graded
M	Silt		H	Highly Plastic
C	Clay		L	Low Plastic
O	organic			

3.3 Particle Size Distribution, IS: 2720 (Part 4) (1985)

The results from sieve analysis of the soil when plotted on a semi-log graph with particle diameter or the sieve size as the abscissa with logarithmic axis and the percentage passing as the ordinate gives a clear idea about the particle size distribution. From the help of this curve, D-10 and D-60 are determined. This D-10 is the diameter of the soil below which 10% of the soil particles lie. The ratio of, D-10 and D-60 gives the uniformity coefficient (Cu) which in turn is a measure of the particle size range.

3.4 SEM (Scanning Electron Microscope)

The scanning electron microscope (SEM) is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition and other properties such as electrical conductivity.

The types of signals produced by an SEM include secondary electrons, back-scattered electrons (BSE), characteristic X-rays, light (cathodoluminescence), specimen current and transmitted electrons. Secondary electron detectors are common in all SEMs, but it is rare that a single machine would have detectors for all possible signals. The signals result from interactions of the electron beam with atoms at or near the surface of the sample. In the most common or standard detection mode, secondary electron imaging or SEI, the SEM can produce very high-resolution images of a sample surface, revealing details about less than 1 to 5 nm in size. Due to the very narrow electron beam, SEM micrographs have a large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample. A wide range of magnifications is possible, from about 10 times (about equivalent to that of a powerful hand-lens) to more than 500,000 times, about 250 times the magnification limit of the best light microscopes. Back-scattered electrons (BSE) are beam electrons that are reflected from the sample by elastic scattering. BSE are often used in analytical SEM along with the spectra made from the characteristic X-rays. Because the intensity of the BSE signal is strongly related to the atomic number (Z) of the specimen, BSE images can provide information about the distribution of different elements in the sample. Characteristic X-rays are emitted when the electron beam removes an inner shell electron from the sample, causing a higher energy electron to fill the shell and release energy. These characteristic X-rays are used to identify the composition and measure the abundance of elements in the sample. Chemical analysis in the scanning electron microscope is performed by measuring the energy or wavelength and intensity distribution of x-ray signal generated by a focused electron beam on the specimen. With the attachment of the energy dispersive spectrometer (EDS) or wavelength dispersive spectrometer (WDS) the precise elemental composition of material can be obtained with high spatial resolution. When we work with bulk specimen in the SEM very precise accurate chemical analysis.

3.5 X-Ray Diffraction

X-ray diffraction is a technique that provides detailed information about the atomic structure of crystalline substances. It is a powerful tool in the identification of minerals in rocks and soils. The bulk of the clay fraction of many soils is crystalline, but clay particles are too small for optical crystallographic methods to be applied. Therefore, XRD has long been a mainstay in the identification of clay-sized minerals in soils and here is for pond ash. However, its usefulness extends to coarser s fractions as well. X-ray diffraction analysis can be conducted on single crystals or powders. This chapter will be devoted to X-ray powder diffraction (Reynolds, 1989), since that is the technique most applicable to soil mineralogy.
The objective of this chapter is to provide a detailed procedural reference for pond ash mineralogical determination by XRD

3.6 Proctor Compaction Test, IS: 10074 (1982).

This experiment gives a clear relationship between the dry density of the pond ash and its moisture content. The experimental setup consists of (i) cylindrical metal mould (internal diameter- 10 cm and internal height-12.5 cm), (ii) detachable base plate, (iii) collar (5 cm effective height), (iv) rammer (2.5 kg). Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil/pond ash. The maximum dry density (MDD) is achieved when the pon ash/soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). After plotting the data from the experiment with water content as the abscissa and dry density as the ordinate, we can obtain the OMC and MDD. The equations used in this experiment are as follows:

$$\text{Wet density} = \frac{\text{weight of wet soil in mould (gms)}}{\text{volume of mould (cc)}}$$

$$\text{Moisture content \%} = \frac{\text{weight of water (gms)}}{\text{weight of dry soil(gm)}} *100$$

$$\text{Dry density } \gamma d \text{ (gm/cc)} = \frac{\text{wet density}}{1+\frac{Moisturecontent}{100}}$$

3.7. Unconfined Compression Test, IS: 2720 (Part 10) (1987)

This experiment is used to determine the unconfined compressive strength of the pond ash/soil sample which in turn is used to calculate the unconsolidated, undrained shear strength of unconfined pond ash/soil. The unconfined compressive strength (qu) is the compressive stress at which the unconfined cylindrical composite sample fails under simple compressive test. The experimental setup constitutes of the compression device and dial gauges for load and deformation. The load was taken for different readings of strain dial gauge taken. The corrected cross-sectional area was calculated by dividing the area by (1- ε) and then the compressive stress for each step was calculated by dividing the load with the corrected area.

qu= load/corrected area (A')

qu- compressive stress

A'= cross-sectional area/ (1- ε)

3.8 Triaxial Test (UU), IS: 2720 (Part 11) (1993)

This test method covers determination of the strength and stress-strain relationships of a cylindrical specimen of either undisturbed or remolded soils here pond ash . Specimens are subjected to a confining fluid pressure in a triaxial chamber. No drainage of the specimen is permitted during the test. The specimen is sheared in compression without drainage at a constant rate of axial deformation (strain controlled). This test method provides data for determining undrained strength properties and stress-strain relations for pond ash.

Through the measurement of the total stresses applied to the specimen that is the stresses are not corrected for pore-water pressure.

Here,

Axial strain, $\varepsilon = \Delta H/H_0$

Average cross-seticonal area, $A = A_0/(1 - \varepsilon)$

Principal stress difference, $\sigma_1 - \sigma_3 = P/A$

Also,

We calculate C and ϕ,through modified failure envelope using the relation

$$\sin \emptyset = \tan \alpha \quad \& \quad c' = \frac{a}{\cos \emptyset}$$

Where,

α = Slope of modified failure envelope a = Intercept of modified failure envelope

3.9 CBR Test (Unsoaked), IS: 2720 (Part 16) (1987)

Using the moisture content and corresponding dry density the amount of pon ash used for CBR was calculated. The sample was tested using the CBR instruments and the samples are unsoaked for which CBR values was found out.

The CBR is a measure of a material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproductivity is required. The CBR test may be conducted in remolded or undisturbed specimen in the laboratory. US corps of engineers have also recommended a test procedure for in situ test. Many methods exist today which utilize mainly CBR test values for designing pavement structure .The test is simple and has been extensively investigated for field correction of flexible pavement thickness requirement.

The test consists of cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/ min. The loads for 2.5 mm and 5 mm are recorded. This is expressed as a percentage of standard load value at a representive deformation level to obtain CBR value. The standard load values were obtained from the average of a large number of tests on different crushed stones. Are as:-

Calibration factor of the proving ring 1 Div. = 4.518 kg

Surcharge weight used (kg) 2.750 kg

Least count of penetration dial 1 Div. = 0.002 mm

$$CBR\% = \text{Test Load}/\text{Standard Load} * 100\%$$

Table 3 Standard Loads of CBR test

Penetration of plunger (mm)	Standard Load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

3.10 Indirect Tensile Strength Test (Brazilian Test), IS: 10082 (1982).

Measure the diameter and thickness of one of the Brazilian disc specimens to the nearest 0.01 in. and place it in compression testing machine. The disc should be located on its edge at the center of the spherical loading head. Very carefully bring the upper platen of the testing machine into near contact with the top of the disc. Load the specimen slowly until fracture occurs Record this load, make a sketch of the fracture and note the degree of violence of fracture. Repeat for the complete set of test specimens supplied.

$$T = \frac{2P}{\pi t D}$$

Where,

T is the tensile strength,

P is the maximum compressive load recorded during the test,

D is the diameter, and

t is the thickness of the test specimen

CHAPTER-4

RESULTS AND DISCUSSION

4.1 Specific Gravity, IS: 2720 (Part 3) (1985).

The specific gravity of pond ash was determined according to IS: 2720 (Part-III, section-1) 1980 and found to be 2.1, generally lower value compared to soils here sandy silt of specific gravity 2.5.

The reduction in unit weight is of advantage in the case of its use as a backfill material for retaining walls since the pressure exerted on the retaining structure as well as the foundation structure will be less. The other application areas include embankments especially on weak foundation soils, etc. The variation of specific gravity of the pond ash is the result of a combination of many factors such as gradation, particle shape and chemical composition .

The reason for a low specific gravity could either be due to the presence of large number of hollow cenospheres from which the entrapped air cannot be removed, or the variation in the chemical composition, in particular iron content, or both.

4.2 Liquid Limit & Plastic Limit , IS: 2720 (Part 5) (1985).

Index properties are extensively used in geotechnical engineering practice. Among them, liquid limit is an important physical property for use in classification and for correlations with engineering properties. While a number studies have been made on the liquid limit of fine-grained soils not much work has been done on coal ashes.

Currently, Percussion cup method is popular for the determination of liquid limit of fine-grained soils. In the Percussion cup method it is very difficult to cut a groove in soils of low plasticity and the soils have tendency to slip rather than flow. Hence, this method is not suitable for Pond ashes which are non-plastic in nature.

Thus, A new method of determining liquid limit called “Equilibrium water content under *Ko* stress method” has been found to be effective for the determination of liquid limit of coal ashes.The results obtained using the proposed method show that fly ashes have liquid limit water content ranging from 26 to 51%, 22 to 64% for pond ashes, and 45 to

104% for bottom ashes. The liquid limit values exhibited by coal ashes are not due to their plasticity characteristics but are due to their fabric and carbon content

All the coal ashes tested are non-plastic and hence plastic limit could not be determined. It was also not possible to carry out shrinkage limit tests since the ash pats crumbled upon drying. Since the amount of shrinkage is very less, the shrinkage limit will be quite high. Hence shrinkage will not be a constraint. (**N. S. Pandian, 2004**)

4.3 Grain Size Distribution, IS: 2720 (Part 4) (1985).

The extensive investigation carried out on Rajghat pond ashes demonstrates that the Pond ashes consist predominantly of sand size to silt size fraction with some clay-size fraction.

Based on the grain-size distribution, the pond ash can be classified as silty sand. They are poorly graded with coefficient of curvature 1.04 & coefficient of uniformity is 5.09.

Similarly, the soil consists of grains mostly of fine sand to clay size having Coefficient of uniformity and coefficient of curvature are found to be 3.9 & 1.10 respectively, indicating well graded Sandy Silt

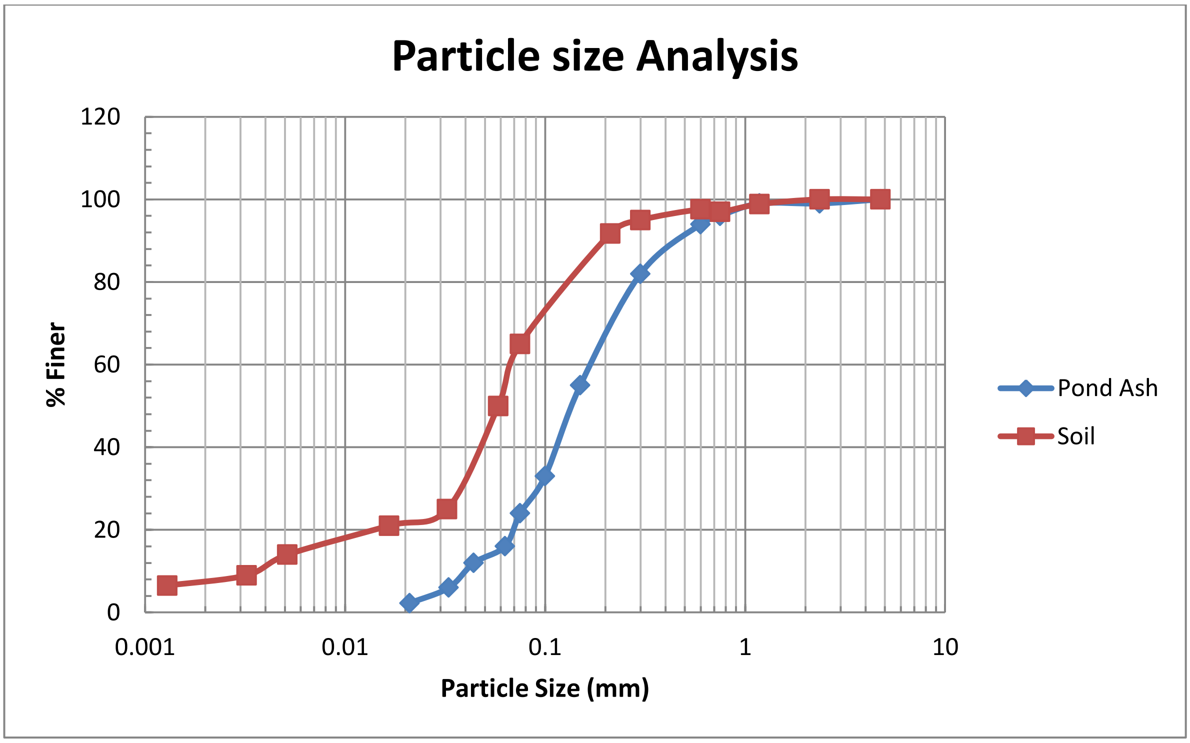

Fig 4 Particle size Distribution

And as obtained from figure both curve are almost parallel to each other over a good range, so the required soil can be used with pond ash to stabilize along with fibre-hair.

4.4 Scanning Electron Microscope Analysis

Scanning Electron Microscope gives information about the morphology of the sample particles. In Pond Ash, fraction of glassy alumina silicate particles and a low percentage of crystalline matter with amorphous carbonaceous particles were present. Micrograph of an irregular aluminosilicatic particle showing numerous sub spherical cavities formed by gaseous emissions during crystallization. Spherical aluminosilicatic particle section which shows a number of cavities, filled with numerous aluminosilicatic particles of micron and submicron dimensions.

Quartz particles which were rounded in shape due to fusion by high temperature can be seen easily. Small fly ash particles were stick together with the large ones due to electrostatic forces. This enables them to flow over each other easily, that is why they have large surface area and act as good pozzolaniac material.

Fig 5 SEM Apparatus in our Nano Lab

Fig 6 Hair Fibre at 500µm scale

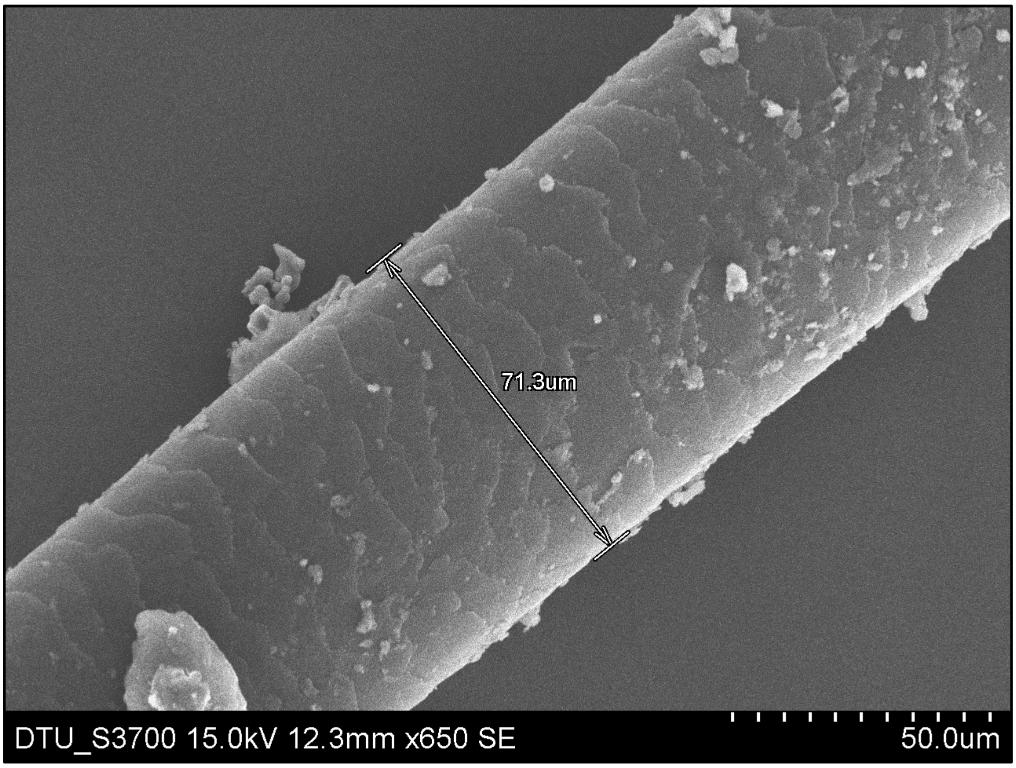

Fig 7 Single Hair Fibre with diameter at 50µm scale

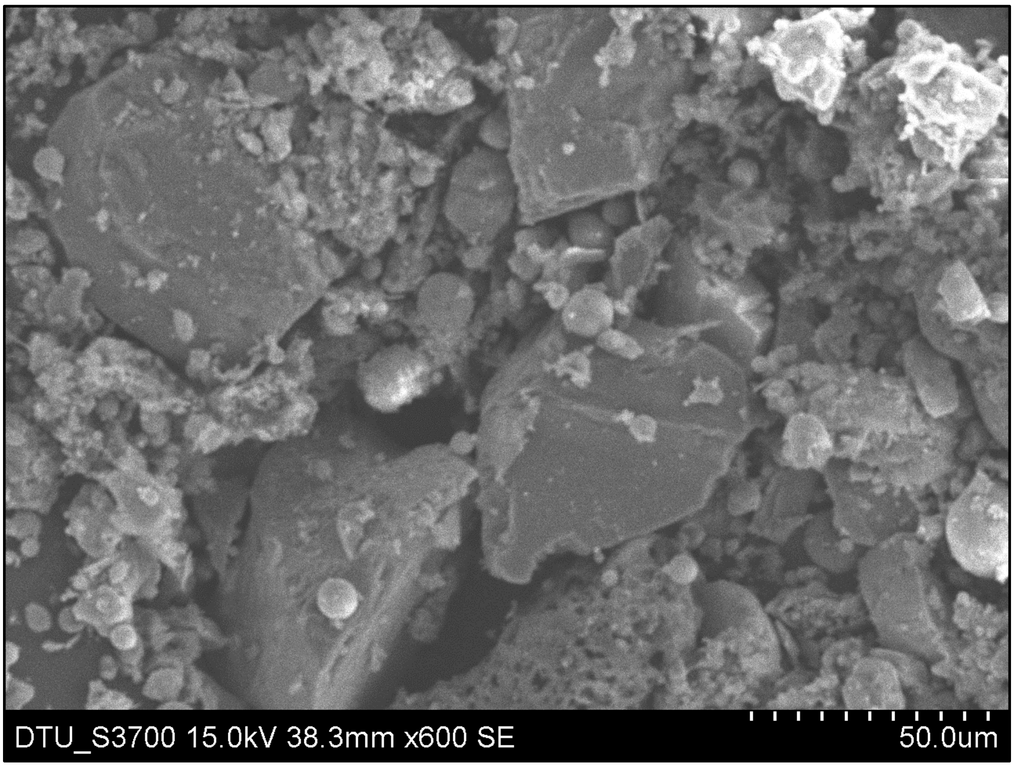

Fig 8 Pond Ash and Lime at 50µm scale

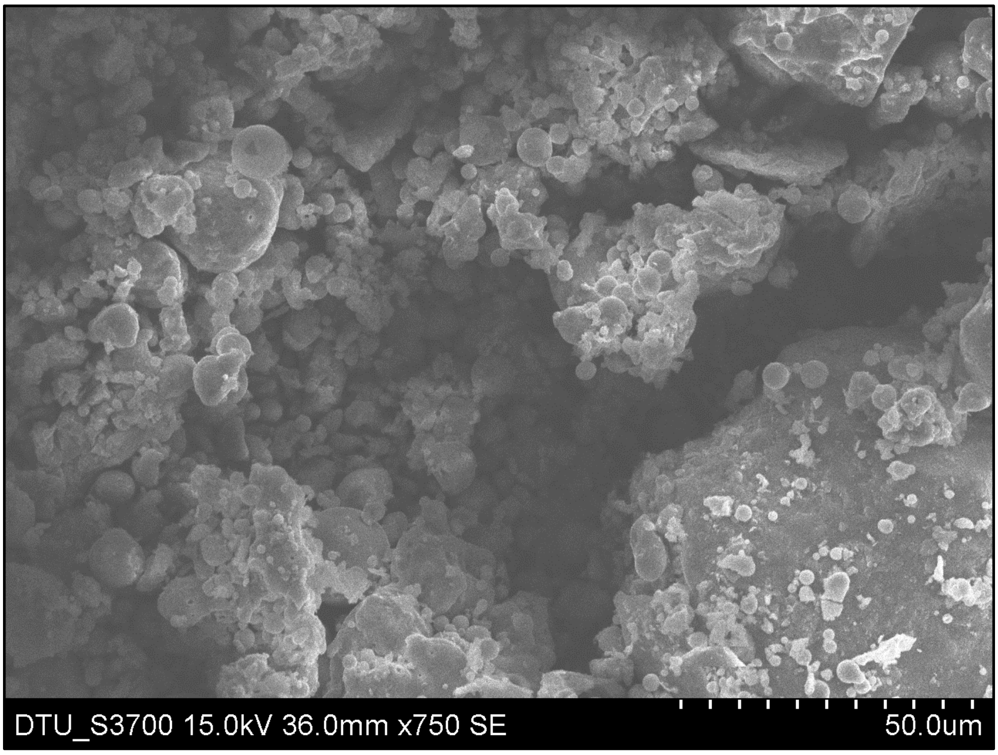

Fig 9 Pond Ash and Soil at 50µm scale

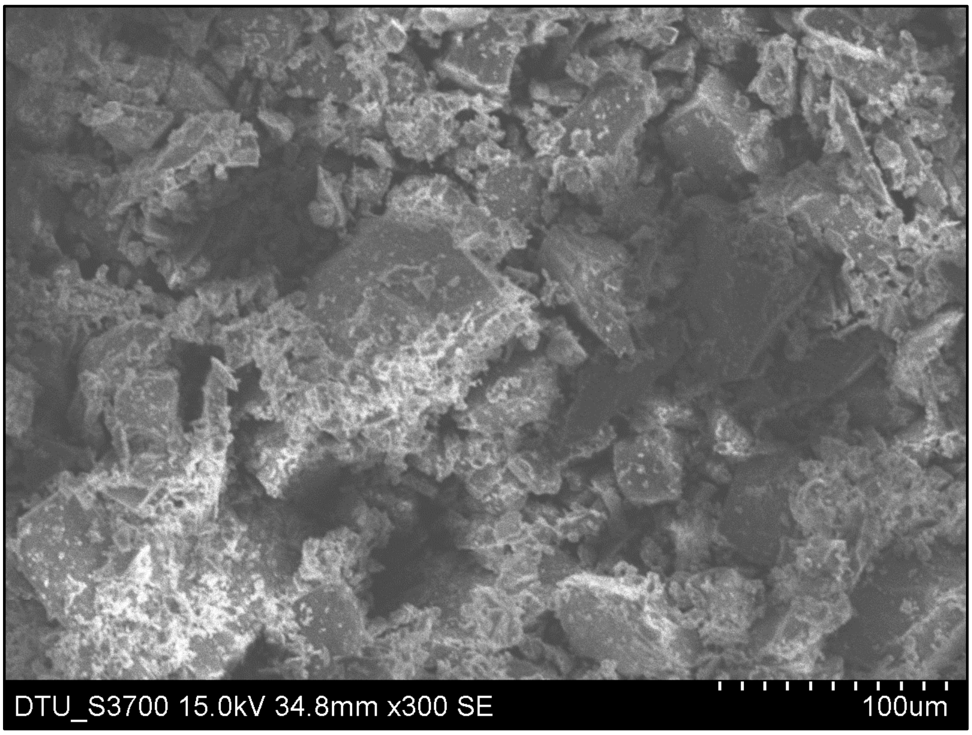

Fig 10 Lime at 100 µm scale.

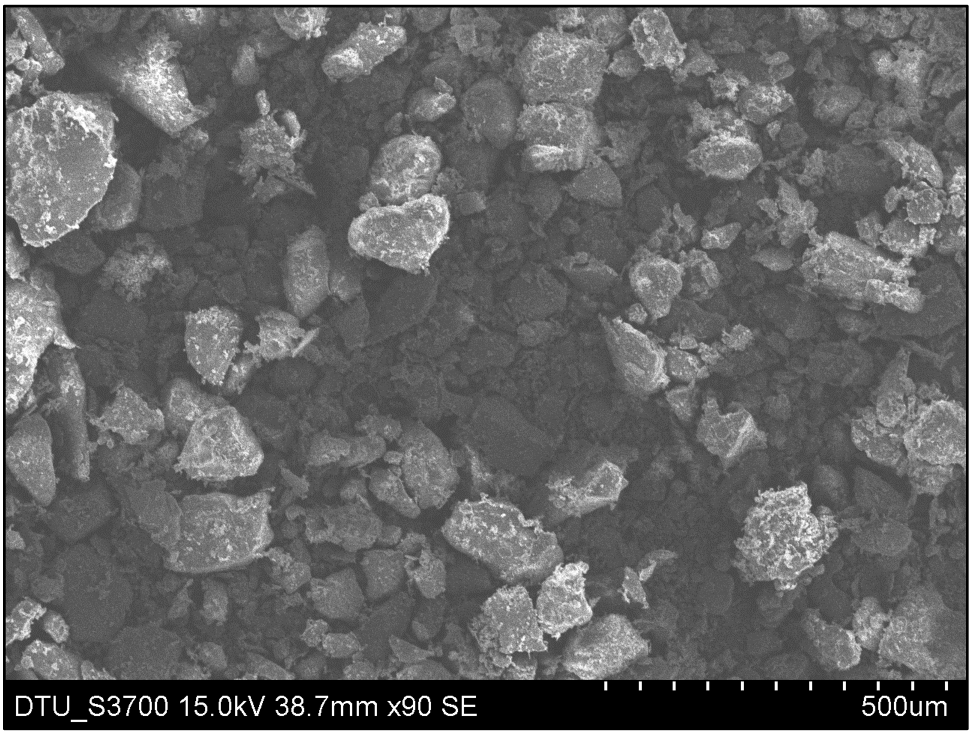

Fig 11 Soil at 500 µm scale.

4.5 X-Ray Diffraction Analysis

Mineral identification is based on d-spacings and relative peak intensities. All minerals generate multiple diffraction peaks. Identification is much simpler if only one mineral is present in the sample, but even then it is not necessarily a matter of certainty and may require calibrating data (e.g., elemental or thermal analysis). Mixtures of minerals can produce complex XRD patterns that present a challenge in mineral identification. However, several factors mitigate the complexity somewhat for pond ash. Most pond ash contain only a few minerals, and these minerals tend to segregate into particle size fractions, which are normally analyzed separately to further reduce complexity. Also, the minerals that occur frequently in pond ash constitute only a small fraction of the >40,000 that have been identified.

Here the mineral information with comparative proportion with other coal ashes like Fly ash,Bottom ash & Soil is given.

Table 3. Chemical composition of Pond Ash with other Indian coal ash & soil (**N Pandian**)

COMPOUNDS	FLY ASH	**POND ASH**	BOTTOM ASH	SOIL
SiO_2	38–63	**37.7–75.1**	23–73	43–61
Al_2O_3	27–44	**11.7–53.3**	13–26.7	12–39
TiO_2	0.4–1.8	**0.2–1.4**	0.2–1.8	0.2–2
$Fe_2\ O_3$	3.3–6.4	**3.5–34.6**	4–10.	9 1–14
MnO	0–0.5	**0–0.6**	0–0.3	0–0
MgO	0.01–0.5	**0.1-0.8**	0.1–0.7	0.2–3.0
CaO	0.2–8	**0.2-0.6**	0.1–0.8	0–7
K2O	0.04–0.9	**0.1-0.7**	0–0.56	0.3–2
Na_2O	0.07–0.43	**0.05-0.31**	0–0.3	0.2–3

Fig 12 XRD Apparatus in our Nano Lab

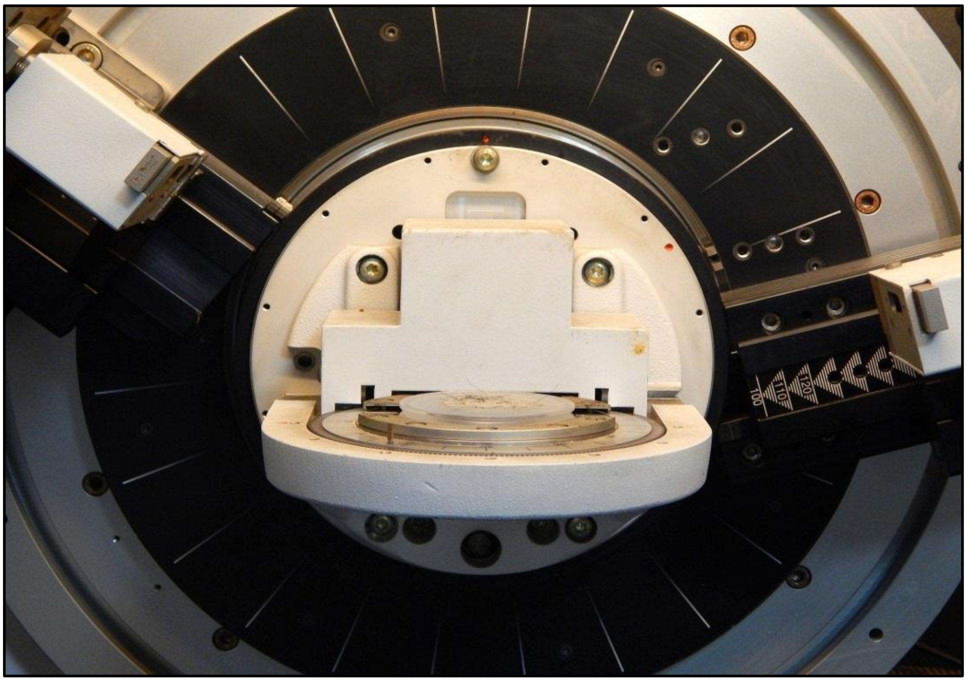

Fig 13 Installation of sample

Diffractogram : POND ASH, LIME & FIBRE

Table: Diffractogram of Pond Ash + Lime + Hair

No.	2-theta	d-spacing	Counts	InT/100
1	3.78	23.3560	246	24.6
2	5.04	17.5195	255	25.5
3	5.96	14.8170	453	45.3
4	6.46	13.6713	261	26.1
5	7.26	12.1665	304	30.4
6	9.44	9.3612	246	24.6
7	11.30	7.8242	167	16.7
8	13.28	6.6617	277	27.7
9	14.46	6.1206	288	28.8
10	16.54	5.3553	252	25.2
11	19.26	4.6047	333	33.3
12	19.74	4.4938	327	32.7
13	20.14	4.4055	302	30.2
14	24.34	3.6539	329	32.9
15	26.96	3.3045	905	90.5
16	28.20	3.1620	538	53.8
17	29.86	2.9898	290	29.0
18	31.16	2.8680	879	87.9
19	32.58	2.7462	153	15.3
20	33.50	2.6728	263	26.3
21	35.56	2.5226	987	98.7
22	41.10	2.1944	286	28.6
23	41.46	2.1762	333	33.3
24	42.18	2.1407	239	23.9
25	42.74	2.1139	311	32.1
26	44.08	2.0527	231	24.9
27	45.20	2.0044	258	26.2

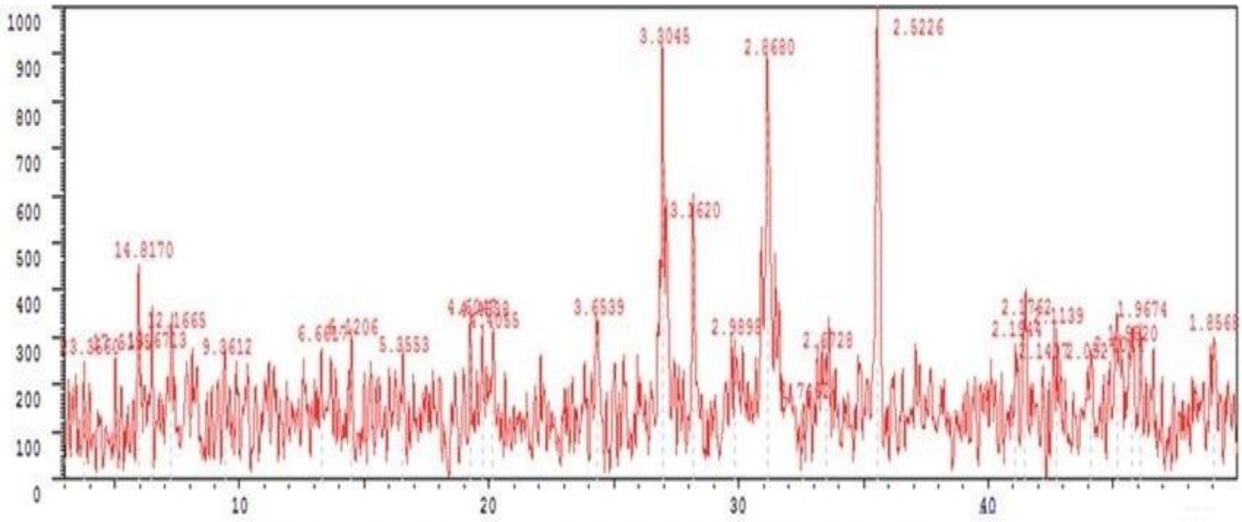

Fig. 14 X-Ray diffraction pattern of Pond Ash + Lime + Hair Mixture

Diffractogram : POND ASH, SOIL & FIBRE

Table: Diffractogram of Pond Ash + Soil + Hair

N	2-theta	d-spacing	Counts	InT/100
1	3.97	22.2387	967	96.7
2	4.61	19.1526	881	88.1
3	5.78	15.2781	870	87.0
4	6.22	14.1983	736	73.6
5	6.27	14.0851	796	79.6
6	17.06	5.1932	667	66.7
7	17.07	5.1902	724	72.4
8	17.10	5.1812	600	60.0
9	17.11	5.1782	514	51.4
10	19.11	4.6405	492	49.2
11	26.87	3.3154	884	88.4
12	30.63	2.9164	230	23.0
13	30.68	2.9118	294	29.4
14	31.46	2.8413	52	5.2
15	31.51	2.8369	184	18.4
16	32.15	2.7819	556	55.6

17	37.37	2.4044	512	55.3
18	42.89	2.1069	474	48.5

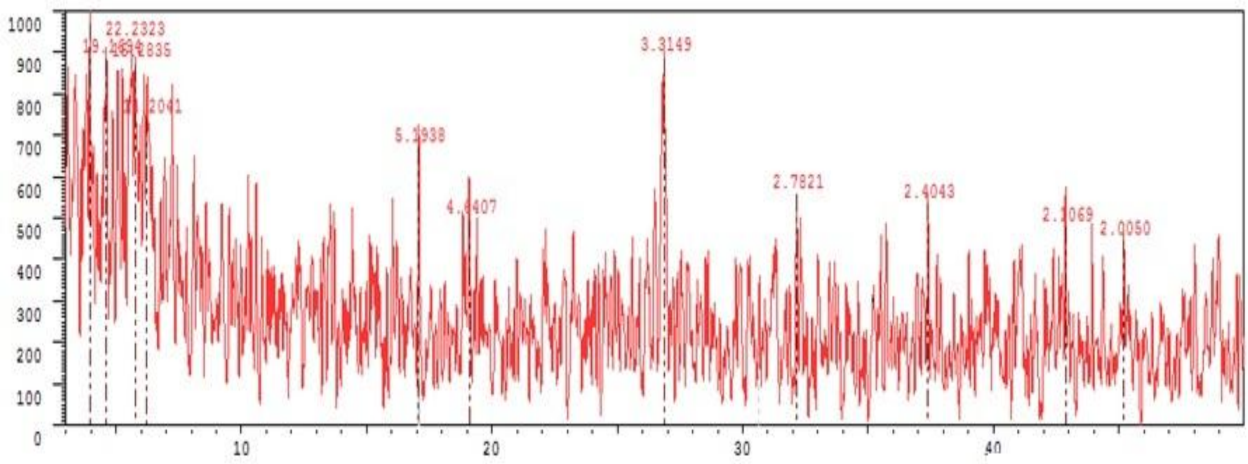

Fig. 15 X-Ray Diffraction of Pond Ash+Soil+Hair Mixture

Here,

The mineralogical fraction of the Pond ash Composite evidenced the presence of the following components: quartz (SiO_2), mullite ($A1_6Si_20_{13}$), hematite (Fe2 O_3), magnetite (Fe_3 O_4),Lime (CaO).

Pond ash showed the sharp peaks at d=3.3045, d=2.868, d= 2.522 confirms the presence of Mullite and other alumina silicates. Silty soil with fibre shows a range of peaks with a bulge and a sharp peak at d=2.392 confirm presence of quardz calcite, and feldspar when matched with JCPDS (*Joint Committee on Powder Diffraction Standards*) data book. But when the whole composite mixture taken simultaneously it shows amorphous material presence as no such isolated peak can be identified.

4.6 Standard Proctor Compaction Test , IS: 10074 (1982).

Sample weight = 3 kg

Mass of mould + base plate (W_1) = 4325 gm

Volume of mould (V) = 981.74 c.c.

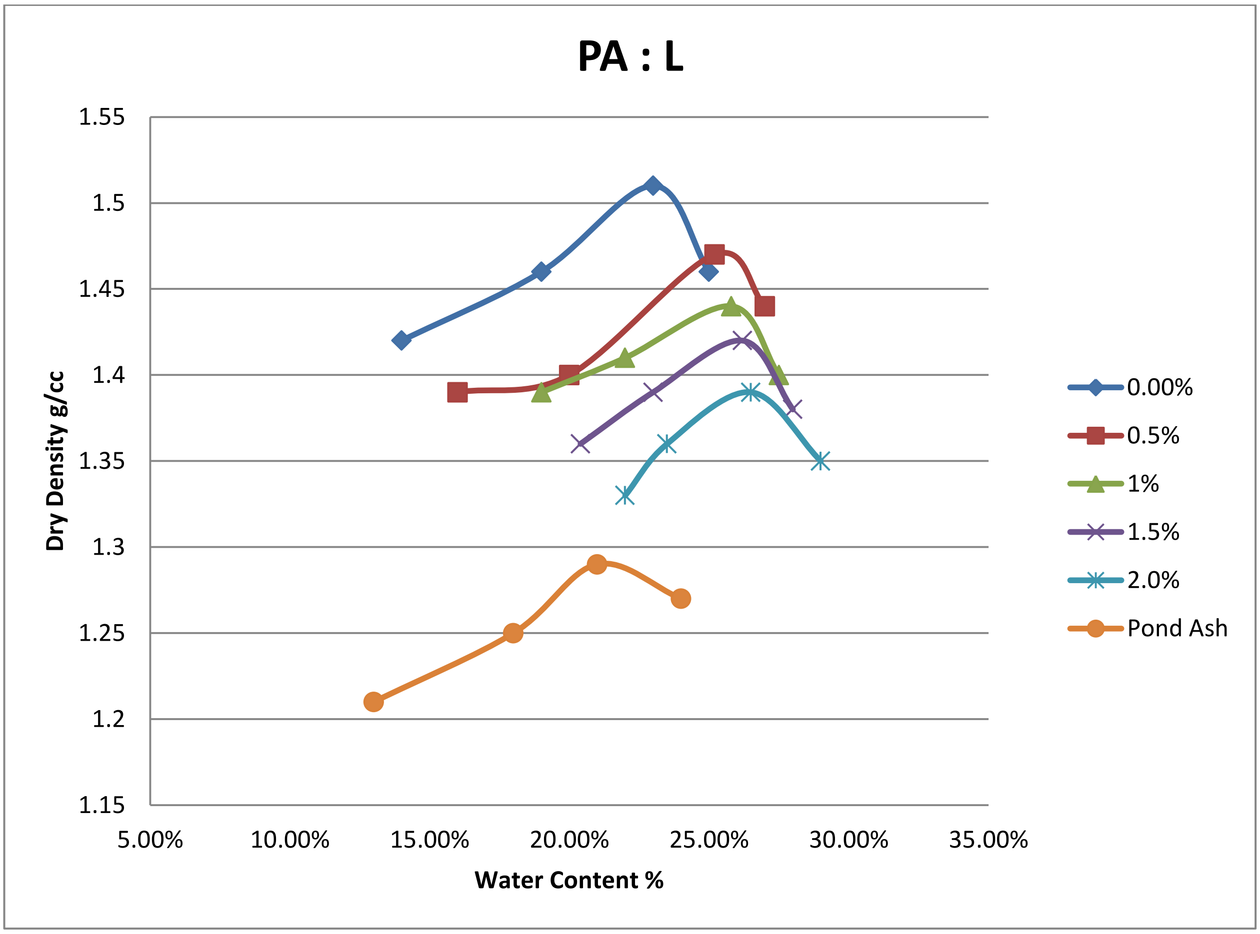

Fig 16 PA:L Proctor compaction test curves for at different reinforcement

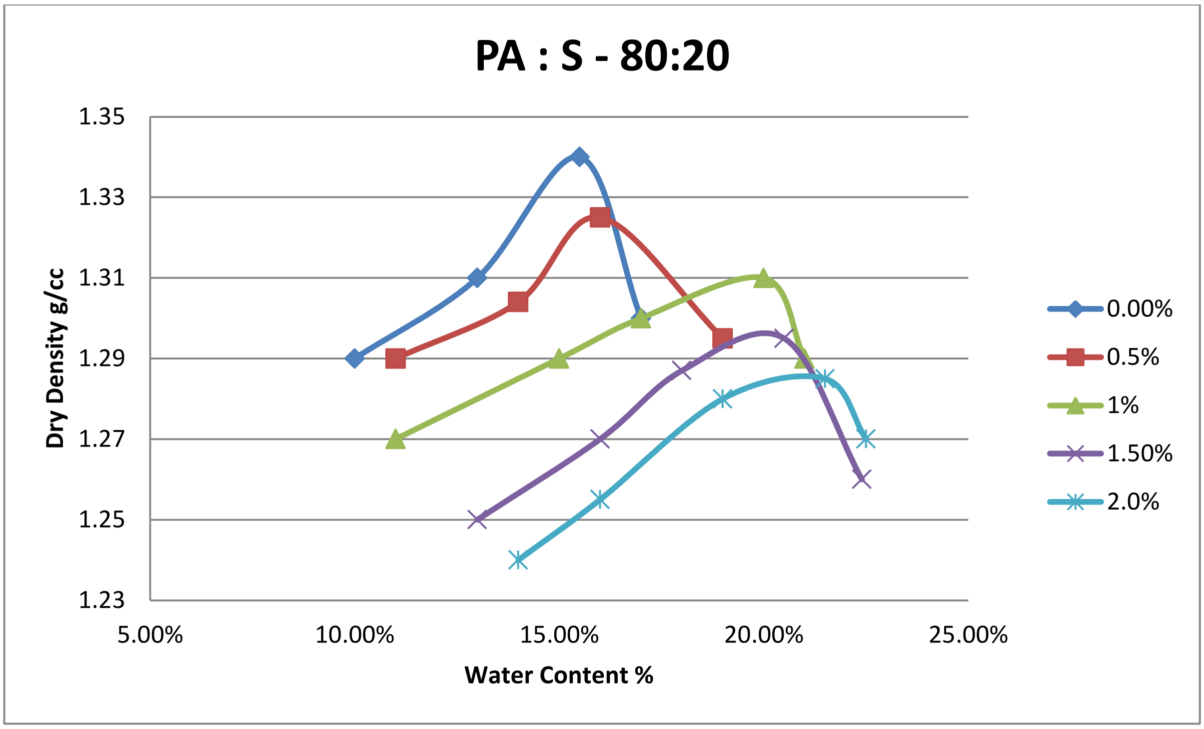

Fig 17 PA:S-80:20 Proctor compaction test curves for at different reinforcement

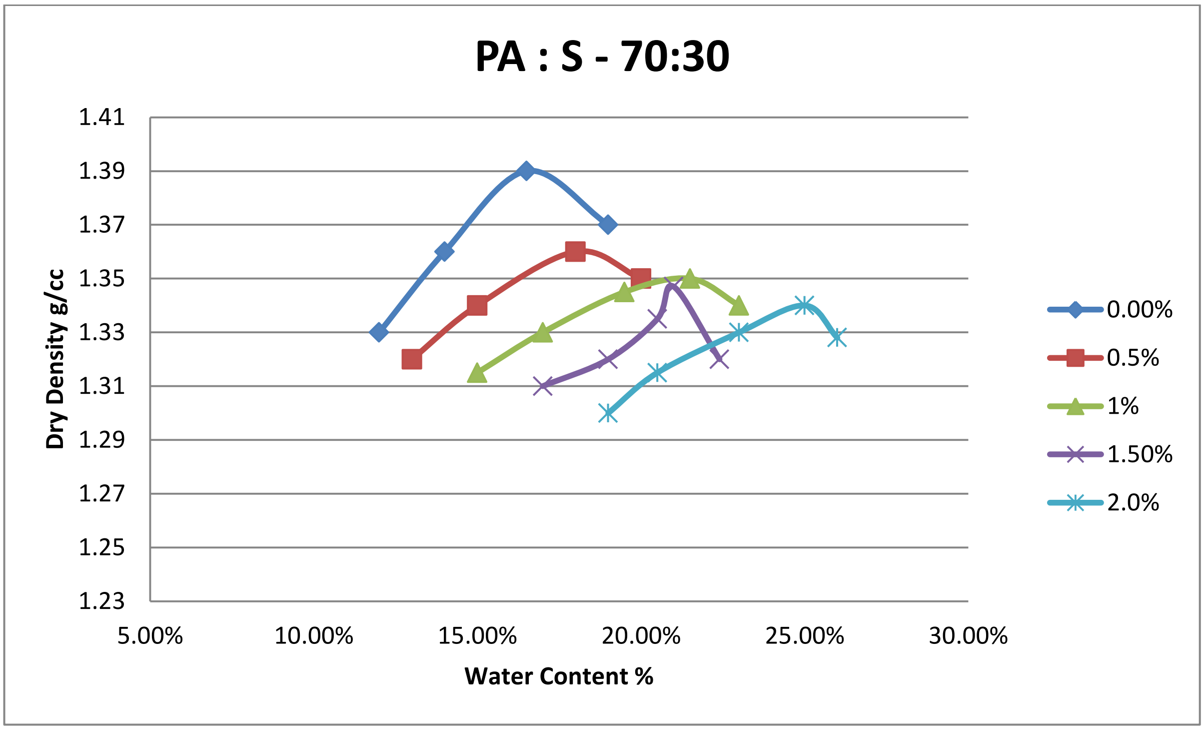

Fig 18 PA:S – 70:30 Proctor compaction test curves for at different reinforcement

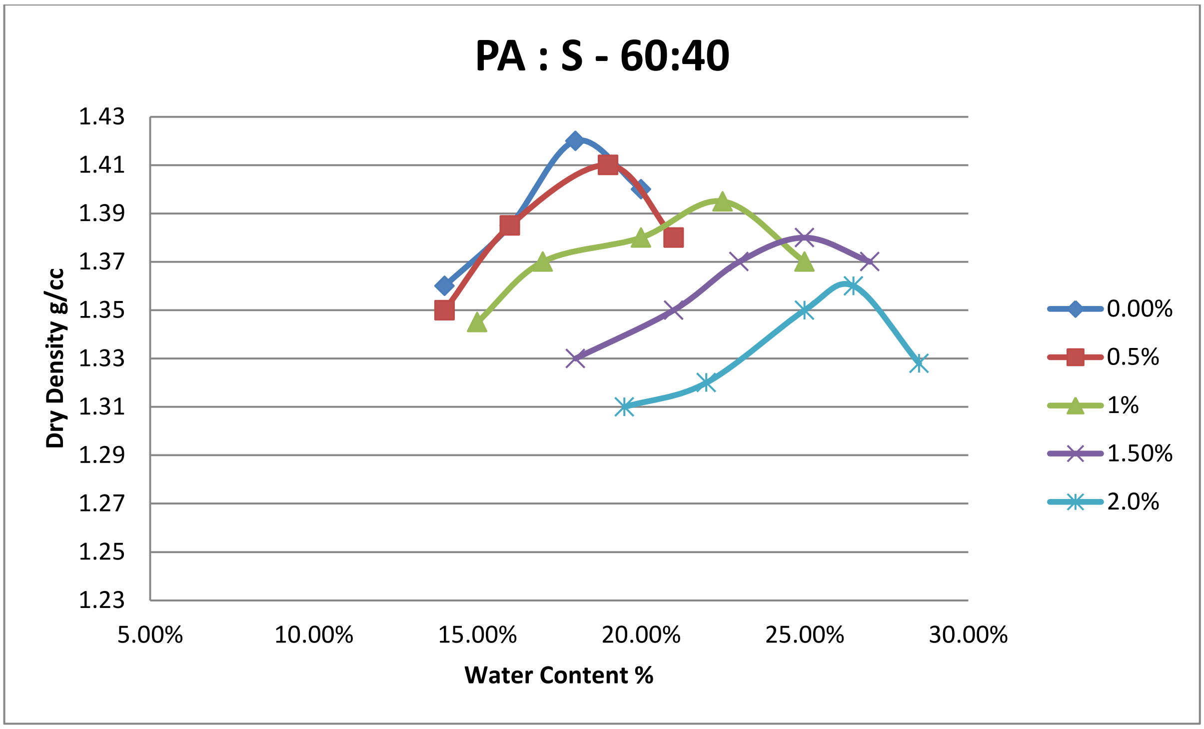

Fig 19 PA:S – 60:40 Proctor compaction test curves for at different reinforcement

Densification of improves the engineering properties. The compacted unit weight of the material depends on the amount and method of energy application, grain size distribution, plasticity characteristics and moisture content at compaction.

Here, from fig 16 can easily get that Pond ash with low MDD get strengthened by the inclusion of Lime but get decreased again by increasing percentage of fibre, which also responsible for increase of OMC of P:L composite mixtures.

While on other hand in P:S mixtures MDD increases as Percentage of soil increases otherwise respond same behaviour for the inclusion of fibre i.e increment of OMC & decrement of MDD with fibre percentage increases

4.7 Unconfined Compression Strength Test, IS: 2720 (Part 10) (1987).

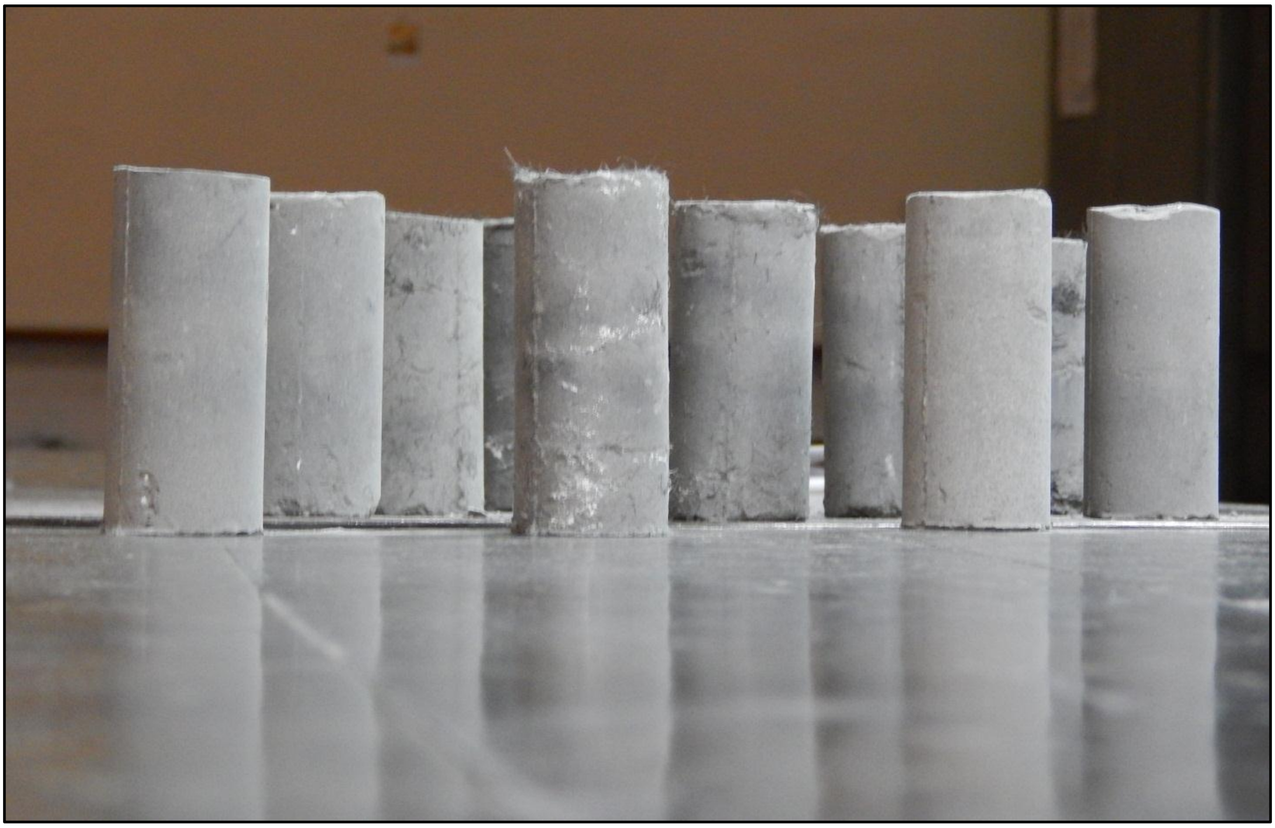

Fig. 20 UCS Samples

Unconfined compressive strength tests were carried out on different pond ash composite samples compacted to their corresponding OMC's.

This experiment is used to determine the unconfined compressive strength of the pond ash composite sample which in turn is used to calculate the unconsolidated, undrained shear strength of unconfined composite samples. The unconfined compressive strength (qu) is the compressive stress at which the unconfined cylindrical sample fails under simple compressive test. The experimental setup constitutes of the compression device and dial gauges for load and deformation. The load was taken for different readings of strain dial gauge taken. The corrected cross-sectional area was calculated by dividing the area by (1- ε) and then the compressive stress for each step was calculated by dividing the load with the corrected area.

Pond Ash –Lime UCS

3-Day UCS

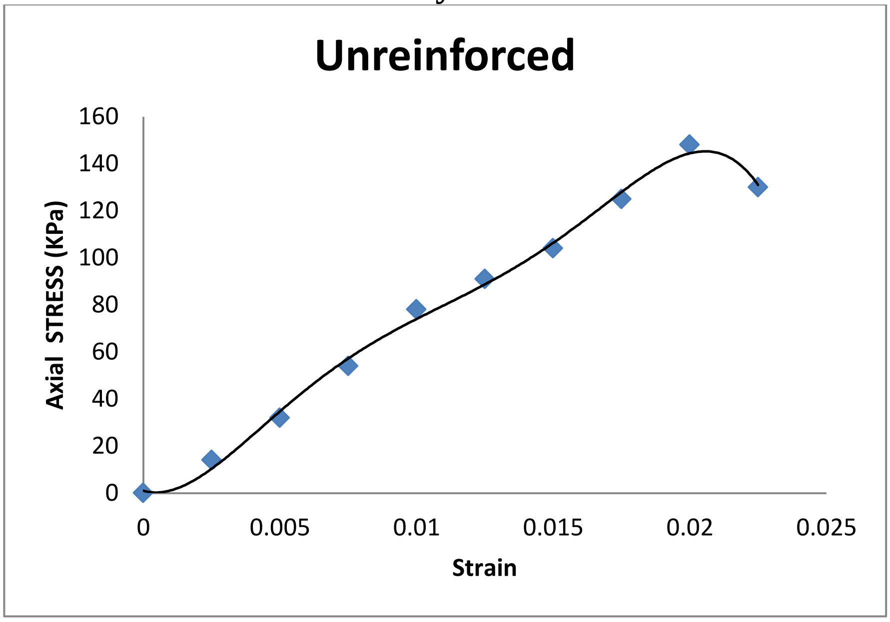

Fig. 21 3 day Pond Ash-Lime 3 day UCS -unreinforced

As obtained from graph,

UCS = 148.65 kPa

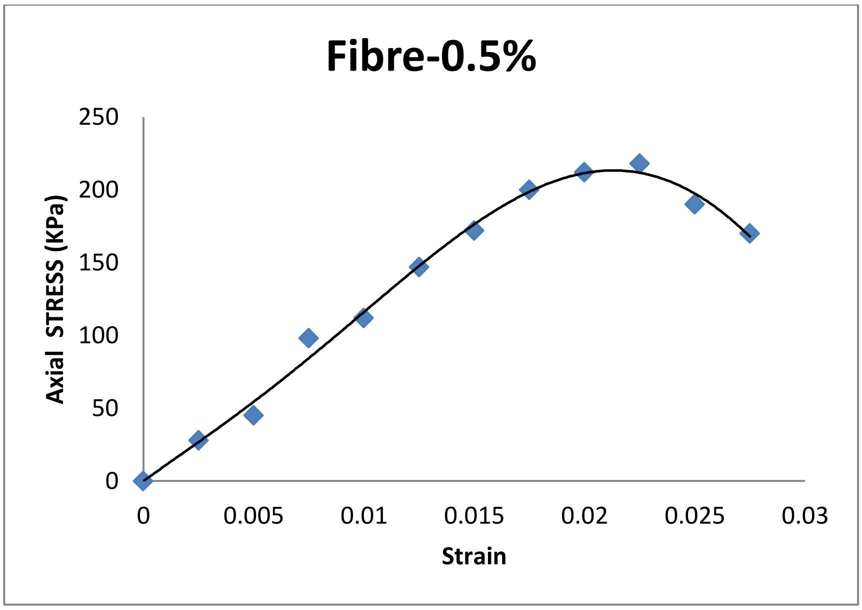

Fig. 22 3 day Pond Ash-Lime 3 day UCS @ 0.5%

As obtained from graph,

UCS = 218.634kPa

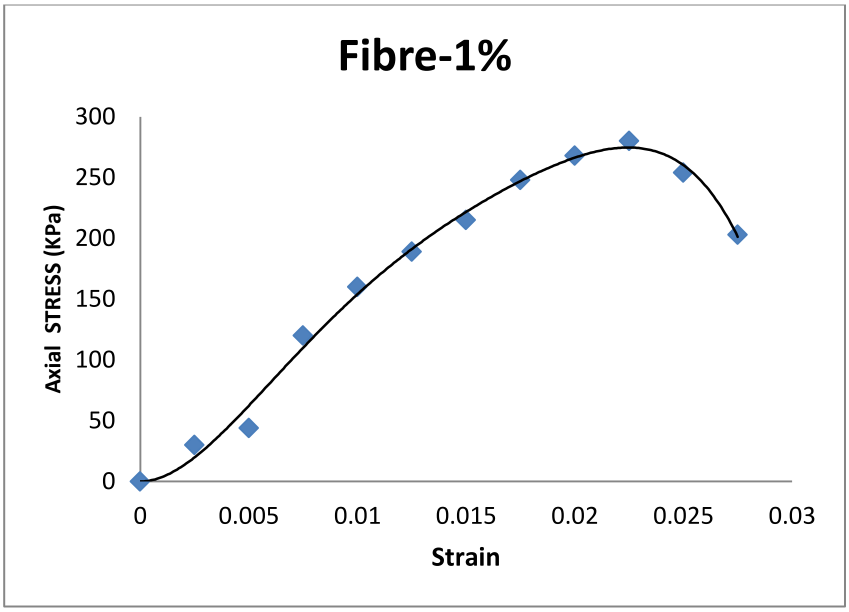

Fig. 23 3 day Pond Ash-Lime 3 day UCS @ 1%

As obtained from graph,

UCS = 280.56 kPa

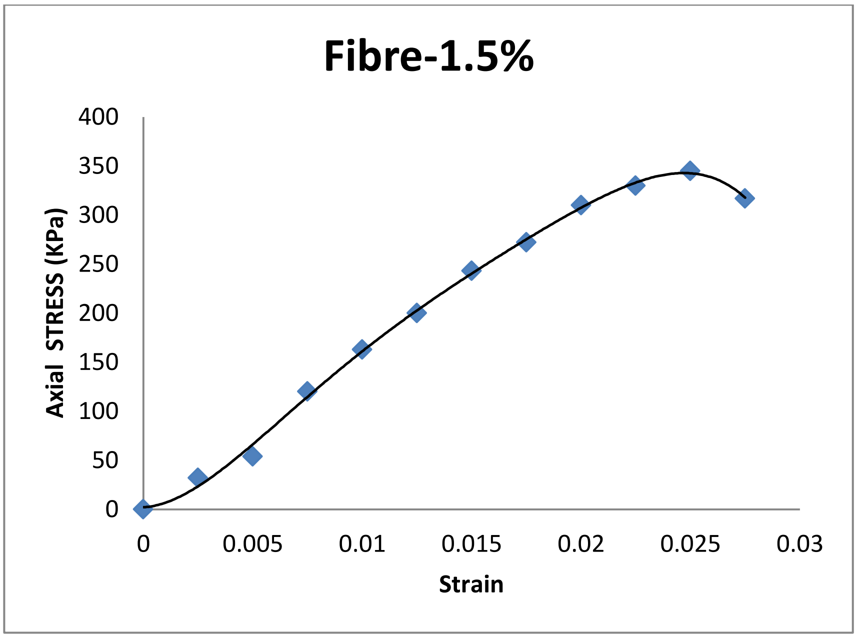

Fig. 24 3 day Pond Ash-Lime 3 day UCS @ 1.5%

As obtained from graph,

UCS = 345.72 kPa

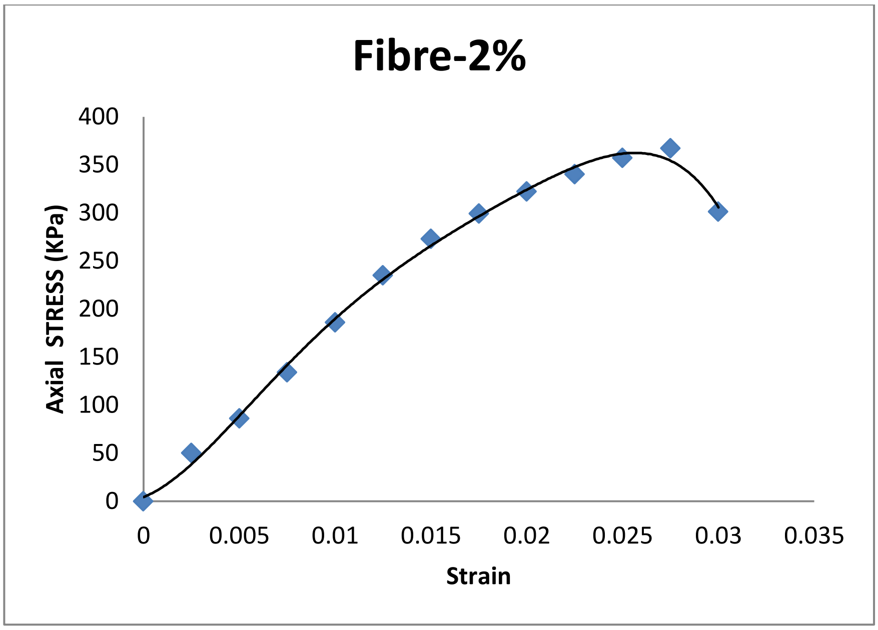

Fig. 25 3 day Pond Ash-Lime 3 day UCS @ 2%

As obtained from graph,

UCS = 367.65 kPa

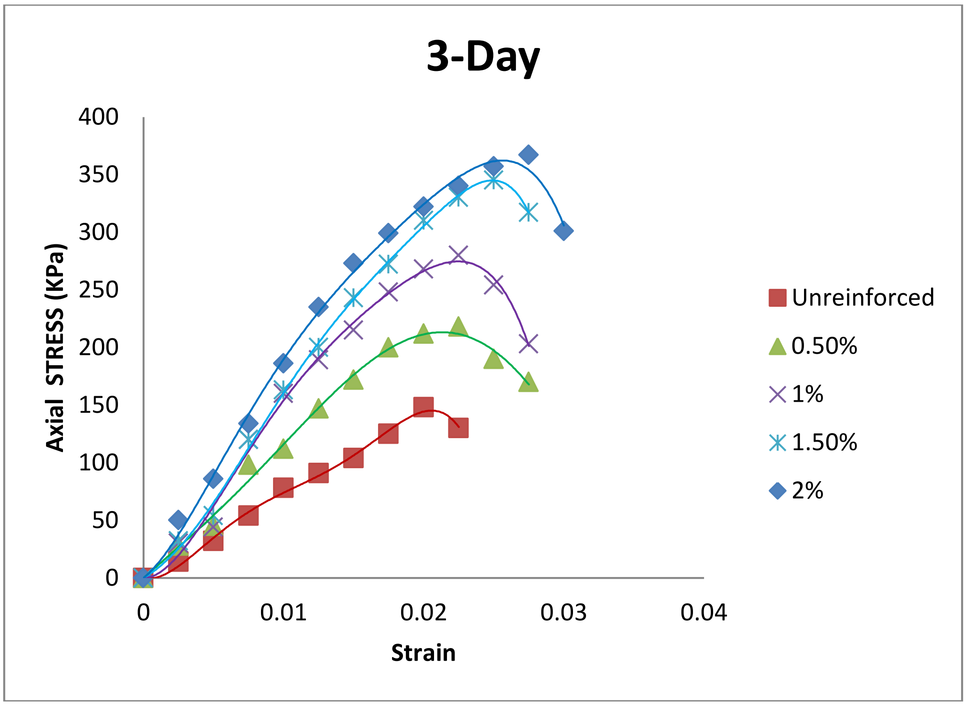

Fig. 26 3 day, UCS test curve comparison of samples at different reinforcement

7-Day UCS

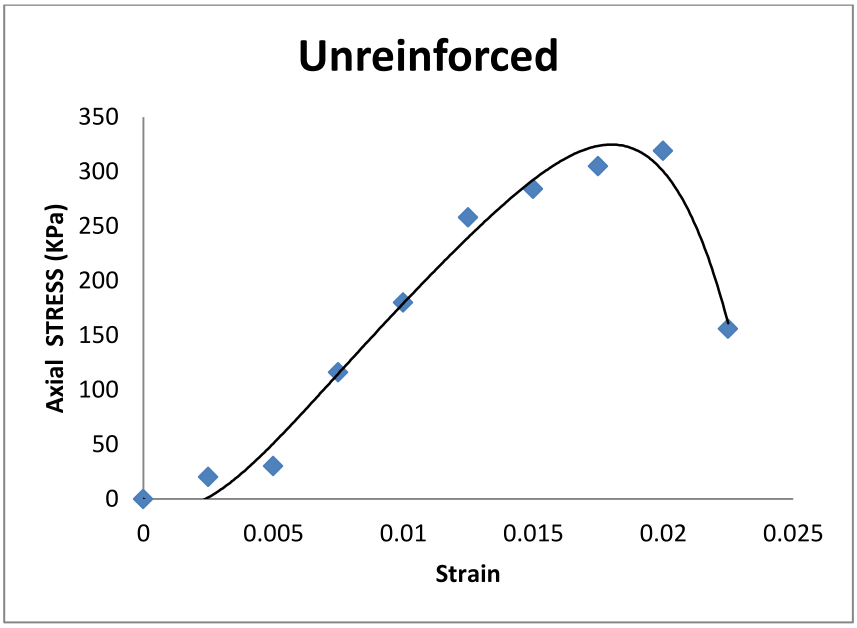

Fig 27 7 day Pond Ash-Lime 3 day UCS-unreinforced

As obtained from graph,

UCS = 319.25 kPa

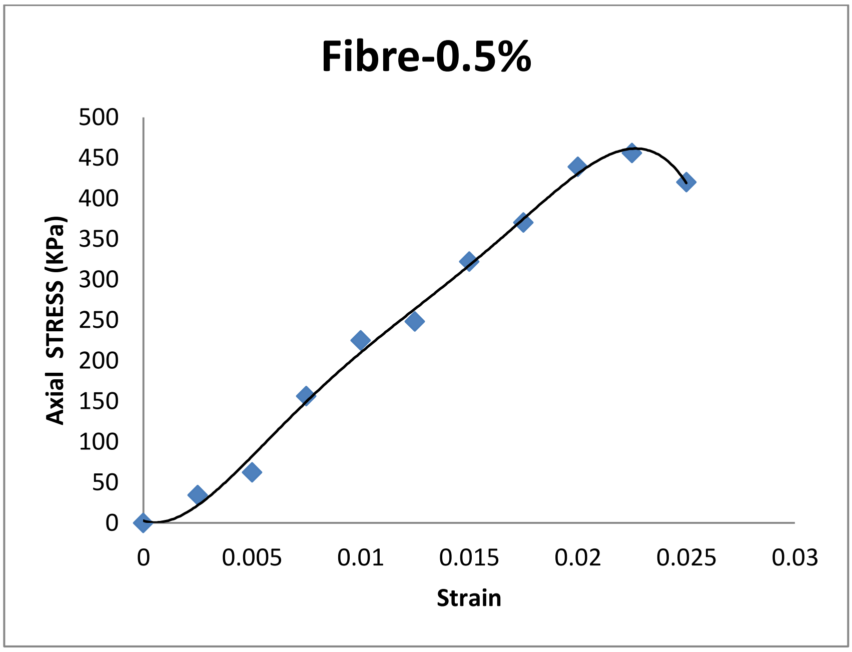

Fig. 28 7 day Pond Ash-Lime 3 day UCS @ 0.5%

As obtained from graph,

UCS = 456.34 kPa

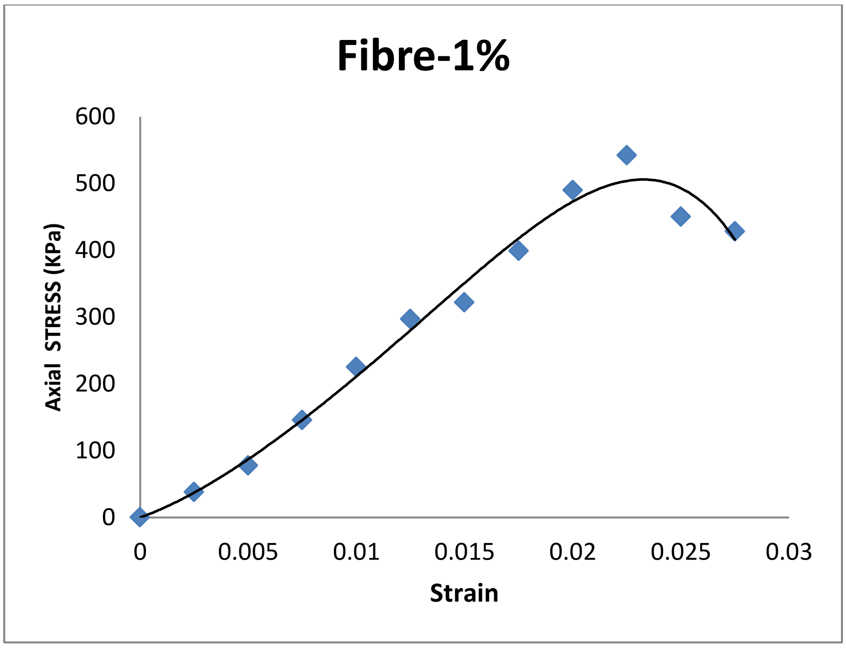

Fig. 29 7 day Pond Ash-Lime 7 day UCS @ 1%

As obtained from graph,

UCS = 549.23 kPa

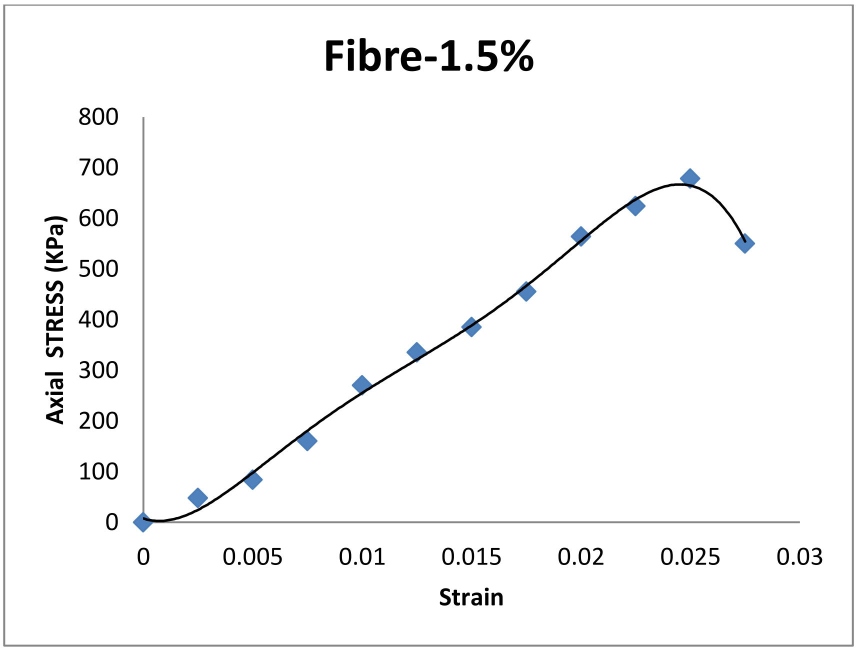

Fig. 30 7 day Pond Ash-Lime 7 day UCS @ 1.5%

As obtained from graph,

UCS = 678.47 kPa

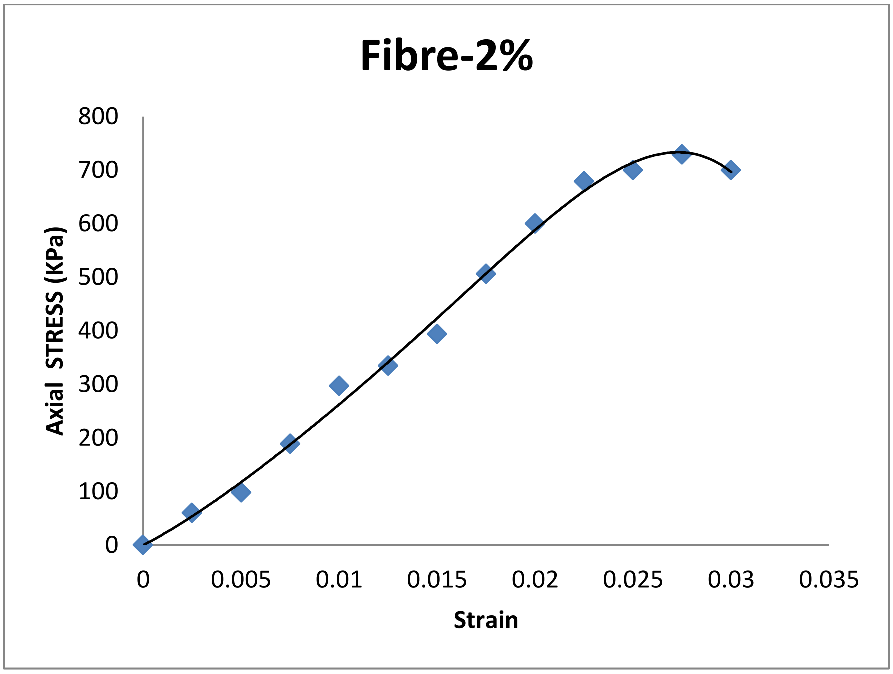

Fig. 31 7 day Pond Ash-Lime 7 day UCS @ 2%

As obtained from graph,

UCS = 729.75 kPa

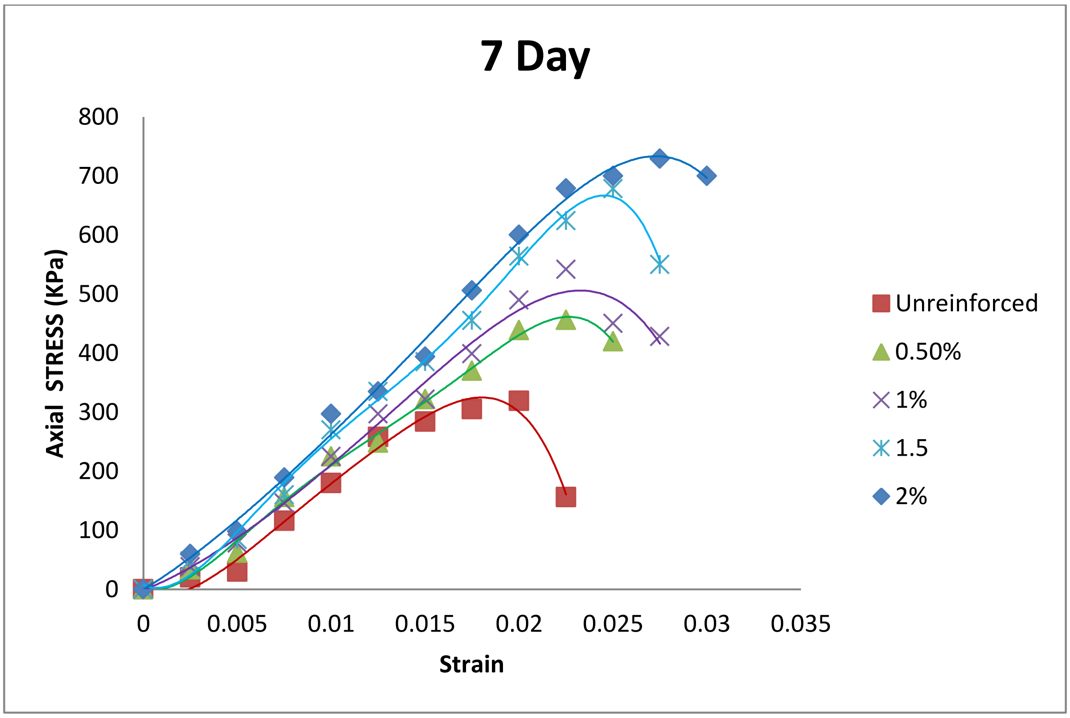

Fig. 32 **7** day, UCS test curve comparison of samples at different reinforcement

28-Day UCS

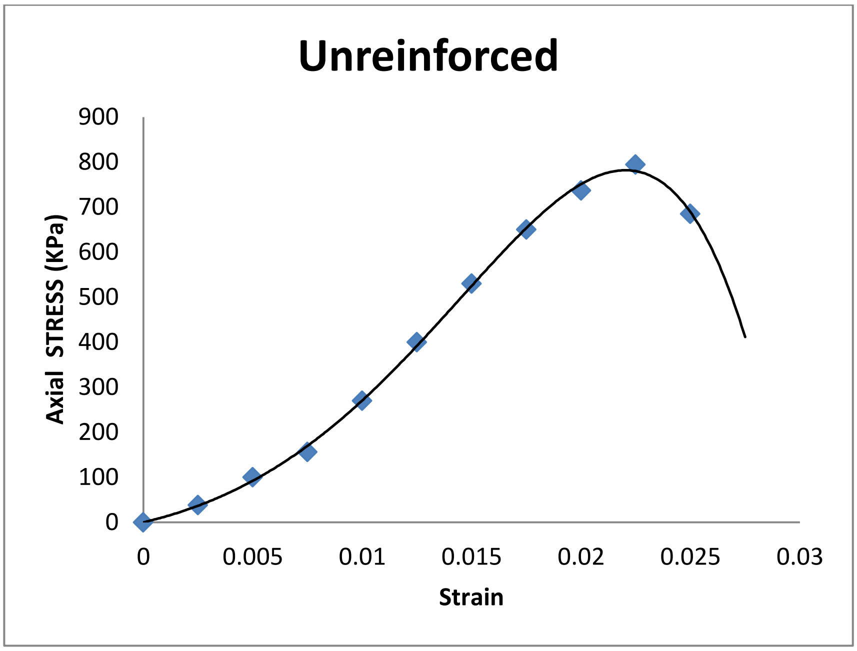

Fig. 33 28 day Pond Ash-Lime 28 day UCS-unreinforced

As obtained from graph,

UCS = 794.21 kPa

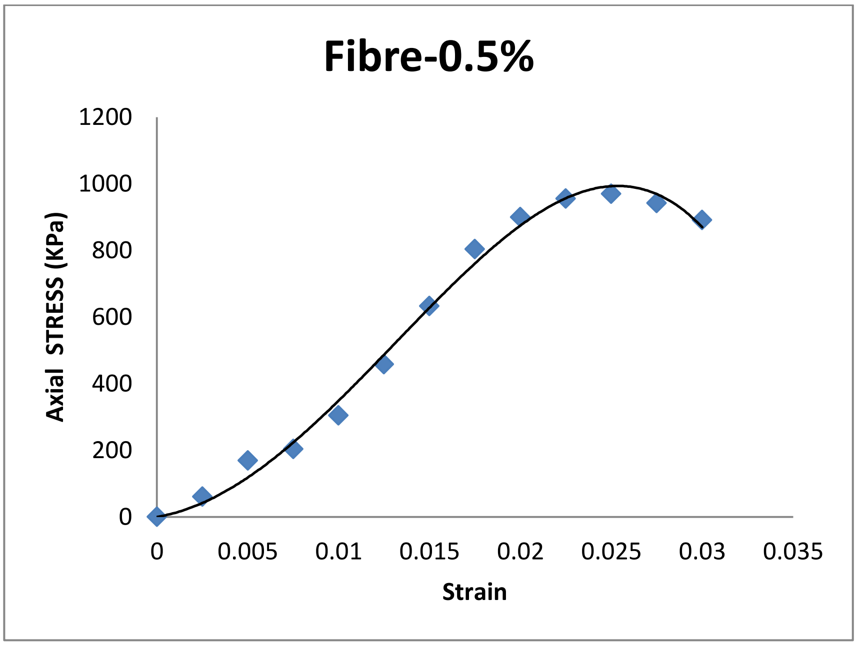

Fig. 34 28 day Pond Ash-Lime 28 day UCS @ 0.5%

As obtained from graph,

UCS = 970.34 kPa

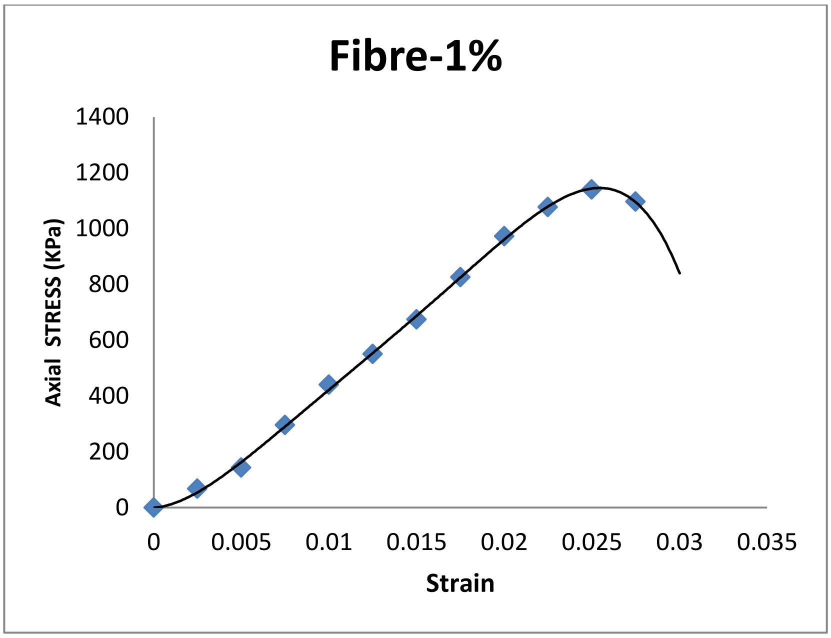

Fig. 35 28 day Pond Ash-Lime 28 day UCS @ 1%

As obtained from graph,

UCS = 1140.65 kPa

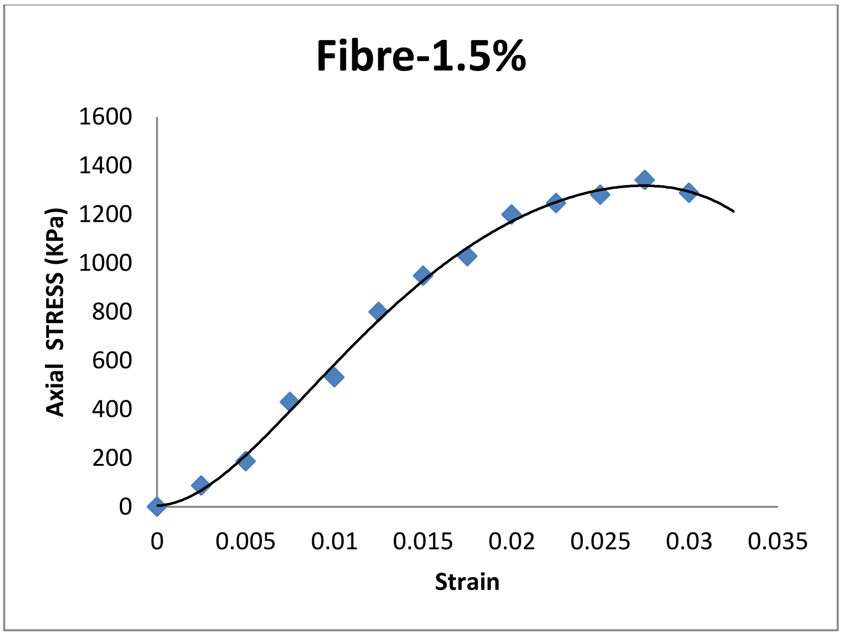

Fig. 36 28 day Pond Ash-Lime 28 day UCS @ 1.5%

As obtained from graph,

UCS = 1340.75 kPa

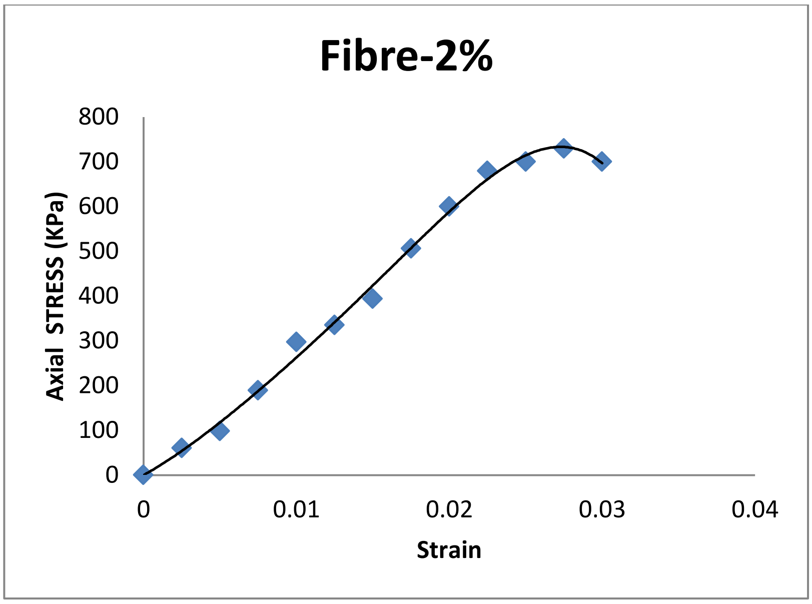

Fig. 37 28 day Pond Ash-Lime 28 day UCS @ 2%

As obtained from graph,

UCS = 1420.36 kPa

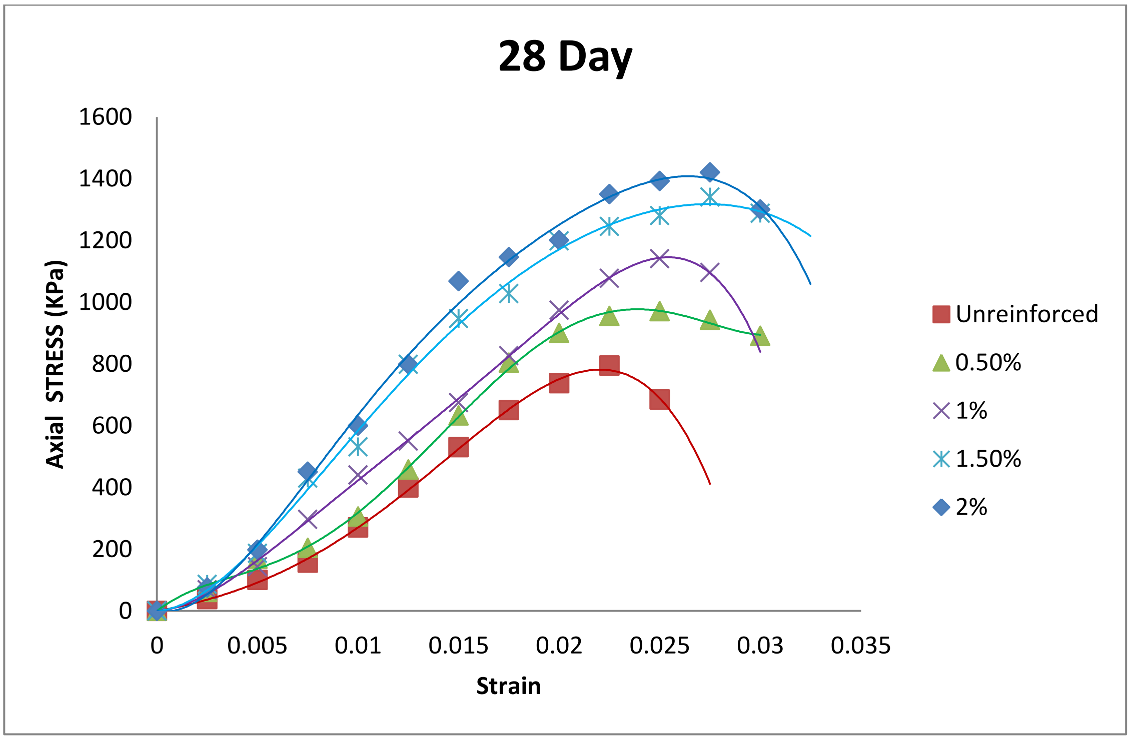

Fig. 38 28 day, UCS test curve comparison of samples at different reinforcement

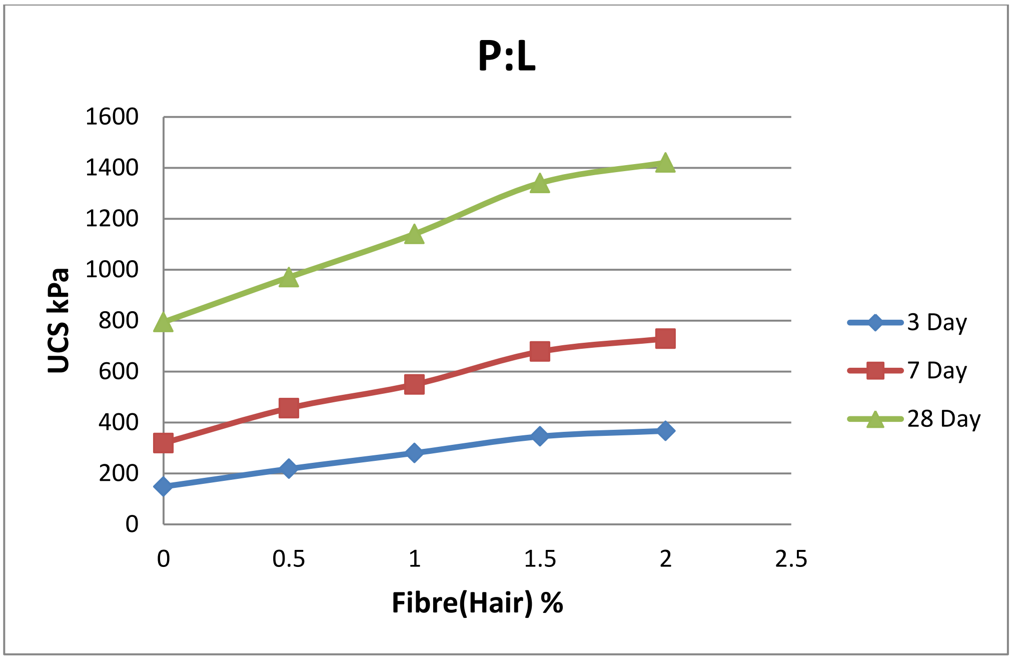

Fig 39 Comparison of UCS test curve of different samples on 3, 7& 28 Days

<u>Pond Ash –Soil (Sandy silt) UCS</u>

P: S – 80:20

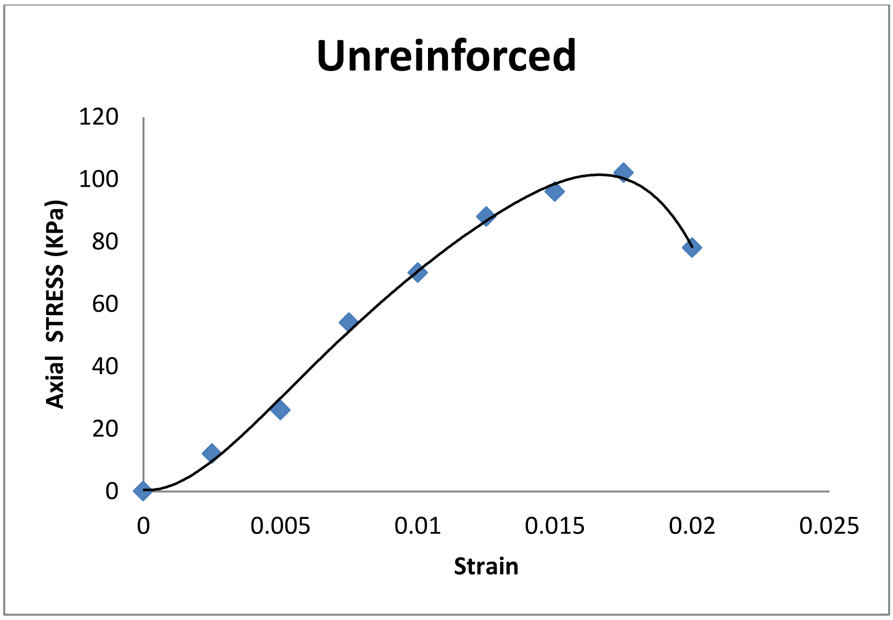

Fig 40 80:20 Pond Ash-Soil UCS-unreinforced

As obtained from graph,

UCS = 102.43 kPa

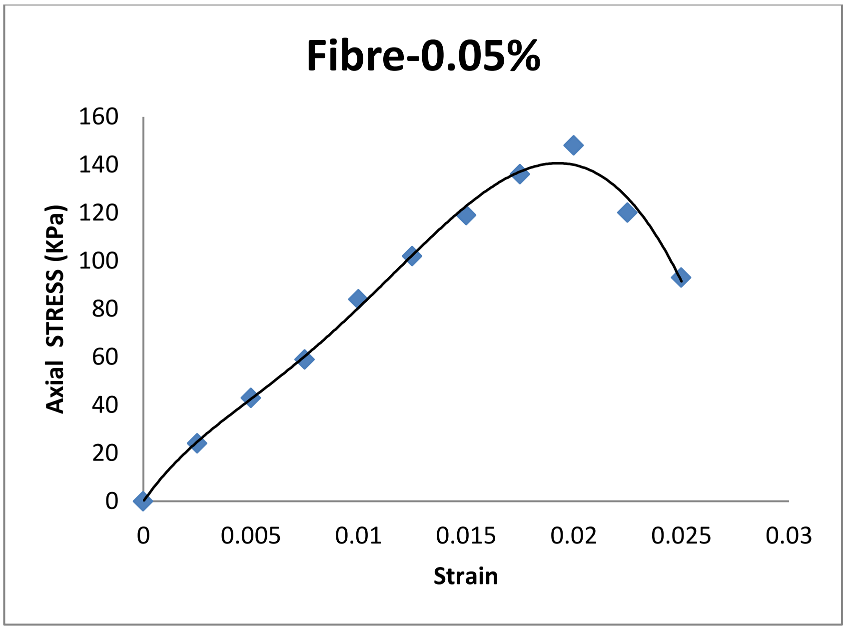

Fig. 41 28 day Pond Ash-Lime 28 day UCS @ 0.05%

As obtained from graph,

UCS = 148.36 kPa

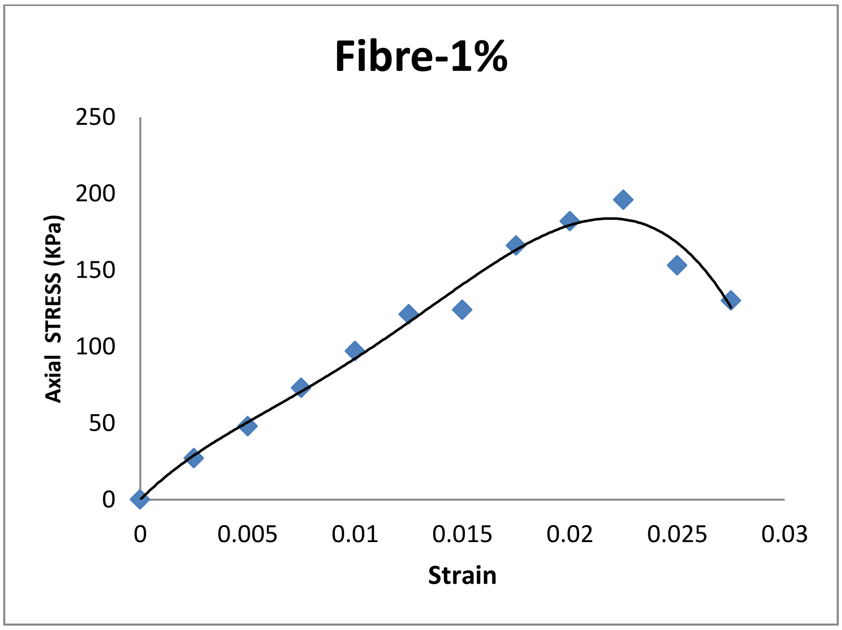

Fig. 42 80:20 Pond Ash-Soil UCS-@ 1%

As obtained from graph,

UCS = 196.33 kPa

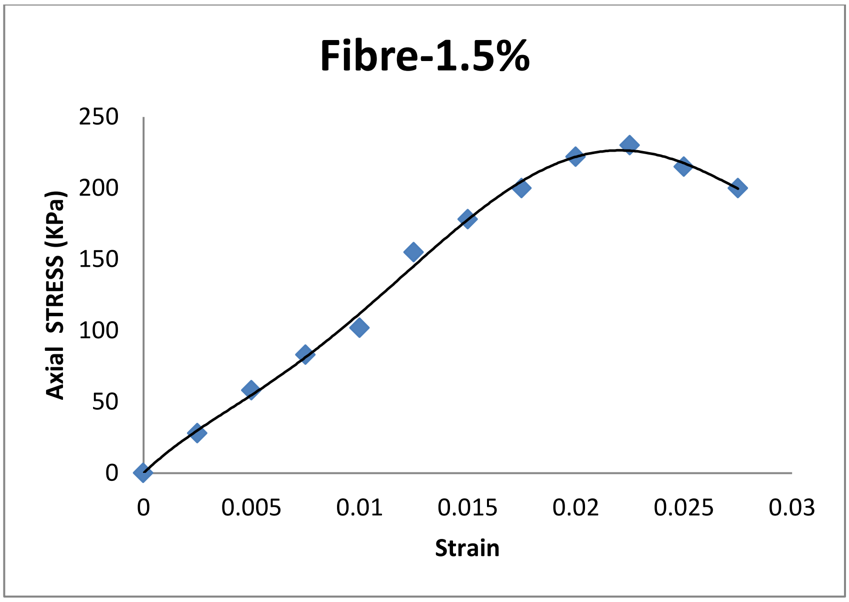

Fig. 43 80:20 Pond Ash-Soil UCS @ 1.5%

As obtained from graph,

UCS = 230.74.kPa

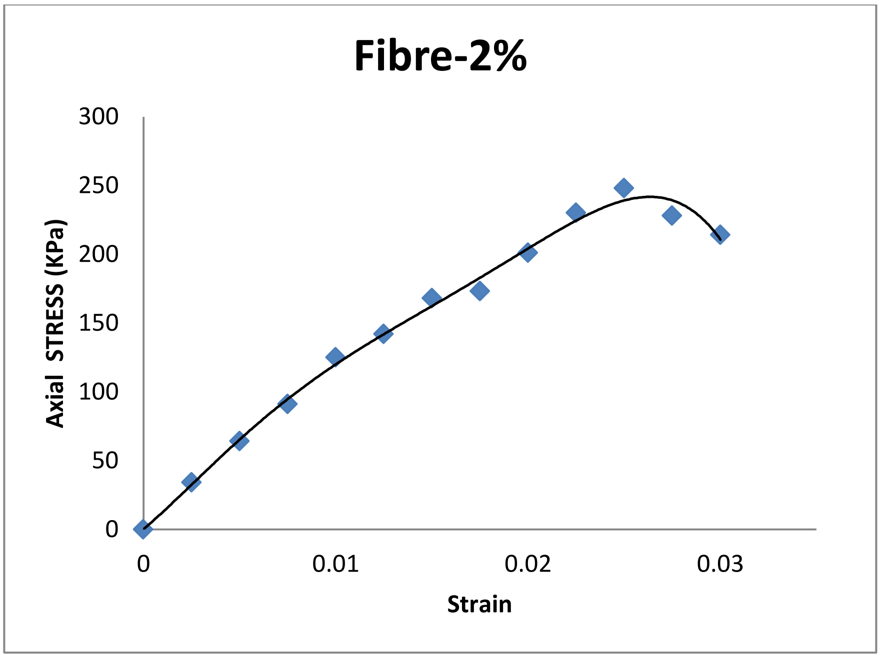

Fig. 44 80:20 Pond Ash-Soil UCS @ 2%

As obtained from graph,

UCS = 248 kPa

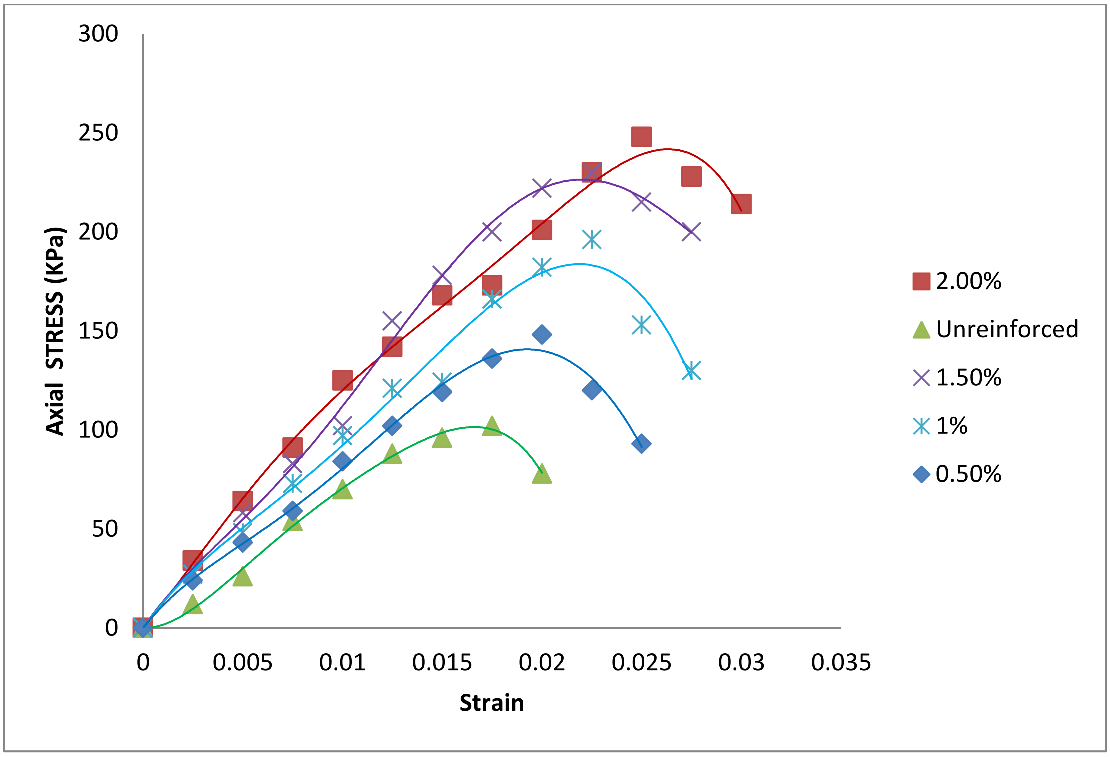

Fig. 45 Comparison of UCS test curve of different samples @ P: S – 80:20

P: S – 70:30

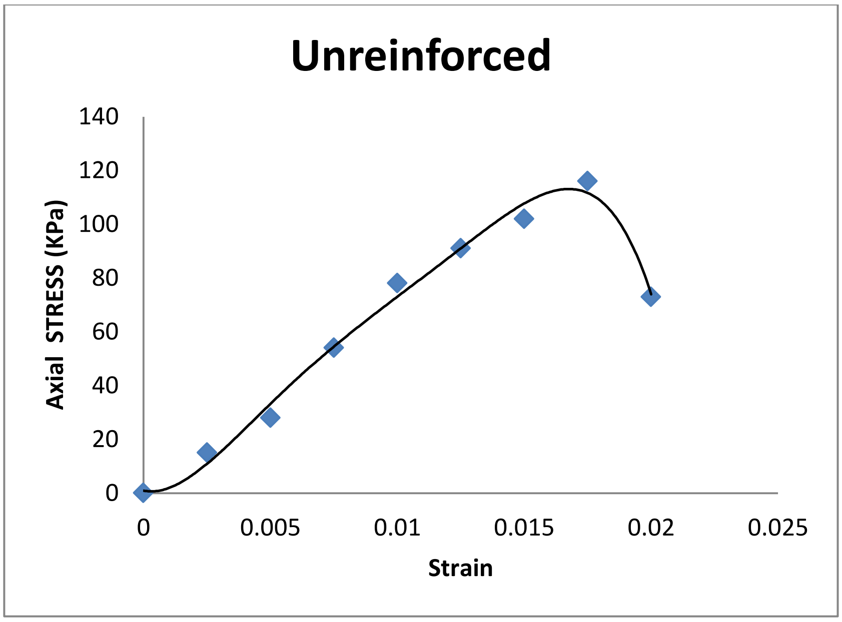

Fig. 46 70:30 Pond Ash-Soil UCS -unreinforced

As obtained from graph,

UCS = 116.44kPa

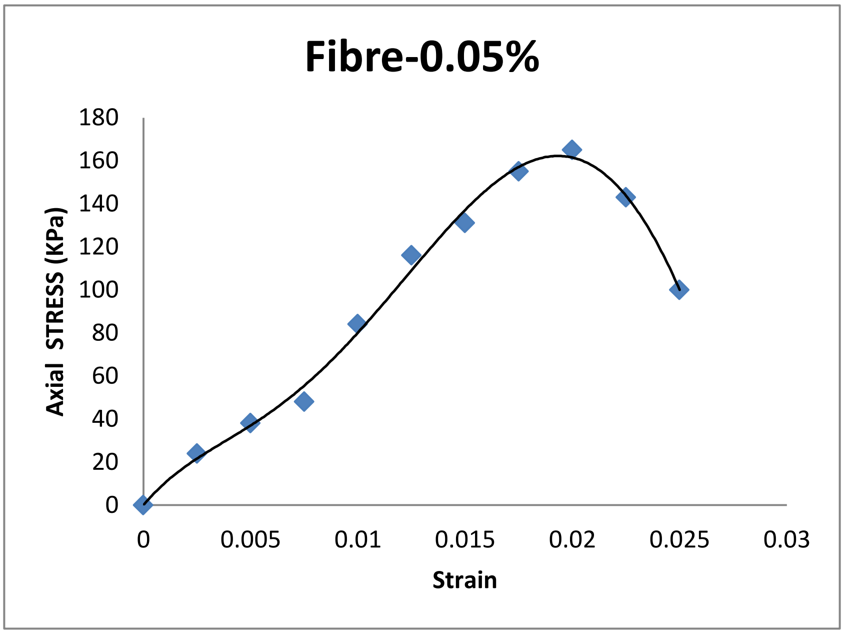

Fig. 47 70:30 Pond Ash-Soil UCS @ 0.05%

As obtained from graph,

UCS = 165.23kPa

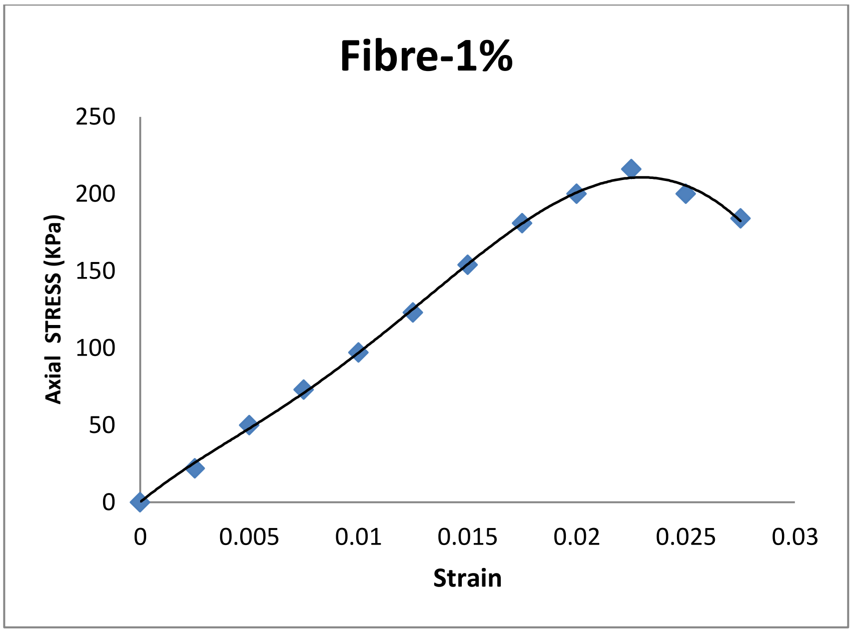

Fig. 48 70:30 Pond Ash-Soil UCS @1%

As obtained from graph,

UCS = 216.57kPa

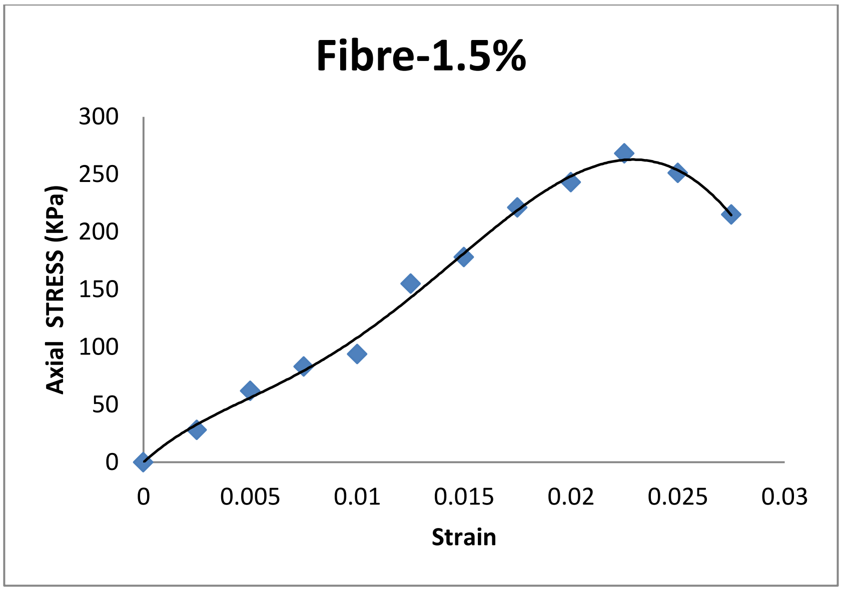

Fig. 49 70:30 Pond Ash-Soil UCS S @ 1.5%

As obtained from graph,

UCS = 268.59kPa

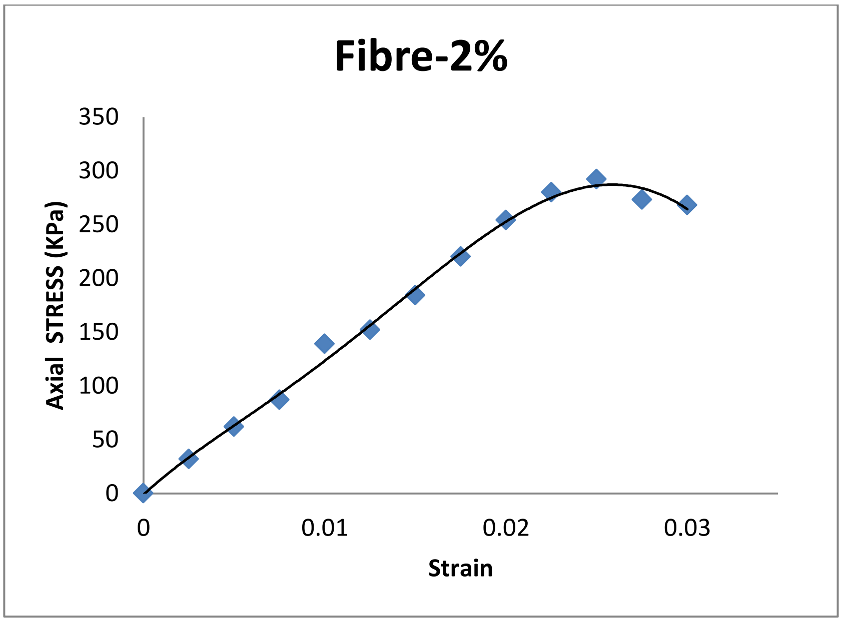

Fig. 50 70:30 Pond Ash-Soil UCS @2%

As obtained from graph,

UCS = 292.36 kPa

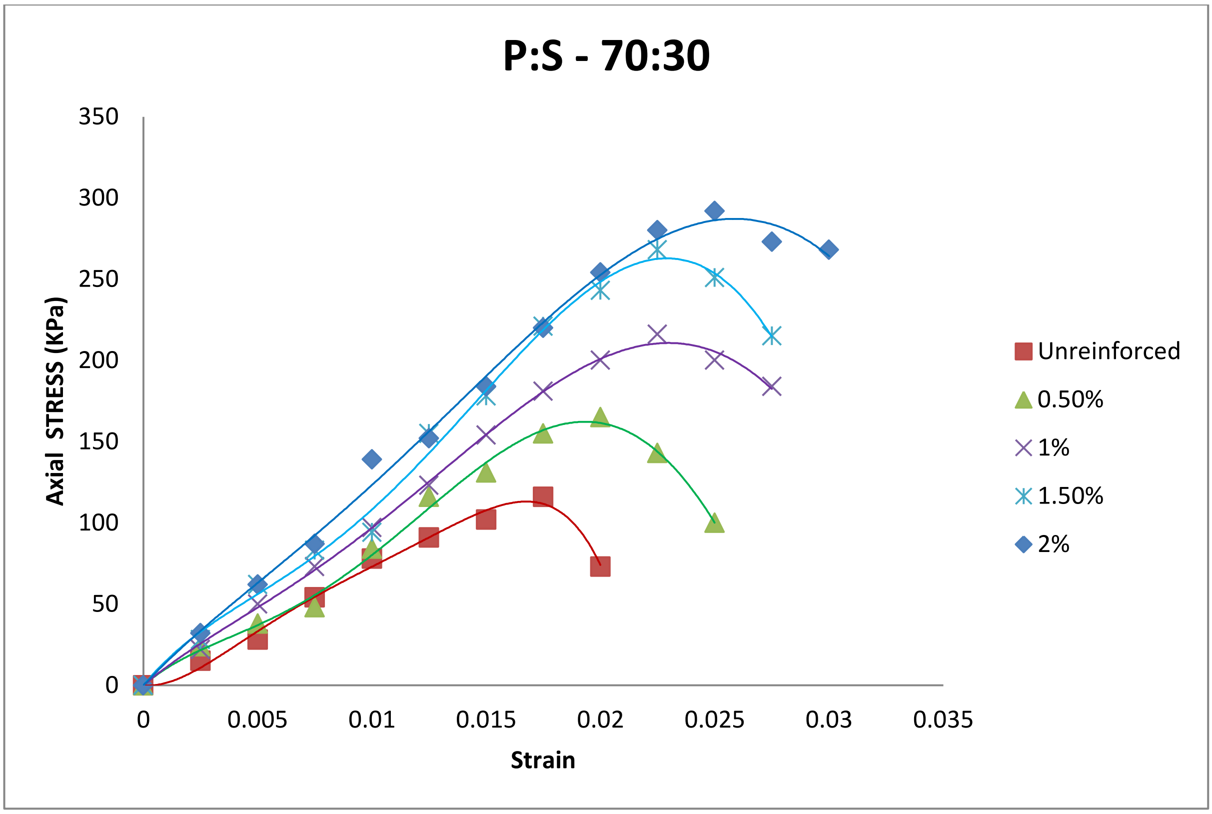

Fig. 51 Comparison of UCS test curve of different samples @ P:S – 70:30

P: S – 60:40

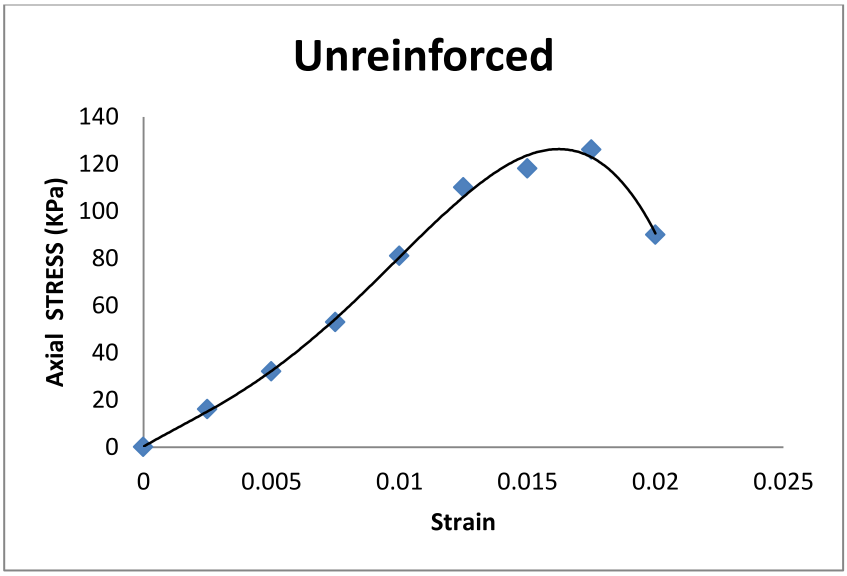

Fig. 52 60:40 Pond Ash-Soil UCS -unreinforced

As obtained from graph,

UCS = 126.94 kPa

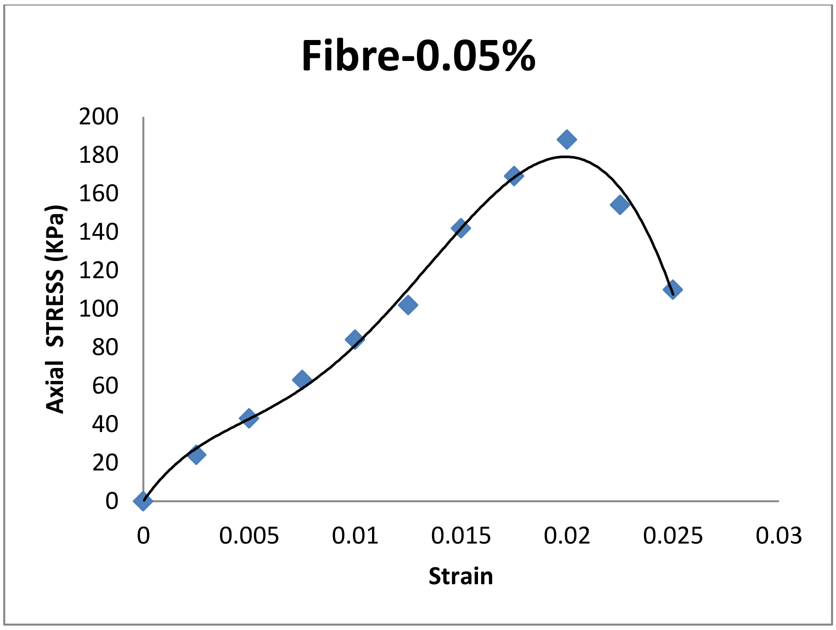

Fig. 53 60:40 Pond Ash-Soil UCS @ 0.05%

As obtained from graph,

UCS = 188.47kPa

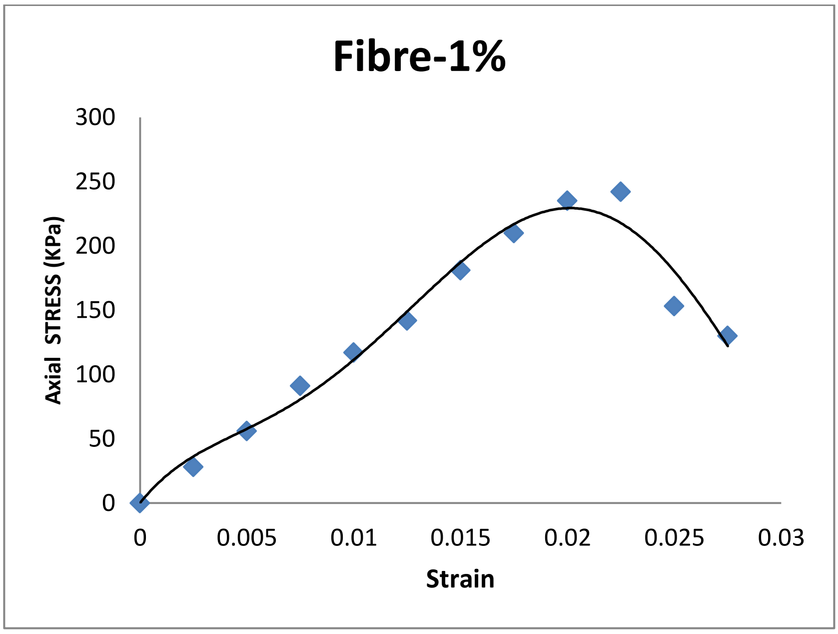

Fig. 54 60:40 Pond Ash-Soil UCS UCS @1%

As obtained from graph,

UCS = 242.35 kPa

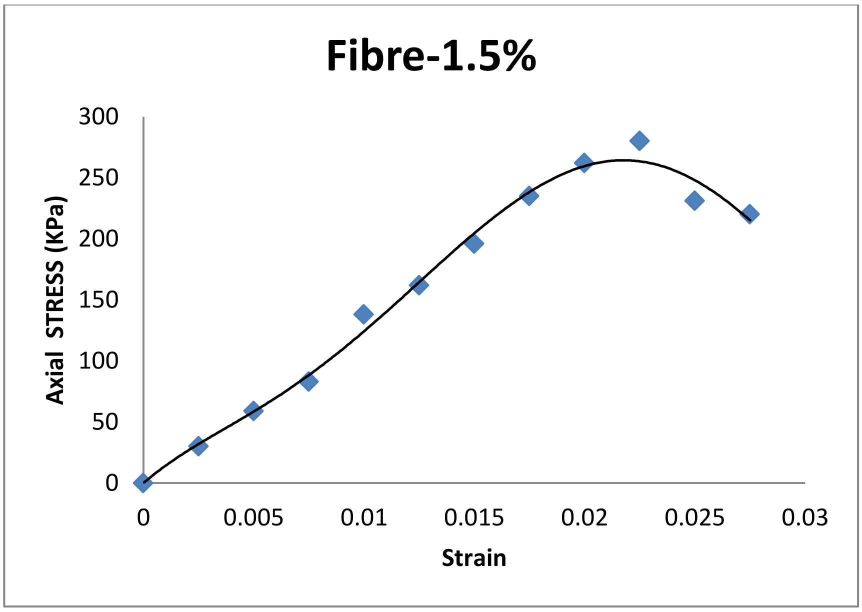

Fig. 55 60:40 Pond Ash-Soil UCS @1.5%

As obtained from graph,

UCS = 280.53 kPa

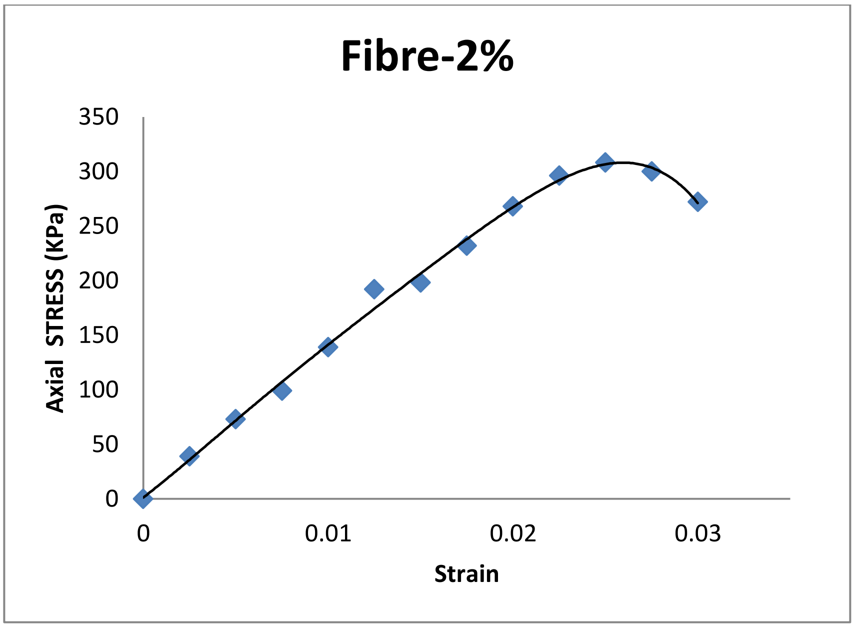

Fig. 56 60:40 Pond Ash-Soil UCS @2%

As obtained from graph,

UCS = 308.33 kPa

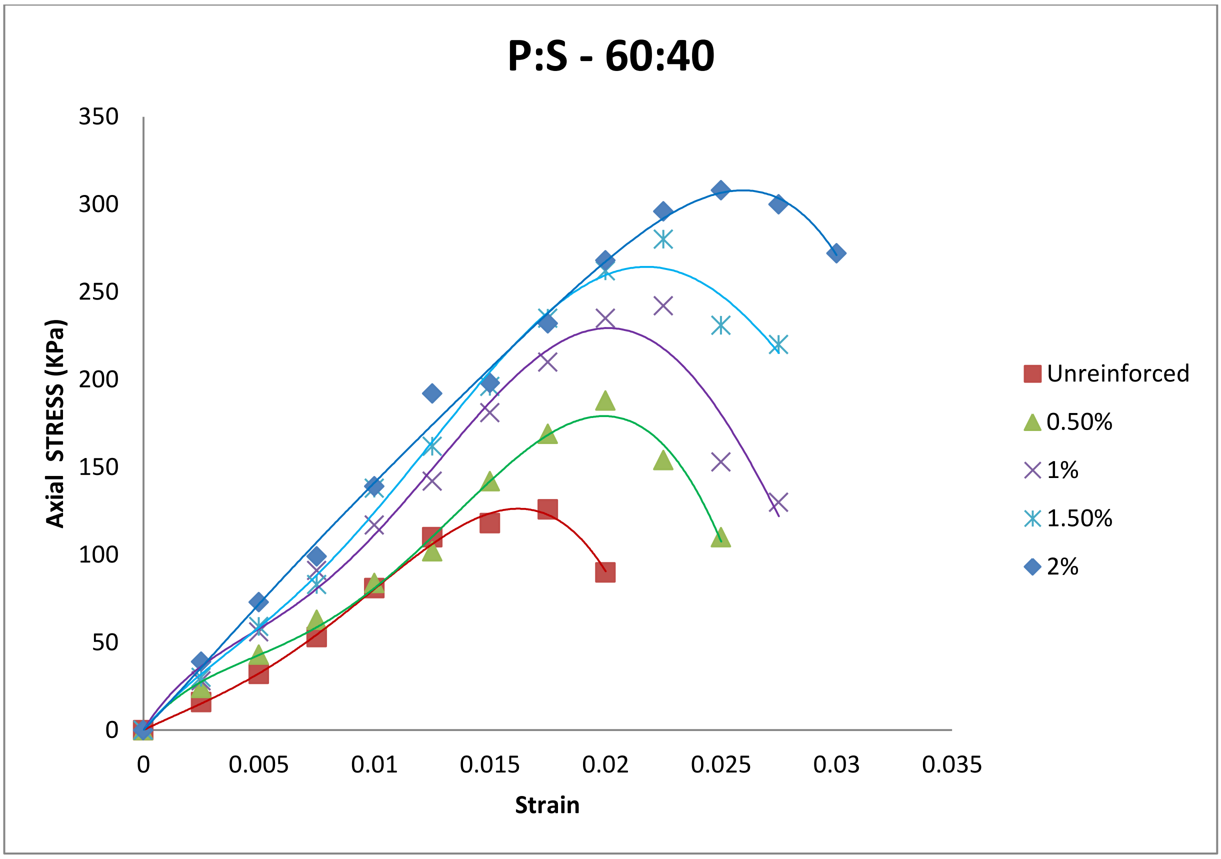

Fig. 57 Comparison of UCS test curve of different samples @ P:S – 60:40

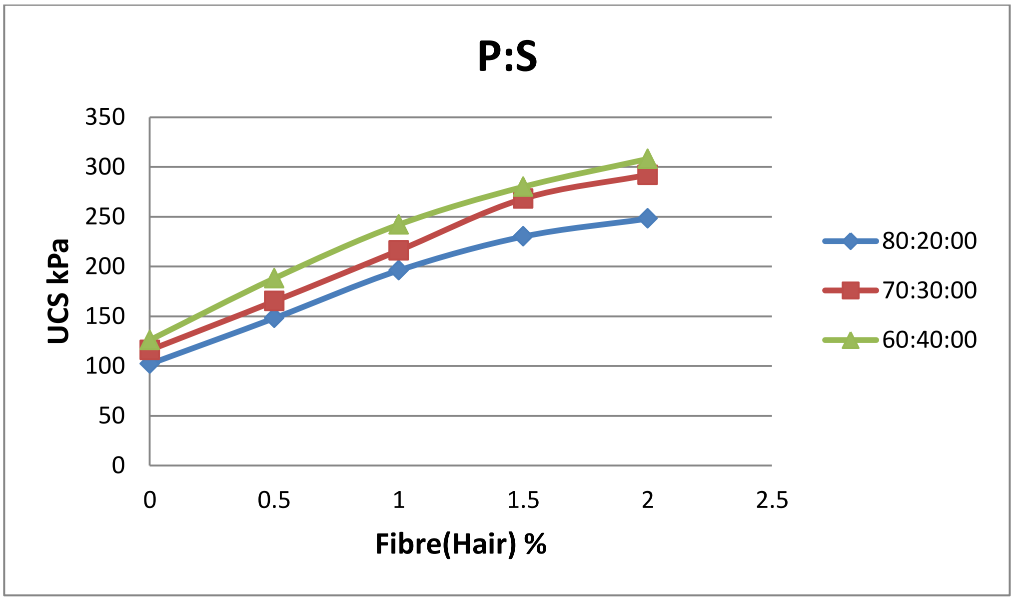

Fig. 58 Comparison of UCS test curve of different samples @ P:S –80:20), (70:30), (60:40)

The failure strains vary from a value of 0.15 to 0.30%, indicating brittle failures in the specimens. The increase in unconfined strength and initial stiffness of specimens with increased compactive effort is attributed to the closer packing of particles, resulting in the increased interlocking among particles. A closer packing is also responsible in increasing the cohesion component in the sample. A nonlinear relationship is found to exist between the unconfined strength and compactive effort.

The unconfined compressive strength of composite specimens are found to increase with the fibre content. However, the rate of increase of strength with fibre content is not linear. Initially the rate of increase in UCS is high, then the same is not that much prominent

Here Lime content contribute to self hardening and randomly oriented discrete inclusions fibres (hairs) incorporated into granular materials improve its load – deformation behaviour by interacting with the pond ash particles mechanically through surface friction and also by interlocking.

On comparing the results from UCS test of soil sample, it is found that the increment in the values of unconfined compressive strength for Hair reinforcement 0%, 0.05%, 1%, 1.5% & 2% up to 30% for 0-0.5% fibre(hair), then 18-20% for 0.5-1% fibre,12.5-17% for 1-1.5% fibre and 8-10% for 1.5-2% fibre at different curing days for Pond ash & lime.Similar case with Pond ash & soil at different proportions in which more prominent for 60:40 ratio PA:S.

4.8 Triaxial Test (UU), IS: 2720 (Part 11) (1993)

Here,

Axial strain, $\varepsilon = \Delta H/H_0$

Average cross-seticonal area, $A = A_0/(1 - \varepsilon)$

Principal stress difference, $\sigma_1 - \sigma_3 = P/A$

Also,

We calculate C and ϕ,through modified failure envelope using the relation

$$\sin \emptyset = \tan \alpha \quad \& \quad c' = \frac{a}{\cos \emptyset}$$

Where,

α = Slope of modified failure envelope

a = Intercept of modified failure envelope

TEST-

Sample weight = 600gm

Volume of mould (V) = 196.35 c.c

Diameter = 5 cm , Length = 10 cm

Pond Ash- Lime

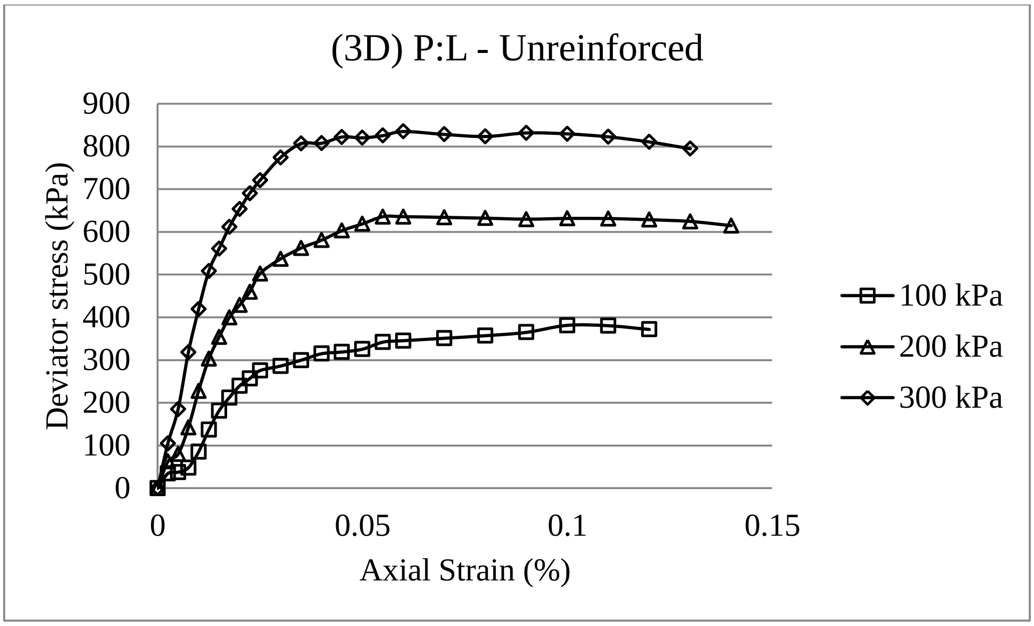

Fig. 59 3 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 0% Fibre

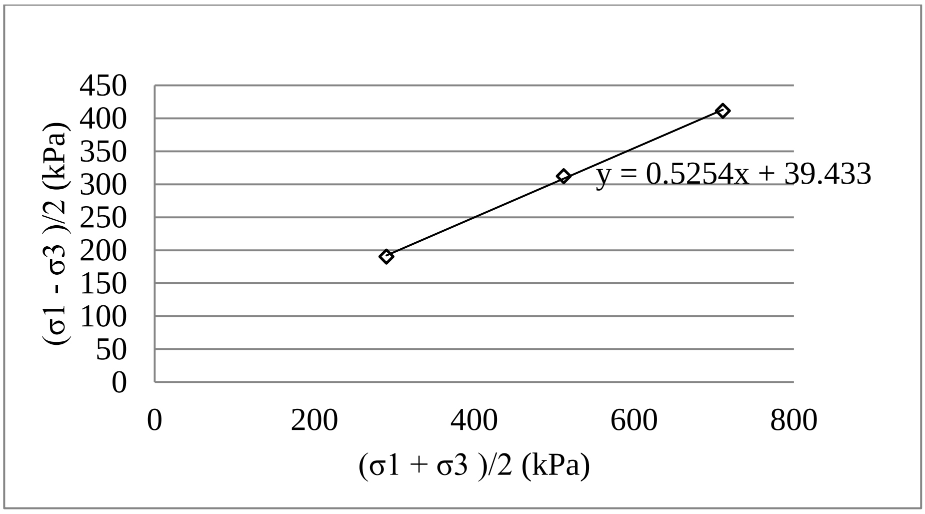

Fig. 60 3 Day, Modified failure envelope for Pond Ash with Lime at 0% Fibre

As obtained from graph,

ą=28, &a=38.78

Thus, ϕ=32.1 & c=44.75

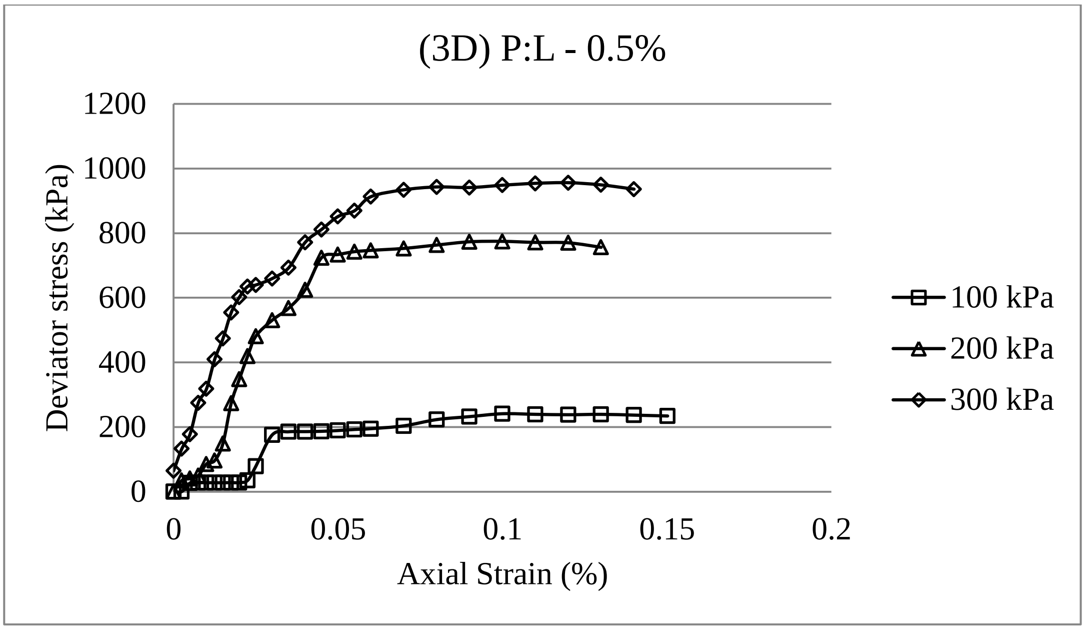

Fig 61 3 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 0.5% Fibre

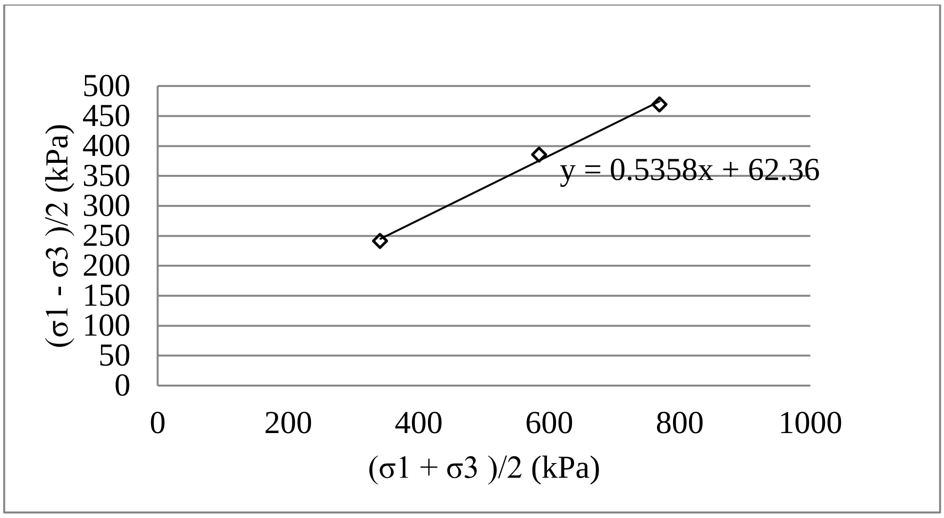

Fig. 62 3 Day, Modified failure envelope for Pond Ash with Lime at 0.5% Fibre

As obtained from graph,

ᾳ=28.15, &a=60.06

Thus, ϕ=32.36 & c=68.12

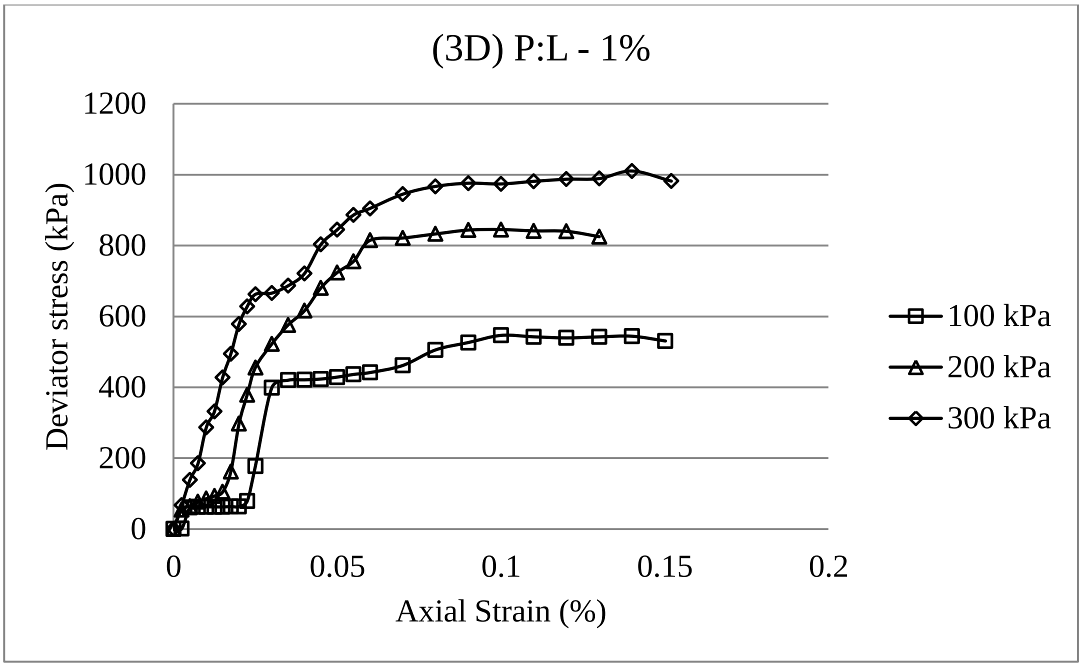

Fig. 63 3 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 1% Fibre

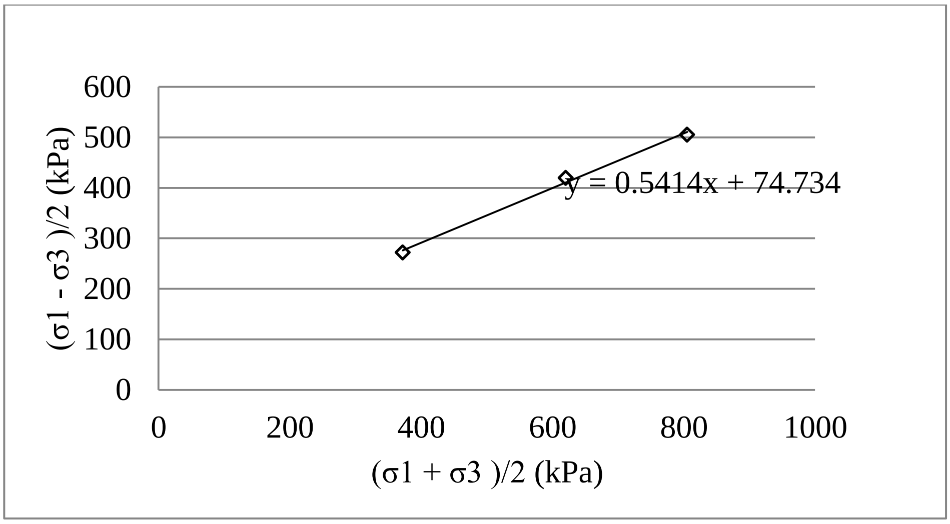

Fig 64 3 Day, Modified failure envelope for Pond Ash with Lime at 1% Fibre

As obtained from graph,

α=28.43, &a=74.36

Thus, ϕ=32.78 & c=88.45

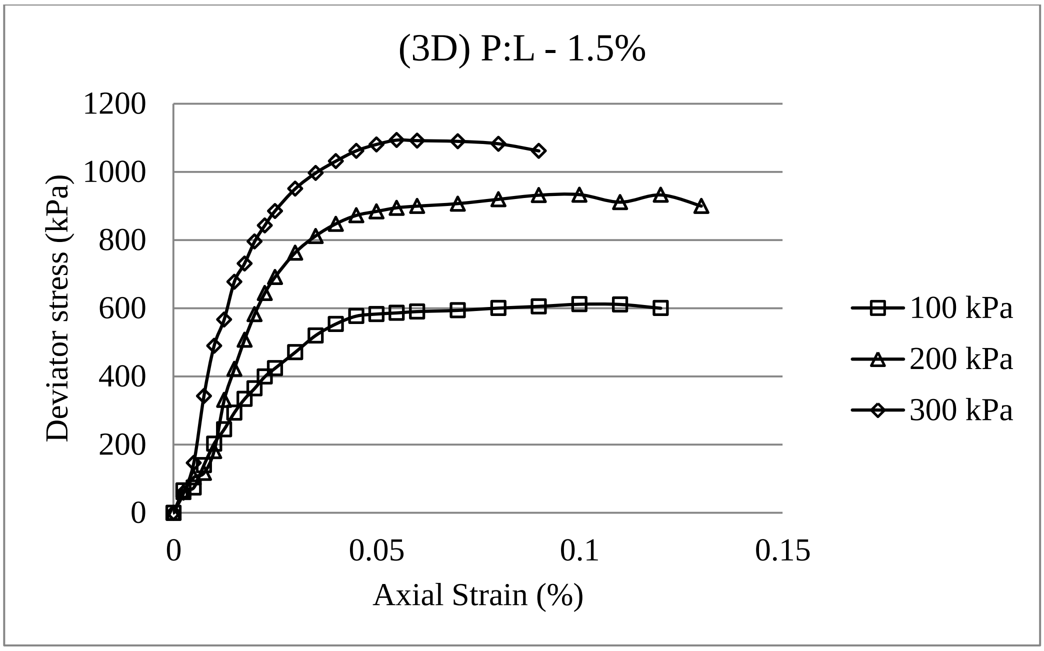

Fig. 65 3 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 1.5% Fibre

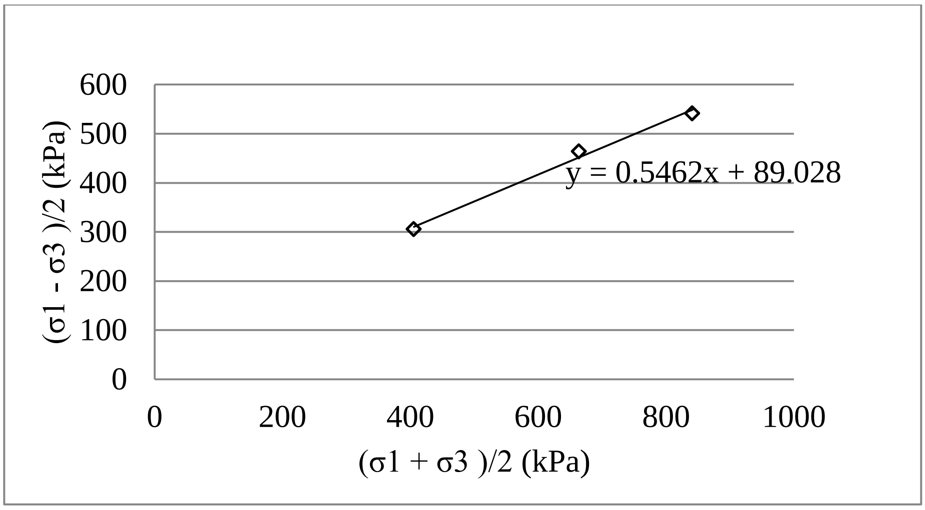

Fig. 66 3 Day, Modified failure envelope for Pond Ash with Lime at 1.5% Fibre

As obtained from graph,

ᾳ=28.62, &a=89.54

Thus, ϕ=33.08 &c=106.87

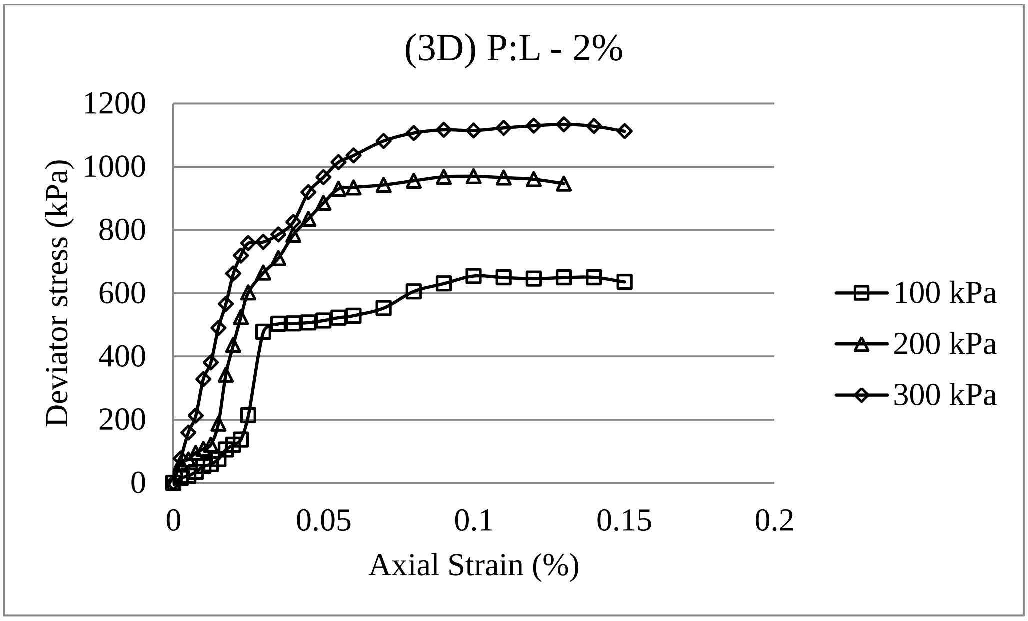

Fig. 67 3 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 2% Fibre

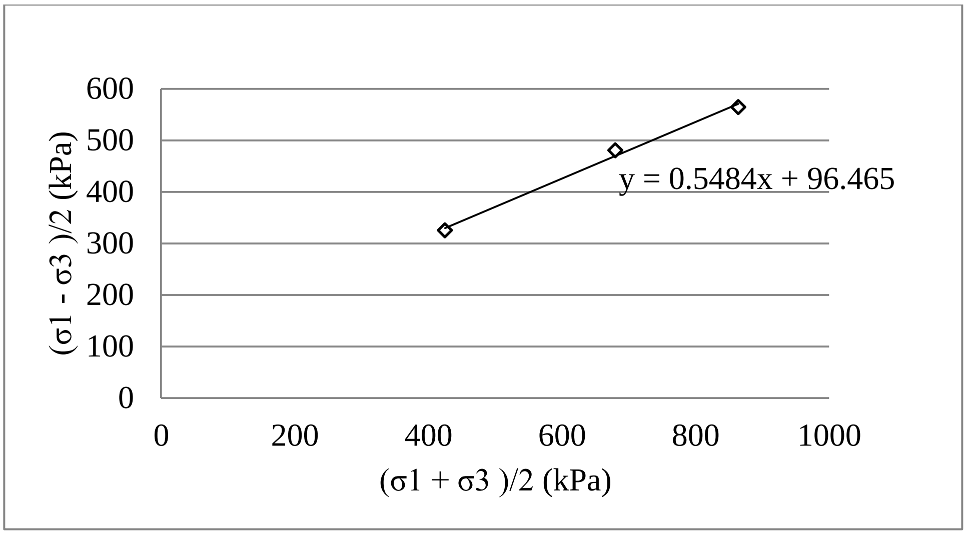

Fig. 68 3 Day, Modified failure envelope for Pond Ash with Lime at 2% Fibre

As obtained from graph,

α=28.7, &a=96.12

Thus, ϕ=33.21 & c=114.89

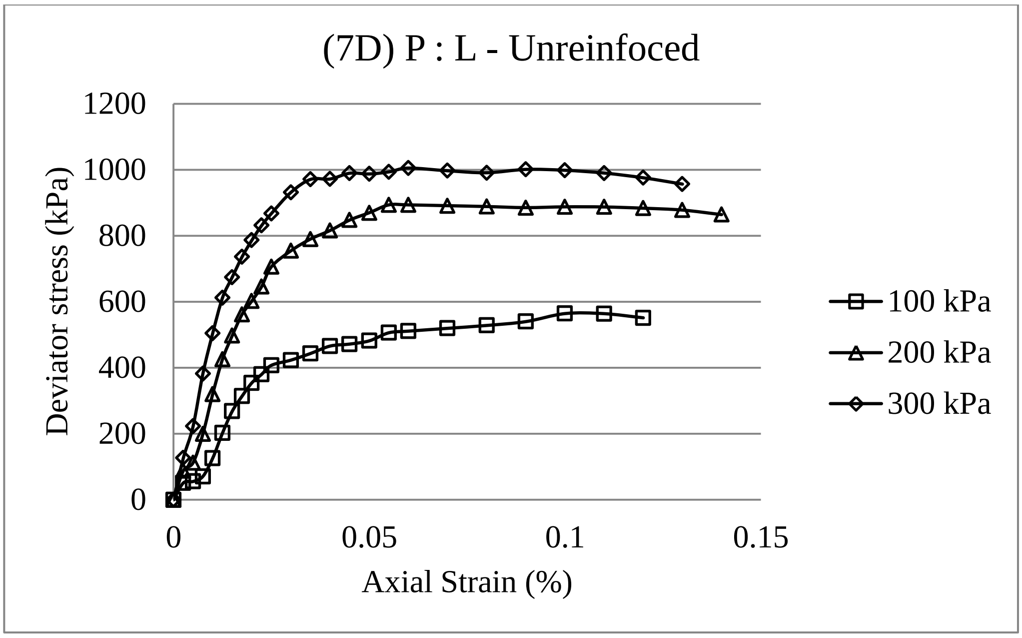

Fig. 69 7 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 0% Fibre

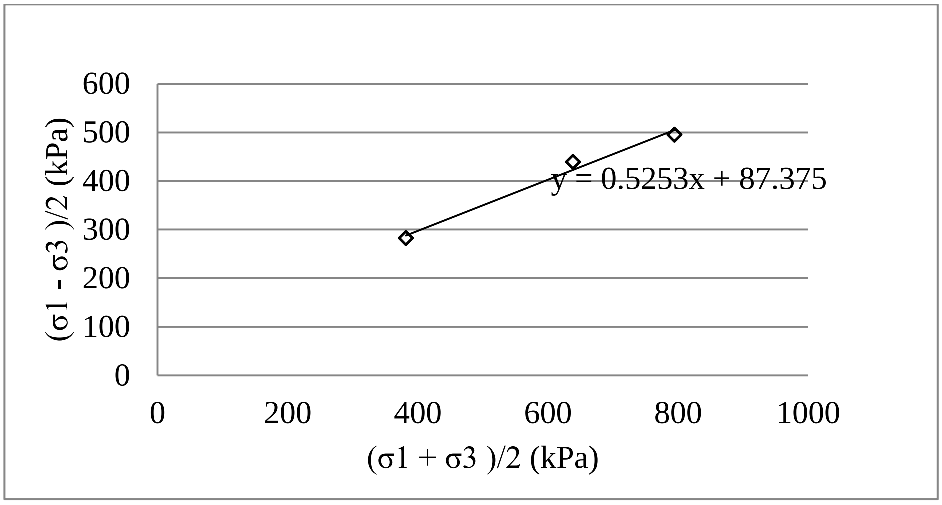

Fig. 70 7 Day, Modified failure envelope for Pond Ash with Lime at 0% Fibre

As obtained from graph,

α=28.10, &a=84.17

Thus, ϕ=32.3 & c=99.43

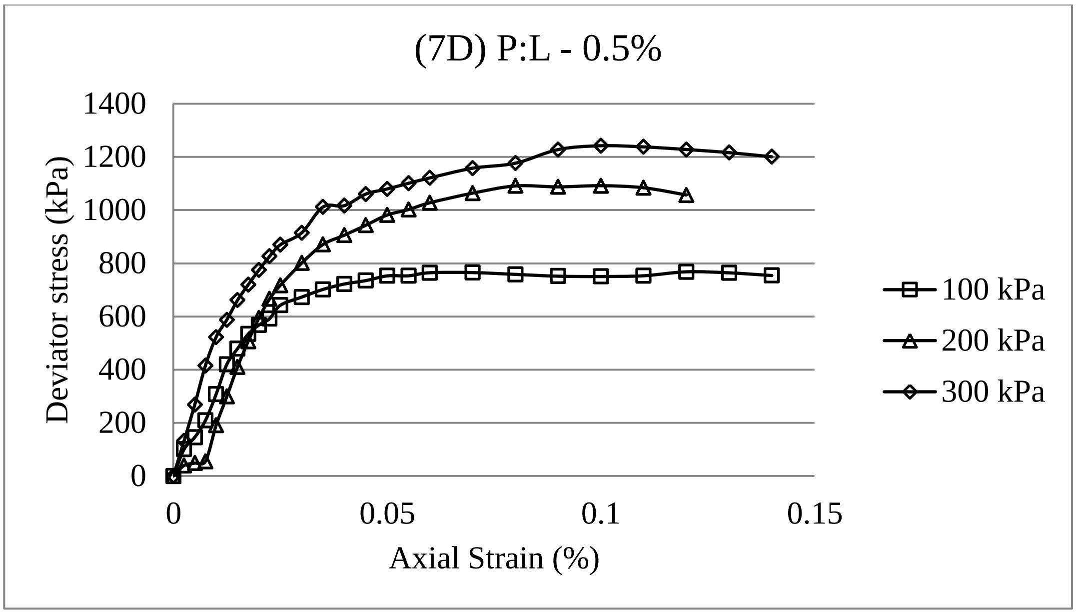

Fig 71 7 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 0.5% Fibre

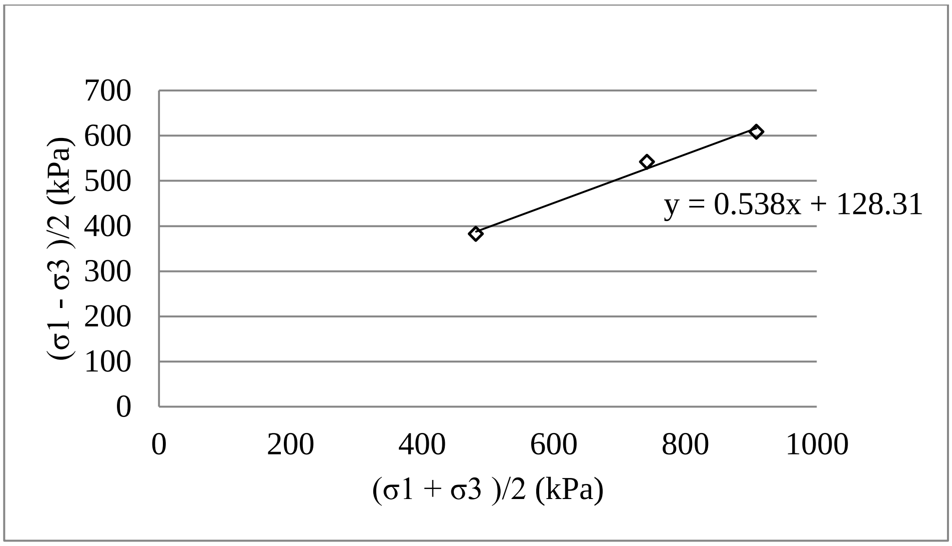

Fig. 72 7 Day, Modified failure envelope for Pond Ash with Lime at 0.5% Fibre

As obtained from graph,

α=28.47, &a=128.91

Thus, ϕ=32.85 & c=152.68

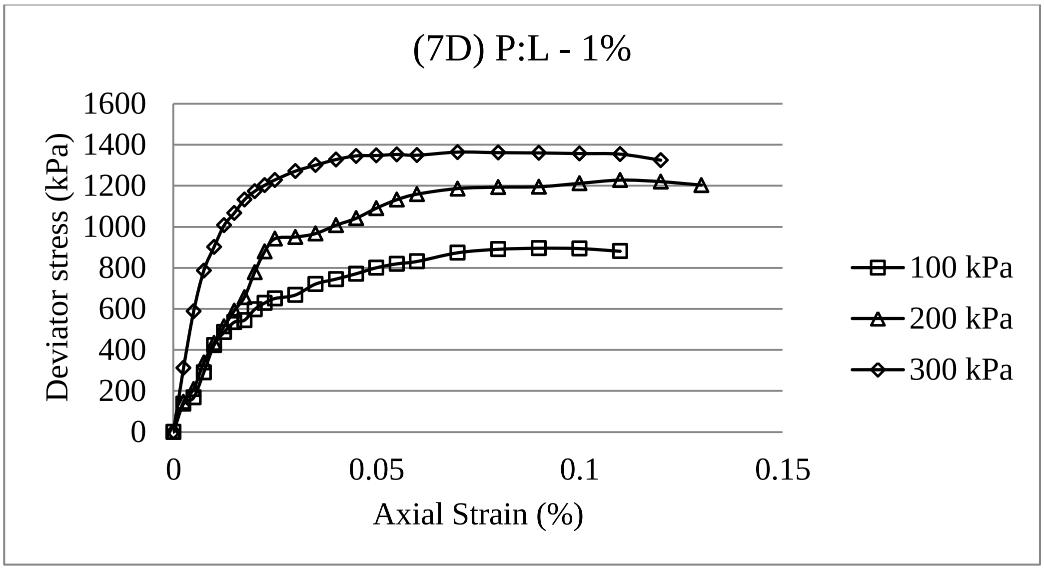

Fig. 73 7 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at1% Fibre

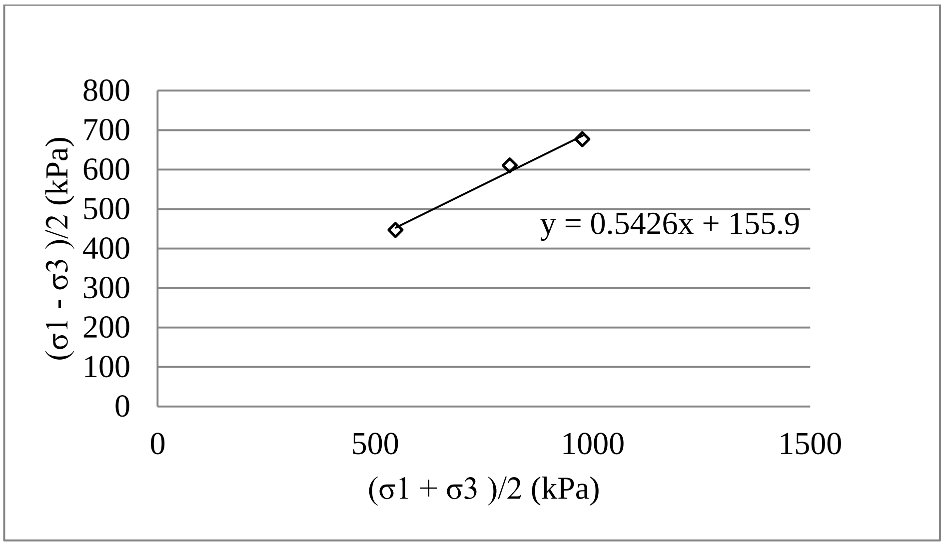

Fig. 74 7 Day, Modified failure envelope for Pond Ash with Lime at 1% Fibre

As obtained from graph,

α=28.47, &a=156.71

Thus, ϕ=32.85 & c=186.54

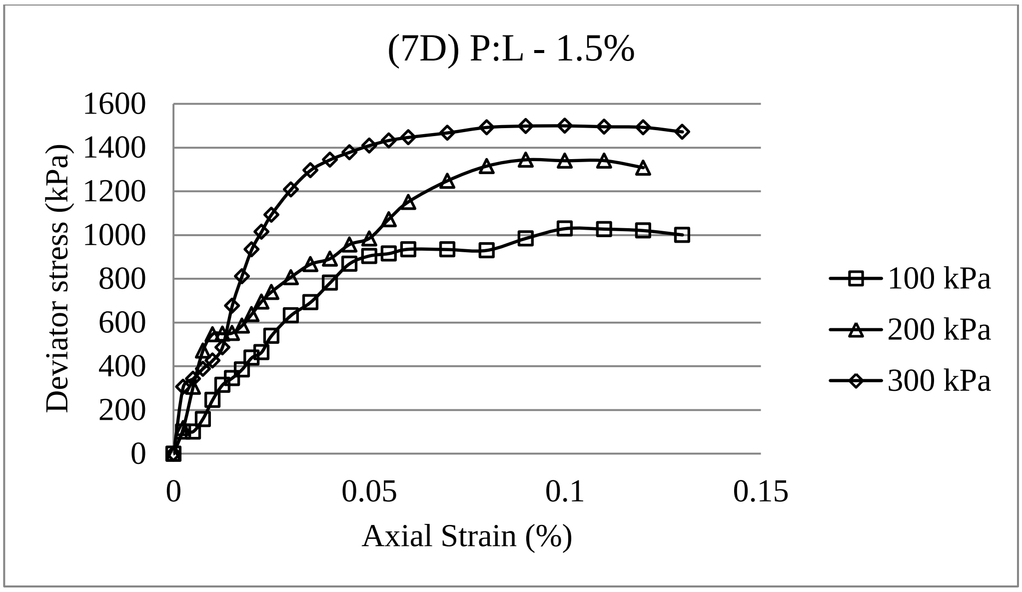

Fig. 75 7 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at1.5% Fibre

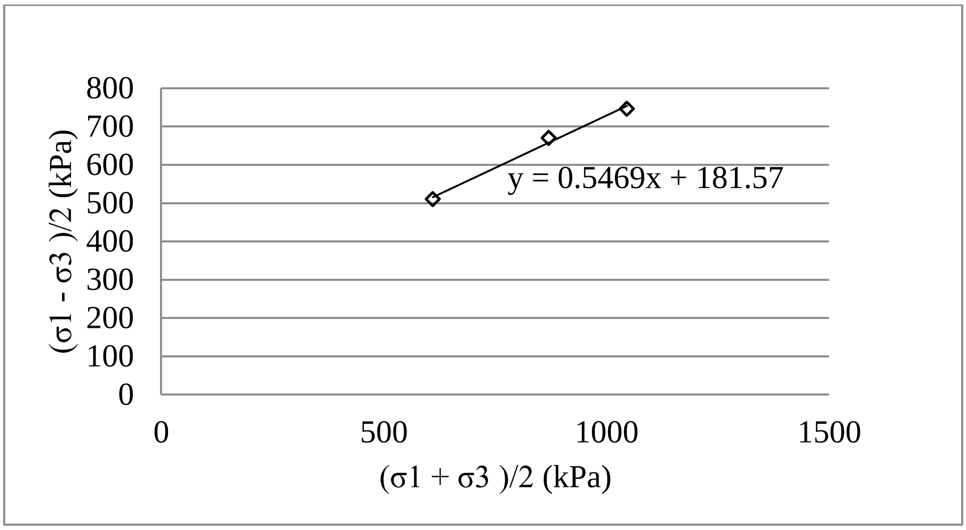

Fig. 76 7 Day, Modified failure envelope for Pond Ash with Lime at 1.5% Fibre

As obtained from graph,

α=28.64, &a=181.56

Thus, ϕ=33.11 & c=216.76

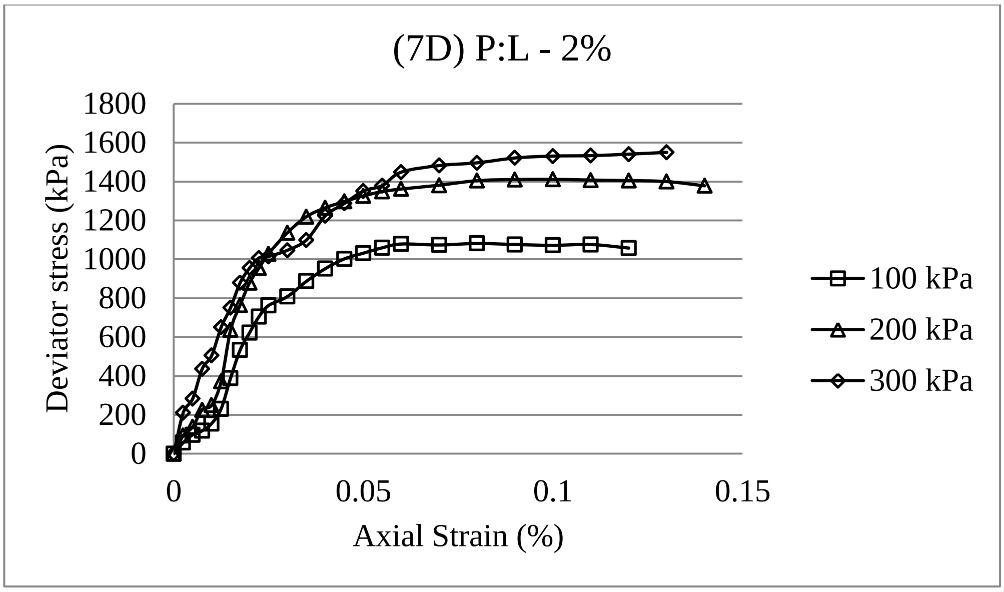

Fig. 77 7 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at2% Fibre

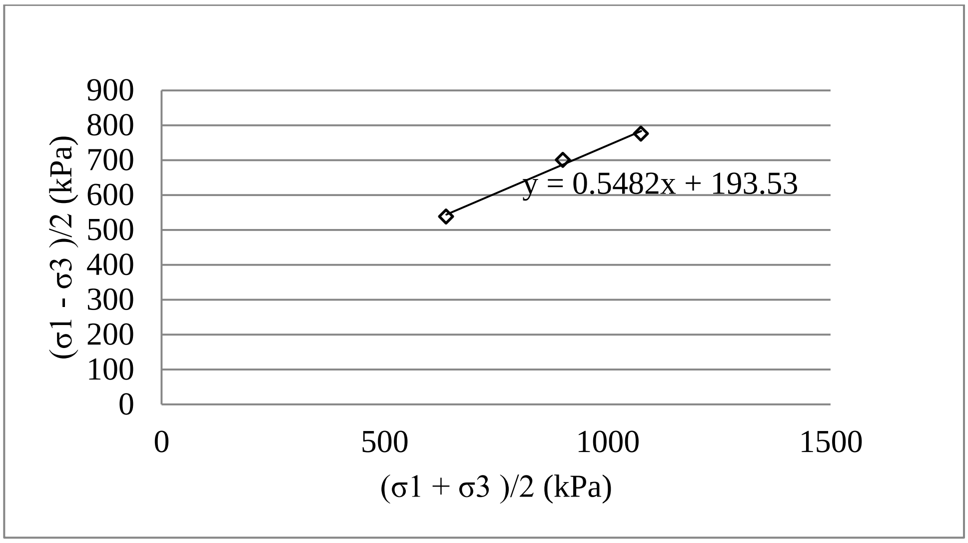

Fig. 78 7 Day, Modified failure envelope for Pond Ash with Lime at 2% Fibre

As obtained from graph,

α=28.73, &a=194.76

Thus, ϕ=33.25 & c=232.89

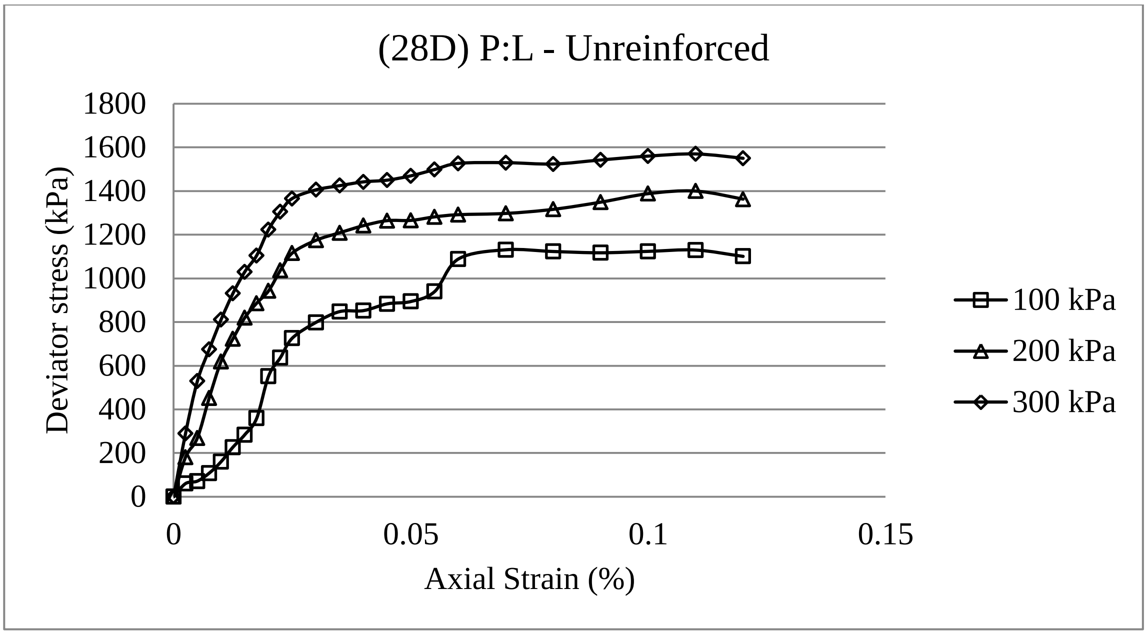

Fig. 79 28 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at0% Fibre

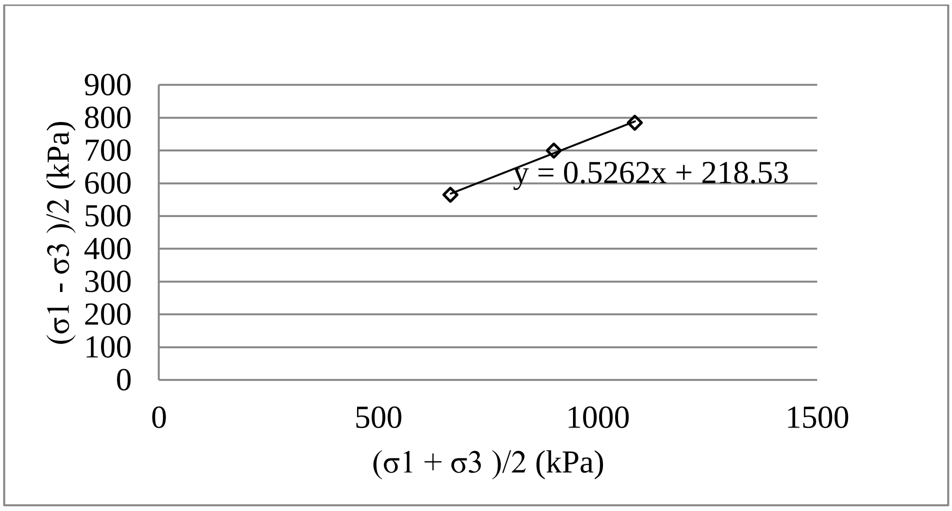

Fig. 80 28 Day, Modified failure envelope for Pond Ash with Lime at 0% Fibre

As obtained from graph,

α=27.73, &a=219.86

Thus, ϕ=31.72 & c=238.47

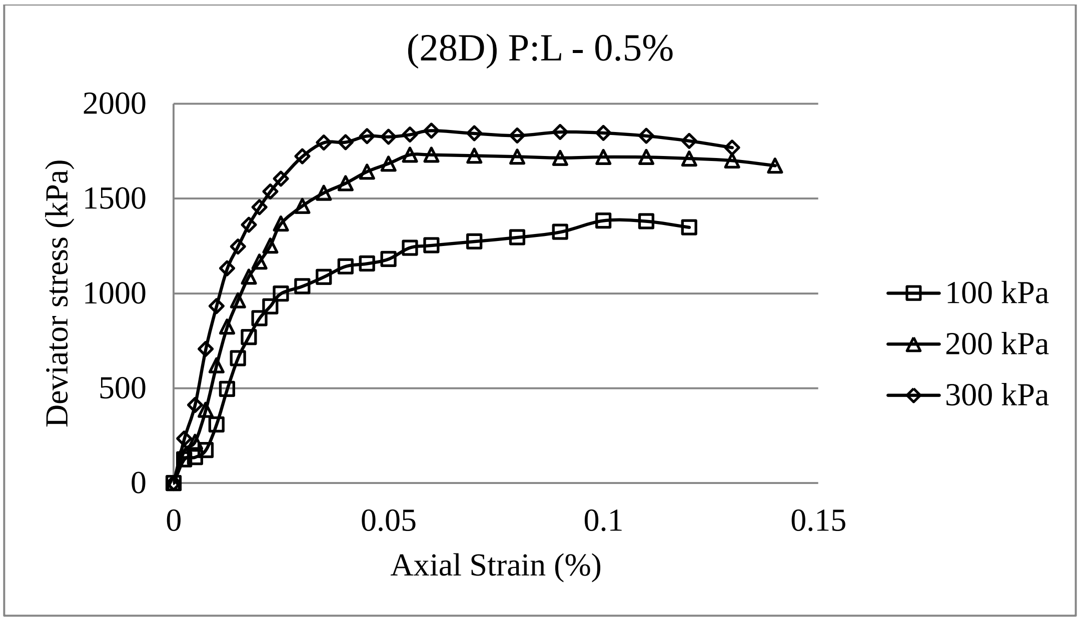

Fig. 81 28 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at0.5% Fibre

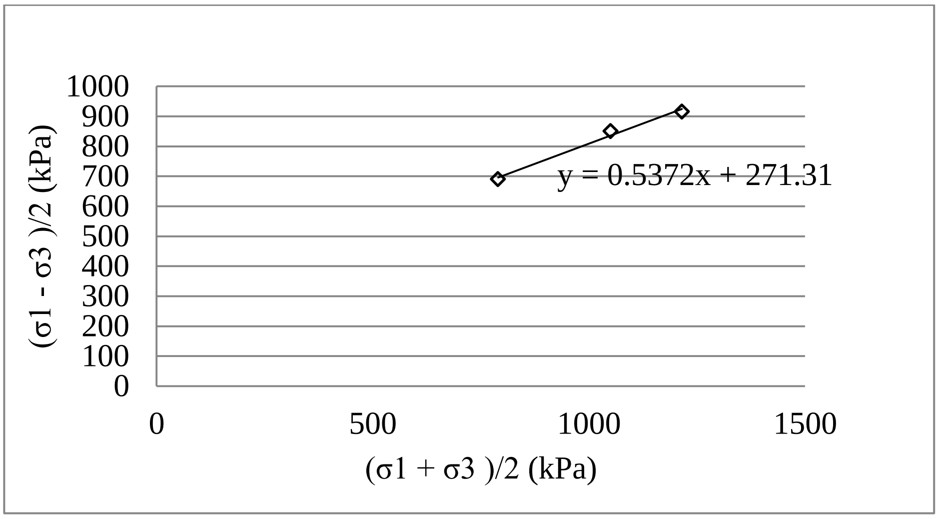

Fig. 82 28 Day, Modified failure envelope for Pond Ash with Lime at 0.5% Fibre

As obtained from graph,

α=27.73, & a=275.89

Thus, ϕ=32.52 & c=310.64

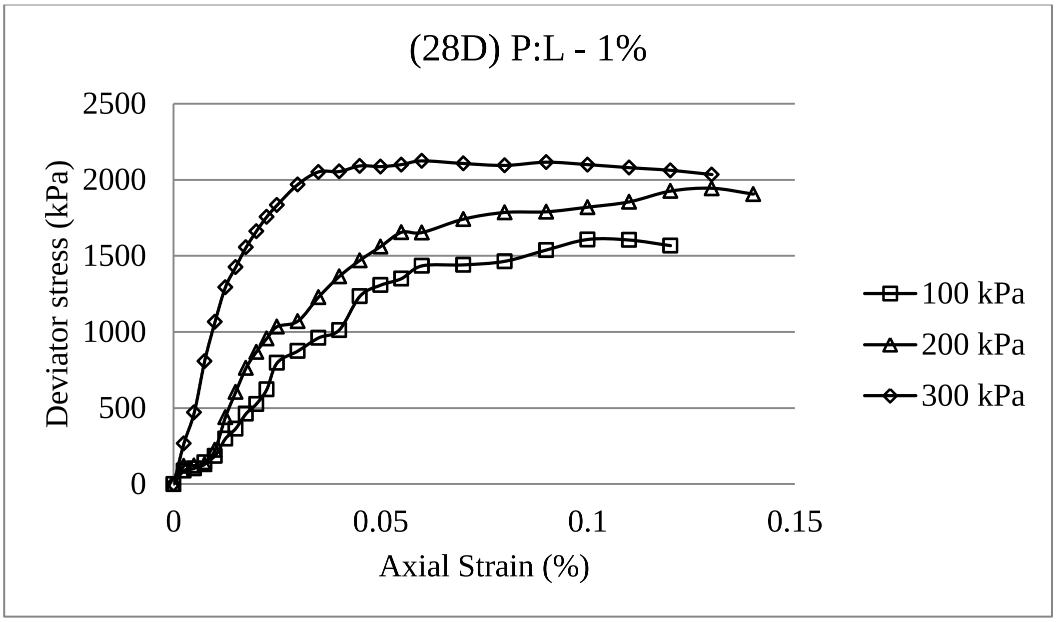

Fig. 83 28 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at1% Fibre

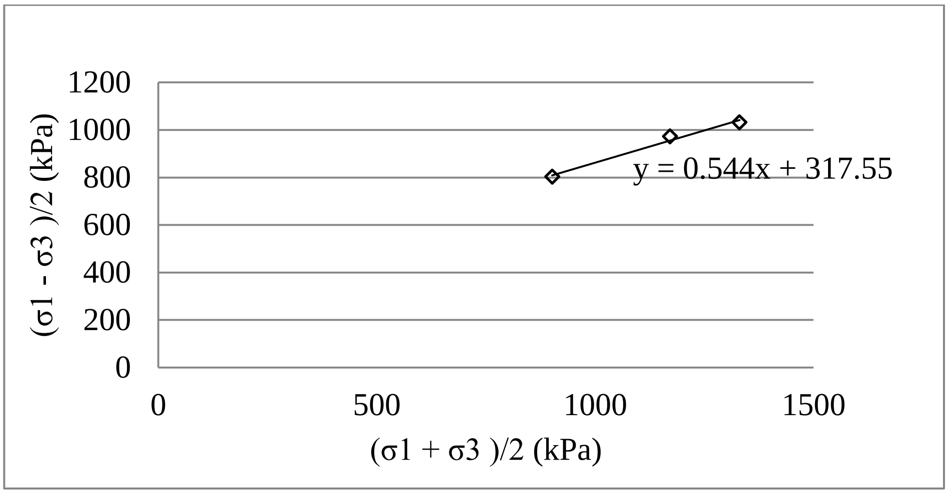

Fig. 84 28 Day, Modified failure envelope for Pond Ash with Lime at 1% Fibre

As obtained from graph,

α=28.54, & a=319.38

Thus, ϕ=32.96 & c=376.65

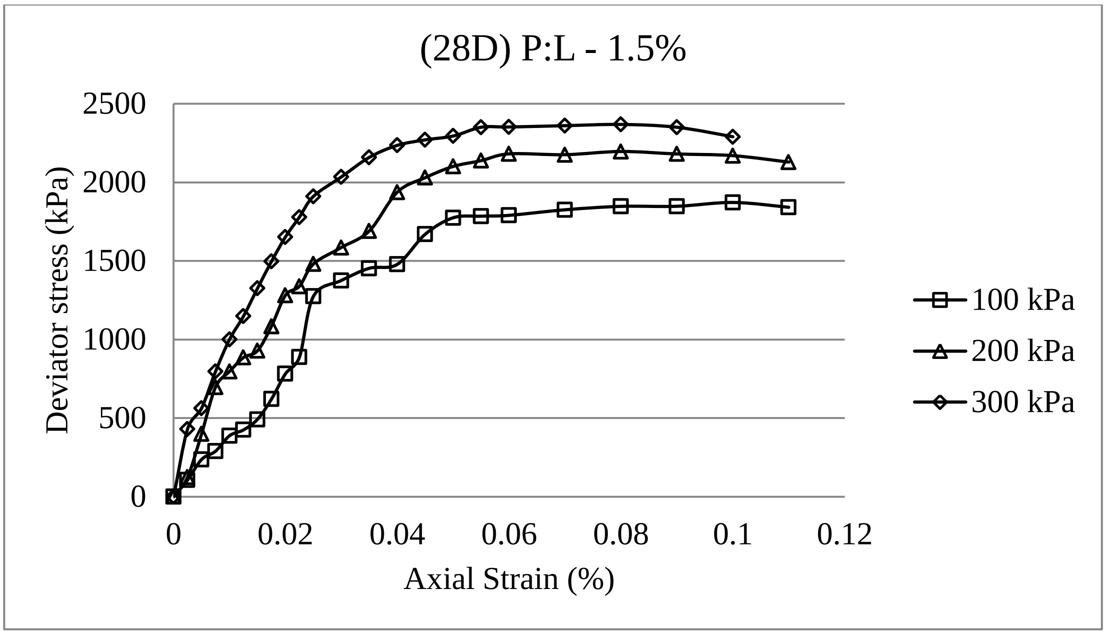

Fig. 85 28 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at1.5% Fibre

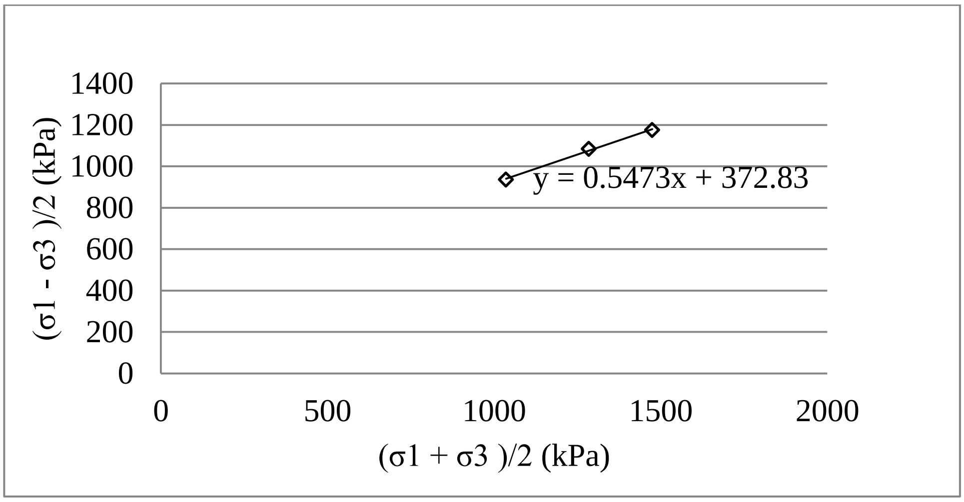

Fig. 86 28 Day, Modified failure envelope for Pond Ash with Lime at 1.5% Fibre

As obtained from graph,

α=28.67, & a=373.60

Thus, ϕ=33.56 & c=446.67

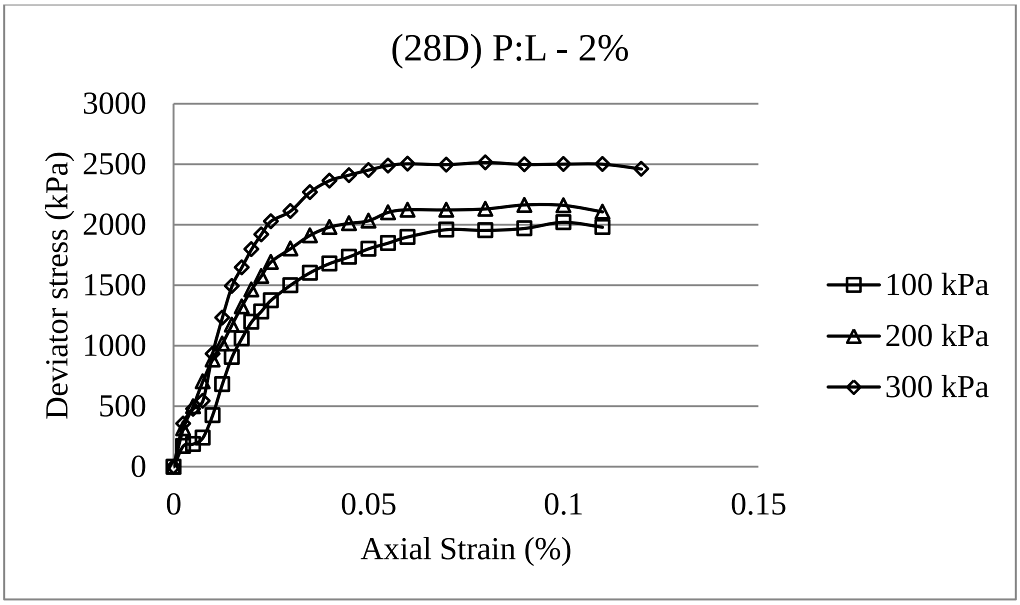

Fig. 87 28 Day, Plot between Deviator Stress and Axial Strain for Pond Ash with Lime at 2% Fibre

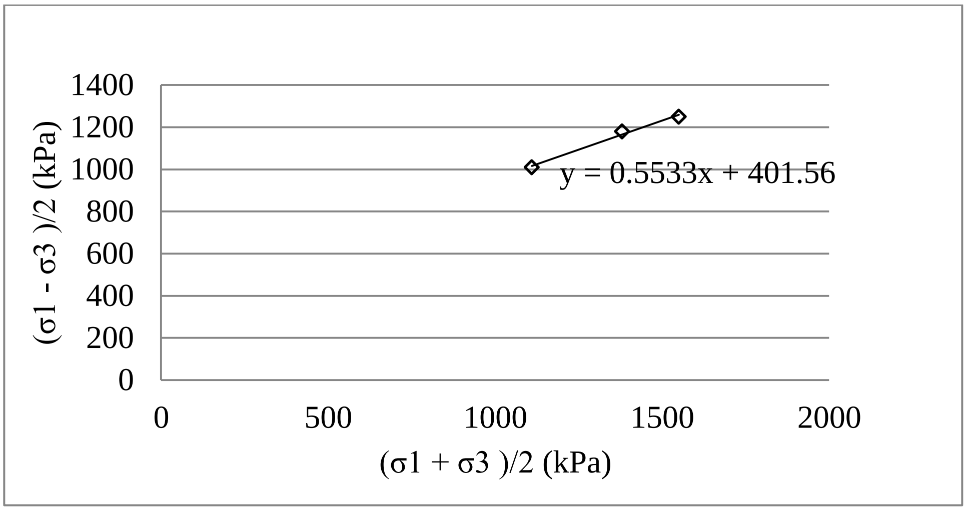

Fig. 88 28 Day, Modified failure envelope for Pond Ash with Lime at 2% Fibre

As obtained from graph,

ɑ=28.93, &a=403.05

Thus, ϕ=33.56 &c=483.6

Pond Ash – Soil

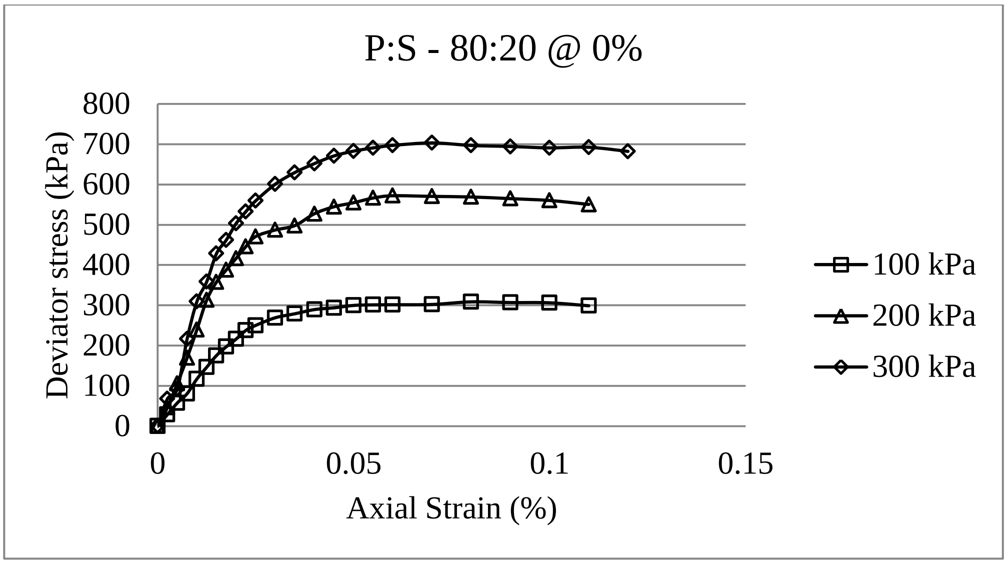

Fig. 89 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (80:20) at 0% Fibre

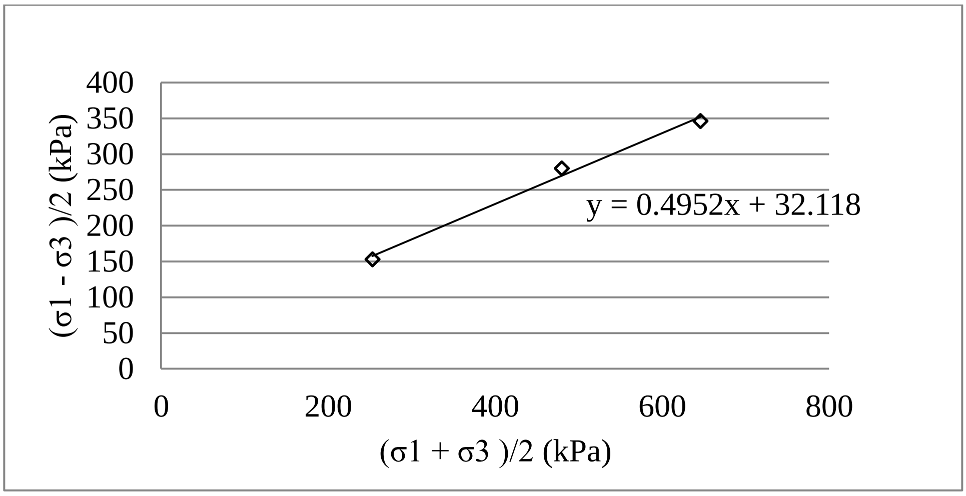

Fig. 90 Modified failure envelope for Pond Ash with soil (80:20)

At 0% Fibre

As obtained from graph,

ɑ=26.34, & a=28.84

Thus, ϕ=29.68 & c=32.6

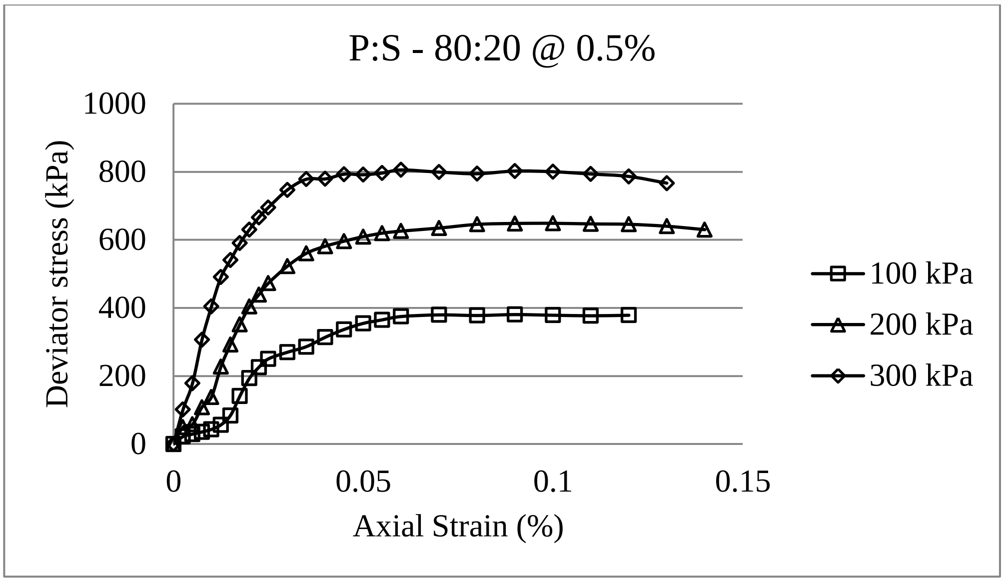

Fig. 91 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (80:20) at 0.5% Fibre

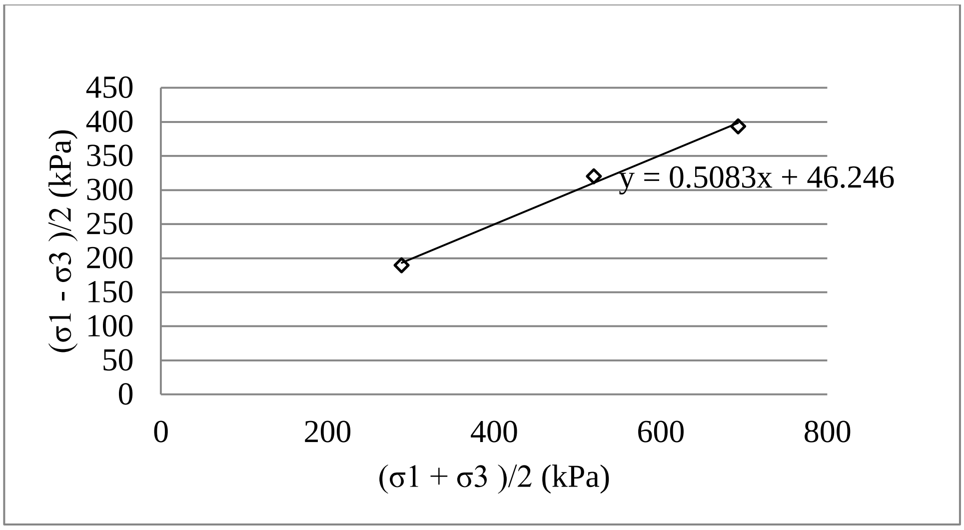

Fig. 92 Modified failure envelope for Pond Ash with soil (80:20) at0.5% Fibre

As obtained from graph,

ą=27.30, & a=46.13

Thus, ϕ=31.08 & c=53.87

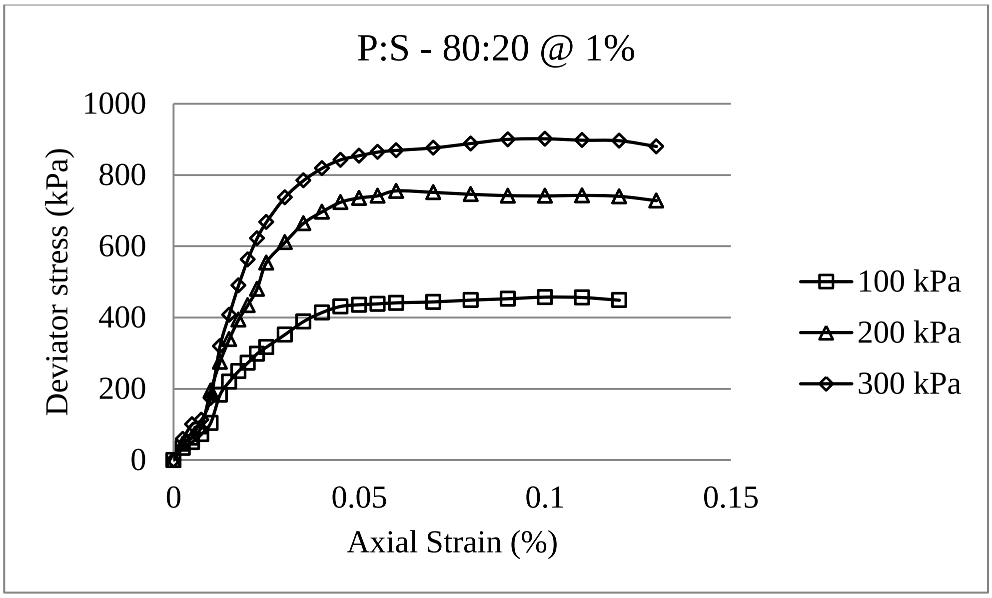

Fig. 93 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (80:20) at 1% Fibre

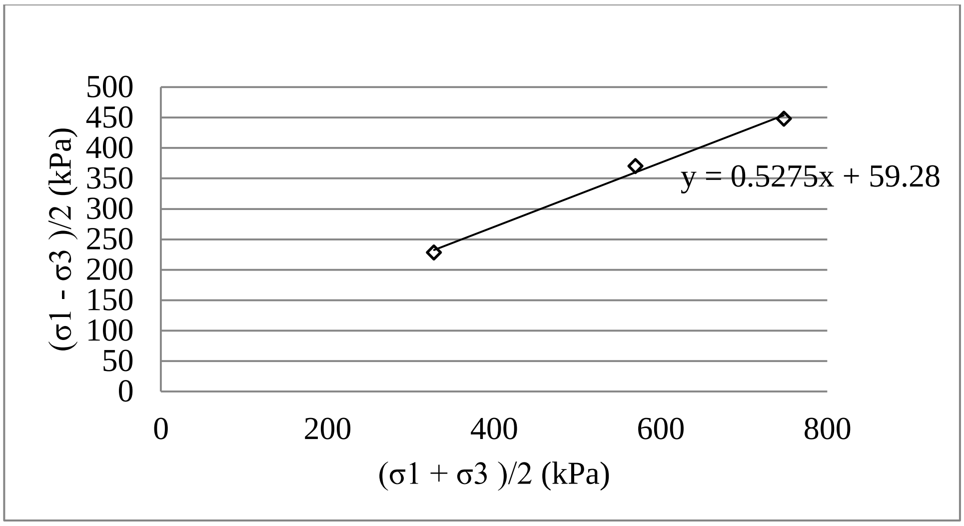

Fig. 94 Modified failure envelope for Pond Ash with soil (80:20) at1% Fibre

As obtained from graph,

α=27.81, & a=59.81

Thus, ϕ=31.84 & c=70.41

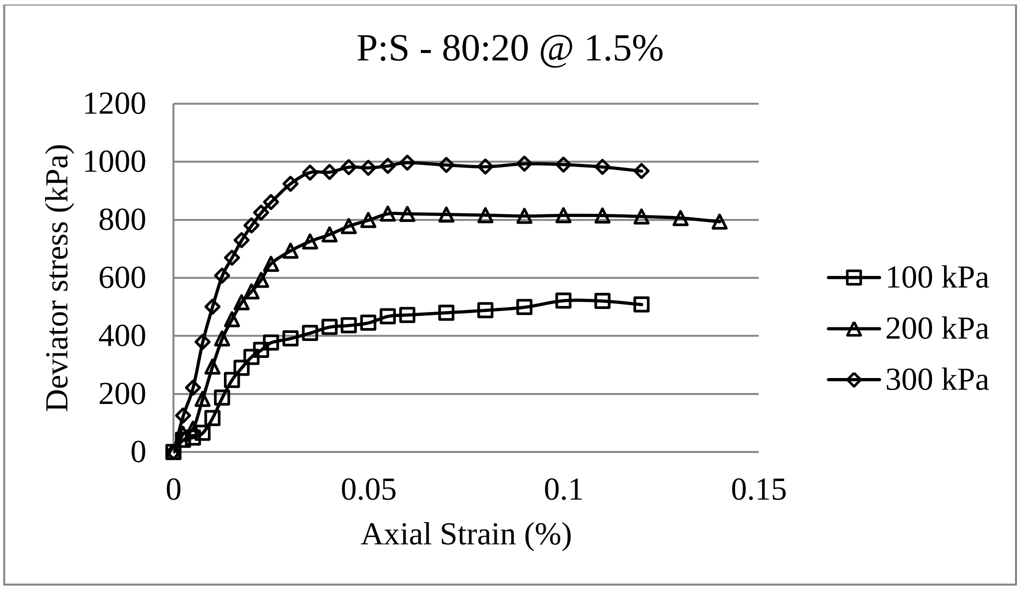

Fig. 95 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (80:20) at 1.5% Fibre

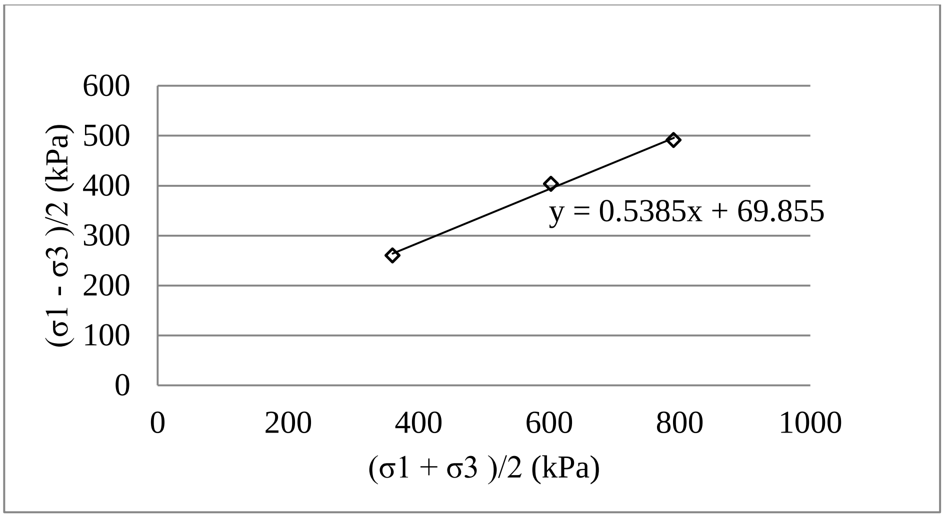

Fig. 96 Modified failure envelope for Pond Ash with soil (80:20) at1.5% Fibre

As obtained from graph,

α=28.30, & a=69.67

Thus, ϕ=32.58 & c=82.69

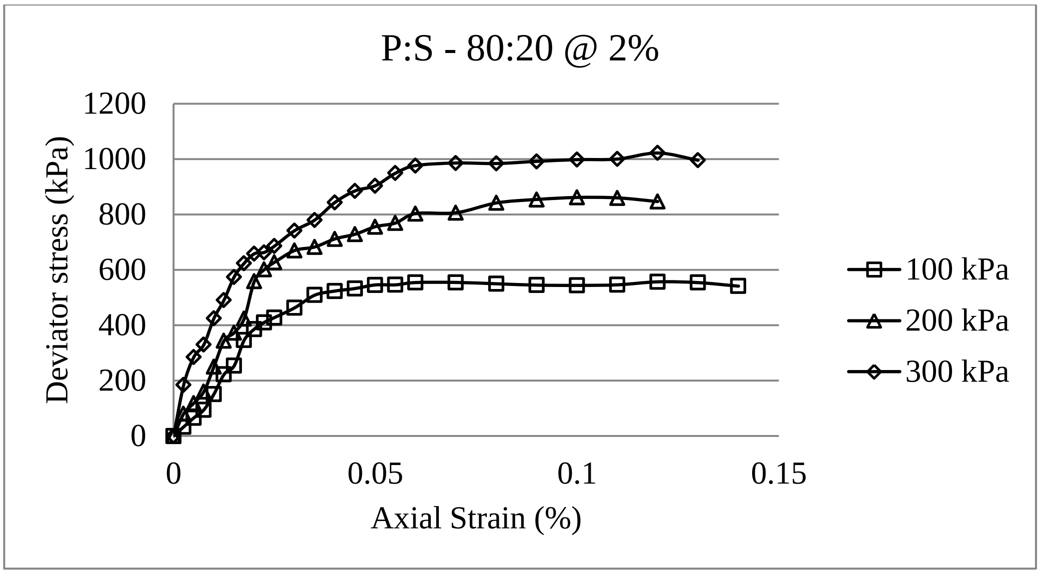

Fig. 97 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (80:20) at 0.5% Fibre

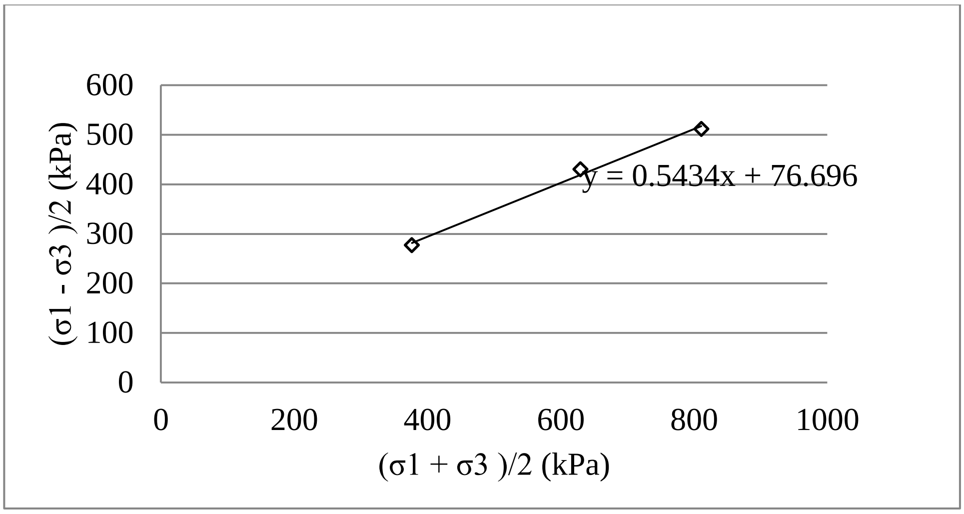

Fig. 98 Modified failure envelope for Pond Ash with soil (80:20) at2% Fibre

As obtained from graph,

ᶐ=28.51, & a=76.02

Thus, ϕ=32.91 & c=90.56

P:S – 70:30

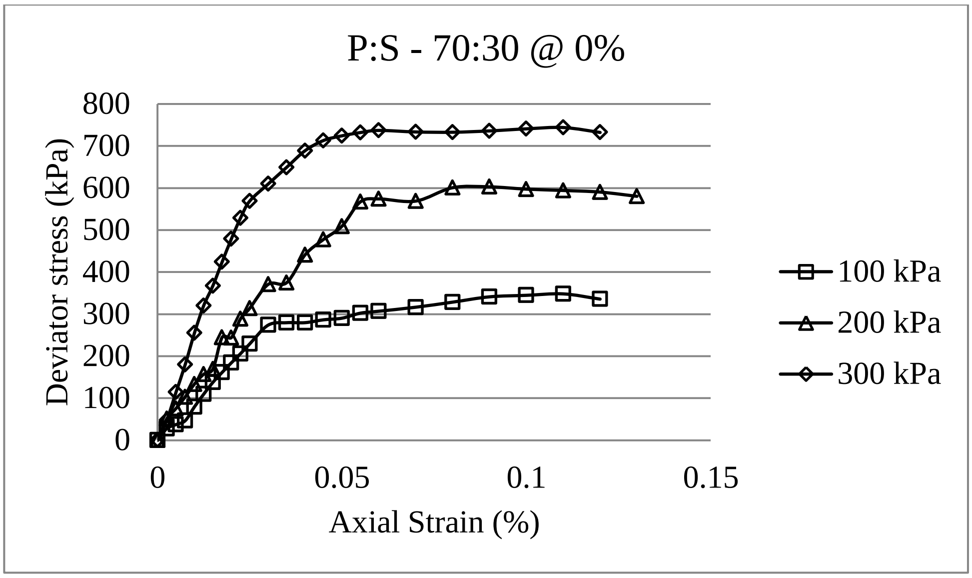

Fig. 99 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (70:30) at 0% Fibre

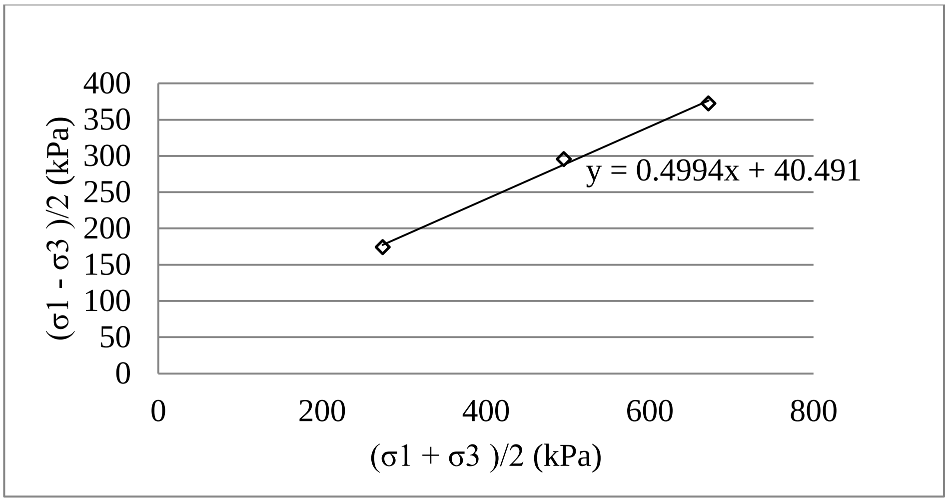

Fig. 100 Modified failure envelope for Pond Ash with soil (70:30)at 0% Fibre

As obtained from graph,

α̧=26.54, & a=33.07

Thus, ϕ=29.97 & c=39.26

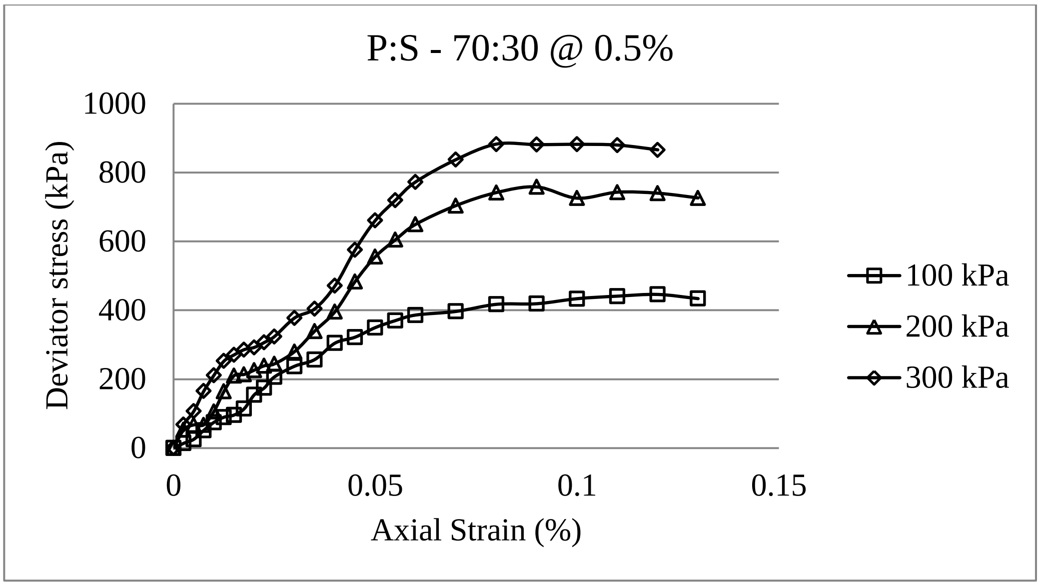

Fig. 101 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (70:30) at 0.5% Fibre

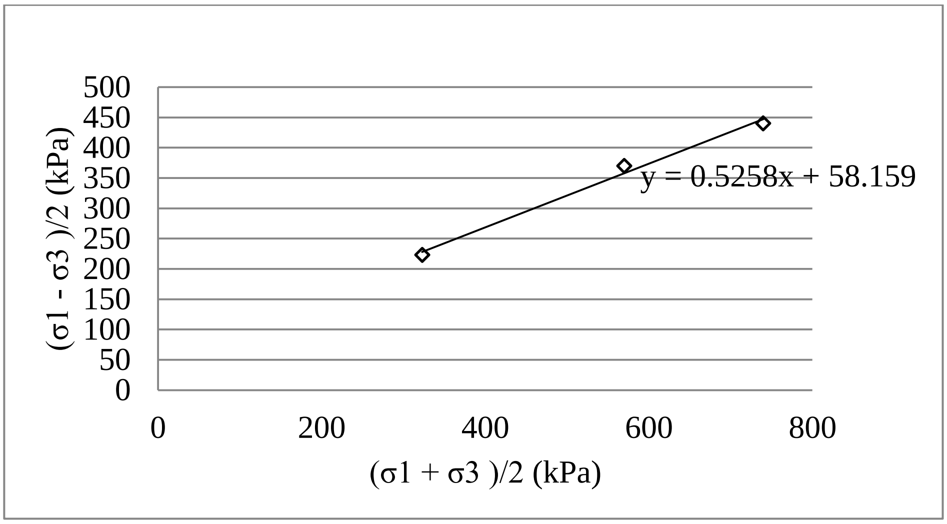

Fig. 102 Modified failure envelope for Pond Ash with soil (70:30)at0.5% Fibre

As obtained from graph,

α=27.71, & a=58.17

Thus, ϕ=31.69 & c=68.37

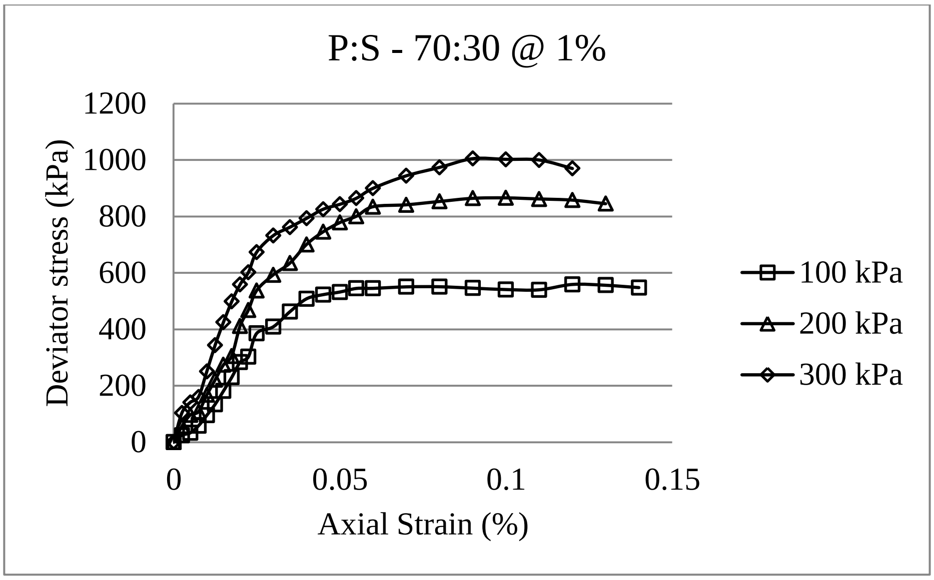

Fig. 103 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (70:30) at 1% Fibre

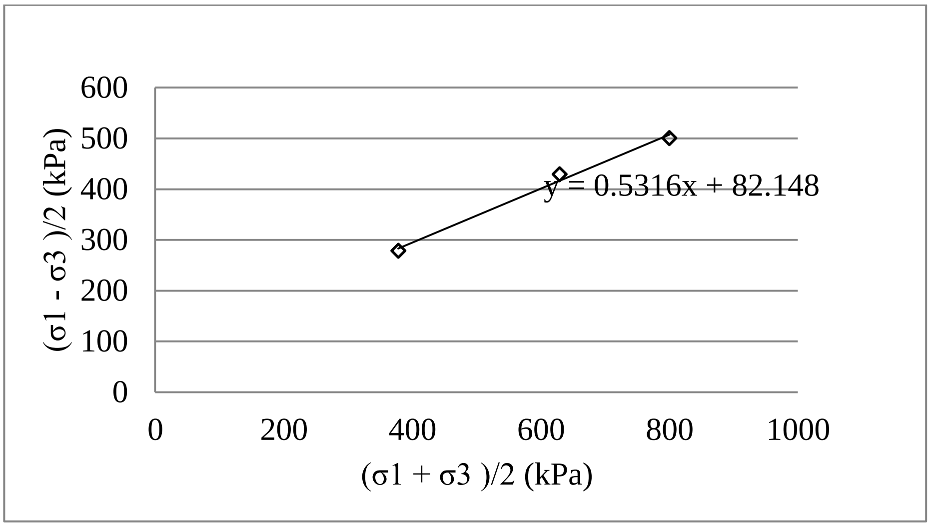

Fig. 104 Modified failure envelope for Pond Ash with soil (70:30)at 1% Fibre

As obtained from graph,

α=27.97, & a=81.22

Thus, ϕ=31.69 & c=95.86

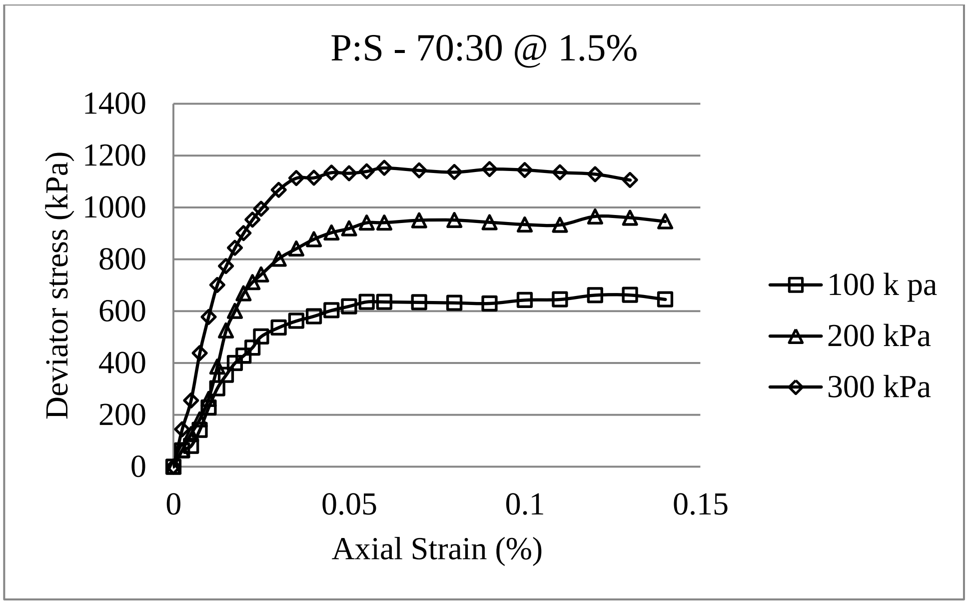

Fig. 105 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (70:30) at 1.5% Fibre

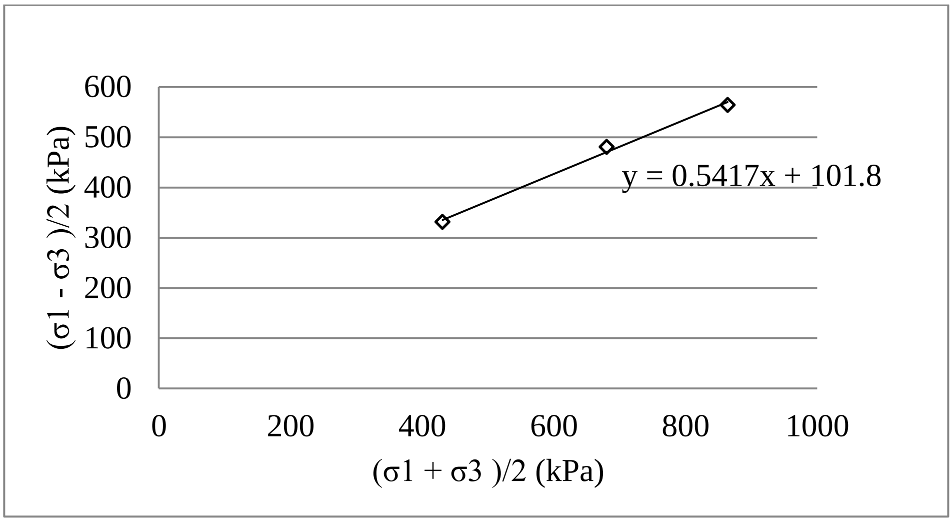

Fig. 106 Modified failure envelope for Pond Ash with soil (70:30)at 1.5% Fibre

As obtained from graph,

α=28.43, &a=101.35

Thus, ϕ=32.78 & c=120.55

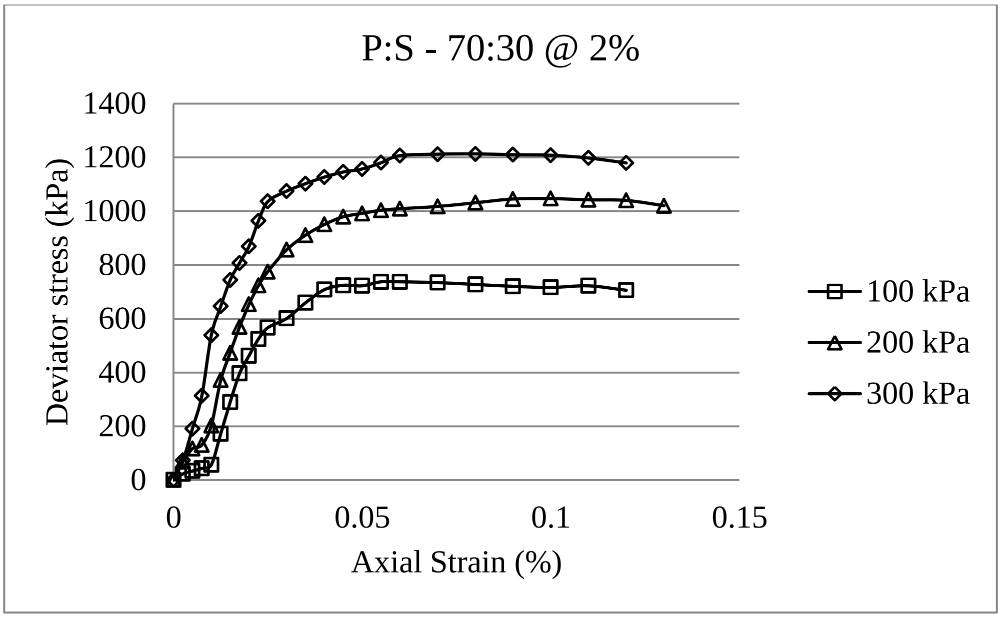

Fig. 107 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (70:30) at 2% Fibre

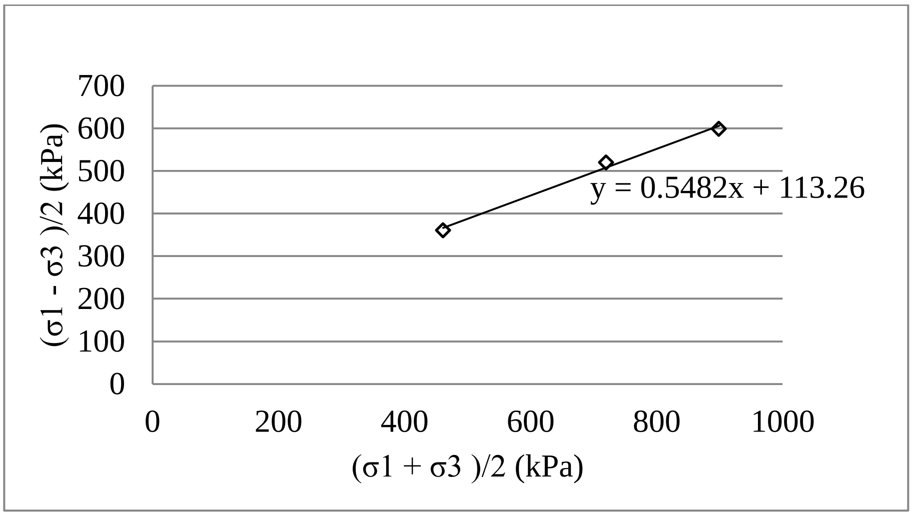

Fig. 108 Modified failure envelope for Pond Ash with soil (70:30)at 2% Fibre

As obtained from graph,

α=28.68, &a=113.77

Thus, ϕ=33.17 & c=135.92

P:S – 60:40

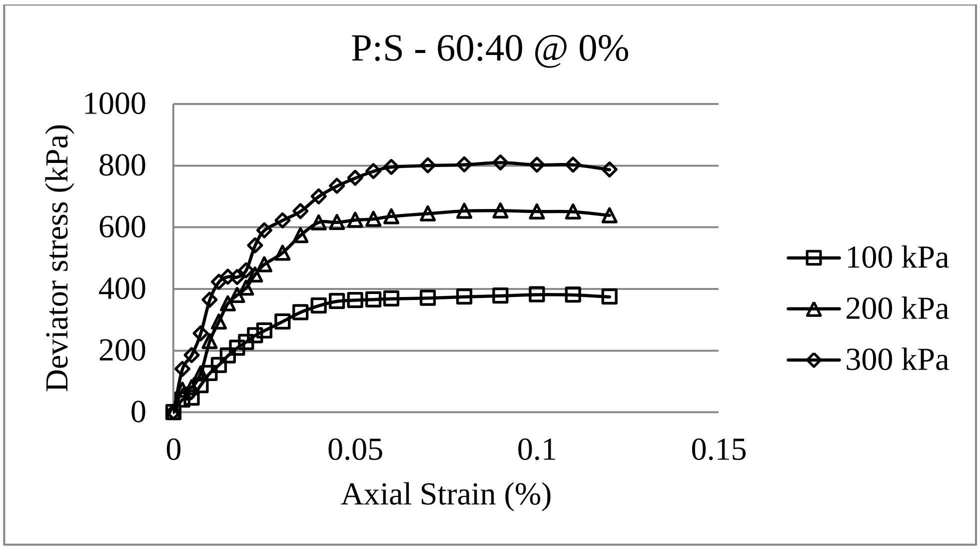

Fig. 109 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (60:40) at 0% Fibre

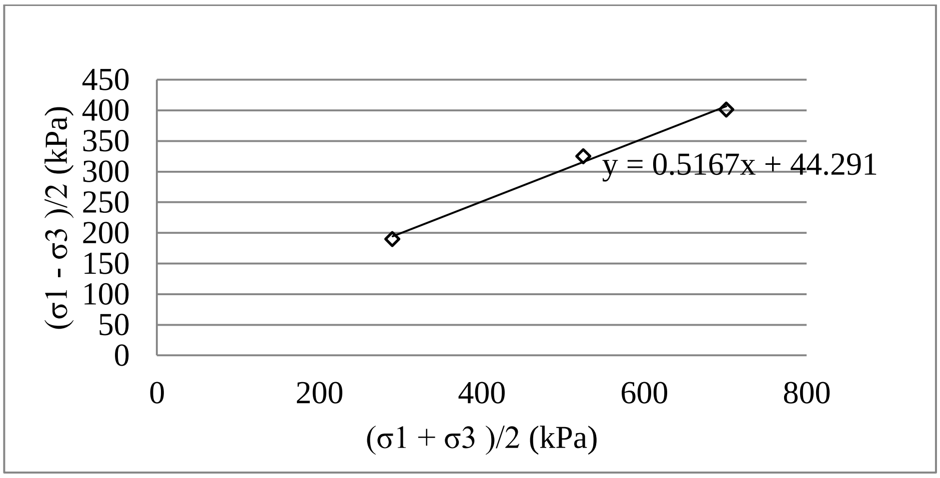

Fig. 110 Modified failure envelope for Pond Ash with soil (60:40) at 0% Fibre

As obtained from graph,

α=27.35, & a=39.06

Thus, ϕ=31.16 & c=44.49

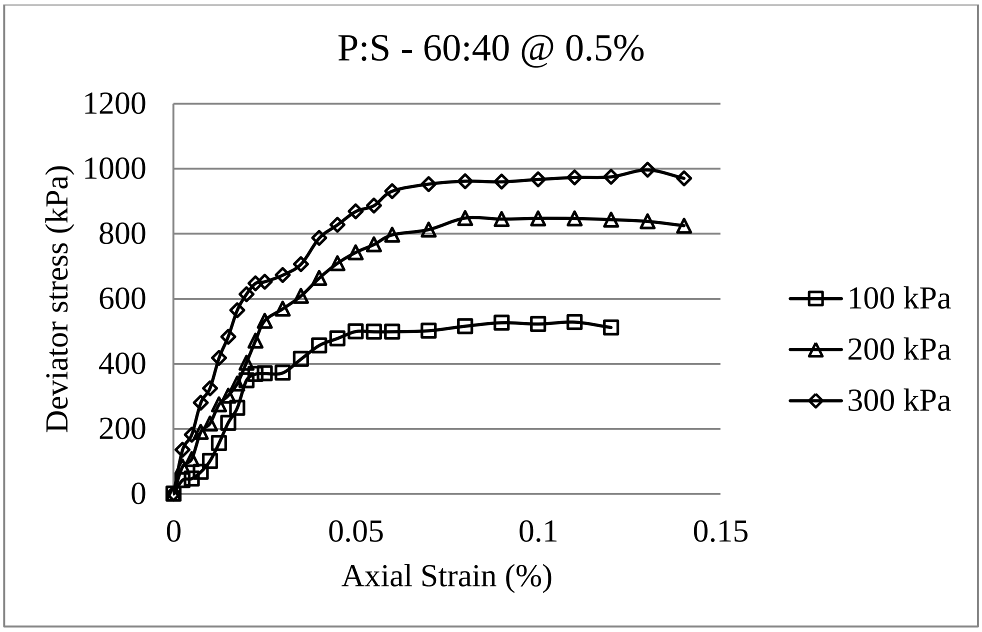

Fig.111 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (60:40) at 0.5% Fibre

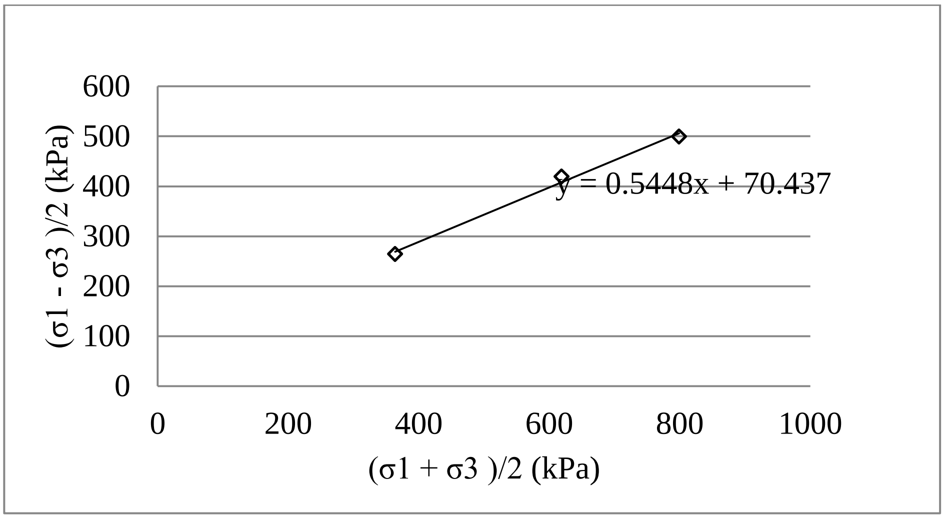

Fig. 112 Modified failure envelope for Pond Ash with soil (60:40)at 0.5% Fibre

As obtained from graph,

α=28.56, & a=65.98

Thus, ϕ=32.98 & c=75.49

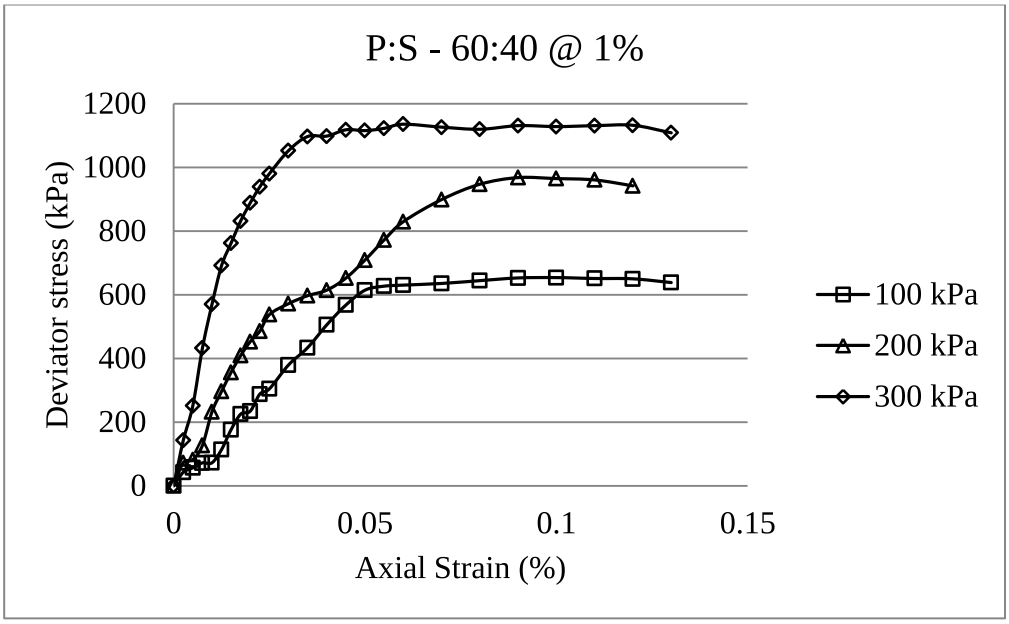

Fig. 113 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (60:40) at 1% Fibre

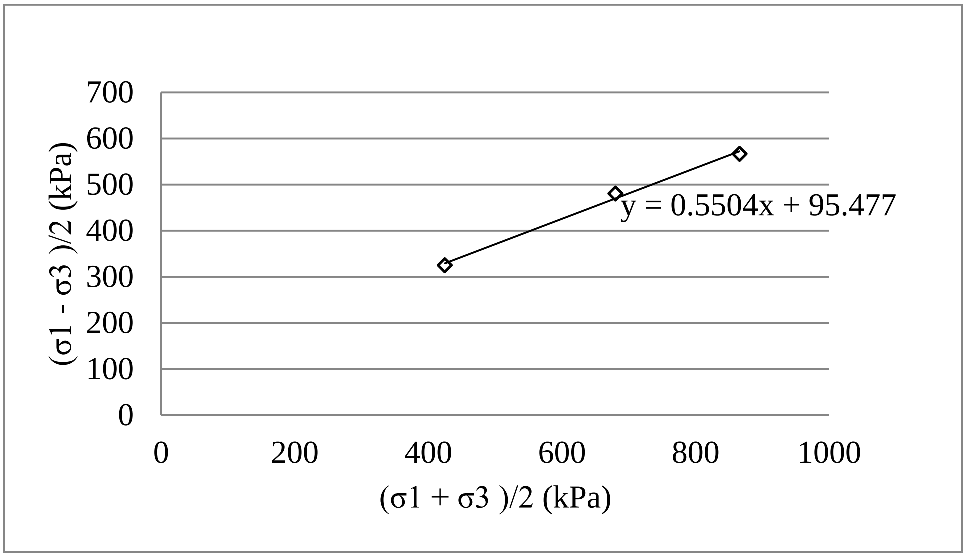

Fig. 114 Modified failure envelope for Pond Ash with soil (60:40)at 1% Fibre

As obtained from graph,

α=28.79, & a=95.93

Thus, ϕ=33.35 & c=114.85

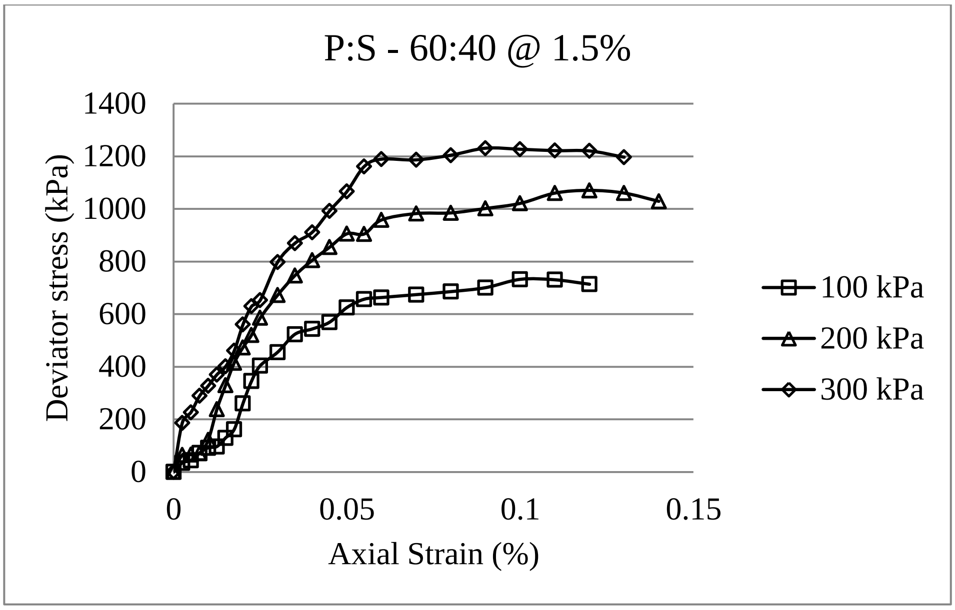

Fig. 115 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (60:40) at 1.5% Fibre

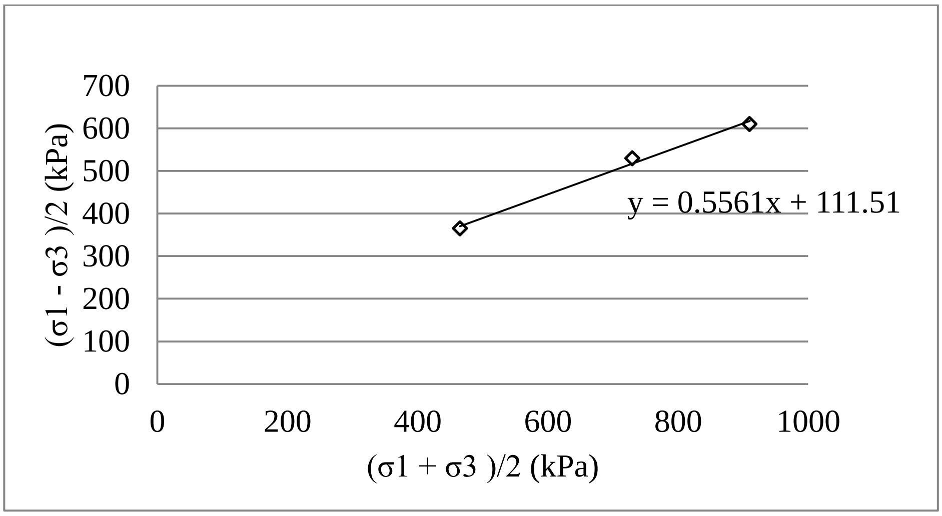

Fig. 116 Modified failure envelope for Pond Ash with soil (60:40)at 1.5% Fibre

As obtained from graph,

ɑ=29.11, & a=111.81

Thus, ϕ=33.84 & c=134.62

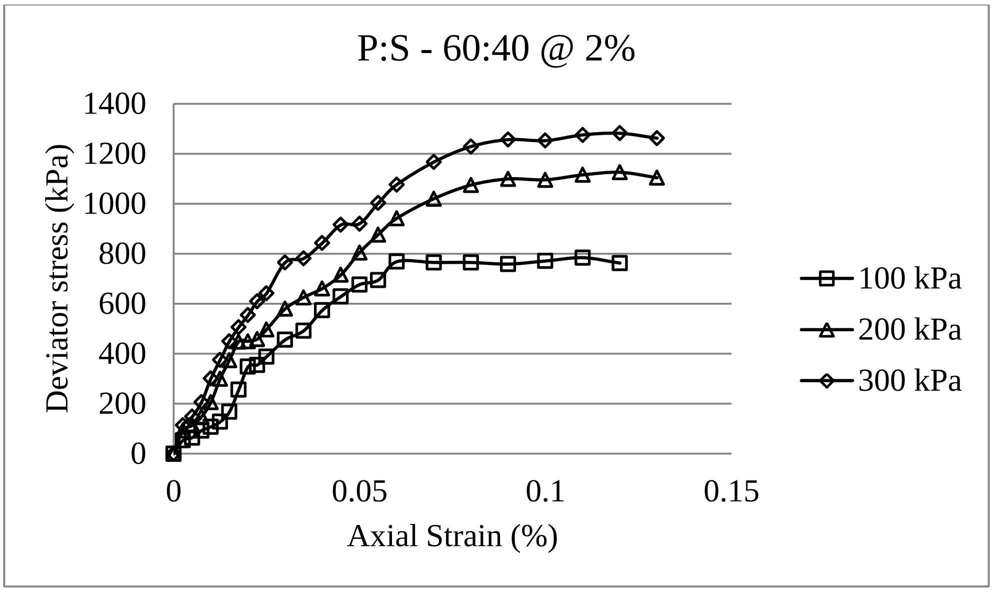

Fig. 117 Plot between Deviator Stress and Axial Strain for Pond Ash with soil (60:40) at2% Fibre

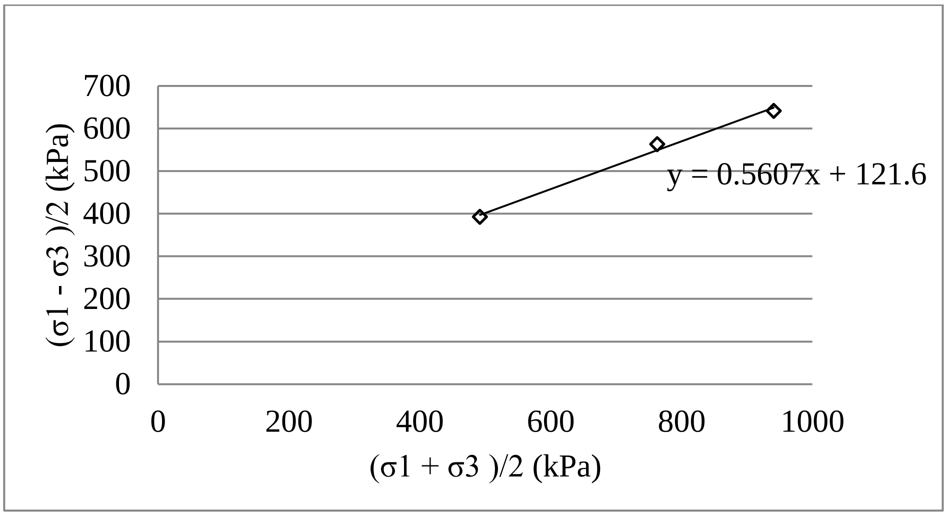

Fig. 118 Modified failure envelope for Pond Ash with soil (60:40)at 2% Fibre

As obtained from graph,

α=29.25, & a=121.58

Thus, ϕ=34.07 & c=146.78

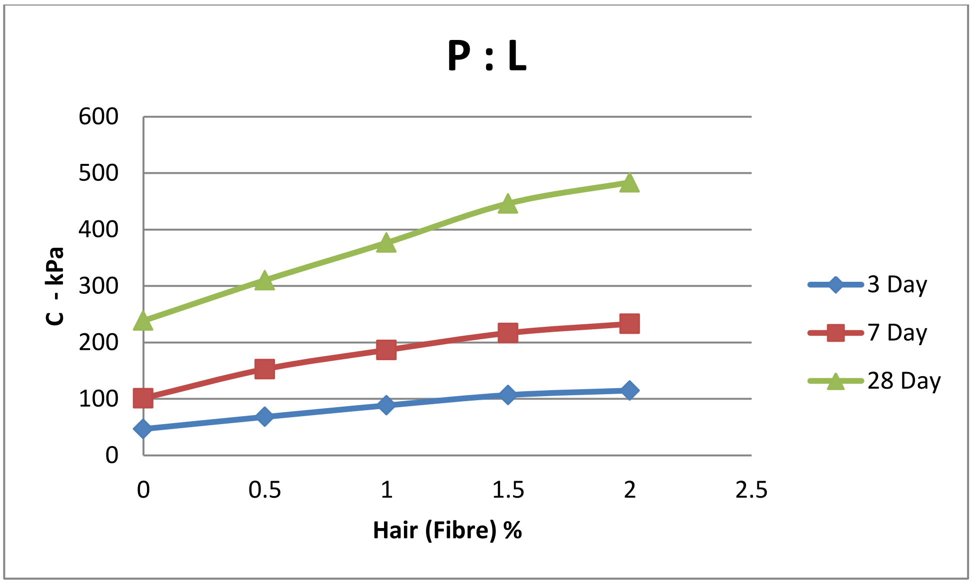

Fig. 119 Comparison of P:L Cohesion with Hair % of different samples on 3,7 & 28 Days

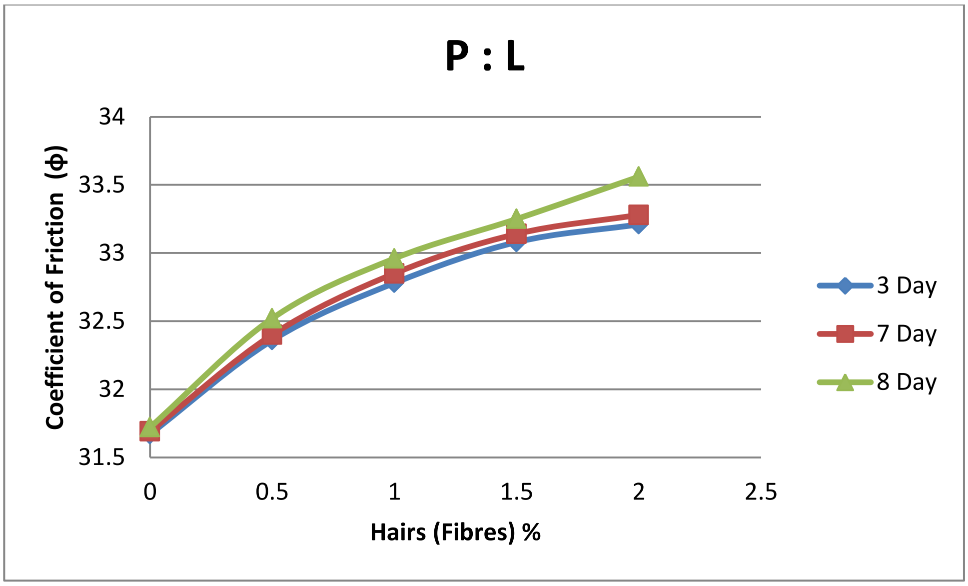

Fig. 120 Comparison of P: L Coff. of friction with Hair % of different samples on 3,7& 28 Days

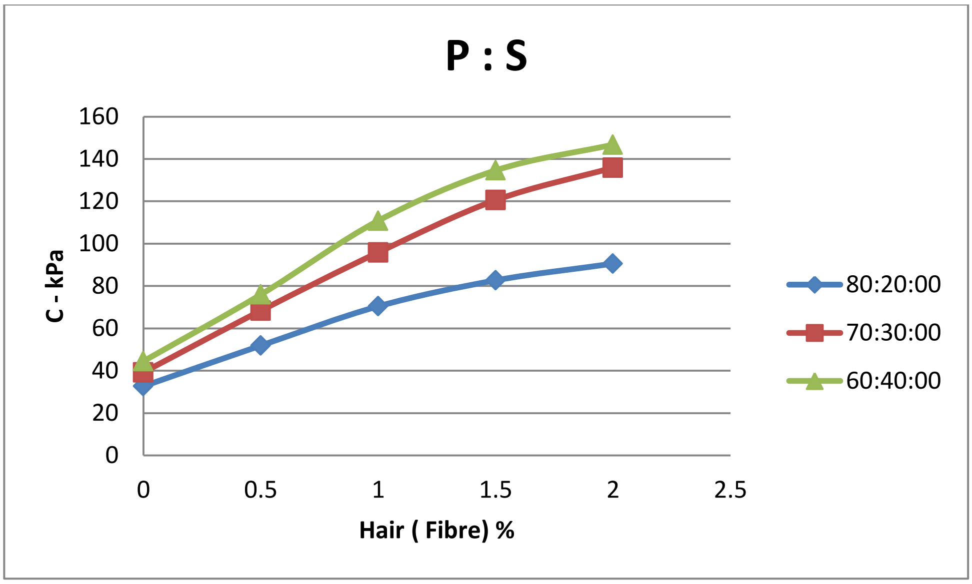

Fig. 121 Comparison of P:S Cohesion with Hair % st different Proportion of samples

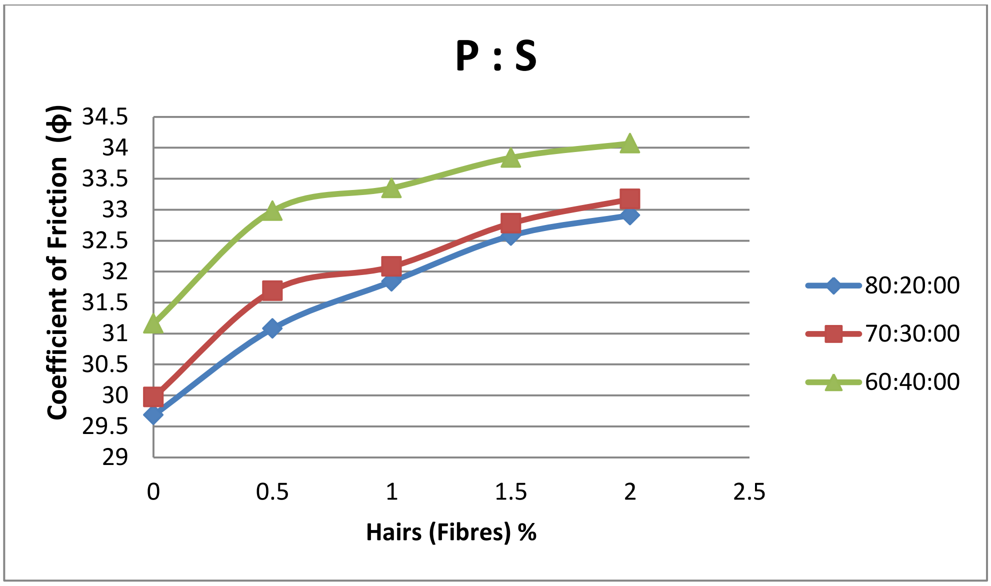

Fig. 122 Comparison of P: S Coff. of friction with Hair % st different Proportion of samples

In Triaxial UU test the trend in the change of *c* and ϕ due to fiber inclusions is not very consistent. Still, the fiber inclusion increases the shear strength.

The Pond ash-composite specimens compacted at the MDD-OMC state exhibit brittle behavior in unconfined compression tests.The fibres modifies the stress condition in the specimens and transfer the shear along the failure plane to the surrounding mass by combined effect of adhesion and friction between the fibre and composite particle material.

The failure envelope in the unconsolidated undrained test plotted as the variation of modified envelope which mainly shows quite a linear behaviour of increment of cohesion & internal friction(ϕ),in which change in ϕ is not so much but that of c shows abrupt increase mainly for P:L as shown in figure from 119 to 121 ,due to lime-effect, inclusion of fibre which provides reinforcement and their own cohesion between particles, which maximises as curing increases.

In case of P: S composite mixtures at different proportions the best results obtain for P:S – 60:40 with maximum values.

4.9 CBR test Comparision, IS: 2720 (Part 16) (1987)

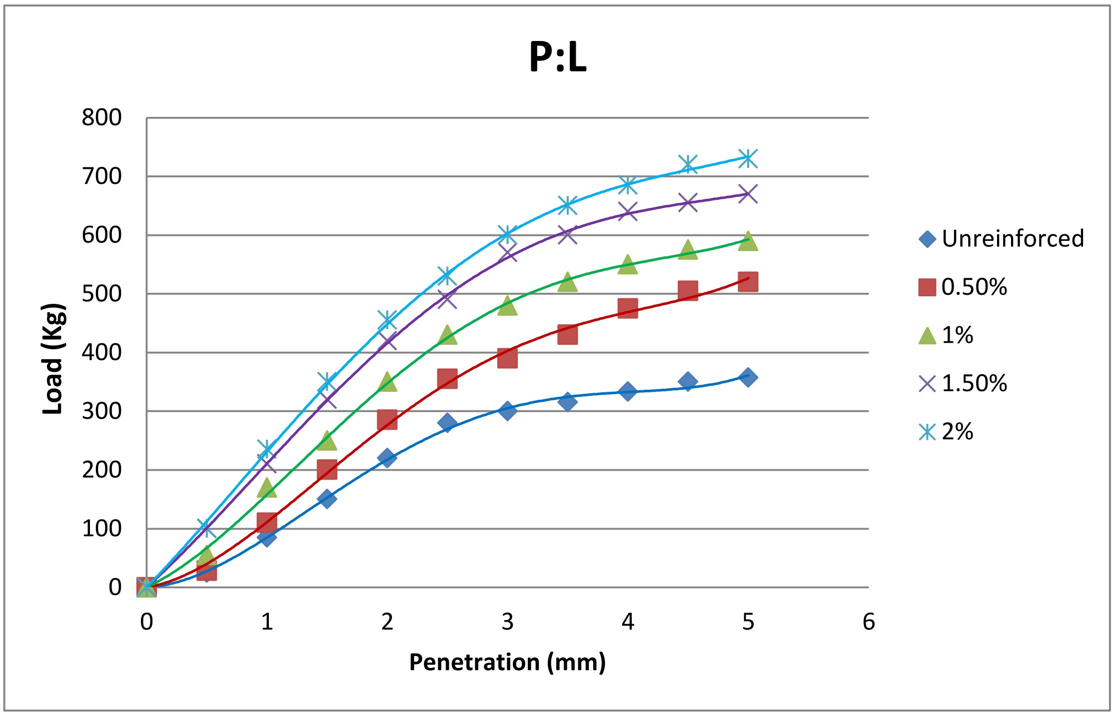

Fig. 123 Comparison of CBR plot between Penetration and Load for Pond Ash with Lime at different Reinforcements

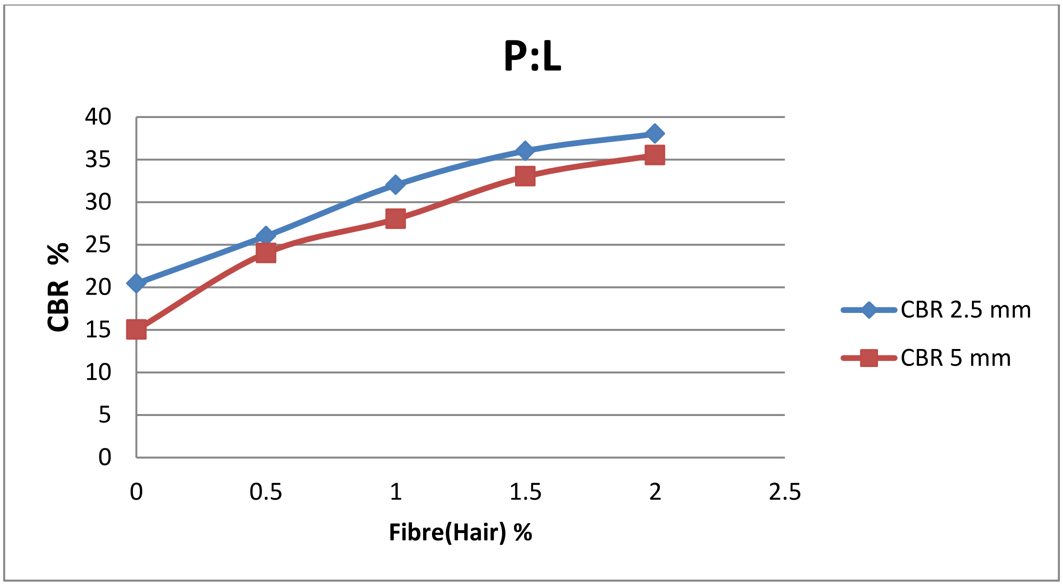

Fig. 124 Comparison of CBR Values at 2.5mm & 5 mm penetration

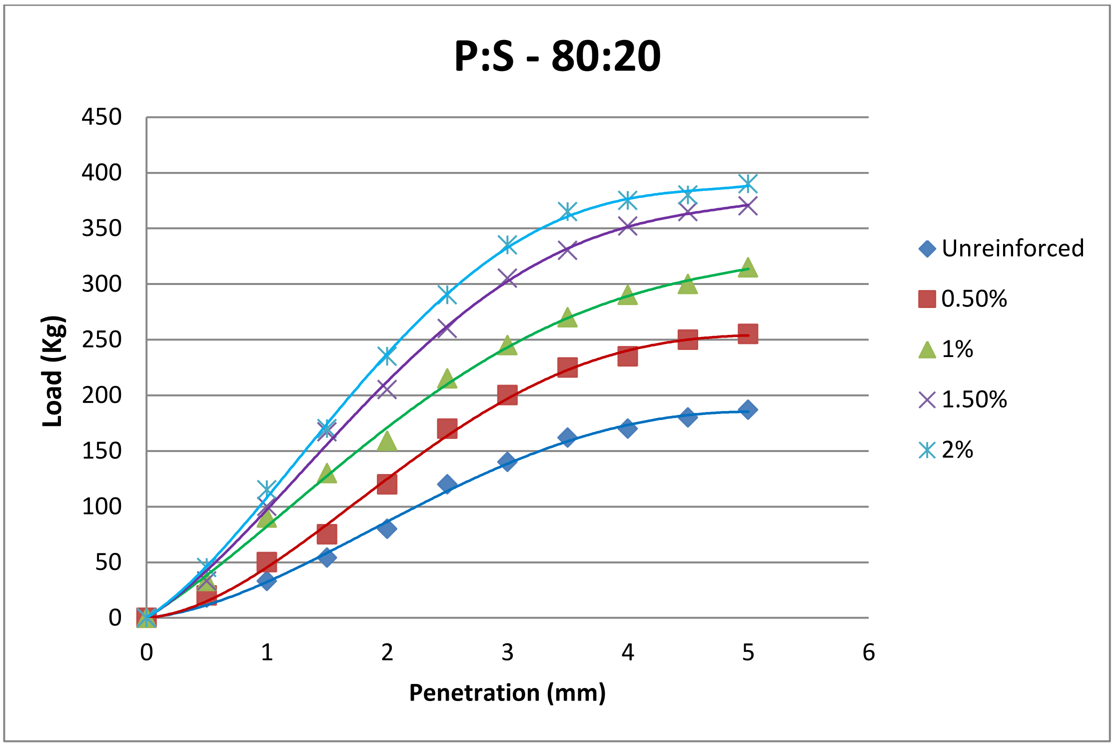

Fig. 125 Comparison of CBR plot between Penetration and Load for Pond Ash with Soil @80:20 at different Reinforcements

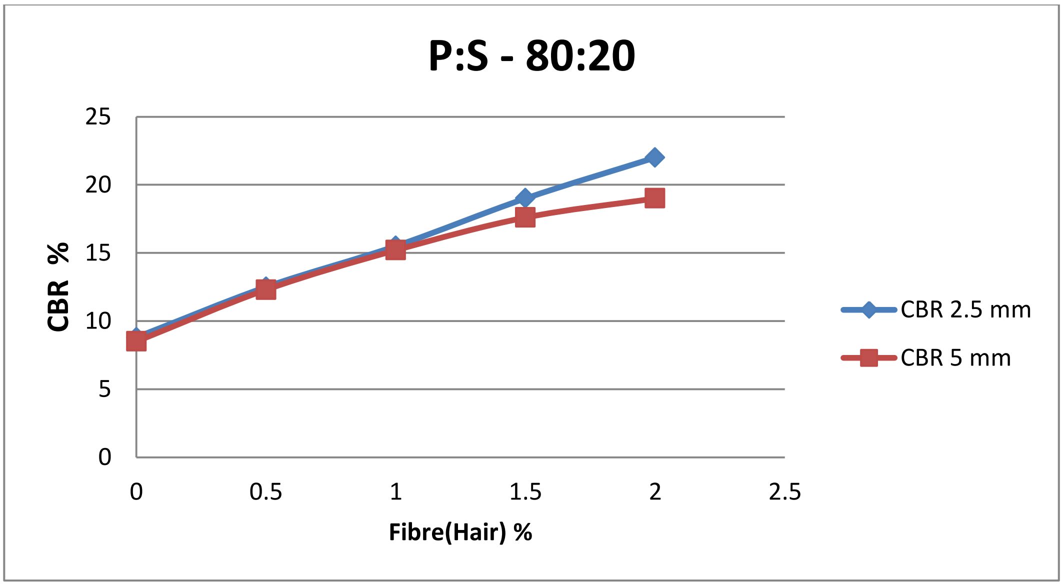

Fig. 126 Comparison of CBR Values at 2.5mm & 5 mm penetration

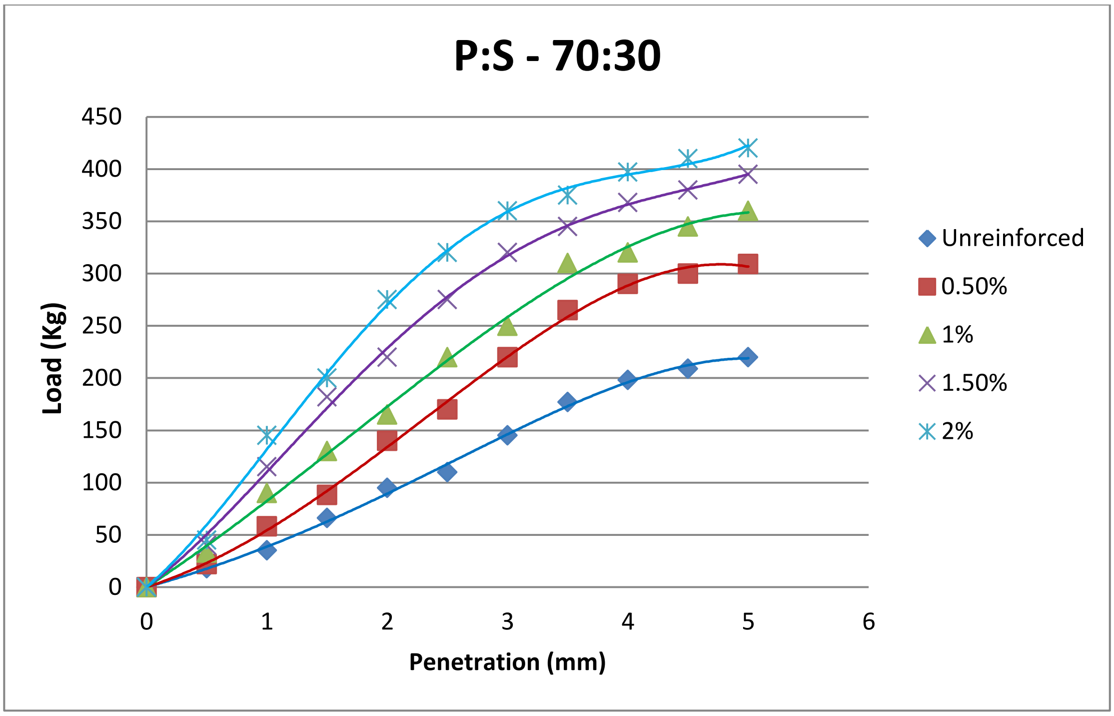

Fig. 127 Comparison of CBR plot between Penetration and Load for Pond Ash with Soil @70:30 at different Reinforcements

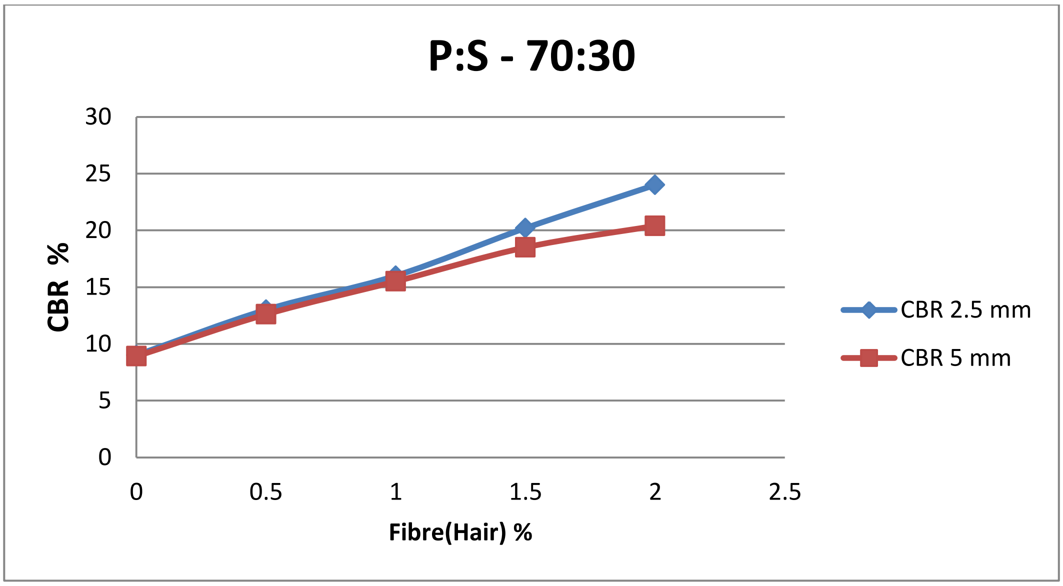

Fig. 128 Comparison of CBR Values at 2.5mm & 5 mm penetration

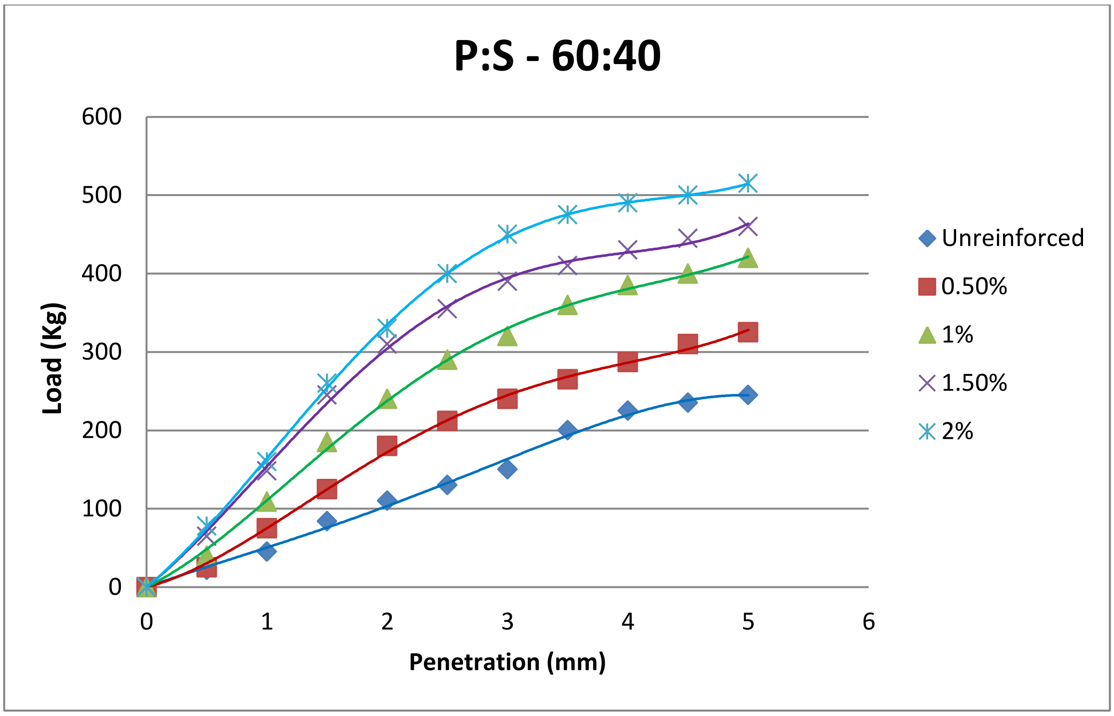

Fig. 129 Comparison of CBR plot between Penetration and Load for Pond Ash with Soil @60:40 at different Reinforcements

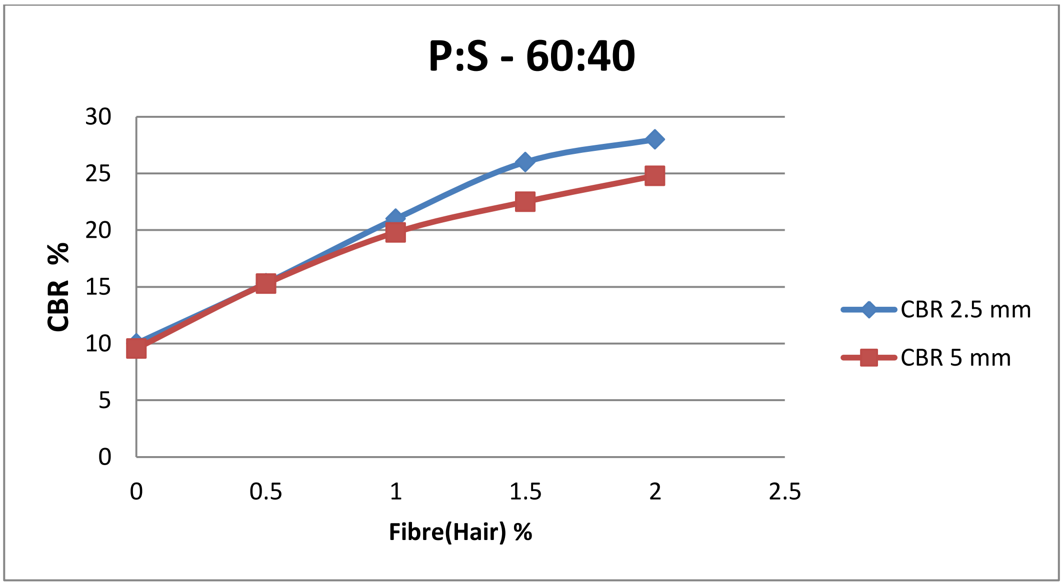

Fig. 130 Comparison of CBR Values at 2.5mm & 5 mm penetration

The CBR test reveals that CBR value increases every time the fibre is increased. This can be due to the interlocking of composite material particles with fibre. Also there could be presence of hydrated lime for P:L sample which provides strength on hydration and acts as a binder between materials. CBR values at 2.5 mm are higher than the values at 5 mm when pond ash mixed with lime as can easily capture from graph but for in case with soil with pond ash the difference can visible after inclusion of fibre more than 1% and are best obtained for P:S – 60:40, uto 25% at 2% fibre(hair).Also higher the curing period higher in CBR value for mixtures of lime.

CBR value increases with fiber content in both cases of soaked and unsoaked conditions here I performed test for Unsoaked condition in which CBR value increases more rapidly with increase in fiber content. Pond ash as such has CBR value of 8.5%, so it cannot be used in subbase as such. After mixing 8% lime with different fibre contents as mentioned, CBR value varying from 20% to 37%, which is more than 15% % in both cases of P:L and P:S and so much suitable for subbases as per SP-20 IRC 2002.

4.10 Indirect Tensile Strength Test (Brazilian), IS: 10082 (1982).

Table 5 Tensile strength of Pond Ash & Lime at different fibre% at different curing days

Samlpes	Curing Days	Percent of Fibre	Brazillian Tensile Strength (kPa)
PA+Lime(8%)	3 Days	0	0
		0.5	0
		1	0
		1.5	63.66
		2	95.66
	7 Days	0	0
		0.5	127
		1	158.66
		1.5	190
		2	222.25
	28 Days	0	95.25
		0.5	190
		1	254.65
		1.5	285.75
		2	317.5

Table 6 Tensile strength of Pond Ash & Soil at different proportions at different fibre%

Samlpes	Proportion	Percent of Fibre	Brazillian Tensile Strength (kPa)
PA+SOIL	80:20	0	0
		0.5	0
		1	0
		1.5	0
		2	0
	70:30	0	0
		0.5	0
		1	0
		1.5	63.66
		2	95.54
	60:40	0	0
		0.5	0
		1	63.07
		1.5	95.54
		2	127

The bonding and interlocking between the pond ash composite mixture particle and reinforcement facilitates the transfer of the tensile strain developed in the mass to the reinforcement and thus, the tensile strength of the reinforcement is mobilized and helps in improving the load capacity of the reinforced mass. The test result shows that the failure stress of reinforced specimen"s increases with fibre content.

Reliable theories and failure criteria that realistically describe soil behaviour here pond ash under tension are still limited to date due to their nonlinearity. Moreover, tension testing is difficult to perform as achieving a well-defined stress state is difficult.Suitable testing apparatus that can accurately measure tensile stress and strain are not
readily available or standardised, and the selection of appropriate sample shape and preparation techniques is cumbersome.

Here for Pond ash composite samples I use Brazillian method for indirect determination of tensile strength, as mentioned for soils the aspect ratio for samples to be kept must be 2, that I kept. Still results obtained by it somewhat non-uniform but of increasing values with fibre.The strength developed in case of P:L at different curing days is of increasing nature as shown in above table, but for the P:S specimen the strength is not sufficiently developed to get from specified apparatus.

There is, however, recognition and great concern over the significance of tensile behaviour of soils here pond ash related to slope and embankment stability, differential settlement of embankment dams, landfill liners, rigid and flexible road pavements and airfields. Tension cracking is a well-know problem in earth structures and in certain cases, the tensile stresses are high enough to produce large cracks in various part of the structure and can detrimentally threaten the stability, performance and integrity of the structure.

CHAPTER-5

CONCLUSION

1. The Scanning Electron Microscopy of Pond ash Composite samples & individual material lightened on their surface morphology, particle size & their interaction with each other on other hand X-Ray Diffraction informs about its mineralogy but gave a pretty much unclear view about the mix. Isolated sharp peaks were very much absent due to the amorphous nature of diffractograms. This can be due to the absence of proper sample preparation and other treatments.

2. A series of compaction test were performed to evaluate the effect of fiber(Hair) inclusion on OMC and maximum dry density of composite Pond ash specimen. Here, from fig 16 can easily get that Pond ash with low MDD strengthened by the inclusion of Lime but get decreased again by increasing percentage of fibre, which also responsible for increase of OMC of P:L composite mixtures.

   While on other hand in P:S mixtures MDD increases as Percentage of soil increases otherwise respond same behaviour for the inclusion of fibre i.e increment of OMC & decrement of MDD with fibre percentage increases.

3. The unconfined compressive strength of composite specimens are found to increase with the fibre content. However, the rate of increase of strength with fibre content is not linear. Initially the rate of increase in UCS is high, then the same is not that much prominent.

   Here Lime content contribute to self hardening and randomly oriented discrete inclusions fibres (hairs) improves its load – deformation behaviour by interacting with the pond ash particles mechanically through surface friction and also by interlocking.

   On comparing the results from UCS test of soil sample, it is found that the increment in the values of unconfined compressive strength for Hair reinforcement 0%, 0.05%, 1%, 1.5% & 2% upto 30% for 0-0.5% fibre(hair), then 18-20% for 0.5-1% fibre,12.5-17% for 1-1.5% fibre and 8-10% for 1.5-2% fibre at different curing days for Pond ash & lime. Similar case with Pond ash & soil at different proportions in which more prominent for 60:40 ratio PA:S.

4. In Triaxial UU test the trend in the change of *c* and ϕ due to fiber inclusions is not very consistent. Still, the fiber inclusion increase the shear strength.

   The Pond ash-composite specimens compacted at the MDD-OMC state exhibit brittle behavior in unconfined compression tests. The fibres modifies the stress condition in the specimens and transfer the shear along the failure plane to the surrounding mass by combined effect of adhesion and friction between the fibre and composite particle material.

   The failure envelope in the unconsolidated undrained test plotted as the variation of modified envelope which mainly shows quite a linear behaviour of increment of cohesion & internal friction(ϕ),in which change in ϕ is not so much but that of c shows abrupt increase mainly for P:L as shown in figure from 119 to 121 ,due to lime-effect, inclusion of fibre which provides reinforcement and their own cohesion between particles, which maximises as curing increases.

   In case of P:S composite mixtures at different proportions the best results obtain for P:S – 60:40 with maximum values.

5. CBR values at 2.5 mm are higher than the values at 5 mm when pond ash mixed with lime as can easily capture from graph but for in case with soil with pond ash the difference can visible after inclusion of fibre more than 1% and are best obtained for P:S – 60:40, uto 25% at 2% fibre(hair).Also higher the curing period higher in CBR value for mixtures of lime.

   CBR value increases with fiber content here in unsoaked condition in which CBR value increases more rapidly with increase in fiber content. Pond ash as such has CBR value of 8.5%, so it cannot be used in subbase as such. After mixing 8% lime with different fibre contents as mentioned, CBR value varying from 20% to 37%, which is more than 15% in both cases of P:L and P:S and so much suitable for subbases as per SP-20 IRC 2002.

6. The bonding and interlocking between the pond ash composite mixture particle and reinforcement facilitates the transfer of the tensile strain developed in the mass to the reinforcement and thus, the tensile strength of the reinforcement is mobilized and helps in improving the load capacity of the reinforced mass. The test result shows that the failure stress of reinforced specimen’s increases with fibre content. Still a

well-defined stress state is difficult and brazillian methods for indirect determination of tensile strength used here along with others are not readily available or standardised.

7. Hence, the strength parameters achieved in present study is comparable to the good quality. Hence, it can be safely concluded that the Fibre(Hair) reinforced the Pond ash samples with lime and sandy silt drawn towards the usability and effectiveness of fiber reinforcement as a especially in Subbases for roads ,slopes, and landfills, with a very important factor of utility of solid waste in a cost effective approach.

Also the research & work using fibre as HAIR is very new, and get very few paper for literature. Thus present work with fibre as hair provide wholesome a sufficient literature that should receive attention to initiate work in further studies.

CHAPTER-6

SCOPE FOR FURTHER STUDIES

For effective functioning of structures made up of reinforced soil, some more aspects may have to be investigated.

.

1) Compressibility and Consolidation characteristics of compacted on these pond ash composite..
2) Bearing capacity of surface and embedded embankments and foundations.
3) Effect of aspect ratio that is different fibre length on strength parameters and to arrive at an optimum value.
4) Effect of other natural and synthetic fibres on geo-engineering properties.
5) Permeability and Liquefaction succesbility of fibre reinforced composites.
6) The decay of organic fibres, creep effect in fibres to be studied.
7) Its effect & capacity when used as fill material in retaining walls.

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