Strength Characteristics of Pond Ash Mixed With Polypropylene Fibre

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Abstract— Pond ash is a by-product obtained from Thermal Power Plants due to burning of coal. It is a mixture of Fly ash and bottom ash which is deposited in slurry form in ash ponds. India's electricity demands are met through Power plants of which most are coal based. Based on some estimation 73 % power plants are coal based from which huge tonnes of Pond ash are generated every year. Disposal of these waste products is a big nuisance and poses threat to environment. Disposal in Pond ash in ash ponds not only causes loss of agricultural land which could provide food to human and animal race, it also renders the land unfit for future use. Because of large amount of Pond ash generation, large amount of land is increasingly being used for its diposal which is posing serious threat to food security. Hence the need of the hour is to look for alternative ways to utilise this by product. The present study is based on the effective utilisation of Pond ash in geotechnical field and its replacement as conventional earth material. The geotechnical characteristics of compacted Pond ash were evaluated using Polypropylene fibres. Polypropylene fibres of 6 mm, 12 mm and 19 mm length were used in 0.5 %, 1 % and 1.5 % of dry weight of Pond ash and their effect on strength characteristics of Pond ash were studied. The effect of fibre reinforcement on compacted density was studies using heavy compaction test. The stress strain behaviour of Pond ash using triaxial tests (unconsolidated undrained) was performed. The results showed increase in ductility of pond ash due to fibre inclusion and also increase in peak deviator stress. Higher strength were obtained in 19 mm fibres but keeping the economical and ease of handling issues in mind 12 mm fibres showed encouraging results. It can be safely concluded that Pond ash can replace conventional earth materials.

Keywords: Seed Sowing, Seed Sowing Techniques, Planting Seed, Farmer

I. INTRODUCTION

A. General

Over the last few years, environmental and economical issues have stimulated interest in the development of alternative materials and reuse of industrial waste/by-products that can fulfill specification that can replace conventional earth materials. A material such as pond ash is a residue collected from ash pond near thermal power plants.

Pond ash is a non-plastic and lightweight material having the specific gravity relatively lower than that of the similar graded conventional earth material. Pond ash is a fine-coarse, 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. Massive generation of pond ash by thermal power plants has become a major cause of concern for people living in and around thermal power plants. The current rate of generation of coal ash in India has reached 130 million tons per annum with about 75,000 acres of precious land under the cover of abandoned ash ponds.

It is estimated that the generation of pond ash from coal fired generation units in India will reach 170 million tons per annum by the year 2012 whereas, the current rate of utilization of ash is about 35%. This leads to an ever increasing ponding area for storing ash and related environmental issues. On the other hand, the construction of highways and roads in India, which has taken a boom in the recent years, requires a huge amount of natural soil and aggregates. To meet this demand ruthless exploitation of fertile soil and natural aggregate is being adopted. This has brought the situation to an alarming state. To address these problems pond ash has been tried in the low lying areas as structural fills and embankment construction for highways. However, due to lack of sufficient knowledge and confidence its use has not taken momentum.

B. Historical Background

1) Early Practices

Soil specially cohesion less material like gravel, sand and coarse silt cannot take even low stress in tension and fails instantaneously. The early man has known this phenomenon from intuition. Men used woven reeds in making sun dried bricks in ancient times even prior to Christian era. Fibrous materials like vines and papyrus are used in earth structures and mud walls in Egypt and Babylon. In the construction of the Great Wall of China where are used extensively, branches of trees were used as reinforcement in the construction of Agar-Quif ziggurat near Baghdad. Romans who developed a high degree of engineering skills in construction to meet the civic needs and military requirements built reed reinforced earth leaves along the river Tiber. Wharf walls in England also were constructed by Romans using wooden scantling as earth reinforcement. In the last century Col. Palsey introduced reinforced earth for military construction in British army. The Dutch used reinforced earth by faggoting for sea protective works.

C. Modern Development

The modern approach to reinforced earth techniques was first introduced in France and USA. In 1925, the concept was first introduced by Monster. The structure built was retaining wall with reinforced earth, wood was used as reinforcement. In the early fifties, the French constructed retaining walls constructed of granular fill with membrane. This cladding membrane was anchored with flexible ties. The first major work on reinforced earth was introduced in large scale from 1964 onwards both in USA and Europe and this was followed by detailed experimental and theoretical investigation to study the mechanism of the reinforced earth in France. This programmed was introduced by Henry Vidal and François Schlosser and the scientific approach to the study of reinforced earth structures can be said to have opened up since then.

D. Reinforcing Materials

1) General

A number of materials have been reported to be successfully used as reinforcements such as steels, geofabrics, geogrids, aluminium, glass fibre, wood, rubber and concrete. In developed countries polypropylene based synthetic fibres and grids are now preferred due to their availability with desired properties and durability. However, they are yet to be used widely in India as they are more costly. The reinforcement may take the form of strips, grids, sheet materials, rope and other combinations. The major requirements of the reinforcing materials are strength, durability, ease of handling, high adhesion or friction with soil and availability at low-cost.

Resistance to ultraviolet radiations and surface conformity should be considered for all jobs.

Soil has used as a construction material from times immortal. Being poor in mechanical properties, it has been putting, challenge to civil engineering’s to improve its properties depending upon the requirement which varies from site to site and economic constrains. There are many techniques employed to improve the engineering and mechanical properties of soil can be put into five major categories:

1) Soil stabilization
2) Reinforced earth
3) Soil nailing
4) Texsol
5) Fibre reinforced oil or ply soil

2) Fibre Reinforced Soil (Ply Soil)

Randomly distributed fibres reinforced soil –termed as RDFS is among the latest ground improvement techniques in which fibres of desired type and quantity are added in soil, mixed randomly and laid in the position after compaction. Thus, the method of preparation of RDFS is similar to conventional stabilization techniques. RDFS is different from the other soil – reinforcing methods in its orientation. In reinforced earth, the reinforcement in the form of strips, sheets, etc. is laid horizontally at specific intervals, where as in RDFS fibres are mixed randomly in soil thus making a homogenous mass and maintain the isotropy in strength. Modern geotechnical engineering has focused on the use of planar reinforcement (e.g. metal strips, sheet of synthetic fabrics). However reinforcement of soil with discrete fibres is still a relatively new technique in geotechnical project.

Concepts involving the reinforcement of soils using fibres have been used since ancient times. For example, early civilizations added straws and plant roots to soil bricks to improve their properties, although the reinforcing mechanism may have not been fully understood. While building the Great Wall of China, the clay soil was mixed with tamarisk branches. The ancient method of addition of straw of wheat locally called “Turi” to the clay mud plaster is still very popular in villages. Improvement of soil by trees roots is similar to the work fibres. Gray (1947, 1978), Waldron (19770 and Wu et al. (1988) reported that plant roots increase the shear strength of the soil and, consequently the stability of natural slopes. Synthetic fibres have been used since the late 1980s, when the initial studies using polymeric fibres were conducted. Specially, triaxial compression tests, unconfined compression tests, direct shear tests and CBR tests had been conducted to study the effect of fibre reinforcement on strength characteristics and other engineering properties of RDFS. During last twenty –five years, much work has been done on strength deformation behavior of RDFS and it has been established beyond doubt that addition of fibre in soil improves the overall engineering performance of soil. Among the notable properties that improve are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. RDFS has been used in many civil engineering projects in various countries in the recent past and the further research is in progress for many hidden aspects of it. RDFS is effective in all types of soil (i.e sand, silt and clay)

3) Advantages of Fibre-Reinforced Soil

Randomly distributed fibre reinforced soil (RDFS) offers many advantages as listed below:

1) Increased shear strength with maintenance of strength isotropy.
2) Beneficial for all type of soils (i.e. sand, silt and clay).
3) Reduce post peak strength loss.
4) Increased ductility.
5) Increased seismic performance.
6) No catastrophic failure.
7) Great potential to use natural or waste material such as coir fibers, shredded teire and recycled waste plastic strips and fibers.
8) Provide erosion control and facilitate vegetation development.
9) Reduce shrinkage and swell pressure of expansion soil.
10) No appreciable change in permeability.
11) Unlike lime, cement and other chemical stabilization methods, the construction using fiber – reinforcement is not significantly affected by weather conditions.
    1) Fiber-reinforcement has been reported to be helpful in eliminating the shallow failure on the slope face and thus reducing the cost of maintenance

II. LITERATURE REVIEW

Pond ash is a waste product of coal combination in thermal power plants. Itpossess problems for the safe disposal and causes economic loss to the power plants. Thus, the utilization of pond ash in large scale geotechnical constructions as a replacement to conventional earth material needs special attention. The inherent strength of pond ash can be improved by reinforcing.

Reinforced earth is a composite material, which is a combination of soil and reinforcement, suitably placed to withstand the developed tensile stresses and also it improves the resistance of the soil in the direction of the greatest stress. The essential features of reinforced earth are the friction between the earth and reinforcement, by means of friction the soil transfer to the reinforcement the forces built in the earth mass. The reinforcement thus develops tension when the earth mass is subjected to shear stresses along the reinforcement.

Digioa (1972) says that with drainage, the ash can be effectively and economically utilized as a fill material to construct stable embankment for land reclamation on which structure can be safely founded.

Leonards (1972) reported that untreated pulverised coal ash with no cementing quantities was used successfully as a material for structural fill. Although, the ash was inherently variable, it could be compacted satisfactorily, if the moisture content was maintained below the optimum obtained from standard laboratory tests and if the percentage of fines (passing the No.200 sieve) was below 60%.

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.

Pandey et al. (2002) attempted to devise the ways for the use of this mixed ash for manufacturing mixed ash clay bricks successfully. The bricks thus made are superior in structural and aesthetic qualities and portents huge saving in the manufacturing costs with better consumer response.

Kumar and Stewart (2003) conventionally found that physical properties of coal ashes are assumed to be similar to natural sands, as it has appearance of natural sands and their particles are in the range of fine sands.

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

Das and Yudhbir (2005) gave the experimental studies with regard to some common engineering properties e.g., grain size, specific gravity, compaction characteristics and unconfined compression strength of both low and high calcium fly ashes to evaluate their suitability as embankment materials and reclamation fills. In addition morphology, chemistry, and mineralogy of fly ashes were studied using scanning electron microscope, electron dispersive x-ray analyzer, x-ray diffractometer and infrared absorption spectroscopy. The distinct difference between self-hardening and pozzolanic reactivity was also emphasized.

Bera et al. (2007) presented the study on compaction characteristics of pond ash. Three different types of pond ash have been used in this study. The effects of different compaction controlling parameters, viz. compaction energy, moisture content, layer thickness, mould area, tank size, and specific gravity on dry density of pond ash are highlighted. The maximum dry density and optimum moisture content of pond ash vary within the range of 8.40–12.25 kN/m^3 and 29–46 %, respectively. In the present investigation, the degree of saturation at optimum moisture content of pond ash has been found to vary within the range of 63–89%. An empirical model has been developed to estimate dry density of pond ash, using multiple regression analyses, in terms of compaction energy, moisture content, and specific gravity. Linear empirical models have also been developed to estimate maximum dry density and optimum moisture content in the field at any compaction energy. These empirical models may be helpful for the practicing engineers in the field for planning the field compaction control and for preliminary estimation of maximum dry density and optimum moisture content of pond ash.

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

Chand et al. (2007) presented the effects of lime stabilization on the strength and durability aspects of a class F pond ash with a lime constituent as low as 1.12% are reported. Lime contents of 10 and 14% were used, and the samples were cured at ambient temperature of around 30°C for curing periods of 28, 45, 90, and 180 days. Samples were subjected to unconfined compression tests as well as tests that are usually applied to rocks such as point load strength tests, rebound hammer tests, and slake durability tests. Unconfined compressive strength (UCS) values of 4.8 and 5.8 MPa and slake durability indices of 98 and 99% were achieved after 180 days of curing for samples stabilized with 10 and 14% lime, respectively. Good correlations that are particularly suitable for stabilized materials of low density and low strength have been derived for strength parameters obtained from UCS tests, point load strength tests and Schmidt rebound hammer tests and also between UCS and slake durability index.

Oscar Victor M. Antonio, Mark Albert H. Zarco (2007) determined the engineering properties of Calaca, Batangas bottom ash. These engineering properties used to find and assessed the possible ways of utilizing and maximizing the potential of such byproduct in a manner that is both environmentally friendly as well as economically viable.

Bera et al. (2009) studied the shear strength response of reinforced pond ash, a series of unconsolidated un-drained (UU) triaxial test were conducted on both unreinforced and reinforced pond ash. In the present investigation the effects of confining pressure (σ3), number of geotextile layers (N), and types of geotextiles on shear strength response of pond ash were studied. The results demonstrate that normal stress at failure (σ1f) increases with increase in confining pressure. The rate of increase of normal stress at failure (σ1f) is maximum for three layers of reinforcement, while the corresponding percentage increase in r1f is around (103%), when the number of geotextile layers increases from two layers to three layers of reinforcement. With increase in confining pressure the increment in normal stress at failure, Δr increases and attains a peak value at a certain confining pressure (threshold value) after that Δr becomes more or less constant. The threshold value of confining pressure depends on N, dry unit weight (γ_d) of pond ash, type of geotextile, and also type of pond ash.

Ghosh et al. (2010) presented the laboratory test results of a Class F pond ash alone and stabilized with varying percentages of lime (4, 6and 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 were conducted on specimens compacted at maximum dry density and optimum moisture content obtained from standard Proctor compaction tests and were cured for 7, 28 and 45 days. Both un-soaked and soaked bearing ratio tests were 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 were presented to estimate soaked bearing ratio from un-soaked bearing ratio of stabilized pond ash. The experimental results indicated that pond ash-lime-PG mixes have potential for applications as road base and sub base materials.

Jakka et al. (2010) studied the geotechnical characteristics of pond ash samples sampled from the outflow and inflow points of two ash pond areas in India. Strength characteristics were obtained using CD (consolidated drained) and CU (consolidated undrained) triaxial tests with pore water pressure measurements, conducted on loose and compacted specimens of pond ash samples under different confining pressures. Ash samples collected from the inflow point of ash pond area exhibited similar behaviour to sandy soils in many aspects. Their strength were higher

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

III. METHODOLOGY ADOPTED

A. *Introduction*

Experiments were done to determine geotechnical characteristic of pond ash and change in the behavior of pond ash using Polypropylene fibres as a reinforcing material. Physical and Chemical properties were noted. Engineering properties of unreinforced pond ash were also noted.

B. *Materials Used*

1) Pond ash
2) Polypropylene fibres

1) *Pond Ash*

Pond ash was collected from Ropar Thermal Power Plant.

Physical parameters	Values	Physical parameters	Values
Colour	Light grey	Shape	Rounded/sub-rounded
Silt &clay (%)	41.6	Specific Gravity, G	2.17
Fine sand (%)	44.6	Plasticity Index	Non- plastic
Medium sand (%)	12.2	Optimum moisture content,	27 %
Coarse sand (%)	1.6	Max. dry density(g/cm^3)	1.205

Table 3.1: Physical properties of pond ash

a) Chemical Properties of Pond ash

Compound	Percentage
Silica	67.02
Alumina	19.44
Iron oxide	8.5
Calcium oxide	2.7
Magnesium Oxide	0.45
Sulphur	0.30
Loss of ignition	3.46

Table 3.2: Chemical Properties of Pond ash

*By Sonaware Prashant and Diwedi Amit from American Journal of Engineering Research (AJER) e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-02, Issue-09, pp-110-117

b) Polypropylene fibres

Polypropylene fibres are used as the reinforcing material throughout the study. Polypropylene fibres used in the experiment were provided by the Nina Concrete Systems. Polypropylene is one of the most versatile polymers available with applications, both as a plastic and as a fibre, in virtually all of the plastics and end-use markets. The general properties of the fibre used are given in table below:

6 mm , 12 mm and 19 mm fibres

PROPERTY	VALUE
Specific gravity	0.9- 0.91
Cut length	6 mm , 12 mm , 19 mm
Water Absorption	0.3 % (after immersion in water for 24 hours)
Colour	White
pH value	Not Applicable
Melting Point	165 ^{0}
Solubility in water	Below 0.1 %
Acid resistance	Excellent
Alkali resistance	Excellent

Table 3.3: Properties of Polypropylene fibres

C. List of Experiments Performed

1) Specific Gravity test using Pyncometer
2) Modified Proctor Tests (Compaction Tests)
3) Triaxial Tests (Unconsolidated Undrained)

1) Specific gravity test (IS 2720 – 1980)

The specific gravity of Pond Ash was determined using pycnometer.

Weight of bottle (w 1)	0.471g	0.473 g	0.473g
Weight of Bottle+ Pond Ash (w 2)	0.673 g	0.676 g	0.675 g
Weight of bottle+ Pond ash + water(w 3)	1.371g	1.375g	1.374g
Weight of bottle+water (w 4)	1.264g	1.264g	1.264g
Specific Gravity	2.12	2.20	2.19

Table 3.4: Observation of values during the test

Taking average of the three values obtained, we have

$$G = (2.12 + 2.20 + 2.19) / 3 = 2.17$$

Hence we take Pond ash value as 2.17

Sridharan has specified the range of values Indian coal ashes between 1.46-2.66.Hence the value obtained is well within the range specified.

2) Compaction test (IS 2720(VII)-1980

Compaction tests are generally used to determine moisture content-dry density relationship of soil. There are two types of Compaction tests

1) Standard Proctor test (Light Compaction test)
2) Modified Proctor test (Heavy Compaction test)

In light compaction test sample at different water content is compacted in the mould in three layers with 25 blows in each layer given by a rammer of 2.6 kg with a drop of 310mm.

In heavy compaction test sample at different water content is compacted in the mould in five layers with 25 blows in each layer given by a rammer of 4.5 kg with a fall of 450mm. Heavy Compaction Test was performed in the laboratory. Graph was plotted between moisture content and dry density from which Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) values were found out.

Tests were performed for various combinations of Fibres and Pond ash. The results are shown in Table 3.5 and Compaction curves are shown in fig 3.1 to 3.8

Fibre Length	Combination	MDD	OMC(%)
-	100 % Pond ash	12.12	27
6 mm	PA + 0.5 % PF	11.72	30
6 mm	PA + 1 % PF	11.64	30
6 mm	PA + 1.5 % PF	11.44	30
12 mm	PA + 0.5 % PF	11.69	30
12 mm	PA + 1 % PF	11.56	30
12 mm	PA + 1.5 % PF	11.28	30
19 mm	PA + 0.5 % PF	11.44	30
19 mm	PA + 1 % PF	11.44	30
19 mm	PA + 1.5 % PF	11.46	30

Table 3.5: Modified Proctor test results

* PA= Pond ash ,PF=Polypropylene fibres, MDD=Maximum Dry Density, OMC=Optimum moisture content

IV. RESULT DISCUSSION AND CONCLUSION

A. Specific gravity test

The value obtained is 2.17 which is well within the range specified by Sridharan according to whom the limit of Indian coal ashes is 1.46-2.66

B. Atterberg limits

Pond ash is non plastic and hence its liquid limits was not found

C. Modified compaction tests

The tests were conducted on modified proctor test set up with 4.5 kg hammer with a free fall of 450 mm. 25 blows were given to 5 equal layer in the mould.

The following were observed :-

1) The maximum dry density was obtained with no reinforcement of fibres. It was found out at 12.12 kN/m^3 at 27 % optimum moisture content.(Fig 3.1)
2) On addition of 6 mm Polypropylene fibres in 0.5,1 and 1.5 % of dry weight of Pond ash, the maximum dry density (MDD) decreased slightly with increase of Optimum moisture content by 3 %. MDD was obtained at 11.72 KN/m^3 and OMC at 30 %. (Fig 3.2)

   The decrease in MDD can be probably be attributed to the complex mechanism of mixing between fibres and pond ash. The fibres filling in the voids of Pond ash can be another possible reason for the decrease. In research work done by researchers on Pond ash like Dr. Raju Sarkar whose results show increase in MDD with increase in fibre content of polypropylene fibres , my decrease in results is not that significant which is not a matter of grave concern.
3) On increase of fibre content of 6 mm fibres to 1.5 % from 0.5 %, the MDD decreased slightly but there was no change in the OMC. Hence it can be rightly claimed that the effect of reinforcement was insignificant.
4) On addition of 12 mm fibres by 0.5 to 1.5 % by dry unit weight of Pond ash the MDD was decreased from 11.69 to 11.28 KN/m^3 and OMC remained unchanged at 30 % showing insignificant change in moisture content due to fibres.(Fig 3.3)
5) On addition of 19 mm fibres by 0.5 to 1.5 % by dry weight of Pond ash the MDD was found out to 11.44 KN/m^3 to 11.46 KN/m^3 and OMC remained unchanged at 30 % which again proved that there fibre reinforcement has no effect on OMC .(Fig 3.4)

The possible reason can be the hydrophobic nature of Polypropylene fibres and complex mixing mechanism between Pond ash and fibres.

D. Triaxial tests (Unconsolidated Unconfined)

The samples of Pond ash and Pond ash with different mixes of Polypropylene fibres were tested for shear strength parameters. The following were observed:-

1) With no reinforcement of fibres the shear strength parameters cohesion intercept(c) and angle of internal friction were found out to be 14.067 and 35.95.(Fig 3.10) The values obtained were very much near the values obtained by R. Kumar, V.K. Kanaujia and D. Chandra whose “c” and angle of internal friction were 16 and 37^0 at MDD 11.76 KN/m^3 and 27 % OMC.
2) With addition of 6 mm Polypropylene fibres with 0.5 % to 1.5 % reinforcement by weight of Pond ash the range of “c” was 24- 34 and range of angle of internal friction obtained was 35-46^0. Though some papers suggest a range of 33-43^0 for pond ash, the results obtained were satisfactory. (Fig 3.12, 3.14, 3.16)
3) On addition of 12 mm Polypropylene fibres with 0.5 % to 1.5 % reinforcement by weight of Pond ash the range of “c” was 39-47 and angle of internal friction was obtained at 38-47^0.The non- linear increase in values of c and angle of internal friction were in line with the values obtained in other research works.(Fig 3.18,3.20, 3.22)
4) On addition of 19 mm Polypropylene fibres with 0.5 % to 1.5 % reinforcement by weight of Pond ash the range of “c” was 39-45 and angle of internal friction was 41-48^0(Fig 3.24,3.26,3.28).

1) Deviator stress

1) The peak deviator stress for Pond ash with no fibre reinforcement was found out to be 1165.64 KN/m^3 at 294.3 KPa which was more than 98.1 kPa and 196.2 kPa. (Fig 3.9)
2) The peak deviator stress for Pond ash mixed with 0.5 % 6 mm polypropylene fibres was found to be 1212.43 KN/m^3 at confining pressure of 294.3 kPa .(Fig 3.11)
3) The peak deviator stress for Pond ash mixed with 1 % 6 mm polypropylene fibres was found to be 1393.02 KN/m^3 at confining pressure of 294.3 kPa .(Fig 3.13)
4) The peak deviator stress for Pond ash mixed with 1.5 % 6 mm polypropylene fibres was found to be 1987.37 KN/m^3 at confining pressure of 294.3 kPa .(Fig 3.15)
5) The peak deviator stress for Pond ash mixed with 0.5 % 12 mm polypropylene fibres was found to be 1379.35 KN/m^3 at confining pressure of 294.3 kPa .(Fig 3.17)
6) The peak deviator stress for Pond ash mixed with 1 % 12 mm polypropylene fibres was found to be 1780.07 KN/m^3 at confining pressure of 294.3 kPa .(Fig 3.19)
7) The peak deviator stress for Pond ash mixed with 1.5 % 12 mm polypropylene fibres was found to be 2128.71 KN/m^3 at confining pressure of 294.3 kPa .(Fig 3.21)
8) The peak deviator stress for Pond ash mixed with 0.5 % 19 mm polypropylene fibres was found to be 1632.19 KN/m^3 at confining pressure of 294.3 kPa. (Fig 3.23)
9) The peak deviator stress for Pond ash mixed with 1% 19 mm polypropylene fibres was found to be 2207.13 KN/m^3 at confining pressure of 294.3 kPa.(Fig 3.25)
10) The peak deviator stress for Pond ash mixed with 1.5 % 19mm polypropylene fibres was found to be 2317.43 KN/m^3 at confining pressure of 294.3 kPa. (Fig 3.27)

There is increase in deviator stress due to addition of polypropylene fibres. With the increase of fibre content/percentage from 0 % to 1.5 % the peak deviator stress was increases considerably. The possible reasons can be bridging effect produced due to inclusion of fibres. Also the brittle behaviour of Pond ash is changed to ductile because of which it can endure more amount of stress in comparision to no amount of fibres inclusion. It can be safely concluded that because of effect of fibre inclusion stresses are increased and so is the strength of pond ash.

The polypropylene fibers act a reinforcement to the soil. It appears that it prevents the formation of cracks in the sample and along with fly ash, binds the soil particles together, leading to an increase in values of the stabilized soil.

REFERENCES

[1] AI-Refeai, T.O. “Behaviour of granular soils reinforced with discrete randomly oriented inclusions.” J.Geotextiles and Geomembranes, Vol.10(4) ,(1991):pp. 319-333

[2] Andersland, O.B. and Khattak A.S. “Shear strength of kaolinite/fibre soil mixture.” Proc. 1st Int. Con. on Soil Reinforcement, Vol. 1, Paris, ,(1979):pp. 11-16.

[3] Bera, A. K., Ghosh, A. and Ghosh , A. “Compaction Characteristics of Pond Ash”, Journal of Materials in Civil Engineering @ ASCE,(2007):pp.349-357.

[4] Bera, A. K., Ghosh, A. and Ghosh , A. “Behaviour of Model Footing on Pond Ash”, Goetech Geol Eng,(2007):pp. 315-325.

[5] Bera, A. K., Ghosh, A. and Ghosh, A. “Shear Strength Response of Reinforced Pond Ash”, Construction and Building Materials, vol.23,(2009):pp. 2386–2393.

[6] Chand, S.K. and Subbarao, C. “Strength and Slake Durability of Lime Stabilized Pond Ash”, Journal of Materials in Civil Engineering @ ASCE,(2007):pp. 601-608.

[7] DiGioia, A.M. and Nuzzo, W.L. “Pond ash as Structural Fill”, Journal of Power Division, ASCE ,vol. 98(1), (1972):pp.77-92.

[8] Gopal Ranjan, R.M. Vasan and Charan, H.D.”Mechanism of fibre reinforced soil state of art”. Indian Geotechnical Journal, vol.24(3),(1994):pp.241-262.

[9] IS: 2720(Part 8), 1980 Methods of Test for Soils, Determination of water content dry density relationship using heavy compaction test.

[10] IS: 2720(Part 2), 1973 Methods of Test for Soils, Determination of water content

[11] Jakka, R.S., Ramana, G.V. and Datta, M. “Shear Behaviour of Loose and Compacted Pond Ash”. Goetech Geol Eng,Vol.28(6),(2010):pp.763-778

[12] Jakka, R.S., Ramana, G.V. and Datta, M. “Liquefaction Behaviour of Loose and Compacted Pond ash”. Soil Dynamics and Earthquake Engineering, Vol.30,(2010):pp.580-590

[13] Kaniraj, S.R. and Havanagi, V.G. “Behaviour of Cement-Stabilized Fibre-Reinforced Pond ash– Soil

Mixtures", Journal of Geotechnical and Geo-Environmental Engineering, ASCE ,Vol.127 (7), (2001)

[14] Kaniraj, S.R. and Gayathri, V. "Permeability and Consolidation Characteristics of Compacted Pond ash". Journal of Energy Engineering, ASCE ,Vol.130 (1), (2004):pp.18–43

[15] Kumar, R., Kanaujia, V.K. and Chandra, D "Engineering Behaviour of Fibre-Reinforced Pond ash and Silty Sand", Geosynthetics International,Vol.6(6),(1999):pp.509-518

[16] Maher, M.H. and Gray, D.H. "Static response of sands reinforced with randomly distributed fibres." Journal of Geotechnical Engineering, ASCE, Vol.116(7),(1990):pp.1661-1677

[17] Michalowski, R.L. and Zhao, A. "Failure of fibre-reinforced granular soils." Journal of Geotechnical Geoenvironmental Engg., ASCE, Vol.122(3),(1996):pp.226-234

[18] Pandey, P.K. and Agrawal, R.K. "Utilization of mixed pond ash in integrated steel plant for manufacturing superior quality bricks", Bull. Mater. Sci. @ Indian Academy of Sciences, Vol. 25, No. 5, (2002): pp. 443–447.

[19] Saran Swami "Reinforced Soil and its Engineering Applications" Second Edition, I. K. International Publishing House Pvt. Ltd. (2010)

[20] Singh, S.P. and Sharan, A. "Strength characteristics of compacted pond ash" Proc. of 11th National and 1st International Conference on Technological Trends,(2010) C.E, Trivandrum

[21] Kumar Parveen, Singh Shalendra " Reinforced fly ash sub bases in rural roads"

[22] Pandey Piyush, Agarwal Raj "Utilization of mixed pond ash in intergrated steel plant for manufacturing superior quality bricks" Sci vol 25(4) Oct(2002): pp.443-447.

[23] R.K Grover, Jain Rajesh, Singhai "Operation and maintainence of tailing earthen dams specially for disposal of fly ash from thermal power plants" IJSRP, Vol 3(2), Feb (2013).

[24] Sonawane Prashant, Dwivedi Arun "Technical properties of pond ash clay fired brick- an experimental study'' AJER,Vol 2(9):pp.110-117.

[25] Satyanarayana P.V.V,N Pradeep,N.Sai chaitanya "Study on performance of pond ash in place of sand and red soil as a subgrade and fill material" IJEAT, Vol 3(1) Oct(2013).