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Comparative Study of Hair Reinforced Pond Ash Mixed With Soil

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Abstract: The 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 material such as human hair fiber for its stabilization as reinforcement with soil as additive which not only save tons of fertile soil for different purposes but also can replace conventional commercial fiber 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 undrained triaxial tests ,CBR tests, X ray diffraction and Scanning Electron Microscope.
The test result shows that the inclusion of randomly distributed fiber (Human hairs) in Pond ash and soil composite mixtures substantially improves the engineering properties of Pond ash.
Keywords: Pond Ash, Hair Reinforcement, Scanning Electron Micrographs, X-Ray Diffractograms, California Bearing Ratio (CBR), Compressive Strength, Triaxial Test, Brazilian Test.

I. 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. 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".

The combustion of pulverized coal at high temperatures and pressures in power stations produces different types of ash at different levels. The 'fine' ash fragments is move upwards with the flue gases and arrested before reaching the atmosphere by electro static precipitators. This substance called as Pulverized Fuel Ash (PFA) or 'fly ash'. Then 'coarse' ash fragments descend into the grates below the boilers, where it mixed with water and pumped to lagoons. This substance called as Furnace Bottom Ash (FBA) has sand type texture.

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.

Long Hairs of 50% population i.e. of women are very demanding & can't categorized 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 categorized as Waste and is more useful for us like propylene fibers, 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.

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 feasible and common ways to employ these waste products is to go for construction of embankments and roads, highways with the suitable amount of soil.

II. LITERATURE REVIEW

Bumjoo et al. (2005) establish during founding that unconfined compressive strength of clays with high compressibility increases with the addition of fibers and which further increases in clay sand mixtures along with fibers.

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Kumar et al. (1999) has done Lab-investigations on silty sand and pond ash samples reinforced by randomly distributed poly -fibers. The results shows that the inclusion of fibers in soils increases the CBR value, peak compressive strength, ductility & friction angle of the specimens.

N Pandian (2004) carried out investigations on Indian coal ash. He showed how that Fly ash has good potential for use in geotechnical applications by conducting series of laboratory experiments. 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.

P. 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.

Praveen Kumar (2008) conducted a study on fiber reinforced fly ash and concluded that optimum moisture content for fly ash decreases with increase in fiber content and MDD increases with increase in fiber content. Also observed that shear strength and CBR value of fly ash increases with increase in fiber content for both soaked and unsoaked conditions. But the rate of increase is more upto 1.0% fiber content and thereafter the rate of increase is very less.

III.EXPERIMENTAL WORKS

A. Materials used

The Pond Ash sample was collected from the ash pond site of Rajghat thermal power station, Delhi, soil was collected from DTU campus, Delhi and the hairs was procured from the open market. Properties of pond ash and soil, are shown in Table 1 below.

TABLE 1: PROPERTIES OF POND ASH & SOIL

Properties	Pond Ash	Soil
Specific Gravity	2.12	2.53
Liquid Limit	21.54	25.82
Plastic Limit	Non-Plastic	18.25
Maximum dry density (kN/m^3)	12.14	17.23
Optimum moisture content (%)	24.07	14.03
Unconfined compressive strength (kPa)	79.22	124.87

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.

B. Admixture Proportions and Tests Conducted

Different proportions of soil were added to pond ash. Later on at different values of fiber content was added to the soil and pond ash mix of various proportions. The mixing of hair was felt very difficult beyond 2.0% by weight, as the same stick together to form lumps. Sample proportions are given in Table 2 below.

TABLE 2: SAMPLE PROPORTIONS

<table>
<tr><th>Sample</th><th>Proportion</th><th>Fiber content (%)</th></tr>
<tr><td rowspan="15">PA+Soil</td><td rowspan="5">80:20</td><td>0</td></tr>
<tr><td>0.5</td></tr>
<tr><td>1</td></tr>
<tr><td>1.5</td></tr>
<tr><td>2</td></tr>
<tr><td rowspan="5">70:30</td><td>0</td></tr>
<tr><td>0.5</td></tr>
<tr><td>1</td></tr>
<tr><td>1.5</td></tr>
<tr><td>2</td></tr>
<tr><td rowspan="5">60:40</td><td>0</td></tr>
<tr><td>0.5</td></tr>
<tr><td>1</td></tr>
<tr><td>1.5</td></tr>
<tr><td>2</td></tr>
</table>

Specific gravity test was conducted as per IS: 2720 (Part 3)-1980. Liquid & Plastic limit was calculated as per IS: 2720 (Part 5) -1985. Particle size distribution was conducted as per IS: 2720 (Part 4) -1985. Standard Proctor test was conducted as per IS: 2720 (Part 7) -1980. Unconfined compression test was conducted as per IS: 2720 (Part 10) -1987. UU triaxial test was conducted as per IS: 2720 (Part 11) -1983. California Bearing Ratio (CBR) was conducted as per IS: 2720 (Part 16) -1987. Tensile Strength was evaluated using Brazilian test. The formation of bond between pond ash and lime was observed under scanning electron microscope (SEM) and mineral composition of materials was found with x-ray diffraction technique (XRD).

C. Results and Discussion

1) *Scanning Electron Microscope Analysis:* Scanning Electron Microscope gives information about the morphology of the sample particles. SEM results shown in fig. 1 to 3, reveals that in Pond Ash, fraction of glassy alumina silicate particles and a low percentage of crystalline matter with amorphous carbonaceous particles were present. Micrograph showing numerous sub spherical cavities formed by gaseous emissions during crystallization by the irregularities of aluminosilicatic particle .Quartz particles that were rounded in shape due to fusion by high temperature can be seen easily. SEM results of soil implies that the soil particles are sub angular particles.

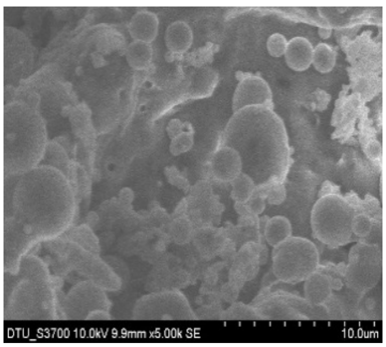

Fig.1: Pond Ash at 10 µm scale

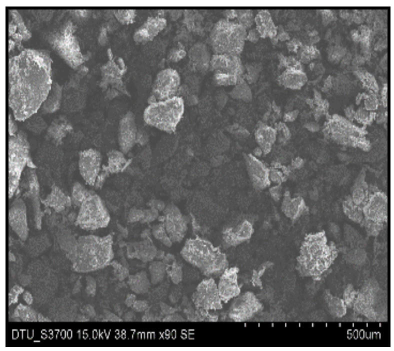

Fig.2: Pond Ash+ Soil at 500 µm scale

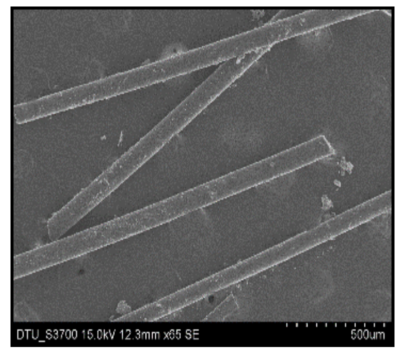

Fig.3: Hair at 500 µm scale

2) *X- Ray Diffraction:* XRD technique gives the information about the chemical composition, crystal structure, and physical properties of materials. The XRD of dry sample are shown from fig. 4 to 5. The XRD results reports presence of quartz (SiO_2), hematite (Fe_2O_3), magnetite (Fe_3O_4), mullite ($A1_6Si_20_{13}$) in pond ash and presence of feldspar & quartz calcite in soil. 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 fiber 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.

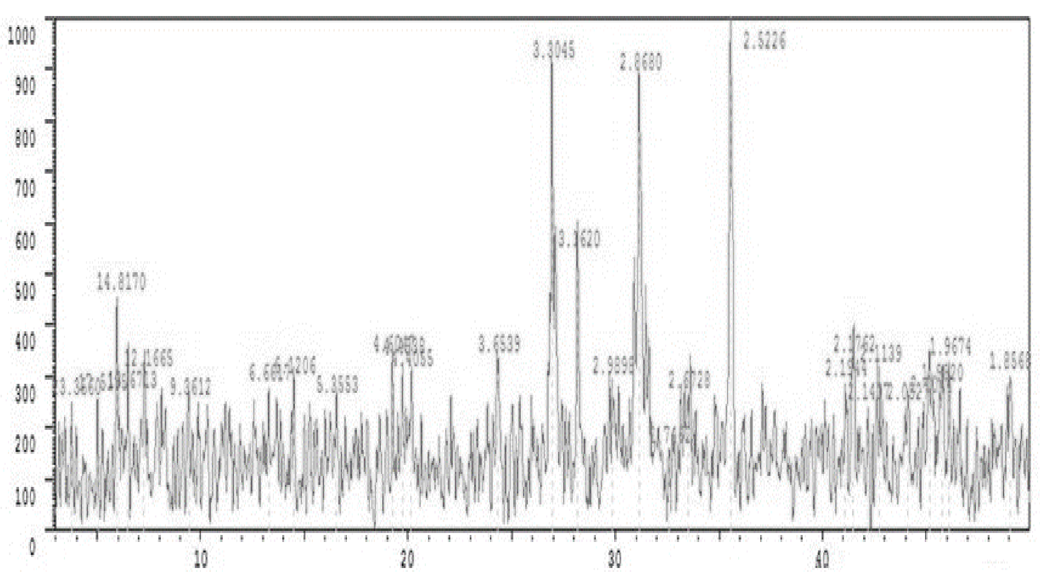

Fig.4: XRD pattern of Pond Ash particles

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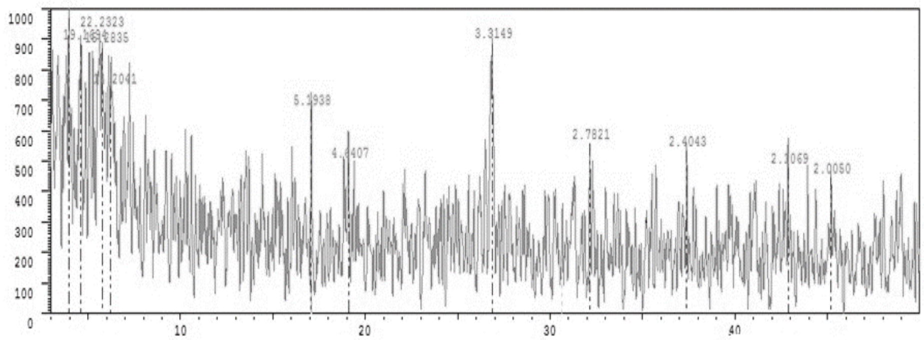

Fig.5: XRD pattern of Soil particles

3) *Particle Size Distribution:* The result of particle size distribution that pond ash is poorly graded silty sand and soil is well graded sandy silt

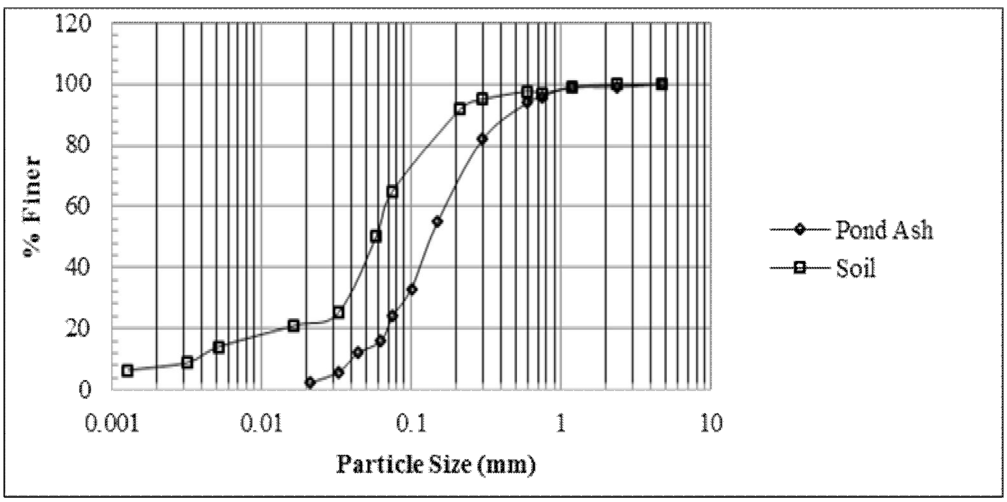

Fig. 6: Comparison of particle size analysis

4) *Standard Proctor compaction test:* The variation in maximum dry density and optimum moisture content for pond ash, soil and hair mixture is represented in fig. 7 and 8. Densification of improves the engineering properties. In PA:S mixtures MDD increases as Percentage of soil increases. MDD increases and OMC decreases with fiber percentage increases.

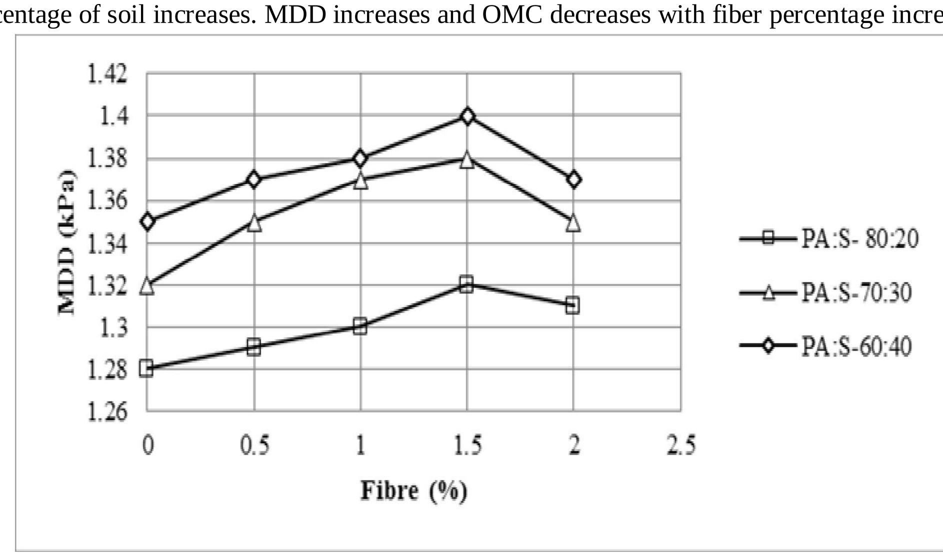

Fig. 7: Influence of hair fiber and soil on MDD

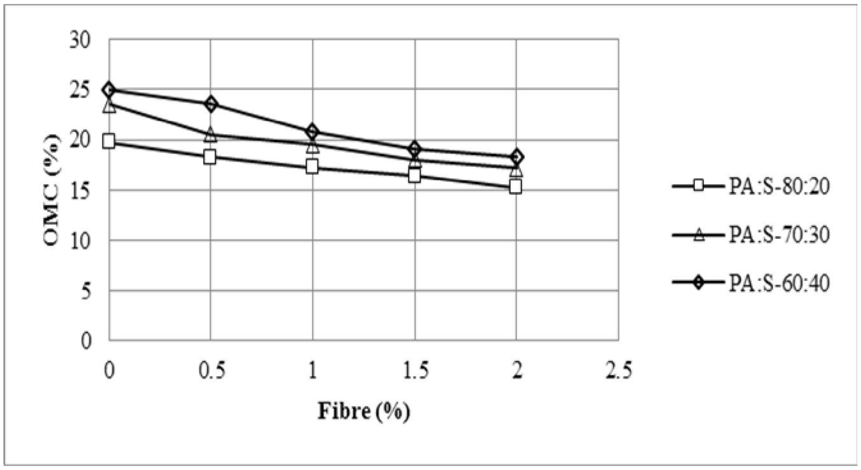

Fig. 8: Influence of hair fiber and soil on OMC

5) *CBR Test (Unsoaked):* The CBR test results is shown in fig. 9. The CBR test results reveals that CBR value increases every time with increase in soil proportion. CBR value also increased when hair fiber content is increased upto 1.5%. But after 1.5 % it has been decreased.

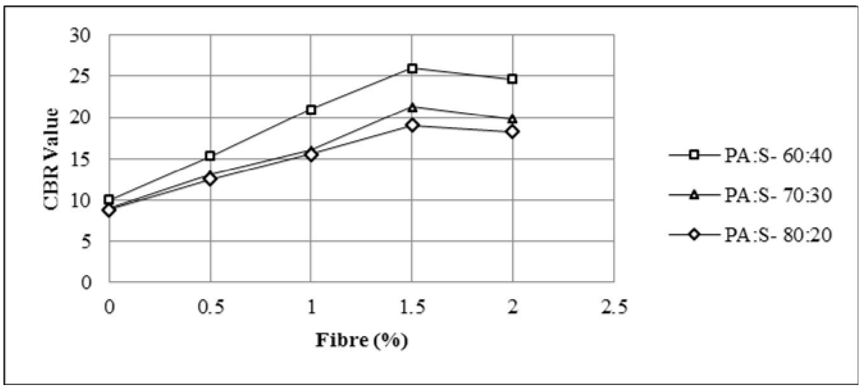

Fig. 9: Influence of hair fiber and soil on CBR values

6) *Unconfined Compressive Strength Test:* The UCS test results shown in fig. 10. reveals that Unconfined Compressive Strength of pond ash increases every time with increase in soil proportion. UCS value also increased when hair fiber content is increased upto 1.5%. But after 1.5 % it has been decreased.

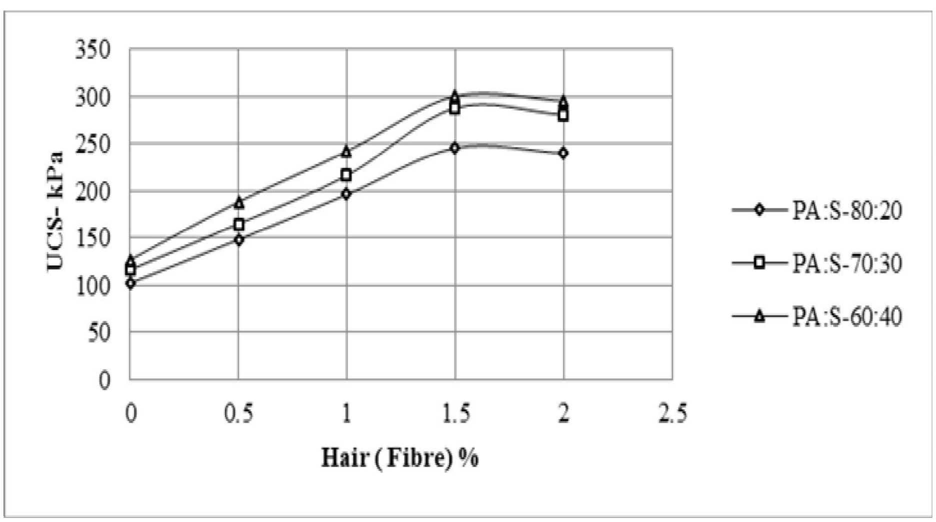

Fig. 10: Influence of hair fiber and soil on UCS values

7) *UU Triaxial test:* In UU Triaxial 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 as shown in fig. 11 to 12. Cohesion(c) and angle of internal friction (ϕ) increases with increase in hair fiber upto 1.5% after that it decreases. In case of P: S composite mixtures at different proportions the best results obtain for PA:S – 60:40 with 1.5% fiber inclusion.

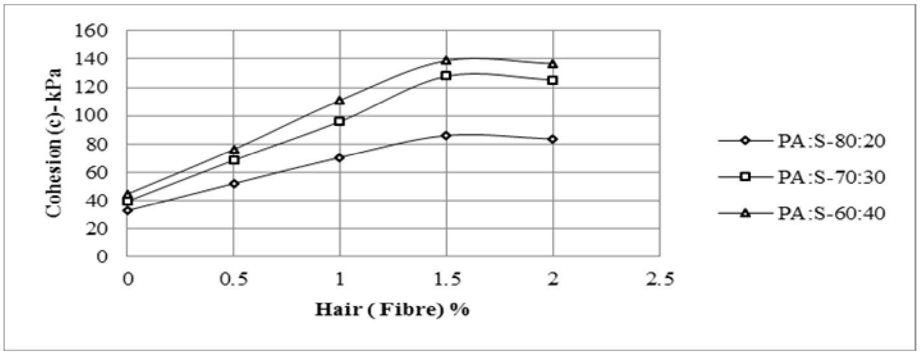

Fig. 11: Influence of hair fiber and soil on cohesion

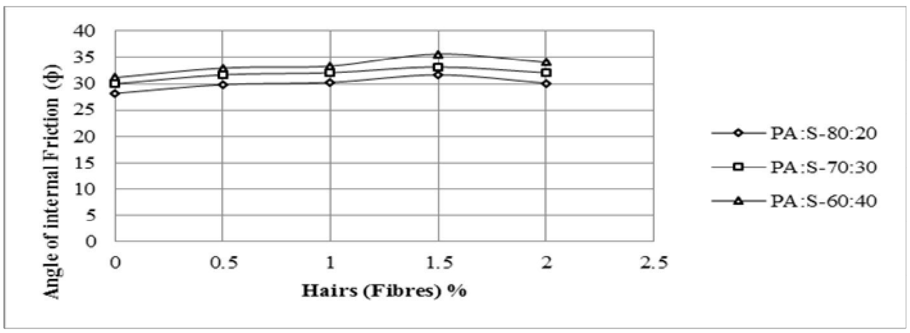

Fig. 12: Influence of hair fiber and soil on angle of internal friction

8) *Indirect Tensile Strength Test (Brazilian):* Results are shown in table 3.

TABLE 3: TENSILE STRENGTH OF POND ASH AND SOIL MIX AT DIFFERENT HAIR FIBER %

Samlpes	Proportion	Hair Fiber (%)	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	65.07
		1.5	115.54
		2	110.23

IV. CONCLUSIONS

A. Scanning electron micrographs reveals about the morphology of the sample. The SEM of pond ash shows the spherules of alumina silicates and quartz particles which were rounded in shape due to fusion by high temperature can be seen easily. SEM results of soil implies that the soil particles are sub angular particles, which shows better interlocking of pond ash particles and soil particles. Hence mixing of pond ash and soil can result in enhanced strength of mix.

B. XRD technique gives the information about the chemical composition, crystal structure, and physical properties of materials. The XRD results reports presence of quartz (SiO_2), hematite ($Fe_2 O_3$), magnetite (Fe_3O_4), mullite ($A1_6Si_20_{13}$) in pond ash and presence of feldspar & quartz calcite in soil.

C. The density bottle tests shows that the specific gravity of the pond ash is 2.12 and of soil is 2.53.

D. The result of particle size distribution tells that pond ash is poorly graded silty sand and soil is well graded sandy silt. Their particle size distribution curve is very much parallel which indicates their suitability to be mixed well.

E. The standard proctor test indicates that in PA:S mixtures MDD increases as Percentage of soil increases. This due to interlocking of soil particles with pond ash as Densification improves the engineering properties of mix .OMC & MDD increases and OMC decreases with fiber percentage increases upto 1.5% at very less rate. The reason may be interlocking of hair fiber in pond ash mixture.

F. The CBR test results reveals that CBR value increases every time with increase in soil proportion. This can be due to the interlocking of soil particles with pond ash. CBR value also increased when hair fiber content is increased upto 1.5%. This can be due to the interlocking of composite material particles with fiber. But after 1.5 % it has been decreased. This can be due to formation of fiber lumps. The best results are obtained for PA:S – 60:40, upto 26% at 1.5% hair fiber, which is more than 15% and so much suitable for sub-bases as per SP-20 IRC 2002.

G. The UCS test results reveals that Unconfined Compressive Strength of pond ash increases every time with increase in soil proportion. This can be due to interlocking of soil particles between pond ash particles. UCS value also increased when hair fiber content is increased upto 1.5%. Because randomly oriented discrete inclusions fibers (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. But after 1.5 % it has been decrease, which can be due to formations of hair lumps at increased percentage of hair fiber.

H. In UU Triaxial 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 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. Cohesion(c) and angle of internal friction (ϕ) increases with increase in soil %. Because a closer packing is also responsible for increase in cohesion component in sample. Also Cohesion(c) and angle of internal friction (ϕ) increases with increase in hair fiber upto 1.5% after that it decreases. In case of P: S composite mixtures at different proportions the best results obtain for PA:S – 60:40 with 1.5% fiber inclusion.

I. 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 fiber 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 standardized. Best results were obtained for PA:S – 60:40 with 1.5% fiber inclusion.

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

V. ACKNOWLEDGMENT

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I would also like to thank all the faculties and lab assistants of Civil Engineering Department, Delhi Technological University.

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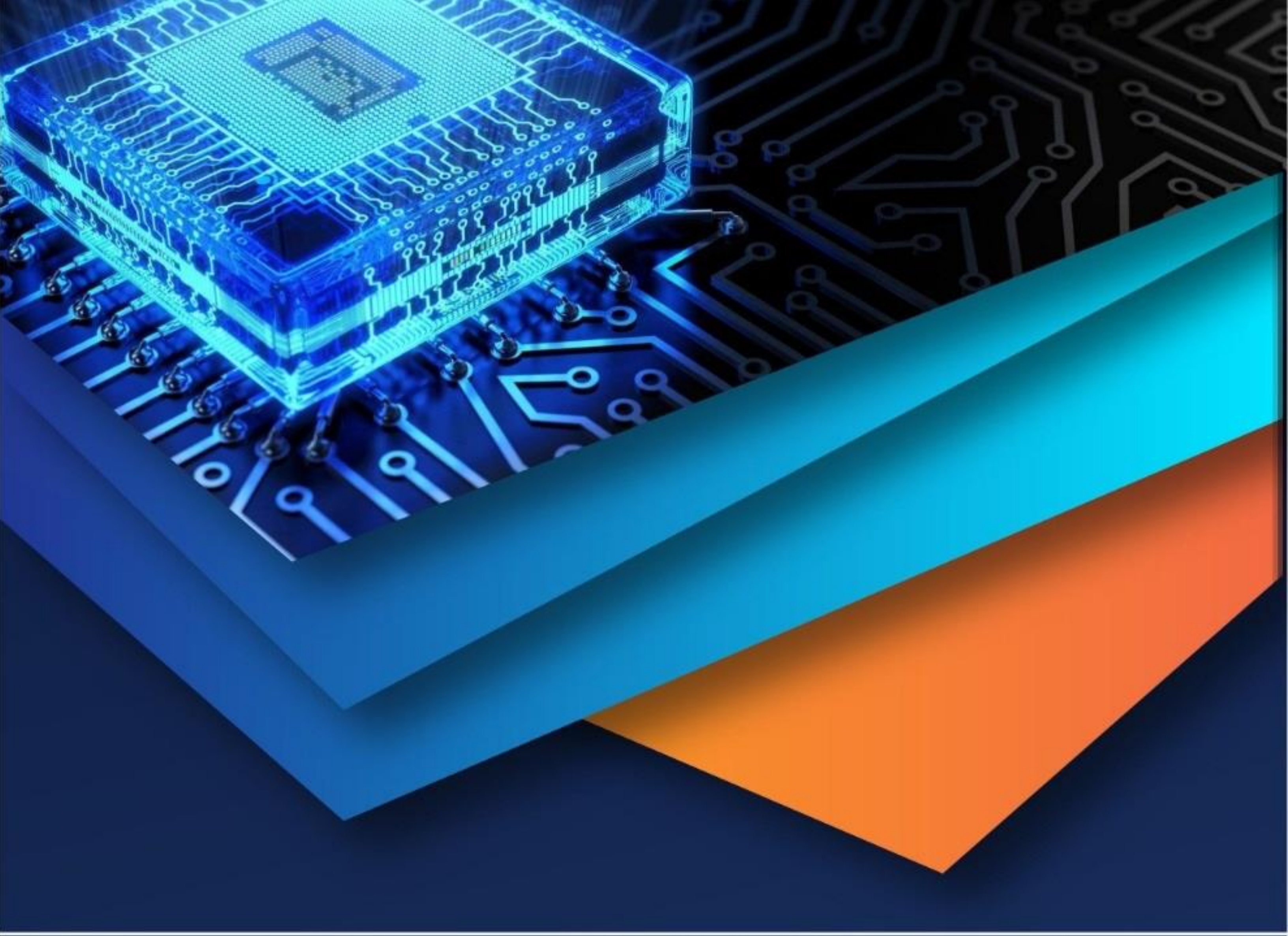

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