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Geotechnical Strength of Randomly Oriented Fiber Reinforced Compacted Pond Ashes

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Abstract: -Fly ash is generated in large quantities as a byproduct of burning coal. Thermal power plants are the major sources of ash generation. Fly ash is disposed in the form of slurry in the ash ponds within the plant area, called coal combustion residue or pond ash. When fly ash is mixed with water, afterwards it gets hardened and forms high strength and low permeability material. Fly ash produced thus possesses both ceramic and pozzolanic properties. The power requirements of the country are rapidly increasing in pace with in industrial developments. Nearly, 73% of India‟s total installed power generation capacity is thermal of which coal based generation are nearly 90% (by diesel, wind, gas and steam adding about 10%). The inherent strength of the compacted pond ash mass reduces considerably due to saturation. In this context to improve and retain the strength of compacted pond ash, cementing agents like cement or lime may be very much beneficial. The stress-strain behavior of compacted pond ash mass can be modified by inclusion of fibre reinforcements. Fibre reinforcements also improve the strength characteristics of the mass. This paper presents the details of the pond ashes, the experiments carried out to characterize them when mixed with fiber and the results and discussions.

Keywords – Pond Ash, Polypropylene Fiber, Geotechnical Characterization, Physical Properties, Triaxial Tests.

1. INTRODUCTION

Reinforcement aids the strength and stability of soil. One of the natural means of incorporating randomly oriented fiber inclusions in the soils is the presence of plant roots. 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. A material such as pond ash is a residue collected from ash pond near thermal power plants. Pond ash is a non-plastic[1] 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 use of reinforcement in improving the strength parameters of geo-materials has taken momentum due to the availability of variety of synthetic materials commercially at cheaper rates. The basic principles involved in earth reinforcement techniques are simple and have been used by mankind for centuries. One of the essential characteristics of reinforced soil is that it is made with two types of elements, soil grains and reinforcements. The basic mechanism of reinforced earth involves the generation of frictional forces between the soil and reinforcement. By means of friction the soil transfers the forces developed in earth mass to the reinforcement thus developing tension. The earth develops pseudo cohesion in the direction in which reinforcement is placed and the cohesion is proportional to tension developed in reinforcement.

The effect of fibre reinforcement on the stress-strain behaviour, strength parameters of compacted mixes has been evaluated through a series of unconfined compression tests, direct shear test, CBR[2] test. The test results show that the inclusions of fibre reinforcement are very efficient in increasing the failure load. The stabilized pond ash has distinct advantages as there is a little loss of strength due to wetting. Hence, it can be used in large scale geo-technical construction like base and sub-base courses of roads, airport pavements, retaining walls, and embankments, structural landfills in conjunction with suitable reinforcements. Fiber inclusion increased the failure displacement and the vertical displacement of fly ash-soil mixture in direct shear tests. In unconfined compression tests, a distinct failure axial stress was reached. In unconsolidated undrained triaxial shear tests on unreinforced specimens, the deviator stress attained a peak and thereafter remained constant. In fiber reinforced specimens, no peak deviator stress was reached. 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. The basic and essential parameters of pond ash, to be used either as structural fill or embankment material.

2. POND ASH/FLY ASH

Pond ash is the by-product of thermal power plants, which is considered as a waste material and its disposal is a major problem from an environmental point of view and also it requires a lot of disposal areas. Actually, there are three types of ash produced by thermal power plants, viz. (1) Fly ash, (2) bottom ash, and (3) pond ash. Pond ash is collected by mechanical or electrostatic precipitators from the flue gases of power plant; whereas, bottom ash is collected from the bottom of the boilers. Then these two types of ash, mixed together, are transported in the form of slurry and stored in the lagoons, the deposit is called pond ash. Besides this steel, copper and aluminium plants also contribute a substantial amount of pond ash[3].

2.1 Factors affecting properties of pond ash

Meyer and Despande represent that the chemical and physical composition of a pond ash is a function of several variables.

(1) Coal source
(2) Degree of coal pulverization
(3) Deign of boiler unit
(4) Loading and firing condition
(5) Handling and storage methods.

Thus, it is not surprising that a high degree of variability can occur in pond ash not only between power plants but single power plants. A change in any of the above factors can result in detectable changes in the pond ash produced.

2.2 Environmental Impact of Pond ash

Some of the current methods of ash disposal can have adverse impacts on the environment, including: land use diversion and resettlement; water resources allocation and pollution; air pollution; and human health. In particular:The construction of large ash disposal areas results in resettlement issues, and loss of agricultural production, grazing land and habitat, as well as other land use impacts from diversion of large areas of land to waste disposal. The design of the ash disposal areas themselves is frequently inefficient in terms of economy of land areas usage. There is no uniformity in ash pond engineering practice in India. Some plants are accumulating ash in shallow ponds by diking off natural low lands, resulting in inefficient usage of land areas for accumulation of high-volume waste[4].

The disposal of ash may pollute water resources, including the contamination of groundwater from leach ate and the contamination of surface water from discharge of ash pond effluent. Ash pond effluent may be used as a source of irrigation water or potable supply by locals. Leakage in ash slurry pipelines[5] is exploited for irrigation and potable supply, since local water resources are scarce, and distribution systems almost non-existent. There may be air pollution from fugitive dust, when ash deposits dry without water or vegetation cover. Typically, most of the area of large ash ponds or ash dikes are not covered by water or wetted. The ash dries up and is an excellent source for fugitive dust emissions. In some instances, reclamation of the dried areas has mitigated fugitive dust emissions. Most areas where the ash ponds are located already have high ambient air concentrations of respirable particulates.

Reclamation[6] of the ash disposal area is often forestalled by engineering and operational practice, extending the time the land use is devoted to non-productive waste disposal. Some ash ponds are being operated as one unit.

The use of reclaimed areas for production of food crops and livestock has the potential to introduce bio-accumulative contaminants into the food chain. Various non-food production reclamation techniques have been tried with success, including wood and silkworm production.

Earth dam failures present a safety and pollution hazard. Loss of life could occur from catastrophic failure of the dam. In addition, any release of ash from such a failure would impact local aquatic resources, thereby potentially contaminating and eliminating habitat. Poor maintenance of earth dams can be observed, with many earth dams in a state of progressive failure, and little observation for monitoring of conditions of earth dam structures.

2.3 Use of pond ash

Pond ash/Fly ash can is used for multifarious applications. Some of the application areas are the following:

- In Land fill and dyke rising.
- In Structural fill for reclaiming low areas.
- Manufacture of Portland cement
- Lime – Flyash Soil Stabilizing in Pavement and Sub-base
- In Soil Conditioning
- Manufacture of Bricks
- Part replacement in mortar and concrete.
- Stowing materials for mines.

3.LITERATURE REVIEW

Pond ash is a waste product of coal combination in thermal power plants. It has posses problem 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 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[7] 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%.

Bera et al. implemented on the effective utilization of pond ash, as foundation medium. A series of laboratory model tests have been carried out using square, rectangular and strip footings on pond ash. The effects of dry density, degree of saturation of pond ash, size and shape of footing on ultimate bearing capacity of shallow foundations are presented in this paper.

Chand et al.[13] 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.

Bera et al. have studied the shear strength response of reinforced pond ash, a series of unconsolidated undrained (UU)[12] triaxial test has been 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 are studied. The results demonstrate that normal stress at failure (σ1f) increases with increase in confining pressure.

Jakka et al. studied carried on the strength and other geotechnical characteristics of pond ash samples, collected from inflow and outflow points of two ash ponds in India, are presented. Strength characteristics were investigated using consolidated drained (CD) and undrained (CU) triaxial [8]tests with pore water pressure measurements, conducted on loose and compacted specimens of pond ash samples under different confining pressures[14]

4. EXPERIMENTAL WORK AND METHODOLOGY

There are three thermal power stations are available in National Capital Region, Delhi viz. Badarpur and Dadri
plant of National Thermal Power Corporation and Rajghat plant of Indraprastha Thermal Power Corporation[15] Pond ash samples used in the present research work was obtained from these plant sites. Tests were conducted to determine the physical properties, and geotechnical properties of all pond ashes.

The specific gravity test was performed for all three of them. Standard and modified proctor tests, consolidated undrained triaxial tests and California Bearing Ratio tests were performed for pond ash alone and various compositions with fiber at an increasing percentage of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5.In the present work the behaviour of randomly reinforced compacted pond ash has been evaluated through a series unconfined compression test, Shear strength parameters and CBR tests.

4.1 MATERIALS USED

POND ASH

Pond ash used in this study was collected from the thermal power plant of CPP- NSPCL, Rourkela Steel Plant. The samples were dried at the temperature of 105-110 degrees. The ash sample was screened through 2mm sieve to separate out the foreign and vegetative matters. Then the pond ash samples were stored in airtight container for subsequent use.

GEO-FIBRE

Geo-fibre[9] used for the test was bought from the market (shop) of 125gm packet having different sizes 6mm and 12mm. The fiber used for reinforced pond ash specimens was a polyester fiber (Recron-3s). These fibers were made from polymerization of pure teraphthalic acid and Mono Ethylene Glycol[10] using a catalyst.

4.2DETERMINATION OF INDEX PROPERTIES

The specific gravity of pond ash was determined according to IS: 2720 (Part-III, section-1) 1980. The specific gravity of pond ash was found to be 2.37.

4.3 Determination of Grain Size Distribution

For determination of grain size distribution, the pond ash was passed through test sieve having an opening size 75μ. Sieve analysis was conducted for coarser particles as per IS: 2720 part (IV), 1975 and hydrometer analysis was conducted for finer particles as per IS: 2720 part (IV). The percentage of pond ash passing through 75μ sieve was found to be 33.7%.

5.TEST RESULTS AND DISCUSSION

Pond ash a by-product of the coal based thermal power plants contains grains of fine sand to silt size. The use of randomly reinforced pond ash in geo-technical constructions requires a proper understanding of the interaction between the pond ash and reinforced material. The stability of pond ash reinforced structure depends upon the strength characteristics of the composite material.

5.1 INDEX PROPERTIES

Specific Gravity

The specific gravity of pond ash was determined according to IS: 2720 (Part-III, section-1) 1980 and found to be 2.37. The specific gravity of pond ash is found to be lower than that of the conventional earth material. The specific gravity of pond ash depends on the source of coal, degree of pulverization and firing temperature. The presence of foreign materials in the fissures of the coal seams mostly influences the specific gravity of resulting pond ash. Moreover the pond ash is subjected to mixing with other earth materials during its transportation and depositions, which influences its specific gravity. Though the chemical composition of pond ash is very much similar to earth material but as the particles are cenospheres[11] it results in a lower specific gravity.

Grain Size Distribution

The pond ash consists of grains mostly of fine sand to silt size. Coefficient of uniformity and coefficient of curvature are found to be 2.15 & 1.25 respectively, indicating uniform gradation of samples. The presence of foreign materials in pond ash also influences its grain size distribution. In ash pond the original particles undergoes flocculation and conglomeration resulting in an increase in particle size.

6.CONCLUSION

The pond ash consists of grains mostly of fine sand to silt size with uniform gradation of particles. The specific gravity of particles is lower than that of the conventional earth materials. An increase in compaction energy results in closer packing of particles resulting in an increase in dry density where as the optimum moisture content decreases. Dry unit weight of compacted specimens is found to change from 10.90 to 12.70kN/m3 with change in compaction energy from 357 to 3488kJ/m3, whereas the OMC is found to decrease from 38.82 to 28.09%. This shows that pond ash sample responds very poorly to the compaction energy. When the percent of water content reduces from the optimum moisture content the unconfined compressive strength increases at a sustained degree of saturation of 13% and 14 % and then, decreases in standard and modified proctor density, it is due to the added water lubricates the surface of ash particles. Hence, the strength parameters achieved in the present study is comparable to the good quality, similar graded conventional earth materials. Hence, it can be safely concluded that pond ash can replace the natural earth materials in geo-technical constructions.

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