ISSN: 2395 - 2180

Available online at http:// www.ijemmr.co.in

International Journal of Engineering, Management & Medical Research (IJEMMR)

VOL - 6, ISSUE - 8, AUGUST - 2020

ANALYSIS OF REINFORCED EARTH WALL USING POND ASH - A LABORATORY STUDY

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ABSTRACT –

Pond ash produced as a by-product of the coal based thermal plants whose disposal is often a major environmental and economic issue. Reinforced earth wall is preferred over conventional RCC rigid retaining wall as it is not only cost effective but also has better performances during earthquake. But it uses the natural resources sand as the filler material. In this work, a possible use of pond ash and its mixture with sand as a fill material for reinforced earth wall is investigated. The major issue about the use of pond ash a fill material is the development of shear resistance or pull out capacity. In this work the shear behavior of pond ash, sand and its mixture is studied. A polymeric reinforcement is considered and the friction between the polymeric reinforcement and the pond ash mixture is studied using a laboratory pull out test. Experiments have been conducted on a model of the pond ash mix with reinforcement. The results have been compared with the simulation using a finite element based commercial software, PLAXIS 2D.

KEYWORDS –

Reinforced, polymeric, PLAXIS 2D, finite element, shear resistance

ISSN: 2395 - 2180

Available online at http:// www.ijemmr.co.in

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1. INTRODUCTION –

1.1 Overview

In coal based thermal Power Plants, coal is used as a fuel for steam generation. In the past, coal used to be charged into the furnace of grate boilers in the form of lumps. These lumps used to get sintered progressively on a travelling gate. With an increase in temperature, the ash assumes the molten state. Upon cooling, this solidifies into cinder with very less ash. The old grate boilers were proved to be non-energy efficient. In a quest to optimize the energy tapping from the coal, technologically upgraded modern coal bays thermal power plants used pulverized coal for combustion results in the generation of huge quantity of coal ash of improved quality. This pulverized coal is injected into the combustion chamber where it bones instantaneously and more efficiently. The resulting ash is known as Coal ashes. Based on the method of collection and disposal, coal ashes can be broadly classified into four categories. Fly ash, Bottom ash, Pond ash or Lagoon ash and Mound ash. Pulverized fuel ash extracted from flue gases by any suitable process such as ESP is called Fly ash. Pulverized fuel ash collected from bottom of boilers by any suitable process is called bottom ash. Fly ash or Bottom ash or both mixed in any proportion and conveyed in the form water slurry and deposited in ponds is called Pond ash.

1.2 Reinforced Earth Wall

Reinforcement may be incorporated into engineering fill, or inserted into the natural ground either to provide steeper slopes than would otherwise be possible or to improve load carrying capacity. Reinforcement may also be used to improve the performance of weak soils to support embankments or other resilient structures. These applications, which are illustrated in Figure 1.1, may involve the use of a range of reinforcement types and techniques including. Metallic strips, grids or meshes, Geosynthetics as polymeric strips, Geotextiles, geogrids or meshes and Anchors or multi-anchors (but not ground anchors).

Soil has an inherently low tensile strength but a high compressive strength which is only limited by the ability of the soil to resist applied shear stresses. An objective of incorporating soil reinforcement is to absorb tensile loads, or shear stresses, thereby reducing the loads that might otherwise cause the soil to fail in shear or by excessive deformation. There is some similarity to the principle of reinforced concrete as the reinforced mass may be considered a composite material with improved properties, particularly in tension and shear, over the soil or concrete alone.

1.2 Objective

To study the behavior of pond ash, sand and its mixture as a fill material for reinforced earth wall.

1.1 Scope

- Shear properties of pond ash and sand mixture
- Friction between polymeric reinforcement and pond ash, sand and their mix using laboratory pull out test

2. LITERATURE REVIEW

2.1 Reinforced Earth Wall using Pond Ash

Kumar (2012) Reinforced earth retaining wall is comparatively a new construction technique. Due to its simplicity, economy and faster pace of construction, several such retaining walls have been constructed all over the world and this technique has almost replaced the conventional reinforced concrete and gravity retaining walls. To reduce the congestion on National Highway-2 at the crossing of Kalindi Kunj near Sarita Vihar, New Delhi, a flyover was constructed along Badarpur-Ashram direction. The construction of approach road was carried out with reinforced retaining wall with friction polymeric ties (geosynthetic material) as reinforcement material. Instead of conventional earth, pond ash from the nearby Badarpur thermal power plant was used as backfill material

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 pulverized 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 fibers. The test results reveal that the inclusion of fibers in soils increases the peak compressive strength, CBR value, peak friction angle, and ductility of the specimens. It is concluded that the optimum fiber 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 35 structural and aesthetic qualities and portents huge saving in the manufacturing costs with better consumer response.

Mahlab et al.(2011),investigated the effect of fly ash characteristics on the behavior of pastes prepared under varied brine composition mixed with the two types of fly ash. The results showed that fly ash plays a more prominent role in the behavior of pastes than brines.

Sivakumar et al (2012), evaluates the properties of controlled low-strength material (CLSM) made using industrial waste incineration bottom ash and quarry dust. The results showed that the addition of quarry dust enhanced the performance of CLSM made using bottom ash with regard to stability, strength, and CBR.

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, mold area, tank size, and specific gravity on dry density of pond ash are highlighted herein. The maximum dry density and optimum moisture content of pond ash vary within the range of 8.40–12.25 kN/m3 and 29–46%, respectively.

Bera et al. (2007) 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

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,

ISSN: 2395 - 2180

Available online at http:// www.ijemmr.co.in

International Journal of Engineering, Management & Medical Research (IJEMMR)

VOL - 6, ISSUE - 8, AUGUST - 2020

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

Jakka et al. (2010) 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 tests with pore water pressure measurements, conducted on loose and compacted specimens of pond ash samples under different confining pressures.

Laba and Kennedy (1986) an experimental and theoretical study was conducted to assess the maximum tensile forces mobilized in a reinforced earth retaining wall, subjected to a vertical surcharge strip load or the combined action of vertical and horizontal surcharge strip loads. A simple design method for determining the maximum magnitude of the tensile force and its distribution with depth of the reinforced earth backfill was developed. The design method takes into consideration the ability of the reinforced earth wall system to retain its internal equilibrium by stress transfer from overstressed regions to those regions where the reinforcing elements have not yet reached their full frictional or strength capacity.

3. MATERIALS AND METHODS

3.1 Material Used

3.1.1 Pond ash

Pond ash was collected from ash ponds Vedanta *industry at* Jharsuguda (Orissa). The sample was sieved through 2mm sieve to separate out the foreign and vegetative matters. The collected samples were mixed thoroughly to get the homogeneity and oven dried at the temperature of 105-110^{0}C. The pond ash samples were stored in airtight container for subsequent use.

3.1.2 Sand

The sand was collected from a local river near *Vedanta* industry at *Jharsuguda* (*Orissa*). Sand was sieved through a 4.75 mm sieve and removed boulders from sample then kept in the oven dried at the temperature of 110^{0}C degree. The sand was stored in airtight container for subsequent use and protected from water moisture. Then it was sieved in 2 mm and 0.425 mm sieve. The sand which are passed in 2 mm and retained in 0.425mm sieve was taken for the research work. The specific gravity of the soil particles was measured according to the ASTM standard and has an average value of 2.61. The maximum and minimum dry unit weight of sand is 16.25 and 13.75 kN/m^{3}and corresponding values of minimum and maximum void ratios are 0.606 and 0.897 respectively. The particle size distribution was determined using a dry sieve method. The mean particle size (D_{50}), the uniformity coefficient (C_u) and coefficient of curvature (C_c) for the sand was 0.75, 2, and 1.01 respectively. The relative densities of the sand are 30, 45, 60, 75, and 90 respectively and the estimated internal friction angle is 33.2°, 35. 22˚, 37.5˚, 39.4°, and 43.1˚ respectively

3.1.3 Fly Ash

The fly-ash is light weight coal combustion byproduct, which results from the combustion of ground or powdered bituminous coal, sub-bituminous coal or lignite coal. Fly ash is generally separated from the exhaust gases by electrostatic precipitators before the flue gases reach the chimneys of coal-fired power plants. Generally this is together with bottom ash removed from the bottom of the furnace is jointly known as coal ash. The fly ash is highly heterogeneous material where particles of similar size may have different chemistry and mineralogy. There is a variation of fly ash properties from different sources, from the same source but with time and with collection point and variation in load generation (Das and Yudhbir, 2005).

3.1.4 Geopolymer sheet

Figure 3.1 Geopolymer sheet

Geopolymers are new materials for fire and heat-resistant coatings and adhesives, medicinal applications, high-temperature ceramics, new binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation. The properties and uses of geopolymers are being explored in many scientific and industrial disciplines. Single layer reinforcement is used in the present study middle of the tank for pond ash and sand samples to study the effect of reinforcement on bearing capacity and shear strength. The woven reinforcement used in the present study is shown in Figure 3.1.

3.2 Methods

The present study consists of both experimental and numerical methods for characterization of pond ash, fly ash and sand and analysis of the reinforced earth wall using pond ash with a geopolymer sheet. The experimental methods refer for investigation of fly ash in terms of morphology, chemical, mineralogical and geotechnical properties. The laboratory investigation of the model footing is also part of the experimental methods. The numerical method refers to the finite element analysis of model footing on red mud and analysis of embankment using red mud. The experimental methods and numerical methods used in the present study are elaborated as follows.

3.3 Experimental methods

3.3.1 Determination of specific gravity:

The specific gravity is the ratio of the weight of a given volume of soil solids at a given temperature (27^0C) to the weight of an equal volume of distilled water at that temperature, both weights taking in air .The specific gravity is determined by the experiment by using pycnometer as per IS 2720 Part 3 Sec 2 1980. To get the specific gravity first the weight of the dry clean pycnometer has taken. Then put 50gm of soil into it and recorded the weight of pycnometer along with soil mass. Add the water up to three-fourth of pycnometer and shacked properly. Then Put it in a vacuum up to 15 to 20minutes to reduce the entrapped void. Add distill water up to a mark level after cooling and clean the outer surface and recorded the weight of pycnometer with soil and water. After clean the pycnometer it filled with water up to mark level and the weight is recorded.

Specific gravity is defined by the ratio of the mass of a given volume of solids to the mass of an equal volume of distilled water with a stated temperature. The specific gravity experiment has done in pycnometer method. The equipment used in the experiment like

ISSN: 2395 - 2180
Available online at http:// www.ijemmr.co.in
International Journal of Engineering, Management & Medical Research (IJEMMR)
VOL - 6, ISSUE - 8, AUGUST - 2020

Figure 3.1 Pycnometer with water and pond as

Figure 3.2 Balance Weight Machine

3.3.2 Determination of grain size distribution:

The percentage of various sizes of particles in a given dry soil sample are founded by the mechanical analysis which performed in two stages, i.e. sieve analysis and sedimentation analysis .The sieve analysis is performed is done if all particles do not pass through the square opening 75 micron as per IS: 2720 part (IV) and hydrometer analysis is conducted for the finer (pass through 75micron) particles as per IS: 2720

3.3.3 Determination of Compaction characteristics

Compaction is done to determine the relationship between the moisture content and dry density of a specified soil in a specified compactive effort. The compactive

3.3.4 Determination of permeability:

The property of soil mass which permits the seepage of water through its interconnecting voids is called permeability .The permeable soil has continuous voids. The average velocity of flow that will take place through the total cross sectional area of soil under unity hydraulic gradient , is known as the co-efficient of permeability

3..3.5 Determination of unconfined compressive strength:

The aim of the unconfined compressive strength test (UCS) is to determine the unconfined compressivestrength of soil that possess sufficient cohesion to allow for testing in the unconfined state which is then use calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. The UCS test is performed as per IS: 2720 (Part 10) 1991.The test specimen is prepared from freshly prepared soil sample and store the samples for 7days in a constant water content desiccator .For purposes of testing RMSM specimen we use 5 and 20knN proving ring according to their strength.

Figure 3.6 Pond ash as unconfined compression

ISSN: 2395 - 2180

Available online at http:// www.ijemmr.co.in

International Journal of Engineering, Management & Medical Research (IJEMMR)

VOL - 6, ISSUE - 8, AUGUST - 2020

4. Experimental analysis

The pull out test was conducted to study the stress and strain behavior of pond ash, sand and pond ash sand mix proportions under different loads. The test of compacted pond ash sample specimen were conducted by varying density as 1.136 and 1.20gm/cm³ which has got from their respective compaction energy .That sample was prepared in dimension of 400mm x 200mm x 200mm rectangle tank with pulley. The pull out test was conducted very carefully by increasing the loads gradually 0.5 kg/cm², 0.1 kg/cm² ,1.5 kg/cm², 2 kg/cm², 2.5 kg/cm² and up to 8.5 kg/cm² .Loads are placed in a stand which is connected to geo polymer sheet with thin metal wire through pulley. Dial gauge is fixed to the side face of the tank and it is placed on the Geo polymer sheet to know strain deformation.

4.1 Numerical analysis with PLAXIS 2D

4.3. 1Example

The 1st attempt was tried to analyze the shear failure to pull out test with sand. Model diagram with its deformation mesh is shown in Figure 5.3. Pull out test model sets up in PLAXIS 2D Figure 5.4 . Figure 5.8 The PLAXIS model with its deformation for sand and geo polymer Figure 5.5 The shear failure surface as per PLAXIS model for using only sand.Figure 5.6 The PLAXIS model for Total displacement in pull out test for sand Figure
5.7 Load Vs displacement graph for sand in PLAXIS 2D Figure 5.8 total displacement of Geo polymer.

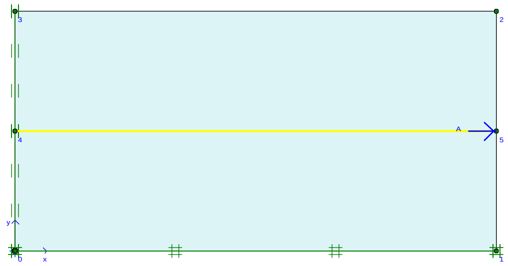

Figure 5.3 Pull out test model set up in PLAXIS 2D

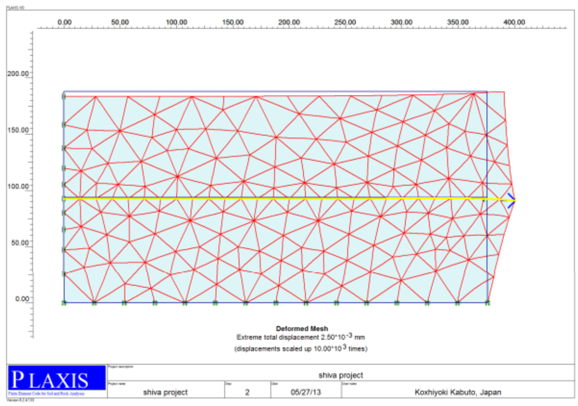

Figure 5.4 The PLAXIS model with its deformation mesh using sand

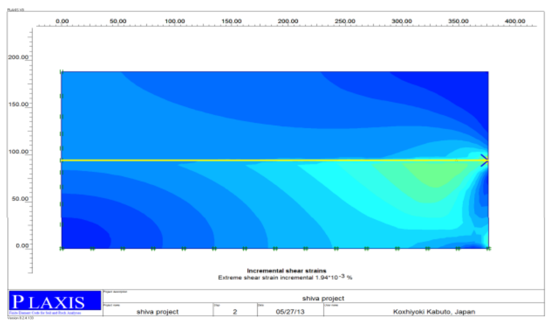

Figure 5.5 The shear failure surface as per PLAXIS model for using only sand.

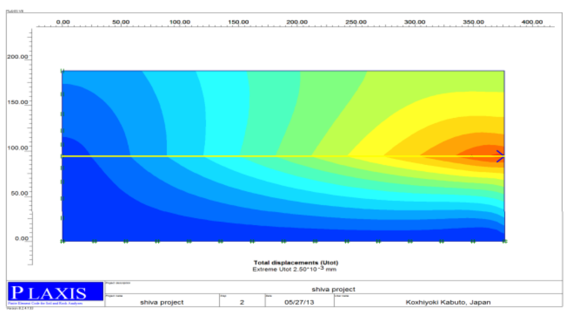

Figure 5.6 The PLAXIS model for Total displacementin pull out test for sand

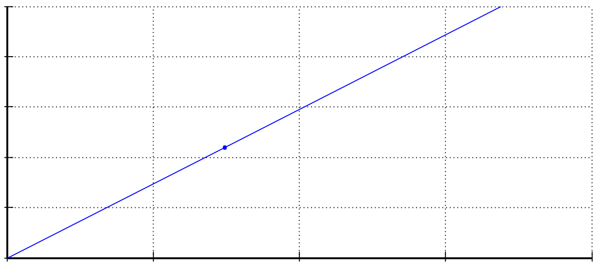

Figure 5.7 Load Vs displacement graph for sand in PLAXIS 2D

5. CONCLUSIONS

Based on the laboratory study on pond ash, sand and their mixture following conclusions can be made.

- It was observed that pond ash is coarse like sand but its shear resistance is less than that of sand and may be due to the shape of the particle.
- The pond ash and sand mixture found in effective fill material.
- The pull out capacity of the reinforcement with pond ash and sand mixture found to more than that of sand and pond ash used separately.
- The numerical model analysis using PLAXIS 2D found to have a similar trend to that of laboratory results.
- Such a study will professional to use the pond ash sand mixture as a fill material.

SCOPE FOR FUTURE WORK

- Field validation of results
- Use of pond ash with reinforcement ash embankment

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