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

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A thesis

Submitted by

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Roll Number: 211CE1233

in partial fulfilment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

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Under the Guidance of

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MAY 2013

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THESIS CERTIFICATE

This is to certify that the thesis entitled **"DESIGN OF REINFORCED EARTH WALL USING POND ASH - A LABORATORY STUDY"** submitted by **T SIVARAMAKRISHNA SHARMA** bearing Roll Number: **211CE1233,** in partial fulfilment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in "Geotechnical Engineering" at National Institute of Technology Rourkela, is a bonafide record of project work carried out by him under my supervision. To the best of our knowledge, the contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Project Guide

Place: Rourkela

Date: 28/05/2013

Prof. Sarat Kumar Das
Department of Civil Engineering,
NIT Rourkela,
Rourkela.

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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 as 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.

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CHAPTER 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.

Over the last few years, environmental and economic issues have stimulated interest in the development of alternative materials that can fulfill specification. Also the development of alternatives for reusing industrial by-products mostly brings environmental and economic benefits. In India currently more than 70,000 acres of land are occupied by ash pond. The worldwide production of pond ash is growing every year. The disposal of such a huge quantity does pose challenging problems in the form of land uses, health and environmental hazards. About 67% of Indian pond ashes are alkaline content. The supernatant pond water contaminates the surface water and also affects the aquatic life. The water from the ash ponds, if used for agriculture, may have harmful effects on plants. It pollutes the ground water. It consumes a vast area of land, which is otherwise useful, apart from a large capital investment. Depending upon the ash content of the coal and the level of power generation, 0.5 to 5 acres of land per MW of power generation is required. Both in disposal, as well as in the utilization, proper methods should follow to safeguard the human life, wildlife and the environment**.**

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.

In most practices of seismic design (e.g., Elias et al., 2001), the reinforcement load is obtained by analysis of limit equilibrium. The reinforced soil wedge bounded by a Rankine's or Coulomb's failure surface is used together with a maximum seismic acceleration in the horizontal direction to calculate the reinforcement load. Maximum load in each reinforcement layer is assumed to occur at the failure surface. It is necessary to check the validity of these assumptions on GRS walls using marginal backfills and subject to seismic loading during service life

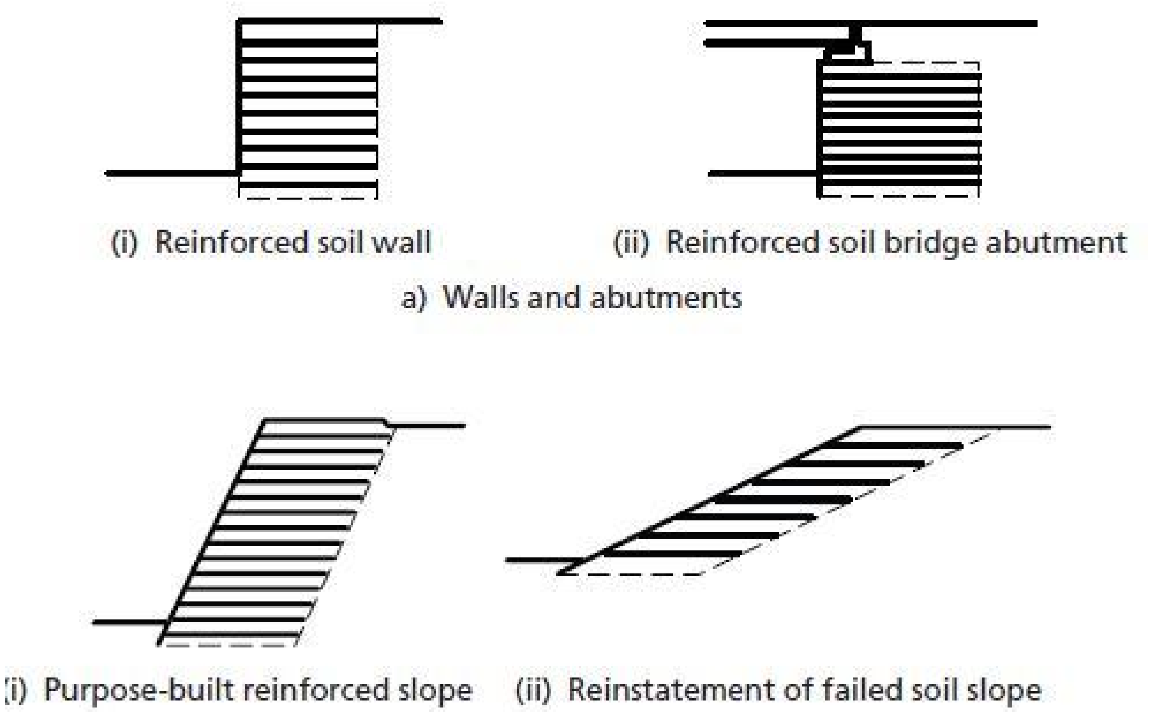

Figure 1.1 Range of applications of reinforced soils

1.3 Objective

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

1.4 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

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Pond ash is the product of combination of fly ash and bottom ash and are by-products of thermal power plants. Together these are mixed with water to form a slurry. That slurry is pumped to the ash pond. In ash pond area, excess water is removed and the ash settles as residue. This residual deposit is called pond ash. This is used as filling materials including in During construction of roads, dams & embankments, pond ash is used as a filler material . Any special type of pond ash is used for manufacturing of earth retaining walls and building materials like lime fly ash bricks/ blocks etc.

Thermal power plants contribute a major quantity of pond ash. Besides this aluminium, steel, and copper plants also produce a substantial amount of pond ash.

2.2 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. The paper discusses the properties of geosynthetic reinforcement; backfill material, design details and the methodology adopted for construction of reinforced approach embankments. Conclusions have been drawn about the suitability of geosynthetic material as a reinforcement and pond ash as a backfill material for the retaining wall.

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. 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 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. Local shear failure of a square footing on pond ash at 37% moisture content (optimum moisture content) is observed up to the values of dry density 11.20 kN/m3 and general shear failure takes 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 36significantly 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 stabilizing materials of low density and low strength, have been derived from strength parameters obtained from UCS tests, point load strength tests, and Schmidt rebound hammer tests, and also between UCS and slake durability index.

Bera et al. (2009) have studied the shear strength response of reinforced pond ash, a series of unconsolidated undrained (UU) 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 in shear strength response of pond ash are 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 (σ_{1f}) 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 the 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 (γd) of pond ash, type of geotextile, and also type of pond ash.

Ghosh et al. (2010) presents the laboratory test results of a Class F pond ash alone and stabilized with varying percentages of lime (4, 6, and 10%) and PG (0.5, and 1.0), to study the suitability of stabilized pond ash for road base and sub-base construction. Standard and modified Proctor compaction tests have been conducted to reveal the compaction characteristics of the stabilized pond ash. Bearing ratio tests have been conducted on specimens, compacted at maximum dry density and optimum moisture content obtained from standard Proctor compaction tests, cured for 7, 28, and 45 days. Both un-soaked and soaked bearing ratio tests have been conducted. This paper highlights the influence of lime content, PG content, and curing period on the bearing ratio of stabilized pond ash. The empirical model has been developed to estimate the bearing ratio for the stabilized mixes through multiple regression analysis. The linear empirical relationship has been presented herein to estimate soaked bearing ratio from un-soaked bearing ratio of stabilized pond ash. The experimental results indicate that pond ash-lime-PG mixes have potential for applications as road base and sub base materials.

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. Ash samples from inflow point exhibited behavior similar to sandy soils in many respects. They exhibited higher strengths than reference material (Yamuna sand), though their specific gravity and compacted maximum dry densities are significantly lower than sands. Ash samples from outflow point exhibited significant differences in their properties and values, compared to samples from inflow point. The shear strength of the ash samples from outflow point are observed to be low, particularly in a loose state where static liquefaction is observed.

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. The effect of the magnitude and location of the strip load on this phenomenon of stress transfer is shown. Favorable comparisons were obtained between the results given by the proposed design method and those from model tests.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter discusses about the materials used in the present study. Though the main material characterized in the present study is pond ash and sand. Experimental and numerical methodology followed for characterization of these materials is also discussed. In India currently more than 70,000 acres of land are occupied by ash pond. Such a huge quantity does pose challenges problem, in the form of land uses, health hazards and environmental dangers. Both in disposal, as well as in the utilization, utmost care has to be taken, to safeguard the interest of human life, wildlife and the environment**.** The pond ash deposits are characterized by its very low bearing capacity and high compressibility, rendering them unsuitable for any civil engineering structures constructed over it. Any construction activity over abandoned ash ponds needs a proper understanding of the physical and mechanical properties of these deposits and also the suitability of any ground improvement techniques that can be adopted. Even through adequate substitute for full scale field tests are not available; tests on laboratory scale to provide a means to closely control many of the variable encountered in practice. The trends and behavior pattern observed in the laboratory tests can be used in understanding the performance of the structures in the field and may be used in formulating mathematical relationship to predict the behavior of field structures. Keeping this in mind laboratory investigations was carried out to determine the physical and mechanical properties of pond ash. A brief introduction about the above materials and methodology is presented in this chapter.

3.2 Material Used

3.2.1 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.

3.2.2 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

3.2.3 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). Fly-ash contains some un-burnt carbon and acidic in nature and its main constituents are silica, aluminum oxide and ferrous oxide. In the present study the fly ash collected from the hopper of JSPL, Jindal Steel Plant (JSPL), Raigarh , Talcher of Chhattisgarh. In this JSP plant the fly ash is collected through the hopper and is transferred through trucks. Hence the fly ash in dry state was collected from the plant.

3.2.4 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.

3.3 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.

3.3.1 Experimental methods

3.3.1.1 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 pycnometer, balance, vacuum pump, funnel, spoon as shown in Figure (3.1 and 3.2).

Figure 3.1 Pycnometer with water and pond ash

Figure 3.2 Balance Weight Machine

3.3.1.2 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

3.3.1.3 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 effort is the amount of mechanical energy that is applied to the soil. There are various methods used to compact soil in the field like tamping, kneading, vibration, and static load compaction. R.R.PROCTOR has developed an impact compaction method using some equipment and methodology in the laboratory. Compaction test determines the moisture content and dry density relationship as per IS 2720 (1980).compaction test are 2 type i.e., light compaction and heavy compaction From the dry density and moisture content relationship, optimum moisture content (OMC) and maximum dry density (MDD) were determined. This shows the result of compactive energy on OMC and MDD.Two types of compaction are there.1.standard proctor test.2 .modified proctor test.

Figure 3.3 Light Compaction Apparatus **Figure 3.4** Heavy Compaction Apparatus

3.3.1.4 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 .The permeability of soil sample is determined by falling head parameter and constant head parameter. The permeability of granular soil is determined by the constant head parameter under condition of laminar flow of water as per IS 2720 (part-36). Permeability refers to which the water flows through the soil. This property needs to calculate the seepage through earth dams or under sheet pile walls and the calculation the seepage rate from waste storage facilities. We have done the experiment in the constant head test shown in figure 3.5.


Figure 3.5 Constant Head Permeability Apparatus

3.3.1.5 Determination of unconfined compressive strength:

The aim of the unconfined compressive strength test (UCS) is to determine the unconfined compressive strength 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.

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. According to the ASTM standard, the unconfined compressive strength (q_u) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

Figure 3.6 Pond ash as unconfined compression

3.3.1.6 Scanning Electron Microscope with Energy Dispersive X-ray micro analyzer

SEM is a type of an electron microscope that images a sample by scanning it with a high – energy beam of electron in a raster scan pattern. This study carried out to have a closer view of the individual particles. The electron intact in the atom that make up the sample producing signals that contains information about the sample's surface topography ,composition, and other properties such as electrical conductivity.

The scanning electron microscope (SEM) is becoming one of the most unique and also versatile instruments available for the non-destructive inspection, evaluation and point-to-point characteristics of solid objects. SEM provides Technologist an advantage of the high ultra resolution which can be achieved on the test object SEM with three dimensions of high resolution activity resulting appearance of the objects image presentation on the SEM screen offer important pieces of information which help the technologist to determine the quality significance of the of the item under test.

The samples are prepared with carbon coating before being put in the SEM. Figure 3.7. Shows the layout of SEM set up with the EDX micro analyzer.

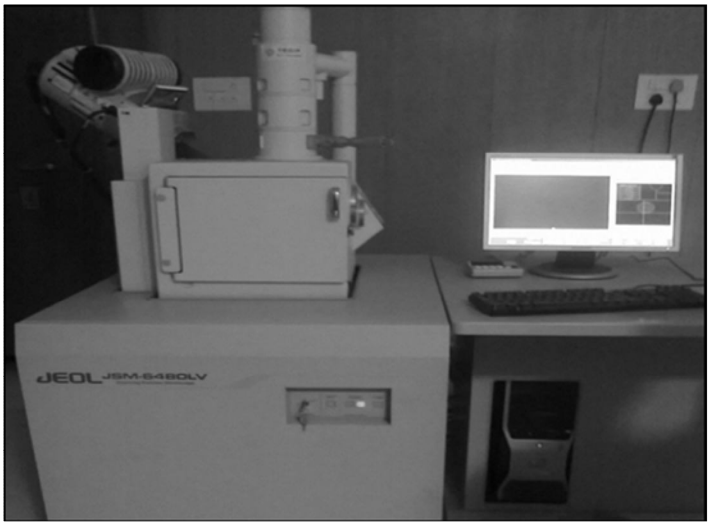

Figure 3.7 SEM model JEOL JSM-6480LV for SEM and EDX analysis

3.3.1.7 Angle of Repose

The angle of repose is the steepest angle of the slope relative to the horizontal plane when the material on the slope face is on the verge of sliding. In general it refers to the maximum angle at which an object can rest on an inclined plane without sliding down. The internal angle between the inclined surface of the material and the horizontal surface is known as the angle of repose and is depends mainly upon to the density, surface area and shapes of the particles, and the coefficient of friction of the material. This angle is in the range 0°–90°. Figure 33.8 (a) shows the arrangement for angle of repose test as per Sridharan and Prakash (2007). The dry red mud is poured into a cylindrical pipe on a level surface and made it full as shown in Figure 3.8 (b). Using the ruler top of the surface of red mud leveled and then cylindrical mould was lifted up. The red mud mound was placed like a conical shape as shown in Figure 3.8 (c) and Figure 3.8(d). The height of the tip of the conical shaped red mud and the diameter of the spread is measured and angle is measured in terms of height and radius of spread.

(a) **(b)**

(c) **(d)**

Figure 3.8 Arrangement of angle of repose test (a) Filled cylindrical pipe mould with pond ash after pouring, (b) Lifting of mould after filling it with pond ash, (c) Heap of red mud after lifting the cylindrical mould, (d) Heap of fly ash after lifting the cylindrical mould.

3.3.1.8 Tensile strength of geotextile reinforcement

As geopolymer has been used as reinforcement for model study, it needs to find its mechanical properties for the FE analysis as per PLAXIS. Mechanical properties of Geo-grid have been found by using Instron 1195 (Instron Corporation, series IX Automated Materials Testing System 1.26) shown in Figure 3.9.

3.3.1.9 Free Swell Index (FSI):

Basically, free swell index has been developed in the field of geotechnical engineering to differentiate between the swelling and non- swelling soils and also to determine the degree of soil expansivity. Bureau of Indian Standards suggests a method to determine the free swell index of fine grained soils (IS:2720-part 40, 977), which is defined as

$FSI= (V_d-V_k)\ 100/V_k$

Where $V_d$is the equilibrium sediment volume of 10gms of oven dried soil passing a 425 micron sieve placed in a 100 ml graduated a measuring jar containing distilled water, and V_k is the equilibrium sediment volume of 10gms of oven dried soil passing a 425 micron sieve placed in a 100 ml graduated a measuring jar containing kerosene. As this method gives negative free swell indices for kaolinite rich soil and underestimates the expansivity of montmorillonitic soils, modified free swell index has come into existence (Sridharan et al., 1985).

Nearly 70% of Indian coal ashes exhibit negative free swell indices calculated as for above equation does not consider the wide variation in the specific gravity of coal ashes. Hence it is preferable to calculate free swell ratio for typical Indian coal ashes. The free swell ratios are either less than one or slightly more than one indicating that they are non swelling materials.

3.3.1.10 Model for Tensile Test Arrangement

The testing program has been designed to evaluate the different geopolymer/soil interlock capacity by means of a pull out testing.

The model set up consist of the test tank of size 400mm x 200mm x 200mm. Fabricated out of 12mm thick Perspex sheet on four sides. A frame has made out of steel riveted joints to strengthen the Perspex tank. A slit is made at the transverse side of tank with size of 8mm, through this slit Geo polymer will comes out for shear failure. A thin metallic wire is taken, one end is attached at the Geo polymer sheet and the other end attaches to loading stand through the support of the pulley. Load is applied directly to the loader frame; it will give reading of load applied for tests. Settlement of the sample at a particular load was measured through dial gauge which were placed at side facing of the tank as shown in Figure 3.10.

The sample was poured into the test box using raining method, the weight of the pond ash sample was compacted in layers was taken and then poured into the model tank and using tamping. After placing 2 layers from bottom of the tank Geo polymer sheet is placed and then remaining 2 layers is placed then kept uniform load throughout the top surface of the tank. By increasing the load gradually shear failure will occur. The results of the above test are presented separately in Chapter 4.

Figure 3.9 Instron Corporation, series IX Automated Materials Testing System 1.26 with specimen

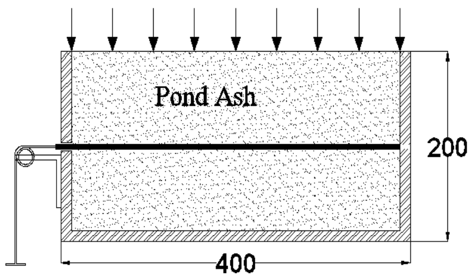

Figure 3.10 Model for pull out test arrangement set up

Table 3.1 Comprehensive list of experimental tests performed

Sl No.	Tests Performed	Materials used
1	SEM	Fly ash
2	EDX	Fly ash
4	pH value	Fly ash , Pond ash
5	Sp. G_v.	Fly ash, pond ash, Sand
6	Sieve analysis	Pond ash
8	Differential free swell (DFS)	Pond ash, Fly ash
9	Compaction	Pond ash, Fly ash, Sand , Fly ash and sand mix
14	Shear test i. Direct shear ii. Triaxial shear iii. UCS	 Fly ash, pond ash, Sand Pon ash Pond ash
15	Permeability i. Constant head	 Pond ash
16	Pull out test (a) With sand reinforcement (b) ii With pond ash reinforcement (c) With pond ash (85%) and sand (15%) (d) With pond ash (80%) and sand (20%) (e) With pond ash (75%) and sand (25%)	 Sand Pond ash Pond ash , Sand Pond ash , Sand Pond ash , Sand

3.3.1.11 PLAXIS

PLAXIS name was derived from PLasticity AXISymmetry, a computer program developed to solve the cone penetrometer problem by Pieter Vermeer and De borst. The commercial version of PLAXIS was released in 1987. Earlier version of PLAXIS was in DOS interface. PLAXIS V-7 was released in windows with automated mesh generation. Advanced soil models were also incorporated. In the present study PLAXIS 2- D version 9.0, with PLAXIS and PLXFLOW module is used.

The implementation of PLAXIS consists of three stages, known as input stage, calculation stage and post processing (curves) stage. Input stage contains model design, assigning the material parameters, boundary conditions, loading and meshing. PLAXIS 2D uses 2nd order 6-node with 3 gauss point and 4th order 15-node with 12 gauss point triangular elements to model the soil. 3 node and 5 node beam elements are available to model shell, retaining wall and other slender members. 3-node element has 2 pair of Gaussian stress points and 5-node element has 4 pair of Gaussian stress points. Bending moments and axial forces of these Plates are calculated from the stresses at the Gaussian stress points 9. In the present analysis 15-node triangular element is considered for meshing which contains 12 stress points. PLAXIS involves automatic mesh generation. PLAXIS produces unstructured mesh generation. The mesh generation is based on robust triangulation procedure. Global refinement (to increase the number of elements globally), Local refinement (to increase the number of elements in particular cluster), Line refinement (to increase the element numbers 10 at the cluster boundaries), Point refinement (increasing the element coarseness around the point) is available to obtain the best results. Mesh coarseness used to keep in from very coarse to very fine. The number of mesh elements considerably affects the results. So a sensitivity study of mesh elements for each analysis should be investigated. In PLAXIS, stresses and strains are calculated at individual Gaussian integration points rather than at nodes.

Mohr-Coulomb (MC) model was applied, which is a simple elastic - plastic model and contains five model parameters (unit weight, cohesion, internal friction, permeability, young’s modulus). The linear Elastic model is based on Hooke’s law. The model involves with two parameters: Young’s modulus (E) and Poisson’s ratio (ν) and is used to simulate the structural elements in soil such as footing, Pile or Rock.

In the present study PLAXIS 9.0 is used to simulate the Settlement of the footing and slope stability of embankments. In the calculation stage, analysis type is chosen such as Plastic, dynamic, consolidation and phi-c reduction. The assigned loads are activated in this stage and analyzed. In the post processing stage, curves are plotted between various calculated parameters such as load Vs displacement.

To compare with the limit equilibrium method in addition to stress-strain calculation, the factor of safety (FOS) of slope is calculated using Phi-c (φ-C) reduction method.

CHAPTER 4

EXPERIMENTAL STUDIES

4.1 Basic properties of materials

Following a series of tests were carried out in this work. The tests aimed at evaluating the physical and mechanical properties of pond ash which includes the index properties of pond ash such as the specific gravity, grain size distribution and the consistency indices. Father the compatibility of pond ash under different combustive energy levels was determined with the help of compaction tests. The shear strength parameters of compacted pond ash specimens at OMC and saturation conditions were also determined from direct shear test and triaxial shear tests. The details of tests conducted and the experimental procedure is outlined below.

4.2 Chemical properties

4.2.1 pH value analysis

pH values of coal ashes mainly depends upon their alkaline oxide content and free lime content. pH of coal ashes can very over a wide range from extremely low, of the order of about 3, to a value as high as about 12. The table lists the pH values of typical Indian coal ashes. While about 50% of the Indian fly ashes are alkaline in nature, about 67% of Indian pond ashes are alkaline. Almost all Indian bottom ashes are dominantly alkaline.

Table 4.1 pH values of typical Indian coal ashes (data source: Sridharan et al., 2001h)

Sl. No.	Source	Type of coal ash	pH
1	Raichur	PA	9.54
2	Raebareli	FA PA BA	7.36 8.03 7.55
3	Korba	FA PA BA	5.13 8.68 6.24
4	Vijayawada	FA PA BA	7.61 9.30 9.02
5	Badarpur	FA PA BA	6.07 6.45 7.59
6	Ghaziabad	FA PA BA	5.52 7.74
7	Ramagundam	FA PA BA	9.66 10.03 9.00
8	Neyveli	FA PA BA	10.59 8.03 8.13
9	Farakka	FA PA BA	5.49 8.68 5.52
10	Vidyanagar	FA PA	8.06 9.93
11	Kahalgoan	FA	5.83

	(130m from DP) (700 m from DP)	PA 1 PA 2 BA	6.51 6.96 7.18
12	Rihana (FF) (LF)	FA FA PA BA	6.61 7.25 7.44 8.56
13	**Jharsuguda (Orissa)**	**PA**	**7.763**
14	**Raigarh Chhattisgarh**	**FA**	**7.21**

FA: Fly ash DP: Discharge point

PA: Pond ash FF: First field

BA: Bottom ash LF: Last field

4.2.2 Scanning electron microscope test for Fly ash

The scanning electron microscope (SEM) is becoming one of the most unique and also versatile instruments available for the non-destructive inspection, evaluation and point-to-point characteristics of solid objects. SEM provides Technologist an advantage of the high ultra resolution which can be achieved on the test object SEM with three dimensions of high resolution activity resulting appearance of the objects image presentation on the SEM screen offer important pieces of information which help the technologist to determine the quality significance of the of the item under test. Results are shown in below figure 4.1

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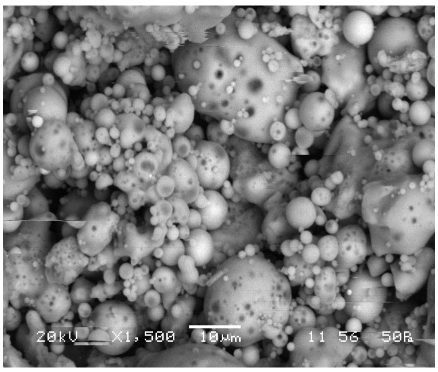


Figure 4.1 Scanning Electron Micrograph of fly ash

4.3 Determination Of Index Properties

4.3.1 Determination of specific gravity

The specific gravity of pond ash was determined according to IS: 2720 (Part-III, Section-1, 1980). Specific gravity of coal ash primarily depends on its chemical composition. Generally, coal ashes exhibit considerable low values of specific gravity when compared with those of soils that have specific gravity varying gravity in a narrow range of 2.6-2.8. The specific gravity of various individual compounds present in coal ashes such as nepheline (G_s=2.5 to 2.6), millite (G_s=3.1 to 3.6), quartz (G_s=2.65), hercynite (G_s= 3.5 to 4.1), fayalite (G_s =4.3), haematite (Gs = 4.9 to 5.3) and magnetite (G_s = 5.18) is higher than those of the local ashes they compose, because of different arrangements in their solid state (Trivedi and Sud, 2002). Coal ash with higher iron content will have relatively higher specific gravity. Table no 4.2 lists the values of specific gravity of typical Indian coal ashes. Specific gravity of Indian fly ashes varies in the range 1.66-2.55. Indian pond ashes and bottom ashes have their specific gravity varying in the ranges 1.64-2.66 and 1.47-2.19 respectively. The specific gravity of an average value was pond ash found to be 2.25, sand 2.67 and fly ash 2.18.

Table 4.2 Value of specific gravity of typical Indian coal ashes (data source: Sridharan et al., 2001e)

Sl. No.	Source	Type of coal ash	Specific gravity
1	Raichur	PA	2.01
2	Raebareli	FA PA BA	2.06 2.10 1.82
3	Korba	FA PA BA	2.10 1.96 2.15
4	Vijayawada	FA PA BA	2.11 2.08 2.04
5	Badarpur	FA PA BA	2.12 2.16 2.10

6	Ghaziabad	FA BA	2.12 2.07
7	Ramagundam	FA PA BA	2.23 2.21 2.17
8	Neyveli	FA PA BA	2.55 2.33 2.05
9	Farakka	FA PA BA	2.17 2.66 1.98
10	Vidyanagar	FA PA	2.21 2.65
11	Kahalgoan (130m from DP) (700 m from DP)	FA PA 1 PA 2 BA	2.21 2.45 2.10 2.17
12	Rihana (FF) (LF)	FA FA PA(DP) PA(MP) PA(EP) BA	2.07 2.29 2.49 2.13 2.19 2.19
13	***Jharsuguda (Orissa)***	**PA**	**2.25**
14	**Raigarh Chhattisgarh**	**FA**	**2.18**

FA: Fly ash MP: Mid point PA: Pond ash

DP: Discharge point BA: Bottom ash EP: Exit point

4.3.2 Determination of grain size distribution

For determination of grain size distribution, the pond ash was passed through an IS test sieve having an opening size 75µ. Sieve analysis was conducted for coarser particles are 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 75 µ sieve was found to be 27.56 %. Hence almost all the pond ash particles are silt size. Coefficient of uniformity (C_u) and coefficient of curvature (C_c) for pond ash are 6.02 and 2.54 respectively. The grain size distribution curve of pond ash is presented in Fig 4.2. The pond ash consists of grains mostly of fine sand to silt size. The coefficient of uniformity and coefficient of curvature of pond ash sample is found to be 6.15 and 2.63 respectively indicating uniform gradation of the sample. The grain size distribution of pond ash mostly depends upon the degree of pulverization of coal and the firing temperature in boiling units. Pond ash is mixed with sand at different proportions and find out the results are shown in fig 4.3 .This modern plant having more efficient coal pulverizing equipment tends to produce ashes of finer texture than those from older stations. Grain size distribution of sand shown in below in fig 4.4.

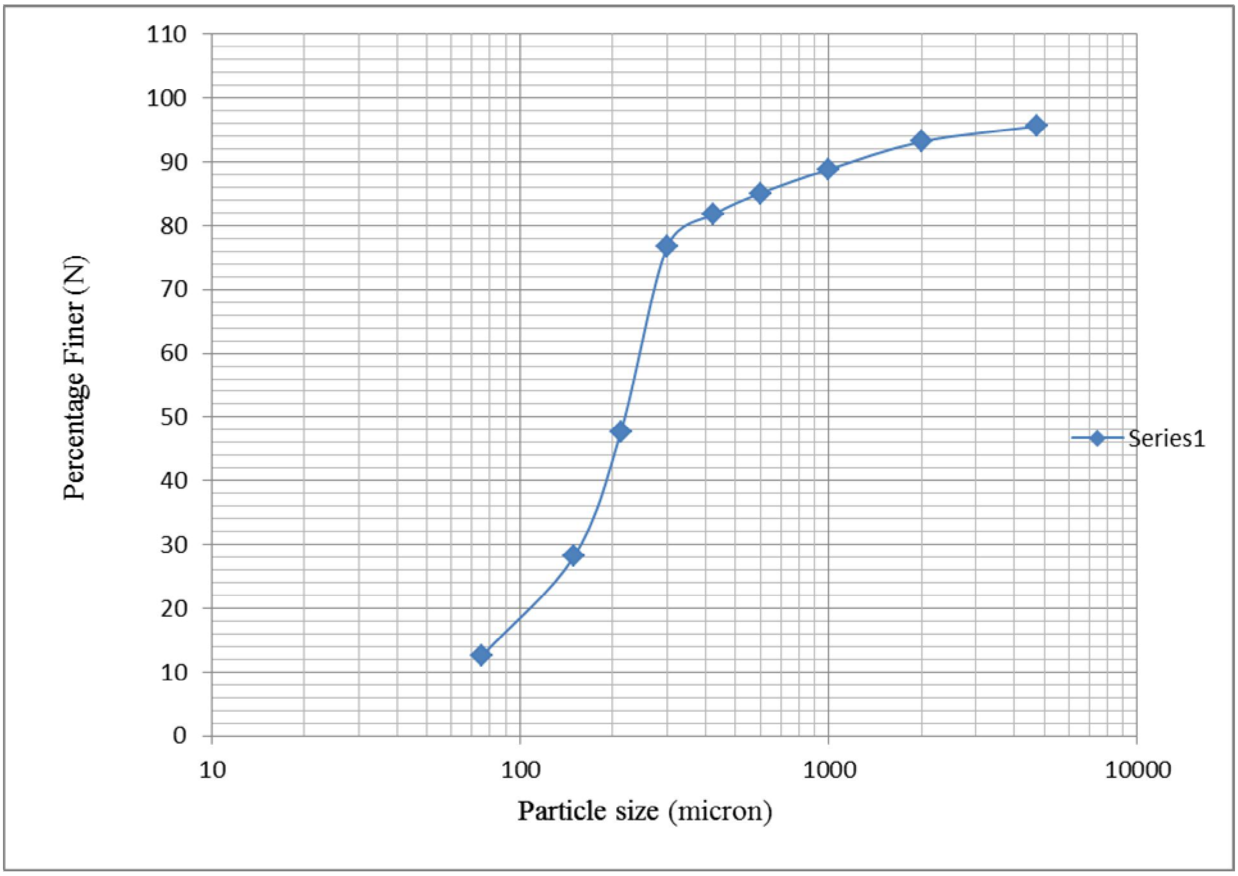


Figure 4.2 grain size distribution curve for pond ash

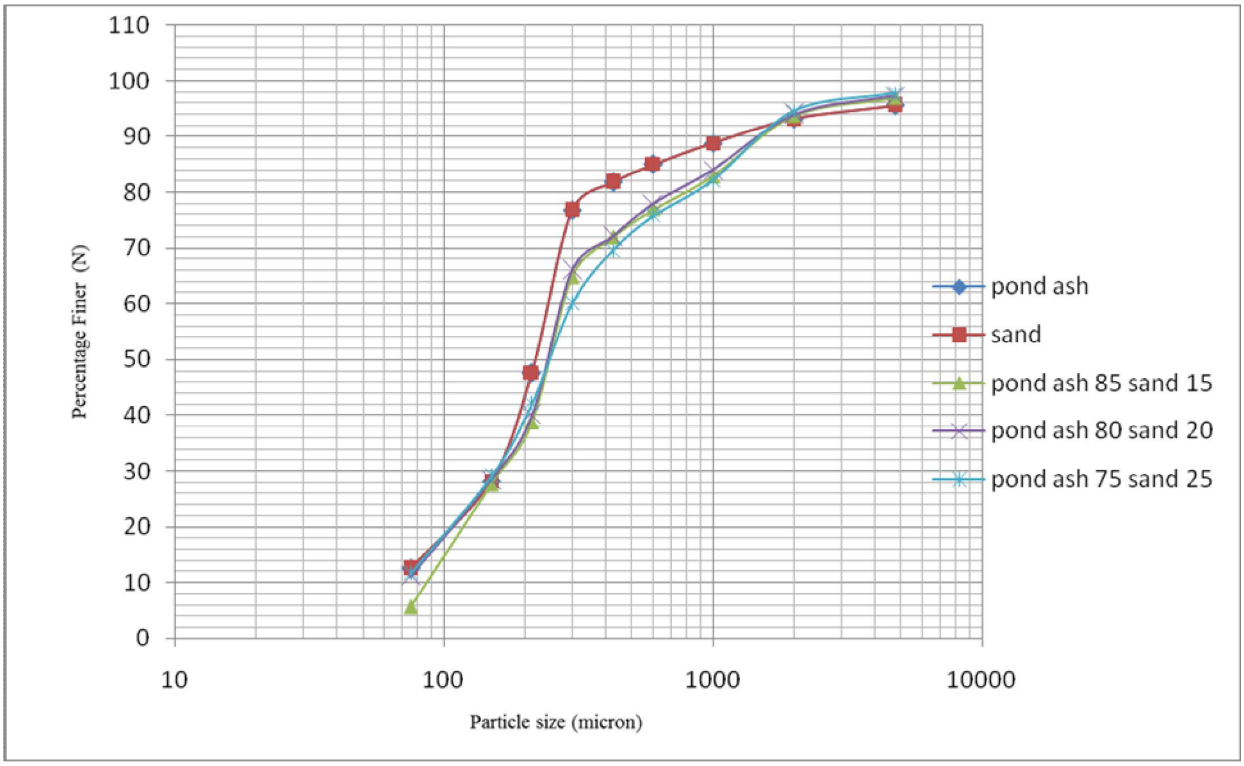


Figure 4.3 grain size distribution curve for pond ash and sand mix

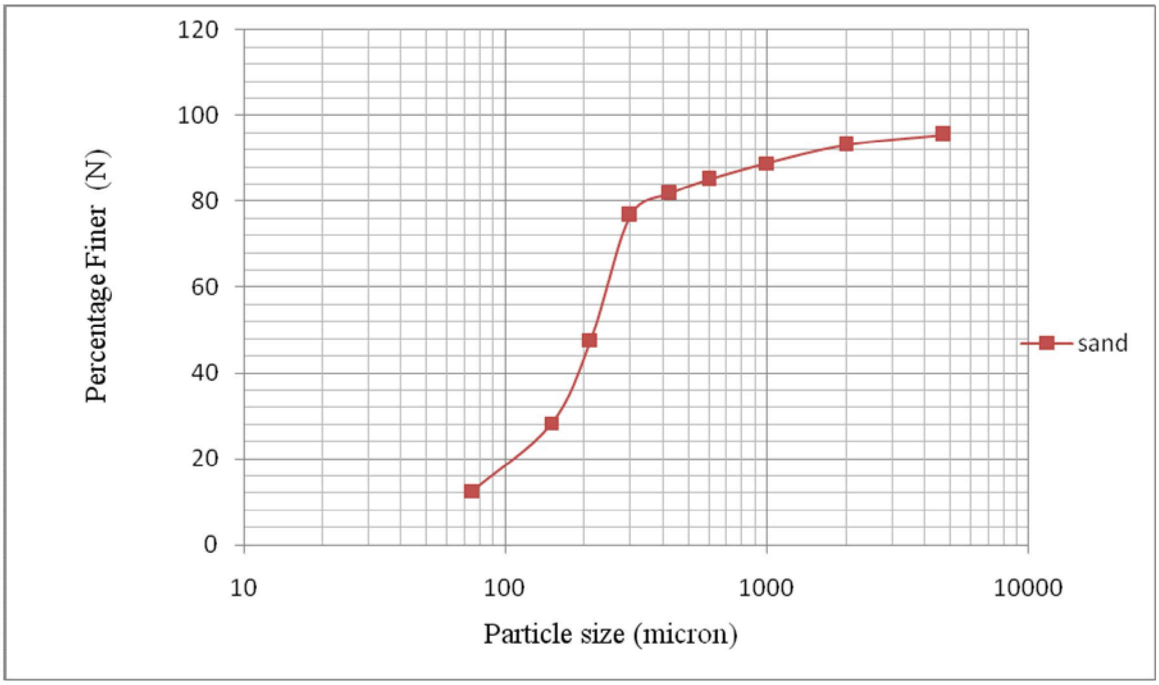


Figure 4.4 grain size distribution curve of sand

4.4 Determination of Engineering Properties

4.4.1 Compaction characteristics of pond ash

The compaction characteristics of pond ash were found by using compaction tests as per IS: 2720 (Part VII) -1980 and IS: 2720 (Part VIII)-1980. For this test, samples were mixed with required amount of water and the wet sample was compacted in Proctor mould of 1000c.c volume, either in three or five equal layers using standard Proctor rammer of 2.6 kg or modified Proctor rammer of 4.5 kg. The number of blows in each layer is adjusted so as to impart energy for standard 595 and modified 2674 kJ/m^3 of compacted volume. The moisture content of the compacted mixture was determined as per IS: 2720 (Part II) 1973. From the dry density and moisture content relationship, optimum moisture content (OMC) and maximum dry density (MDD) were determined. The test results are given in figure 4.5 and Table 4.2.

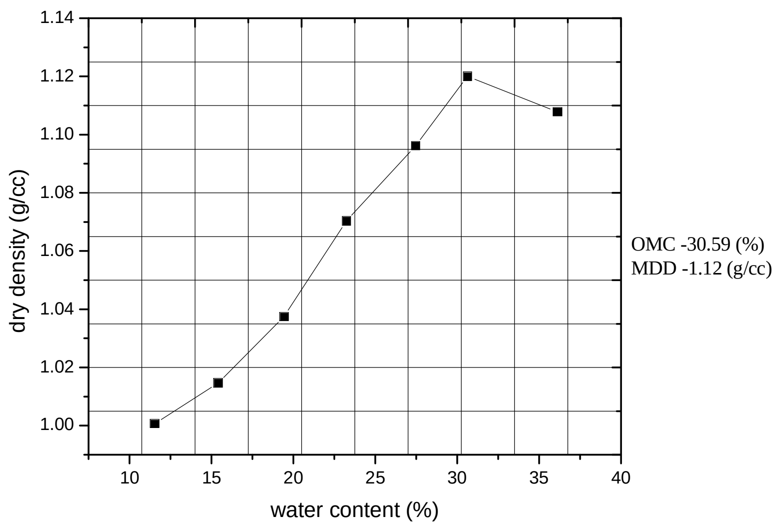


Figure 4.5 compaction curve for pond ash

Table 4.2 Compaction characteristics of pond ash

Comapaction Energy(kj/m^3)	OMC (%)	Dry Density(gm/cm^3)
595	34.56	1.136
2674	30.59	1.20

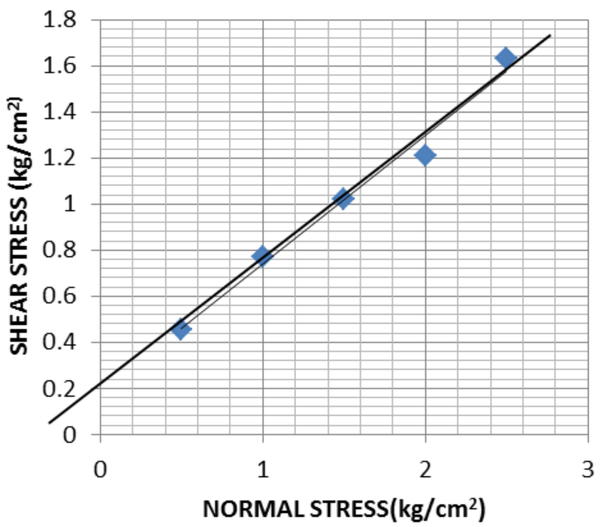
Table 4.3 Compaction characteristics of fly ash and fly ash sand mix with different mix proportions with different compacting Experiments (standard, modified, needle vibrating machine and table vibration.

SOIL	MDD	OMC
Fly ash: Spt Mpt Vibration	 1.258gm/cc 1.312gm/cc 1.38gm/cc	 22.95% 21.15% 15.31%
Fly ash (80%) and sand (20%): Vibration Table	 1.43gm/cc 1.02gm/cc	 18.63% 24.50%
Fly ash (85%) and sand (25%): Vibration Table	 1.45gm/cc 1.01gm/cc	 15.16% 19.98%
Fly ash (70%) and sand (30%): Vibration Table	 1.49gm/cc 1.06gm/cc	 15.13% 20.0%

4.4.2 Determination of Shear Parameters

Pond ash

The Direct shear test is one of the common tests used to study the strength parameter of soil. To get the strength parameter, Direct shear tests on pond ash specimens compacted to their corresponding MDD at OMC with compactive effort varying as 595 and 2674 kJ/m^3 were performed according to IS: 2720 (Part X)-1991. For this test specimens were prepared corresponding to their MDD at OMC in the metallic split mould with dimension 60mm (breadth) × 60mm (width)× 26mm(height). These specimens were tested on a direct shear testing machine with strain rate of 1.25 mm/minute till failure of the sample. The test results are given in Table 3.1.To study the effectiveness of shear parameter under saturation condition the same making and testing procedure of sample specimen was followed as above only the water has poured over the sample specimen for thirty minute to make the sample saturate. The test results are given in Table 4.4.



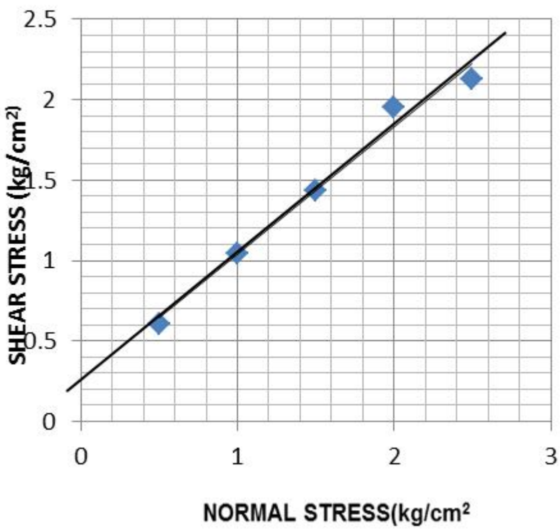


Figure 4.6 shear parameters parameters for light compaction

Figure 4.7 shear for heavy compaction

Table 4.4 Variations of OMC, MDD and shear parameters under unsaturated and saturated condition at different compaction level

Comapaction Energy(kJ/m³)	OMC (%)	Dry Density(gm/cm³)	C in omc	c in saturation	Φ in omc	Φ in saturation
595	34.56	1.136	0.16	0.13	28.62	**595**
2674	30.59	1.20	0.24	0.19	37.8	**2674**

Sand

Relative density

- The maximum void ratio e_{max}=0.1.488.
- The minimum void ratio e_{min}=0.854.

The Direct shear test is one of the common tests used to study the strength parameter of soil. To get the strength parameter, Direct shear tests on sand specimen at different relative densities 60%, 75% and 90% is done. Test results shown in below table 4.5.

Table 4.5. Cohesion and Angle of Internal Friction at different Relative Density

Relative Density (%)	Cohesion (c) (g/cm^2)	Angle of internal friction (Φ)
60	0.05	37˚46’
75	0.06	39˚37’
90	0.01	43˚28’

4.4.3 Determination of Unconfined Compressive Strength at OMC and at saturation

The Unconfined compressive strength test is one of the common tests used to study the strength characteristics of soil and stabilized soil. To get Immediate UCS strength, UCS tests on pond ash specimens compacted to their corresponding MDD at OMC with compactive effort varying as 595 and 2674Kj/m^3. was performed according to IS: 2720 (Part X) -1991. For this test cylindrical specimens were prepared corresponding to their MDD at OMC which were getting from different compaction energy. The sample specimen was prepared in metallic cylindrical mould with dimension 50mm (dia.) × 100mm (high). These specimens were tested in a compression testing machine with strain rate of 1.25 mm/minute till failure of the sample. The test results are given in Table 4.6.

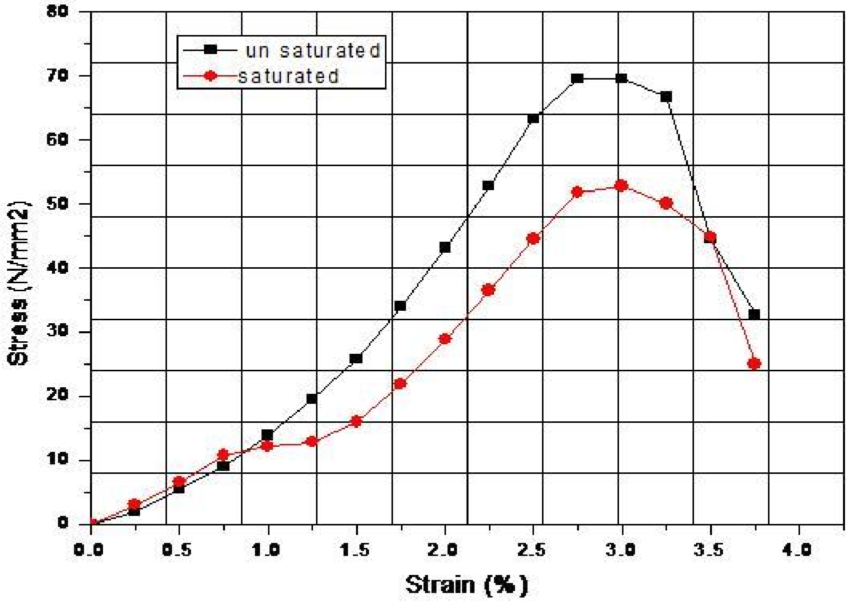


Figure 4.8. pond ash in saturation and un saturation condition for ucs test

Table 4.6 Stress-Strain Response of Pond Ash

	Un saturated	saturated
Compaction energy(kJ/m³)	595	595
Stress in kPa	68	55
Strain in %	2.7	3.05

4.4.4 Triaxial tests on compacted pond ash

The traiaxial test was conducted to study the stress and strain response of pond ash under different confining pressure. 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 595 and 2674kJ/m³.That sample was prepared in dimension of 50mm (dia.) × 100mm (high).The Traiaxial test was conducted very carefully to maintain the confining pressure of 1 kg/cm^2,2 kg/cm^2 and 3 kg/cm^2. The test result is presented in Table 4.7.

Table 4.7 Stress-Strain behavior Of Compacted Pond Ash In Different Confining Pressure

Energy in kJ/m³	Confinement Pressure(kg/cm^2)					
	3		2		1	
	Stress (Kg/cm²)	Strain (mm)	Stress (Kg/cm²)	Strain (mm)	Stress (Kg/cm²)	Strain (mm)
2674	7.56	0.42	5.12	0.53	2.95	0.57
595	5.92	0.55	3.93	0.71	2.0	0.82

4.4.5 Pullout Test

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 595 and 2674kJ/m³.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/cm^2, 0.1 kg/cm^2 ,1.5 kg/cm^2, 2 kg/cm^2, 2.5 kg/cm^2 and up to 8.5 kg/cm^2 .The test result are presented in Figures 4.9 ,4.10 and Table 4.8.

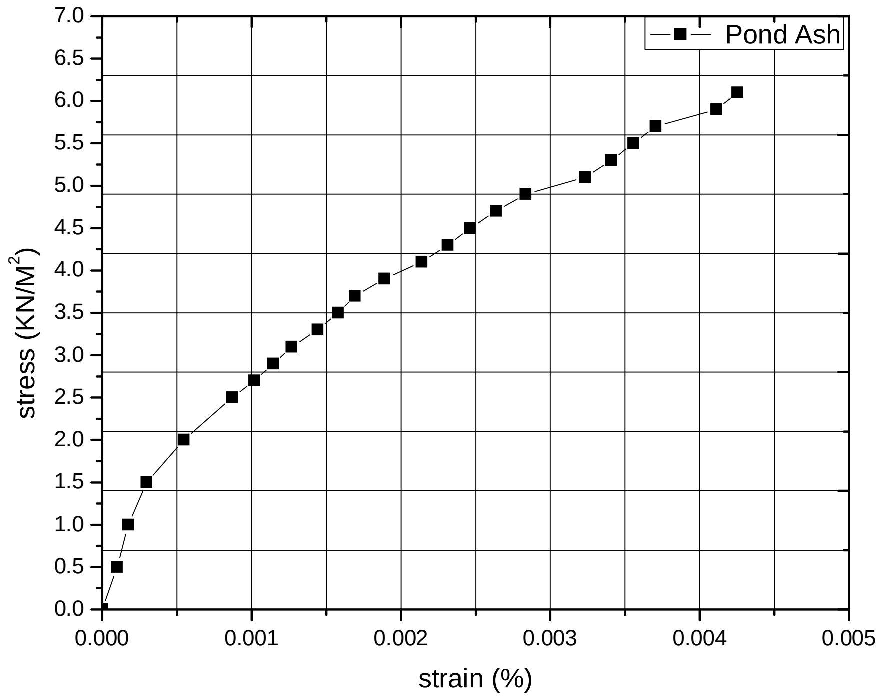


Figure 4.9 Pull out test for pond ash

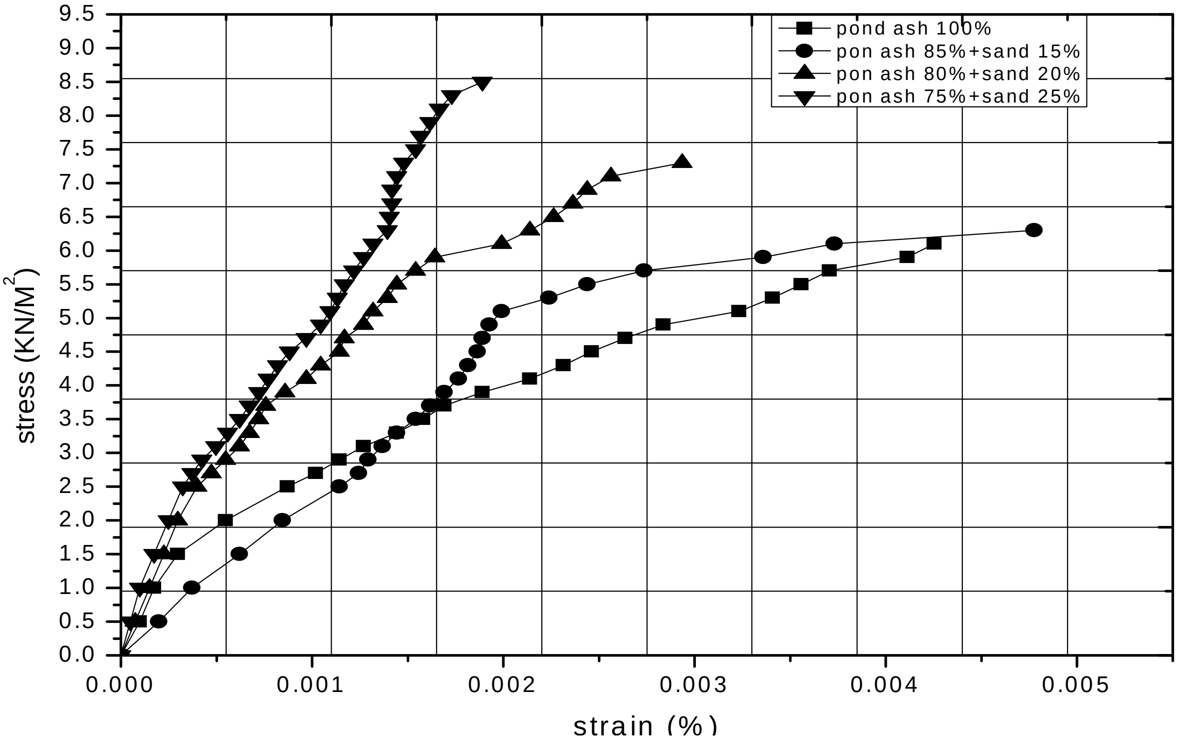


Figure 4.10 Pull out test for pond ash and pond ash sand mix

Table 4.8 Stress-Strain Response of Compacted Pond Ash, Sand and pond ash sand mix with different loads for shear stress.

Sl. no	Sample	Stress (Kg/cm²)	Strain (mm)
1	Pond ash	5.90	0.0043
2	Sand	6.0	0.0030
3	Pond ash (85%) and Sand(15%)	6.3	0.0047
4	Pond ash (80%) and Sand (20%)	7.3	0.0029
5	Pond ash (75%) and Sand (25%)	7.5	0.0019

4.4.6 Permeability Test for Constant Head Method

The permeability of granular soil is determined by constant head parameter under condition of laminar flow of water. Permeability refers to which the water flows through the soil. After mixing the with different proportions 15%, 20% and 25% sand with pond ash permeability value is increasing. Due to the increase of permeability void spaces are more and it settles down drastically. Results for pond ash, fly ash and pond ash sand mix are shown in below table 4.9.

Table 4.9 Permeability value for pond ash, fly ash and pond ash mix with sand

Serial no	Soil type	Coefficient of permeability(cm/sec)
1	Pond ash	$1.92X10^{-4}$
2	Pond ash (85%) and Sand (15%)	$3.28X10^{-4}$
3	Pond ash (80%) and Sand (20%)	$4.28X10^{-4}$
4	Pond ash (75%) and Sand (25%)	$4.96X10^{-4}$
5	Sand	$1.352X10^{-4}$
6	Fly ash	$1.513X10^{-5}$

CHAPTER 5

MODEL STUDY OF PULL OUT TEST USING POND ASH AND SAND

5.1 Introduction

Construction of *high embankments, under ways, flyovers* has become an integral part of major road works in construction of highways, expressways and other connectivity. *These constructions use vast track of natural resources in form of* topsoil which is also a matter of concern as it takes thousands of years to form the soil. Presence of expansive soils, shortage of borrow area soil creates lots of hindrance to such projects. Pond ash is using as fill material replacing the soil and reinforcing with a polymer sheet to strengthening the sample by model tank test set up in the laboratory and verifying numerical with PLAXIS software.

5.2 Experimental analysis

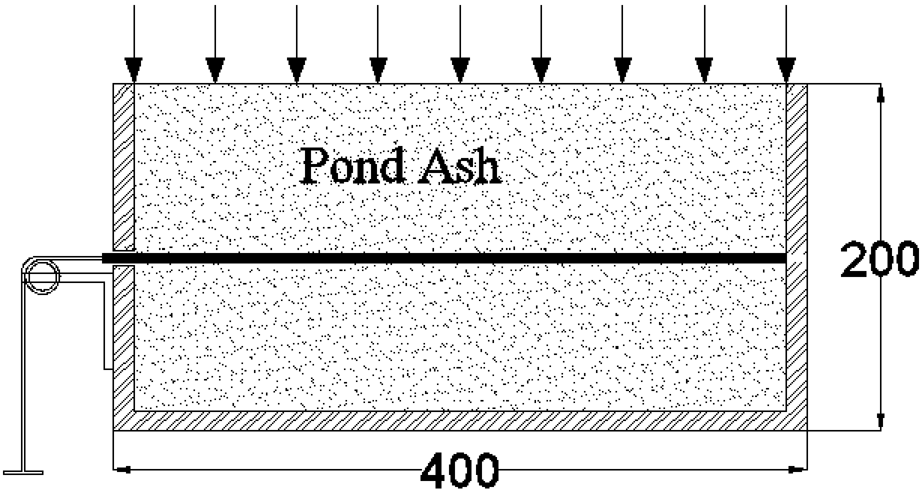
The pull out test was conducted to study the stress and strain behavior of pond ash, sand and pond ash sand mix proportions under different loads. The test of compacted pond ash sample specimen were conducted by varying density as 1.136 and 1.20gm/cm³ which has got from their respective compaction energy .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/cm^2, 0.1 kg/cm^2 ,1.5 kg/cm^2, 2 kg/cm^2, 2.5 kg/cm^2 and up to 8.5 kg/cm^2 .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. The model tank was first made in Auto CAD 2d and then implemented. Model tank in Auto CAD 2d shown in figure 5.2 and original tank for experiment work done is shown in below figure 5.1

(a)

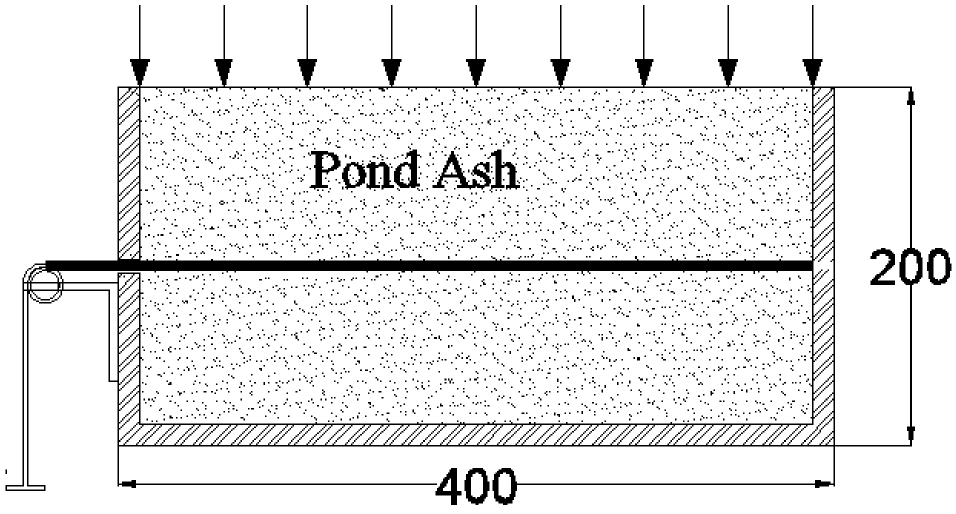
(b)

Figure 5.1 (a) model tank set up in laboratory for pull out test, (b) failure in shear

Model tank set up in Auto CAD 2d set up



(a)



(b)

Figure 5.2 (a) Model tank to pull out test arrangement set up, (b)Model tank for pull out test arrangement set up after shear failure.

5.3 Numerical analysis with PLAXIS 2D

5.3.1 Example 1

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.

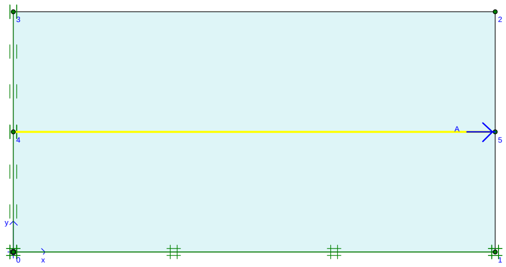


Figure 5.3 Pull out test model set up in PLAXIS 2D

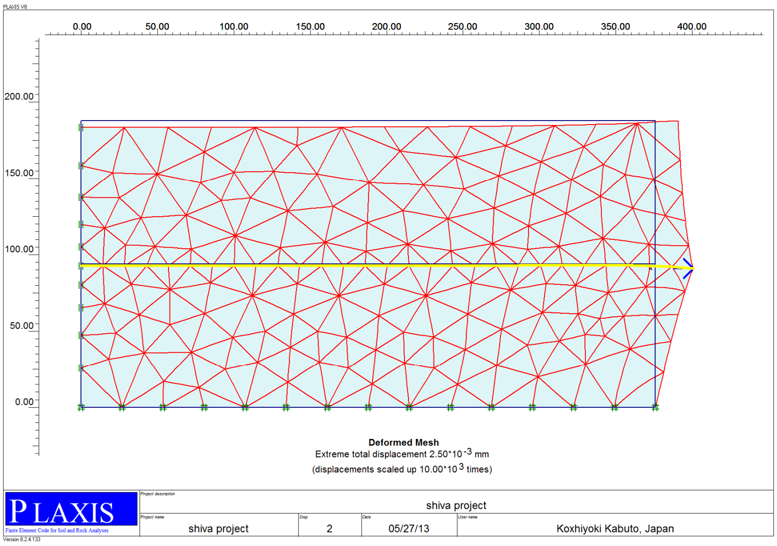


Figure 5.4 The PLAXIS model with its deformation mesh using sand

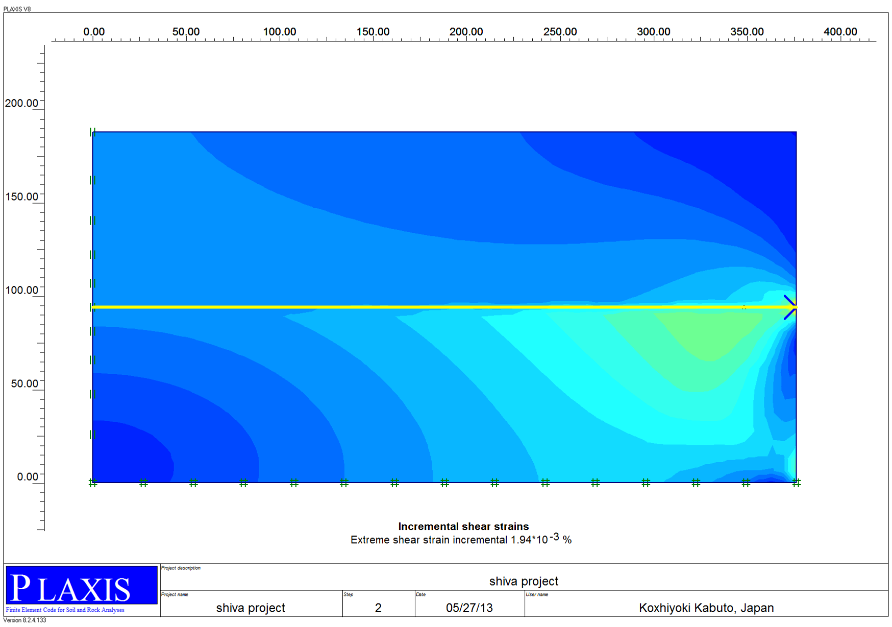


Figure 5.5 The shear failure surface as per PLAXIS model for using only sand.

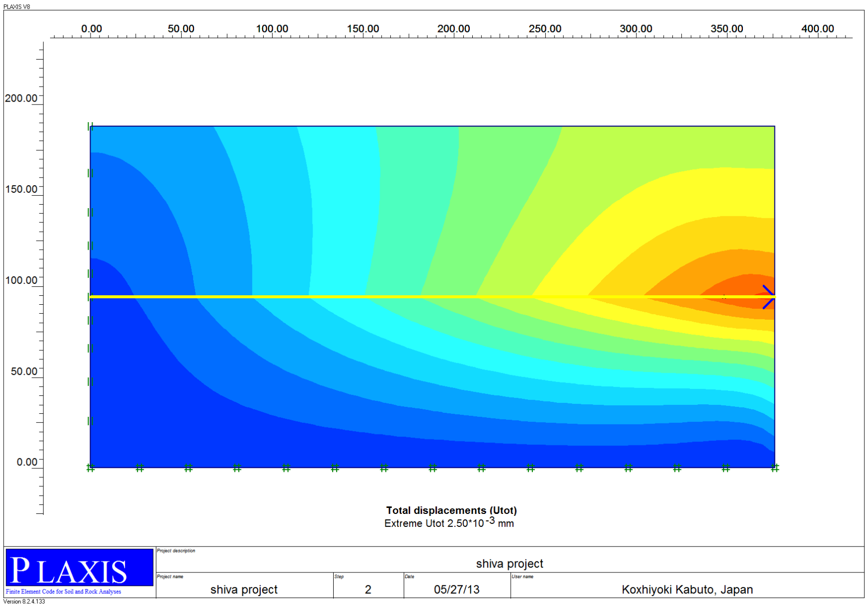


Figure 5.6 The PLAXIS model for Total displacementin pull out test for sand

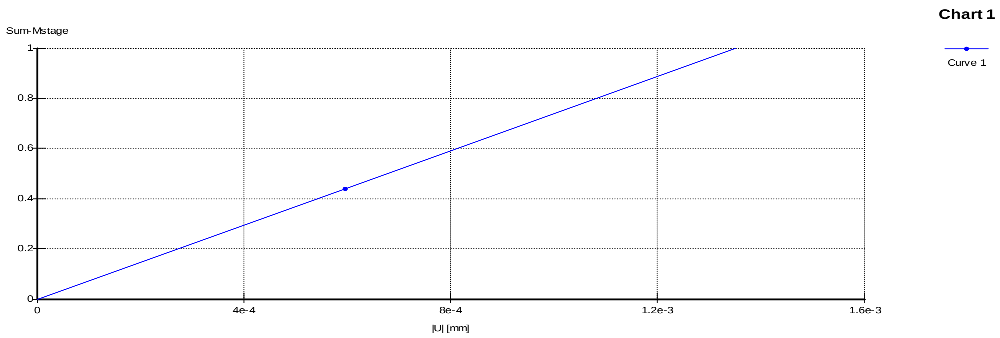


Figure 5.7 Load Vs displacement graph for sand in PLAXIS 2D

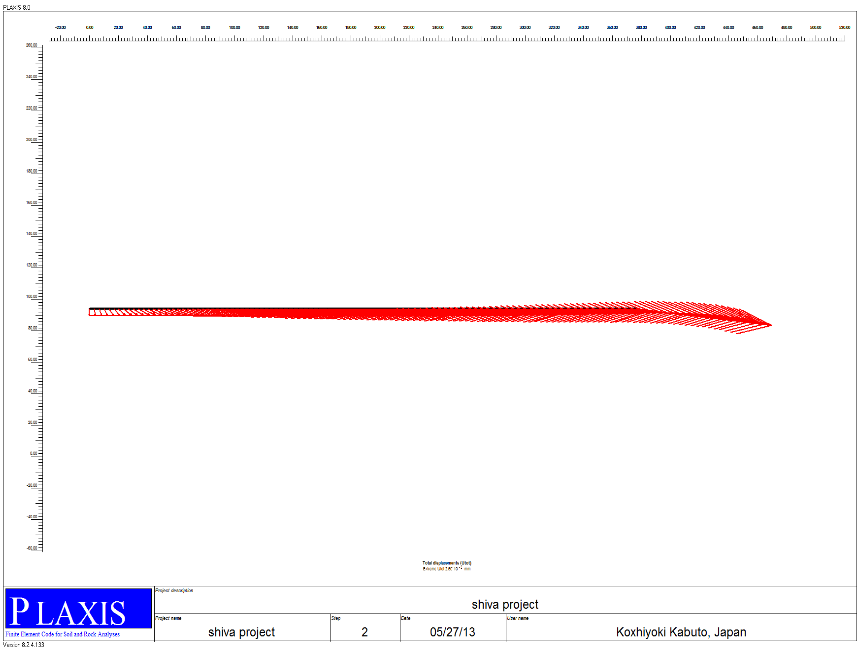


Figure 5.8 Total displacement of Geo polymer

5.3.2 Example 2

The 2nd attempt was tried to analyze the shear failure to pull out the test with pond ash. Model diagram with its deformation mesh is shown in Figure 5.9 The PLAXIS model with its deformation mesh using pond ash, Figure 5.10 effective stress deformation for pond ash, Figure 5.11 incremental strain for pond ash Figure 5.12 total displacement of Geo polymer Figure 5.13 Load Vs displacement graph for pond ash in PLAXIS 2D.

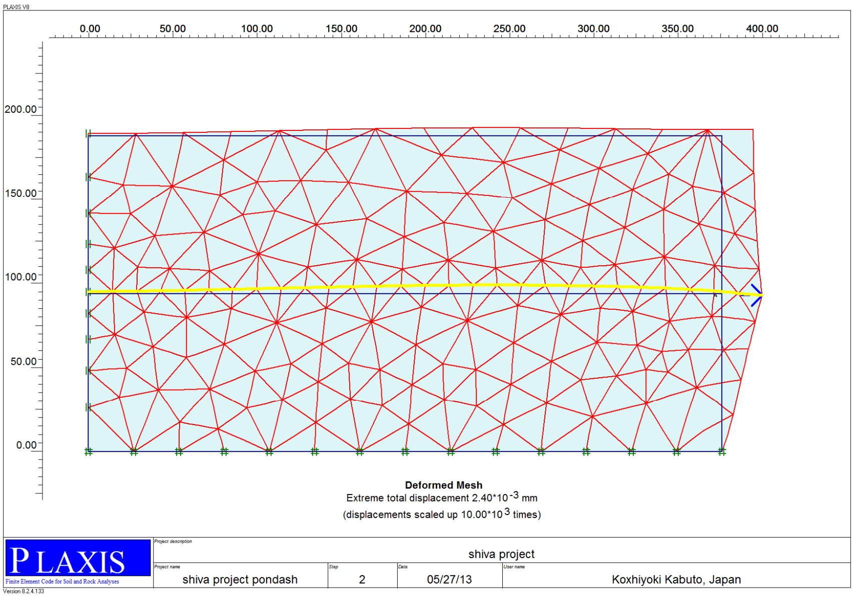


Figure 5.9 The PLAXIS model with its deformation mesh using pond ash.

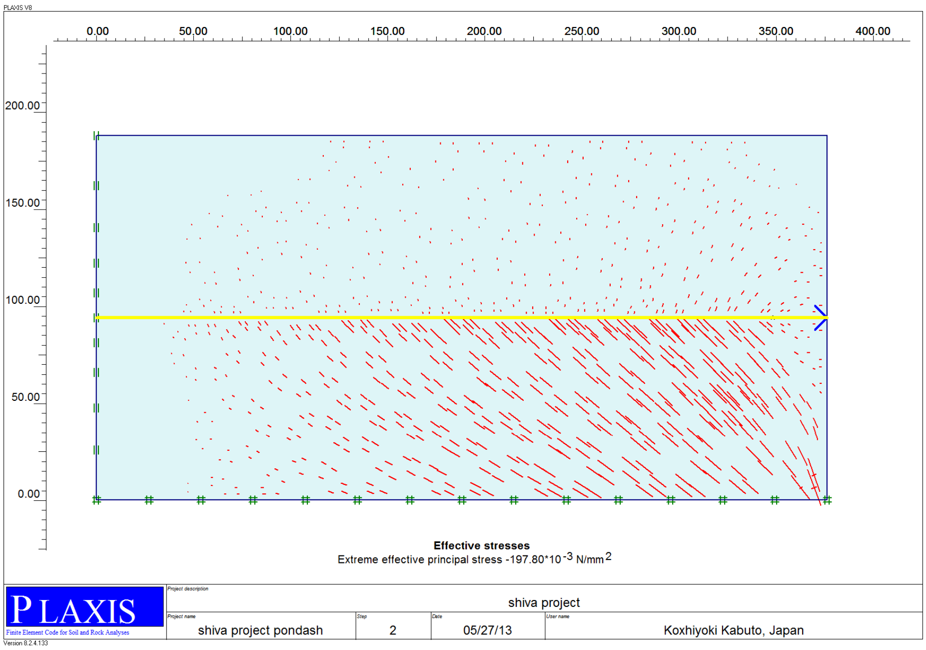


Figure 5.10 effective stress deformations for pond ash

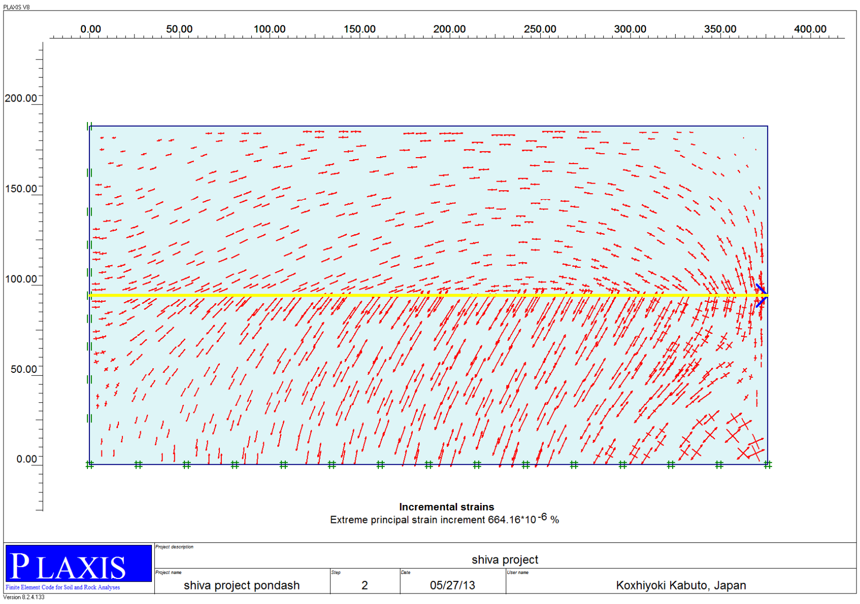


Figure 5.11 incremental strains for pond ash

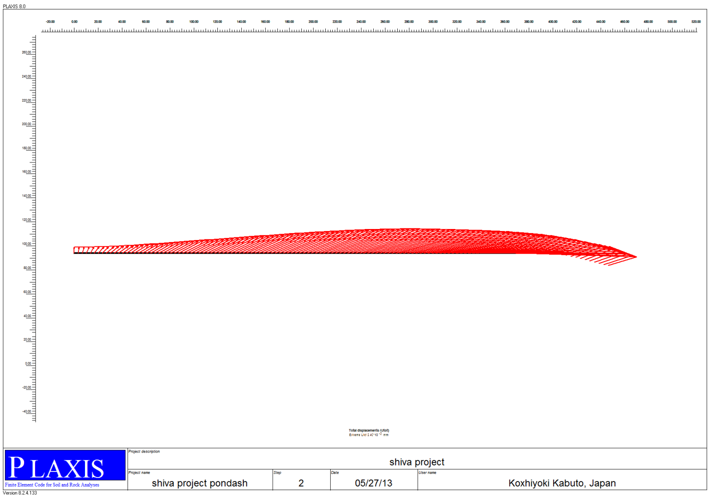


Figure 5.12 total displacement of Geo polymer

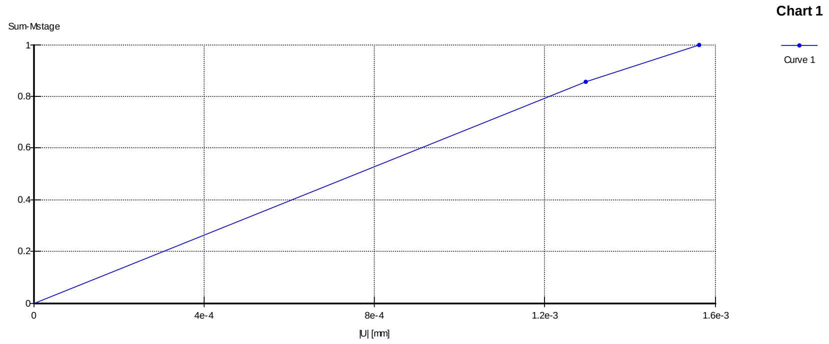


Figure 5.13 Load Vs. displacement graph for pond ash in PLAXIS 2D

CHAPTER 6

CONCLUSIONS

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

1. 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.
2. The pond ash and sand mixture found in effective fill material.
3. 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.
4. The numerical model analysis using PLAXIS 2D found to have a similar trend to that of laboratory results.
5. Such a study will professional to use the pond ash sand mixture as a fill material.

SCOPE FOR FUTURE WORK

1. Field validation of results
2. Use of pond ash with reinforcement ash embankment

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