Analysis of Fly-Ash and Pond Ashmixed withBentonite on The Basis of Different Parameters

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***Abstract*—Thermal power plants are mostly uses for producing power in India. In these power plants are based on coal. Fly ash and pond ash is the byproducts of coal which is produced in very large amount after burning of coal.Fly ash is divided into two categories: Class C and Class F. Even in the absence of lime, Class C fly ash has a high calcium concentration, making it extremely reactive with water. The percentage of lime in Class F ash is lower. The major goal of the research is to see if class F fly ash, which contains as little as 1.4 percent CaO and has been treated with bentonite, can be used as a construction material in various civil engineering sectors.**

Fly ash is waste product of power plant often hazardous in nature, easily flammable, corrosive, and reactive, and so have negative environmental consequences. Fly ash particles with comparable diameters ranging from 0.5 to 300 microns have the ability to become airborne and contaminate the environment due to their light weight. Fly Ash discharge in the sea, rivers, and ponds, if not adequately handled, can also harm aquatic life. Mosquitoes and bacteria love to breed in slurry disposal lagoons and settling tanks. It can also contaminate underground water resources by containing traces of harmful metals.

This study aims to evaluate the usage of coal ash (fly ash and pond ash) as a useful material by combining it with bentonite in various percentages ranging from 3 to 22%. Pond ash and fly ash are both non-plastic and have a low shrinking rate. The plasticity of the combination is expected to increase with the addition of bentonite, and the coal ash is intended to inhibit swelling and shrinking, preventing the creation of cracks. Bentonite in the mixture is predicted to operate as a self-sealing, low permeability hydraulic barrier due to its swelling capabilities. The mixture will be prepared at its optimum moisture content and maximum dry density. laboratory tests will be conduct to obtain various geotechnical parameters such as plasticity, shrinkage, permeability and unconfined compressive strength to determine the viability of coal ash-bentonite mixture as a useful material. It will be ensured that a mixture of bentonite, fly ash, and pond ash with a bentonite is useful for the different purpose like making bricks and liner material.

***Index Terms*—Flyash, pond ash, UCS testing,bentonite compound,fly-ash and pond ash composition**

I INTRODUCTION

Coal is utilized as a primary fuel in thermal power plants and other sectors in many nations, including India. Each year, four countries, China, India, Poland, and the United States, create more than 275 million tons of fly ash, yet only about half of it is utilized. India's coal reserves are estimated to be at 210 billion tons, and its yearly production is around 260 million tonnes. In contrast to affluent countries, the ash content of coal utilized for electricity generation in India is around 30-45 percent. During 2012-13, ash production climbed to almost 136 million tonnes, and this trend is projected to continue.

Fly ash is a waste material produced by thermal power stations when coal is burned. This fine residue from burned coal is conveyed in the flue gas, separated by electrostatic precipitators, and collected in a hopper field. Fly ash is the term for the collected residue, which is classified as an industrial waste that can be utilized in the construction business. One of the most common industrial wastes utilized as a construction material is fly ash. Fly ash can be disposed of in two ways: dry or wet, in which it is mixed with water and deposited as a slurry into ash ponds. One of the most significant difficulties facing India's manufacturing industries is the disposal of residual garbage.

Coal-based thermal power plants are India's primary source of electricity generation, accounting for roughly 59 percent of overall power generation. The ash concentration of Indian coal is found to be high, ranging from 30% to 55%. The amount of Fly Ash produced is determined by the coal quality utilised and the thermal power plant's operating conditions. The yearly production of Fly Ash in India is currently over 114 million tonnes, with ash ponds occupying 65500 acres of land, and is expected to reach 235 million tonnes. Such a large amount of material poses difficult issues in terms of land utilization, health risks, and environmental hazards. Extreme caution must be exercised both in disposal and in utilization.

Human life, wild life, and the environment must all be protected. When pulverized coal is burned to generate heat, the resulting residue contains 80% Fly Ash and 20% bottom ash.

Fly Ash: Overview

It is a very fine powdery particle that is recovered from the gases produced when coal is burned to generate energy in thermal power plants. Silica, alumina, and iron make up the majority of these micron-sized earth elements. When fly ash is combined with lime and water, it forms a cementitious compound with characteristics that are remarkably similar to Portland cement. Fly ash may be utilized as a great alternative for a portion of cement in concrete because of their similar qualities, which provides quality benefits. The concrete made with flyash is denser, resulting in a tighter, smoother surface with less bleeding. With expert textural uniformity and greater detail, fly ash concrete gives an amazing architectural benefit. Coal ash, Pulverized Flue ash, and Pozzolana are some of the other names for Fly Ash.

Classification of Fly Ash:There are two major kinds of fly ash recognised by ASTM C618-03(2003a). These two groups, which are determined by the type of coal used, are:

a) Class C
b) Class F.

Class C fly ashes, which typically contain more than 15% CaO and are also known as high calcium ashes, have become widely available for usage in the concrete industry. Not only are Class C fly ashes pozzolanic in nature, but they are also invariably self-cementitious. Even in the absence of lime, Class C fly ash has a high calcium concentration, making it extremely reactive with water.

Fly ash classified as Class F is made by burning anthracite or bituminous coal and contains a lower amount of lime. Almost all Class F fly ashes on the market today are made mostly from bituminous coal.

Low calcium ashes are classified as Class F fly ashes with a calcium oxide (CaO) composition of less than 6%. They are not self-hardening but do have pozzolanic capabilities.As a result, the majority of studies on the use of fly ash in cement and concrete are classified as Class F. Previous research findings, as well as the majority of existing industrial practices, have already established this.

Impact of Fly Ash on Environment: A large volume of Fly Ash produced by coal-fired thermal power plants could pose a number of environmental issues. These waste products are often hazardous in nature, easily flammable, corrosive, and reactive, and so have negative environmental consequences. Fly ash particles with comparable diameters ranging from 0.5 to 300 microns have the ability to become airborne and contaminate the environment due to their light weight. Fly Ash discharge in the sea, rivers, and ponds, if not adequately handled, can also harm aquatic life. Slurry disposal lagoons/settling tanks can create mosquito and bacterium breeding grounds. With concentrations of harmful metals present in Fly Ash, it can also damage underground water resources.

BENTONITE: Bentonite is a clay that forms when volcanic ash is chemically weathered. It is mostly made up of smectite minerals, most often montmorillonite [$Si_8Al_4O_{20}(OH)_4.nH_2O$]. The clay is a natural material.Two silica sheets and one alumina sheet make up the mineral montmorillonite.

Bentonite clay:Weak Vander Waals forces are responsible for the interlayer bonding between the tops of silica sheets, which is equivalent to essentially no bonding. As a result, water and other polar molecules easily pass through the layers, giving it extraordinarily high swelling properties. Once the water is removed from the lattice, they easily shrink. Bentonite acts as a self-sealing, low permeability hydraulic barrier because to its swelling qualities. As a result, it can be used to line the bottom of landfills. Due to the low hydraulic conductivity of clay soils, soil-bentonite mixes are widely utilized as an impermeable blanket in waste containment systems.

MATERIAL SUITABILITY

The goal of the current project is to identify an exact blend of fly ash and bentonite, as well as pond ash and bentonite, that may be utilized as a compacted clay liner. The following considerations are taken into account while determining the suitability of a liner material:Efficiency, Availability, Resistance to damage, Longevity.

II METHODOLOGY

The fly ash utilized in the experiment came from the NTPC Sipat Bilaspur plant. Bentonite was purchased from an internet market and pond ash was obtained from NTPC, Sipat Bilaspur. Bentonite was combined with coal ash in proportions of 3,5,9,14, and 22 percent dry weight before being compacted. The two types of coal ash employed in this study are Fly ash and Pond ash. For usage as a liner material, the suitable Bentonite-Fly ash mix, Bentonite-Pond ash mix, and range of compaction parameters were determined to provide the desired hydraulic conductivity, strength qualities, and lowest desiccation crack.

MATERIALS USED

Fly ash:As a byproduct of coal combustion in power plants, fly ash is a micron-sized, glassy powder residue. The electrostatic precipitators collect the 'fine' fraction of the ash that is transported upwards with the flue gases. It is pozzolanic in nature, with silica, alumina, and iron as the main constituents. The chemical qualities of fly ash are influenced by the chemical content of the coal burned (anthracite, bituminous, and lignite). Based on the amount of calcium, silica, alumina, and iron content, ASTM C618 defines and classifies it into class C and class F. The burning of anthracite and bituminous coal produces Class F fly ash. It has a low lime concentration (CaO) of less than 20%. When lignite or sub-bituminous coal is burned, Class C fly ash is produced, which includes more than 20% lime (CaO)

Pond ash:Pond ash was produced by slurry disposal of fly ash and bottom ash in constructed structures known as ash ponds. It is a boiler waste product that comprises significantly coarser particles. The pond ash used in this project came from the NTPC in Sipat Bilaspur. Prior to the tests, it was oven dried at 105-110 degrees Celsius.

Bentonite:Sodium bentonite was employed in the project because it is a naturally occurring hydrated aluminium silicate clay. It has a very high swelling and water absorption capacity. In locations with very permeable soil, sodium bentonite has been effectively used as a sealer for earthen darn constructions. This is due to its high-water absorption capacity, which causes swelling and fills existing air and water spaces with a thick plastic mass. During the compaction process, this plastic mass also acts as a bonding agent for the soil particles.

DETERMINATION OF GEOTECHNICAL PROPERTIES:

Determination of Atterberg Limits

Two sets of test samples, each containing six coal ash-bentonite combinations, had their Liquid Limit and Plastic Limit calculated.

Determination of Liquid Limit

For pond ash and fly ash The liquid limit tests were carried out using the one-point penetration method in a cone penetrometer, as shown in fig 2.1, whereas the Bentonite limit tests were carried out using Casagrande's equipment shown in fig 2.2. By combining bentonite with fly ash and pond ash, two sets of samples were created, with all components passing through a 425µ IS sieve. About 120gm of the mixes were combined with water to make pastes, which were then permitted to mature for 24 hours. The liquid limit test was carried out in the Cassagrande liquid limit device according to IS 2720 (part V)-1985. A bit of the paste was placed in the center of the cup and equally spread out, after which the grooving tool was used to make a groove. Turning the handle at a pace of 2 revolutions per second until the two parts of soil collided, the cup was dropped. The liquid limit of that sample was determined to be the water content equal to 24 blows. Table 2.1 shows the results for fly ash-bentonite combinations and table 2.2 shows the results for pond ash-bentonite mixtures.

Table 2.1: Liquid Limit of bentonite-fly ash mixtures

Sample Set 1	LL(%)
0% bentonite-fly ash mixture	51.9
3% bentonite-fly ash mixture	53.2
5% bentonite-fly ash mixture	54.5
9% bentonite-fly ash mixture	56.5
14% bentonite-fly ash mixture	68.2
22% bentonite-fly ash mixture	75.2

Table 2.2: LiquidLimit of bentonite-pond ashmixtures

Sample set 2	LL(%)
0% bentonite-pond ash mixture	36.5
3% bentonite-pond ash mixture	44.5
5% bentonite-pond ash mixture	47.2
9% bentonite –pond ash mixture	52.6
14% bentonite-pond ash mixture	58.3
22% bentonite-pond ash mixture	66.5

Bentonite's liquid limit was discovered to be 305% percent.

Fig. No. 2.1 Cone penetrometer

Fig. No. 2.2 Cassagrande's Liquid Limit Device

Determination of Plastic Limit:As soil reaches its plastic limit, it loses its fluidity and behaves like a brittle substance when it transitions to a semi-solid state. It's also the water content at which a soil begins to collapse when rolled into a 3 mm diameter thread. The plastic limit was determined through tests in accordance with IS 2720(part V)-1985.

Table 2.3 Plastic Limit of bentonite-fly ash mixture mixtures

Sample Set 1	PL(%)
0% bentonite-fly ash mixture	Non-plastic
3% bentonite-fly ash mixture	Non-plastic
5% bentonite-fly ash mixture	Non-plastic
9% bentonite-fly ash mixture	Non-plastic
14% bentonite-fly ash mixture	43.5
22% bentonite-fly ash mixture	46.2

Table 2.4 Plastic Limit of bentonite-pond ash mixtures

Sample Set 2	PL(%)
0% bentonite-pond ash mixture	Non-plastic
3% bentonite-pond ash mixture	Non-plastic
5% bentonite-pond ash mixture	Non-plastic
9% bentonite –pond ash mixture	Non-plastic
14% bentonite-pond ash mixture	28.2
22% bentonite-pond ash mixture	32.5

Bentonite's Plastic Limit was discovered to be 68%.

Determination of Plasticity Index: The difference between the Liquid Limit and the Plastic Limit is used to calculate the Plasticity Index (Ip). Tables 2.5 and 2.6 show the results for the various samples.

Table 2.5: Plasticity Index of bentonite-fly ash mixtures

Sample Set 1	PI(%)
0% bentonite-fly ash mixture	Non-plastic
3% bentonite-fly ash mixture	Non-plastic
5% bentonite-fly ash mixture	Non-plastic
9% bentonite-fly ash mixture	Non-plastic
14% bentonite-fly ash mixture	21.2
22% bentonite-fly ash mixture	26.5

Table 2.6: Plasticity Index of bentonite-pond ash mixtures

Sample Set 2	PI(%)
0% bentonite-pond ash mixture	Non-plastic
3% bentonite-pond ash mixture	Non-plastic
5% bentonite-pond ash mixture	Non-plastic
9% bentonite –pond ash mixture	Non-plastic
14% bentonite-pond ash mixture	27.5
22% bentonite-pond ash mixture	33.2

Bentonite was discovered to have a Plasticity Index of246%.

Determination of Shrinkage Limit

The shrinkage limit was calculated using a shrinkage dish. The sample was prepared by passing 30 gm of dry sample through a 425 micron IS sieve and thoroughly mixing it with distilled water to make a paste, which was then permitted to stand for 24 hours. The paste had a practical consistency that allowed it to be placed in the shrinkage dish without trapping air bubbles. Since the bentonite was being tested, the water injected was around 5% to 10% above the liquid limit. The specimen was tested, and the shrinkage limit values obtained are shown in tables 2.7 and and2.8.

Table 2.7: Shrinkage Limit of bentonite-fly ash mixtures

Sample set 1	SL(%)
3% bentonite-pond ash mixture	40.5
5% bentonite-pond ash mixture	39.5
9% bentonite –pond ash mixture	38.5
14% bentonite-pond ash mixture	37.5
22% bentonite-pond ash mixture	35.5

Table 2.8: Shrinkage Limit of bentonite-pond ash mixtures

Sample set 2	SL(%)
3% bentonite-pond ash mixture	26.5
5% bentonite-pond ash mixture	25.5
9% bentonite –pond ash mixture	24.5
14% bentonite-pond ash mixture	22.2
22% bentonite-pond ash mixture	20.5

Determination of Linear Shrinkage

Linear Shrinkage tests were carried out in moulds that were prescribed by IS 12979, 1990. Paste samples were made by mixing 150 gm of material that passed through a 425 micron IS sieve with water that was around 2% above the liquid limit and allowed to sit for 24 hours. The paste was gently jarred to remove any air pockets before being placed in the shrinkage mound. With the palette knife, it was smoothed off along the top of the mould. The paste was placed in the mould so that it could air dry slowly until the soil had shrunk away from the mould's walls. The mould was initially dried at 60 to 65°C until shrinking had nearly stopped, and then at 105 to 110°C to complete the drying process.

Table 2.9: Linear Shrinkage of bentonite-fly

Sample set 1	L_S(%)
3% bentonite-fly ash mixture	2.5
5% bentonite-fly ash mixture	3.44
9% bentonite-fly ash mixture	3.95
14% bentonite-fly ash mixture	6.15
22% bentonite-fly ash mixture	8.56

Table 2.10: Linear Shrinkage of bentonite-pond ash mixtures

Sample set 2	L_S(%)
3% bentonite-pond ash mixture	3.23
5% bentonite-pond ash mixture	4.95
9% bentonite –pond ash mixture	6.5
14% bentonite-pond ash mixture	8.2
22% bentonite-pond ash mixture	9.8

Determination of Compaction characteristics

The samples were made in two sets: one with bentonite and fly ash, and the other with bentonite and pond ash. Bentonite was mixed with coal ash in proportions of 3 percent, 5 percent, 9 percent, 14 percent, and 22 percent by dry weight to create specimens. After a 24-hour saturation period, compaction tests were performed.

Table 2.11: Compaction Characteristics of bentonite-fly ash mixtures.

Sample set 1	MDD(g/cc)	OMC(%)
3% bentonite-fly ash mixture	1.185	38.5
5% bentonite-fly ash mixture	1.221	36.5
9% bentonite-fly ash mixture	1.286	35.45
14% bentonite-fly ash mixture	1.285	33.5

22% bentonite-fly ash mixture	1.356	32.5

Table 2.12: Compaction Characteristics of bentonite-pond ash mixtures

Sample set 2	MDD(g/cc)	OMC(%)
3% bentonite-pond ash mixture	1.281	26
5% bentonite-pond ash mixture	1.301	23.25
9% bentonite –pond ash mixture	1.378	21.5
14% bentonite-pond ash mixture	1.396	21.85
22% bentonite-pond ash mixture	1.415	20.56

Determination of Unconfined Compressive Strength:
To investigate the strength characteristics of compacted coal ash-bentonite mixes, the Unconfined Compressive Strength test was carried out in accordance with IS 2720(part X). Samples were prepared for testing by combining and compacting them at their corresponding MDD and OMC from the light compaction test and then maturing them for 24 hours. Test specimens with a diameter of 50 mm and a height of 100 mm were sheared at a rate of 1.25 mm/min until the sample failed. Stress versus strain graphs, as well as the failure stress and corresponding failure strain for 0 day at a compactive energy of 595KJ/m^3, were used to determine the unconfined compressive strengths of specimens. Tables 2.13 and 2.14 show the UCS values of bentonite combined with fly ash and pond ash, respectively.

Table 2.13: UCS of bentonite-fly ash mixtures

Sample Set 1	UCS (kPa)
0% bentonite-fly ash mixture	295.56
3% bentonite-fly ash mixture	335.78
5% bentonite-fly ash mixture	340.25
9% bentonite-fly ash mixture	351.45
14% bentonite-fly ash mixture	365.15
22% bentonite-fly ash mixture	445.56

Table 2.14: UCS of bentonite-pond ash mixtures

Sample Set 2	UCS (kPa)
0% bentonite-pond ash mixture	49.15
3% bentonite-pond ash mixture	54.65
5% bentonite-pond ash mixture	85.45
9% bentonite –pond ash mixture	141.85
14% bentonite-pond ash mixture	235.44
22% bentonite-pond ash mixture	296.55

Determination of Permeability
When designing liner materials, the permeability characteristic is the most crucial factor to consider..Samples were prepared by mixing and compacting them at MDD and OMC to the wet side of optimum in permeability moulds with a diameter of 10 cm and a height of 12.5 cm.
Table 2.15 shows the average coefficient of permeability for sample set 1, which consists of compacted bentonite-fly ash combinations, and table 2.16 shows the average coefficient of permeability for sample set 2, which consists of compacted bentonite-pond ash mixtures.

Table 2.15: Permeability characteristics of bentonite-fly ash mixtures

Sample Set 1	Coefficient of Permeablity(cm/sec)
0% bentonite-fly ash mixture	0.0000132
3% bentonite-fly ash mixture	0.0000124
5% bentonite-fly ash mixture	0.0000121
9% bentonite-fly ash mixture	0.0000109
14% bentonite-fly ash mixture	0.000000988
22% bentonite-fly ash mixture	0.000000055

Table 2.16: Permeability characteristics of bentonite-pond ash mixtures

Sample Set 2	Coefficient of Permeablity(cm/sec)
0% bentonite-pond ash mixture	0.000138
3% bentonite-pond ash mixture	0.0000315
5% bentonite-pond ash mixture	0.00000124
9% bentonite –pond ash mixture	0.000000125
14% bentonite-pond ash mixture	0.00000004
22% bentonite-pond ash mixture	0.000000018

IIIRESULTS AND DISCUSSION

Experiments on coal ash combined with various quantities of bentonite were carried out to see if it could be used as a liner material. This chapter discusses and presents a full summary of the outcomes acquired.

Specific Gravity: The density bottle method was used to estimate the specific gravity of fly ash, pond ash, and bentonite in accordance with IS 2720(part III/sec 1). In the instance of bentonite, which had the greatest specific gravity of all with an average of 2.89, kerosene was employed. One of the most essential physical criteria for soil to be regarded as a liner material is specific gravity. Fly ash has a specific gravity of 2.33, while pond ash has a specific gravity of 1.95. Because pond ash is more porous than fly ash, it has a lower specific gravity than fly ash. The average specific gravity of the mixture increased with the addition of bentonite to the coal ash.

ENGINEERING PROPERTIES

Liquid Limit: Fly ash and pond ash had liquid limits of 51.9 percent and 36.5 percent, respectively, which were quite low when compared to bentonite. The liquid limit of the bentonite used for the project work was 305%. The addition of bentonite to the coal ash significantly enhanced the mixture's liquid limit. In Figure No.3.1, the variation is depicted.

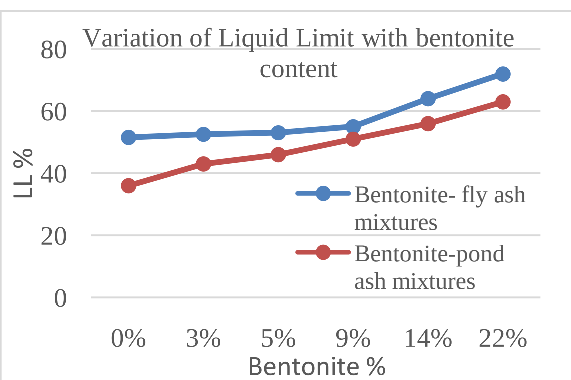

Fig. No. 3.1Variation of Liquid Limit with bentonite content

Plastic Limit: Bentonite's plastic limit was discovered to be 67%. After roughly 14% bentonite content was added to the non-plastic coal ash, the combination demonstrated plasticity. Table 2.3summarizes the outcomes collected.

Shrinkage Limit: For its functionality and endurance, the liner material should have a minimal shrinkage. When the moisture content of bentonite is increased slightly, it shrinks significantly, resulting in the creation of shrinkage fractures. The shrinkage limit of bentonite has been determined to be 5%. The shrinkage limit of the coal ash and bentonite mixture was significantly increased. Figure No.3.2 depicts the many variations.

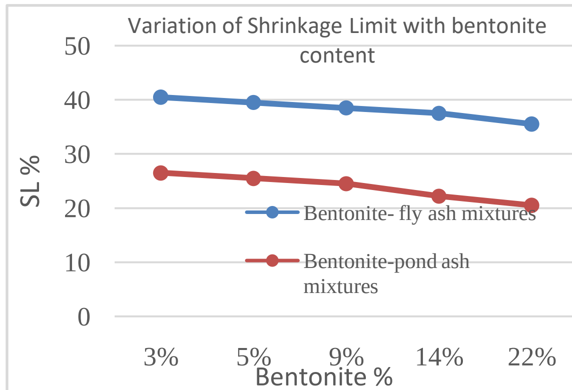

Fig.No. 3.2Variation of Shrinkage Limit with bentonite content.

Differential Free Swell(DFS): Submersion in water causes a soil's volume to rise without any external restraints, known as free swell. Bentonite's DFS was found to be 556 percent. Because of its high cation exchange capacity, bentonite has a very strong swelling behaviour. Figure No.3.3 depicts the fluctuation in DFS as a function of bentonite content.

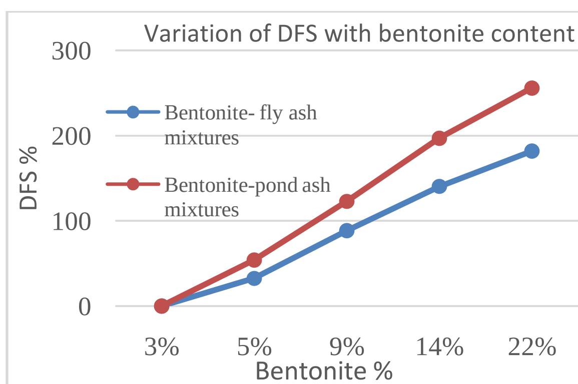

Fig. No. 3.3: Variation of DFS with bentonite content

Linear Shrinkage Index: When it comes to bentonite, the formation of shrinkage cracks is the most important factor to consider when using it as a waste containment liner. The bentonite utilized in the project exhibited a high linear shrinkage index of 45.45% and visible desiccation fissures. The shrinkage of the mixture was significantly reduced when it was combined with coal ash. For both coal ash-bentonite combinations, the linear shrinkage index (LS) stayed within 10%. In Figure 3.4, the variation is depicted.

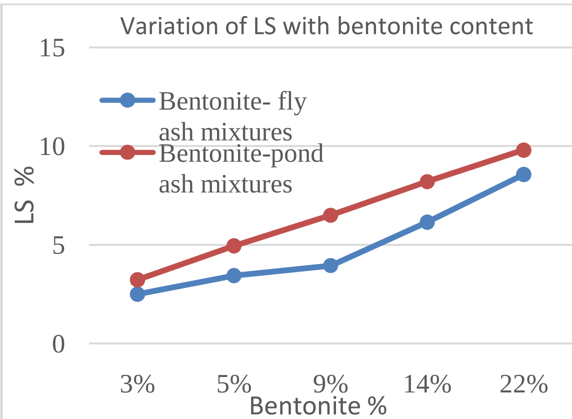

Fig. No.3.4: Variation of LS with bentonite content

Compaction Characteristics: The specimens were subjected to a light compaction test in accordance with IS 2720 (part VII) 1980. Figure 3.5 shows the compaction curves for a fly ash-bentonite mixture, while Figure 3.6 shows the compaction curves for a pond ash-bentonite mixture.

When determining the actual water content of the field-compacted soil liner, the values of OMC and MDD obtained from laboratory compaction tests serve as a reference point.

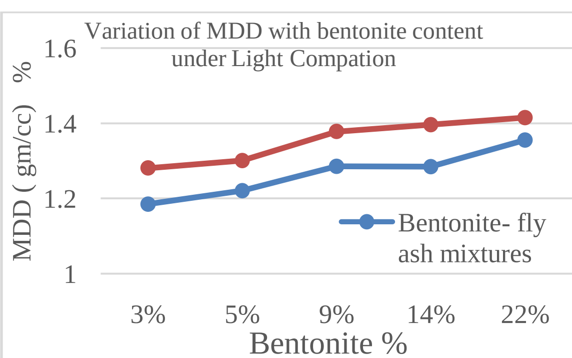

Fig. No. 3.5: Variation of MDD with bentonite content under Light Compation

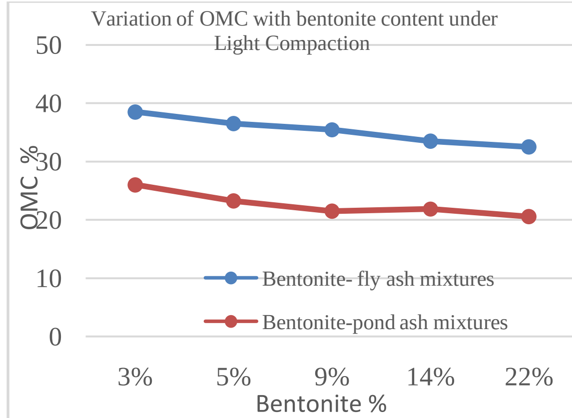

Fig. No.3.6: Variation of OMC with bentonite content under Light Compaction

Unconfined Compressive Strength: Unconfined compressive strength tests were conducted on specimens made by compacting coal ash-bentonite mixes at their MDD and OMC with a compactive energy of 593 kJ/m3 at their MDD and OMC. Figure 3.7 shows the effect of adding bentonite on the UCS value of the combinations.

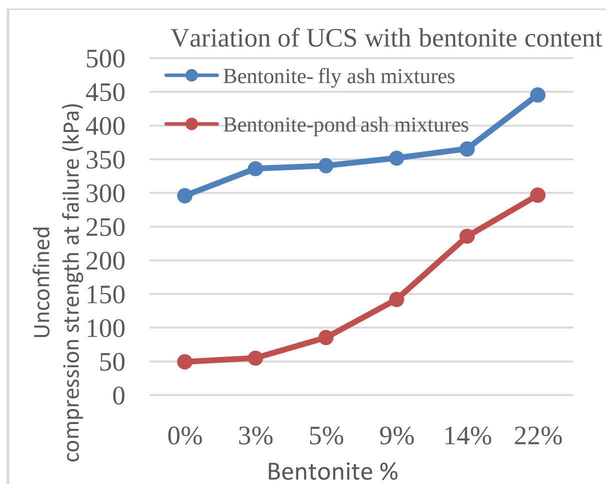

Fig. No. 3.7 Variation of UCS with bentonite content.

PermeabilityCharacteristics:The average coefficient of permeability of flyash specimens was calculated using the Constant Head Permeability method, as per IS: 2720 (Part17) 1986. Figure 3.8 shows the variation of coefficient of permeability of fly ash-bentonite mixture and compacted pond ash-bentonite mixture compacted at the wet side of optimum.

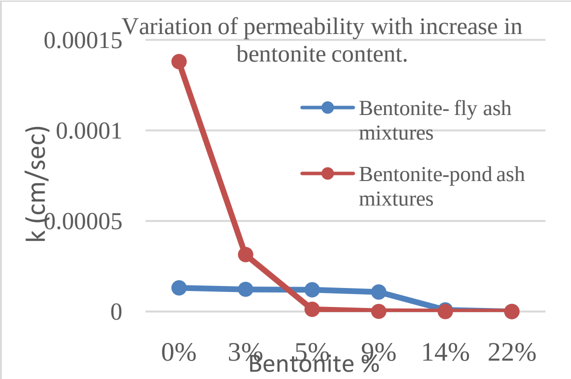

Fig. No. 3.8 Variation of permeability with increase in bentonite content.

Pond ash was shown to have a higher permeability than fly ash due to its rougher texture. Compacted pond ash-bentonite combination revealed a dramatic fall in permeability after adding 0-5 percent bentonite, after which the value remained almost constant. Because fly ash is finer, it has a low permeability, which decreases with the addition of bentonite.

IV. CONCLUSION

The following conclusions were reached from studies conducted on compacted coal ash modified with bentonite.

With the addition of bentonite, the maximum dry density of both coal ash and OMC increased, but the OMC dropped. A similar MDD value was attained with a lower OMC of 26% in the case of pond ash-bentonite mixture than in the case of fly ash-bentonite mixture.

The permeability of the compacted mixture decreased as the bentonite level rose.The permeability of a 20% bentonite-fly ash mixture was less. For pond ash, it was reached at a bentonite level of 14%in the combination.

Plasticity was induced in the coal ash-bentonite mixture by increasing the bentonite content from 14% to 22%, which resulted in better particle bonding when compacted.

With the addition of bentonite, the mixture's Differential Free Swell rose, resulting in a more effective sealant.

With the addition of bentonite, there was a change in Shrinkage Limit and Linear Shrinkage in the coal ash-bentonite mixture, but no noticeable shrinkage cracks formed. The shrinkage limit for a fly ash-bentonite mixture varied between 40.5 and 36.5 %. The range was 28% to 22.5% for pond ash combined with bentonite.

With an increase in bentonite content, the UCS of a compacted coal ash-bentonite mixture grew at a consistent rate.

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