IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 19, Issue 1 Ser. II (Jan. – Feb. 2022), PP 63-71
www.iosrjournals.org

Stabilization of Expansive Soil Using Fly Ash in India

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Abstract: *Nearly 51.8 million hectares of land area in India are covered with expansive soil (mainly black cotton soil). The properties of these expansive soils, in general, are very hard, especially when in dry state. But, they lose all of their strength, when in wet state. In light of this property of expansive soils, these soils pose problems worldwide that serve as a challenge to overcome for the Geotechnical engineers. One of the most important aspects during the construction purposes is soil stabilization. These soil stabilization plays vital role in foundation and road pavement constructions. The soil stabilization regime improves its engineering properties, such as volume stability, strength and durability. In the present study, using fly ash obtained from Katul Board, Durg, Chhattisgarh, stabilization of black cotton soil which is obtained from Durg, is attempted. With various proportions of this additive i.e. 0% to 50%, expansive soils are stabilized. Owing to the fact that fly ash possesses no plastic property, plasticity index (P.I.) of clay-fly ash mixes show a decrease in value with increasing fly ash content. In conclusion, addition of fly ash results in decrease in plasticity of the expansive soil, and increase in workability by changing its grain size and colloidal reaction. Analysis of the formerly found result exposes the potential of fly ash as an additive that could be used for improving the engineering properties of expansive soils. In other words, determining the scope of adding additives, which helps to reduce expansiveness and improve bearing capacity value.*

Key Word**: **Fly ash; cohesion; expansive soil; plastic clay; volume stability;

Date of Submission: 14-01-2022 Date of Acceptance: 29-01-2022

I. Introduction

Expansive soils are extensively distributed worldwide and that have the ability to shrink or swell, and thus change in volume, in relation to changes in their moisture content. As a result of this variation in the soil, significant distress occurs in the soil, which is subsequently followed by damage to the overlying structures. During periods of greater moisture, like monsoons, these soils imbibe the water, and swell; subsequently, they become soft and their water holding capacity diminishes. As opposed to this, in drier seasons, like summers, these soils lose the moisture held in them due to evaporation, resulting in their becoming harder. Generally found in semi-arid and arid regions of the globe, these types of soils are regarded as potential natural hazard – if not treated, these can cause extensive damage to the structures built upon them, as well causing loss in human life. Expansive soils in the Indian subcontinent are mainly found over the Deccan trap (Deccan lava tract), which includes Maharashtra, Andhra Pradesh, Gujarat, Madhya Pradesh, and some scattered places in Odisha. These soils are also found in the river valleys of Narmada, Tapi, Godavari and Krishna. The depth of black cotton soil is very large in the upper parts of Godavari and Krishna, and the north-western part of Deccan Plateau. Basically, after the chemical decomposition of rocks such as basalt by various decomposing agents, these are the residual soils left behind at the place of such an event. Cooling of volcanic eruption (lava) and weathering another kind of rock – igneous rocks – are also processes of formation of these types of soils. Rich in lime, alumina, magnesia, and iron, these soils lack nitrogen, phosphorus and organic content [1].

Fly ash particles are generally spherical in size, and this property makes it easy for them to blend and flow, to make a suitable concoction. It is fine powder which is a by-product of burning pulverized coal in electric generation power plants. It is collected from the exhaust gases by electrostatic precipitators or bag filters both amorphous and crystalline nature of minerals is the content of fly ash generated. In combination with certain minerals (lime and bentonite), fly ash can be used as a barrier material. In the present scenario, the generation of this waste material in picture (fly ash) is far more than its current utilization. In other words, we are producing more fly ash than we can spend.

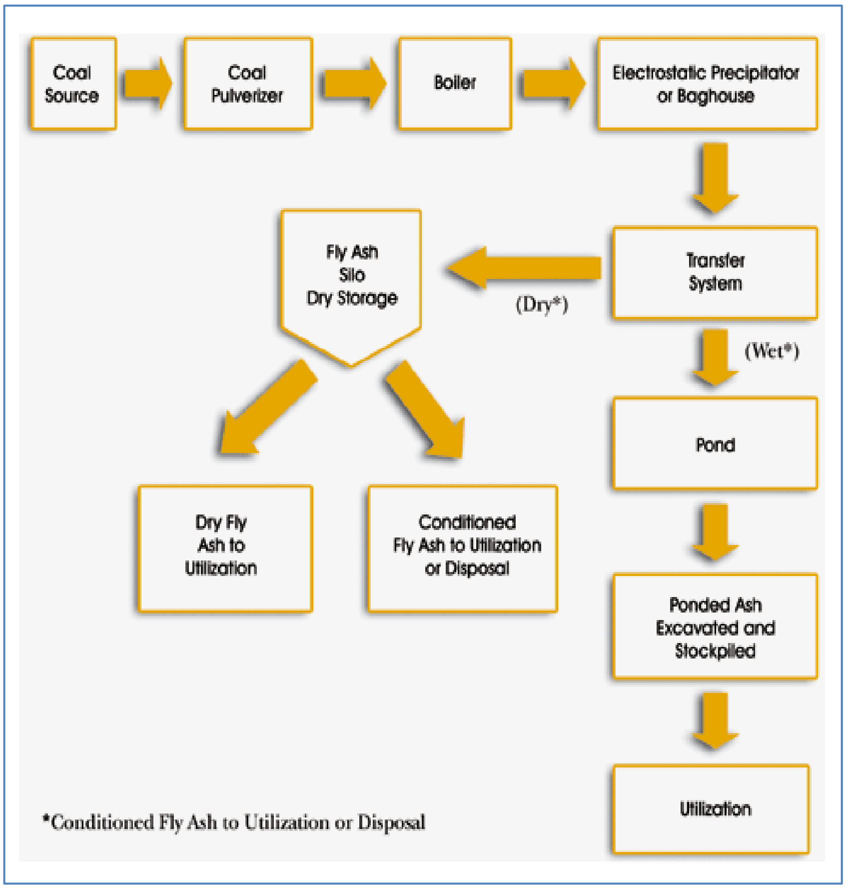

Fig. 1. Generation and Utilization of Fly Ash

Fly also has pozzolanic properties, meaning that it reacts with lime two form cementitious compounds. The demand of power supply has exponentially heightened these days due to increasing urbanization and industrialization phenomena. Subsequently, this growth has resulted in the increase in the number of power supplying thermal power plants that use coal as a burning fuel to produce electricity. The mineral residue that is left behind after the burning of coal is the fly ash. The Electro Static Precipitator (ESP) of the power plants collects these fly ashes. Production of fly ash comes with two major concerns – safe disposal and management of fly ash. Because of the possession of complex characteristics of wasters which are generated from the industries, and their hazardous nature, these wastes pose a necessity of being disposed of in a safe and effective way, so as to not disturb the ecological system, and not causing any sort of catastrophe to human life and nature. Environmental pollution is imminent unless these industrial wastes are pre-treated before their disposal or storage. Essentially consisting of alumina, silica and iron, fly ashes are micro-sized particles [2].

Generation of Fly Ash (Fig. 1): Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the flue gas and causing the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric bag houses [4].

Utilization of Fly Ash: The utilization of fly ash can be largely grouped into following three classes:

❖ The Low Value Utilizations, which includes back filling, structural fills, road construction, soil stabilization, embankment & dam construction, ash dykes, etc.

❖ The Medium Value Utilizations, which includes grouting, cellular cement, pozzolana cement, bricks/blocks, soil amendment agents, prefabricated building blocks, fly ash concrete, weight aggregate, etc.

❖ The High Value Utilizations, which includes, fly ash paints, ceramic industry, extraction of magnetite, distempers, metal recovery, acid refractory bricks, floor and wall tiles, etc.

After these, there is still a large wastage of fly ash material observed; however, this has led to evolution of a large number of technologies for the management of fly ashes. Thanks to this, the utilization of fly ash has increased to 73 MT by the year 2012. Years 2010-2012 saw a wide acceptance of fly ash as a product that can be used in various purposes [5].

Reaction mechanism of Fly ash and expansive soil: Expansive soils cover nearly 20 percent of India's land. Land scarcity appears to be an impending threat as industrialization and urbanisation accelerate. Construction of civil engineering structures on expansive soils, on the other hand, poses a significant risk to the structure due to the increased level of instability in these types of soil. The annual loss of property due to the instability in the expansive soils is estimated to be in the billions of dollars. On the other hand, fly ash disposal has become a growing concern. India, as a developing country, is heavily reliant on coal-fired thermal power plants for energy production, and this reliance is unlikely to change anytime soon. Many waste materials, including fly ash, are produced during the pulverisation of coal in these power plants. Fly ash production increased to 130 MT/year in 2012. However, only 56% of this is true. Generated fly ash waste was utilized. The residual fly ash is disposed off in places, and this poses threat to health, and also the reduction in land area that can be otherwise utilized for purposes other than the disposal of fly ash. Keeping both the issues in mind, this research of stabilizing expansive soil using fly ash is justified. Justification of Research: Almost 20% of land in India is roofed by expansive soils. With the rapid growth in industrialization and urbanization, land scarcity appears to be an imminent threat. Construction of civil engineering structures on expansive soils, however, poses a major risk to the structure in itself, because of the greater degree of instability in these kinds of soil. Tallied in billions of dollars per year is the loss in property every year globally owing to the instability in the expansive soils. On the other hand, disposal of fly ash has become a growing issue. India, as a developing country, is highly dependent on coal based thermal power plants for production energy, and this dependency isn't going to falter anytime soon. Pulverization of coal in these power plants produces many waste materials, including fly ash. As of 2012, the generation of fly ash rose to 130 MT/year. However, only 56% of this generated fly ash waste was utilized. The residual fly ash is disposed of in places, and this poses threat to health, and also the reduction in land area that can be otherwise utilized for purposes other than the disposal of fly ash. Keeping both the issues in mind, this research of stabilizing expansive soil using fly ash is justified [6].

II. Literature Review

Origin and occurrence of expansive soil: Clay mineral is the key element which divulges the swelling characteristics to any ordinary non-swelling/non-shrinking soil. Montmorillonite, out of several types of clay minerals, has the maximum amount of swelling potential. In-situ formation of chief clay minerals occurs under alkaline conditions, or sub-aqueous decomposition of blast rocks can be seen as the origin of such soil – expansive soil. This type of soil can also be formed due to weathering under alkaline environments, and under adequate supply of magnesium or ferric or ferrous oxides. Given there's a good availability of alumina and silica, the formation of Montmorillonite is favored.

Nature of expansive soil: Swelling in clays can be sub-categorized into two distinctive types, namely: Elastic rebound in the compressed soil mass due to reduction in compressive force; Imbibing of water resulting in expansion of water-sensitive clays. Swelling clays are the clays that exhibit the latter type of swelling, where the clay minerals with largely inflating lattice are present. One of the fundamental characteristics of clayey soil is that they display little cohesion and strength when wet, but they become hard when devoid of water. However, all of them do not swell due to wetting action. Decrease in ultimate bearing capacity at saturation, and large differential settlement due to this occurs. Thus, clayey soils exhibit foundation problems.

Clay Mineralogy: On the basis of their crystalline arrangement, clay minerals can be categorized into three general groups, namely: Kaolinite group; Montmorillonite group; Illite group. **Kaolinite group (Fig. 2):** A clay mineral which has a chemical composition $Al_2Si_20_5(OH)_4$ is called Kaolinite. This type of clay mineral has a layered silicate, with linkage to one octahedral sheet of alumina through oxygen atoms. China clay or Kaolin is the name given to rocks that are rich in this mineral. A thickness of 7Å is exhibited by the stacked layers of kaolinite; as a result of this, the kaolin group of minerals are seen to be the most stable, which is also because of the fact that water cannot enter between the sheets to inflate that unit cell [6]. **Montmorillonite Group:** Two silica tetrahedral sheets combined with a central alumina octahedral sheet comprise the structural arrangement of Montmorillonite (Fig. 3). The bond between crystalinks is weak here. Thus, the soil containing higher percentages of Montmorillonite minerals demonstrate high shrinkage and swelling characteristics, depending on the nature of exchangeable cation present. The common layer of a Montmorillonite unit is formed by one of the hydroxyl layers of the octahedral sheet and the tips of the tetrahedrons from each silica sheet. Atoms which are common to both silica and gibbsite layers never participate in the process of swelling. During weak bond between the crystal forms, water can penetrate, breaking the structures to 10Å structural units. **Illite Group:** As far as structural arrangement is concerned, Illite minerals fall between the Montmorillonite and Kaolinite groups. As in case of Montmorillonite unit structure, two silica tetrahedral sheets combined with a central alumina octahedral sheet comprise the structural arrangement of Illite [7]. The spacing between the elementary silica-gibbsite-silica sheets depends largely upon the availability of water to occupy the space. Owing to this reason, Montmorillonite is believed to have an expanding lattice. However, in presence of excess water, Illite can split up into individual layers of 10Å thick (Fig. 4).

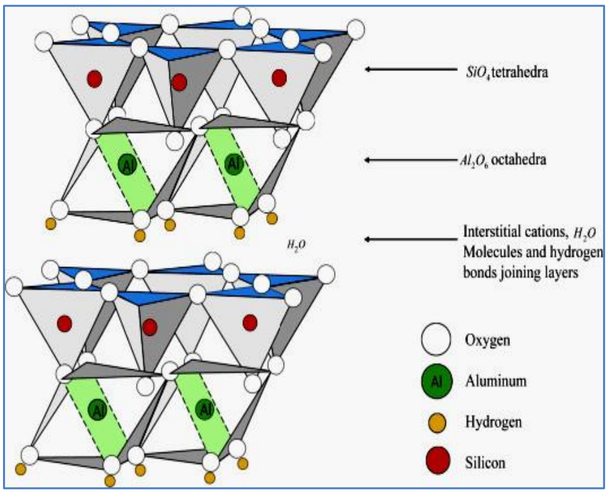

Fig. 2. Chemical Composition of Kaolinite

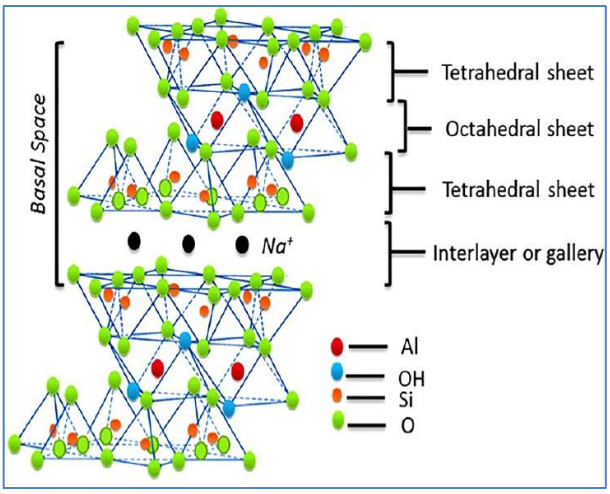

Fig. 3. Chemical Composition of Montmorillonite

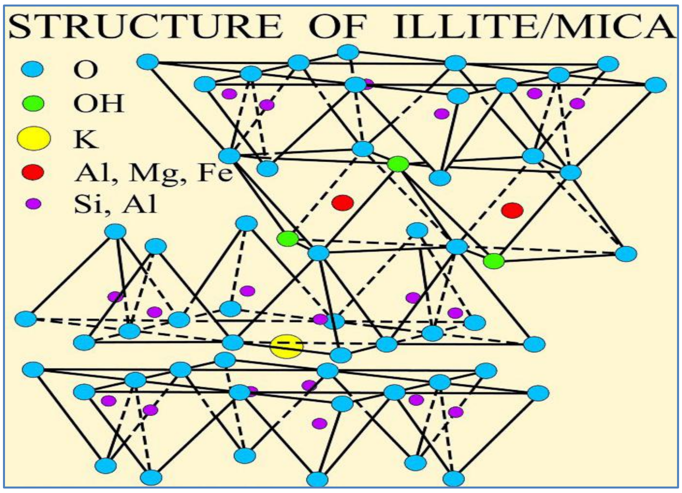

Fig. 4. Chemical Composition of Illite Group

Identification and classification of expansive soils: Some laboratory tests are available for the identification purposes of swelling soils using differential thermal analysis, Microscopic examination, and X-ray diffraction. The presence of Montmorillonite in clay minerals allows the judgment of the expansiveness of the soil. This aspect is however very technical in nature. A simple aspect, as opposed to the aforementioned methods, is the free-swell test, that's done in the laboratory. This test is conducted by adding 10 gm of dry soil, passing through a 425 µ sieve into two separate 100 cc graduated jar – one filled with water, and the other with kerosene. Swelling occurs in the jar containing water. The swelled volume of the soil is then noted (after 24 hours period), and subsequently, the free swell index values, in percentage, are calculated. IS: 2720-II was followed for free swell index test. Good grade, high swelling, commercial Bentonite has been reported to have free swell values varying from 1200% to 2000% [8]. In general, the swelling potential of a soil is related to the plasticity index. With corresponding range of plasticity index, various degrees of swelling capacities are as indicated through the following table 1:

Table 1. Swelling potential vs. Plasticity Index

Swelling potential	Plasticity Index
Low	0-15
Medium	15-24
High	24-46
Very High	>46

Method of recognition of expansive soil: The swelling potential of a soil basically depends upon its mineral composition along with the in situ moisture content and density. Soil permeability also affects the rate of swelling on site. In general, clays with plasticity indices > 25, liquid limits > 40, and natural water content near the plastic limit or less are more likely to swell. Based upon the Atterberg limits, the degree of expansion of a soil can be classified as presented in Table 11.3. Similarly, as per the ASTM D4829-11, the degree of expansion may be very low (EI = 0–20), low (EI = 21–50), medium (EI = 51–90), high (EI = 91–130), and very high (EI > 130), where EI is the expansion index. Soils containing coarse-grained particles, i.e. cobbles, pebbles, and sands, may also be expansive depending upon the percentage and type of clay minerals present in its fine content. Clays basically belong to the family of silicates minerals and their principal elements are silicone, aluminum, and oxygen. However, there are many elements that can become incorporated into the clay mineral structure, such as hydrogen, sodium, calcium, magnesium, sulfur, etc. The presence and abundance of various dissolved elements or ions affect the swelling and shrinkage potentials of clays. The types of clay minerals present in soils can be identified in different ways (i.e. microscopic examination, X-ray diffraction, differential thermal analysis, infrared analysis, dye adsorption analysis, chemical analysis). Some of the clay minerals exhibiting swelling behavior include smectite, bentonite, montmorillonite, beidellite, vermiculite, attapulgite, nontronite, and chlorite [9].

Problem associated with expansive soil [9]: The following are the problems occurring are structural damage to lightweight structures such as sidewalks and driveways; lifting of buildings, damage to basements, and building settlement; cracks in walls and ceilings; damage to pipelines and other public utilities; lateral movement of foundations and retaining walls due to pressure exerted on vertical walls; loss of residual shear strength causing instability of slopes, etc.; because of sinkage and swelling properties of expansive soil, differential settlement is caused in the foundation; these cracks may be 10 to 15 cm wind on the ground surface and may be 0.5 to 2 m deep, these cracks result in removal of support beneath the footing, resulting in high settlement; Some expensive and shrinkable soil sticks to the footing base and pulls the putting down when they shrink , resulting in horizontal cracks in walls and other flexible units of structure; this redistributes the structural load causing concentration of loads on a certain portion of foundation and large change in moment and shear force in structure not previously accounted for in the standard design practice.

Stabilization using fly ash: Fly ash is the combustion product of sub bituminous coal in electric power plants and requires being land filled. However, many countries have promoted the reuse of these types of wastes in the interest of sustainable construction. Therefore, the use of fly ash as a binding admixture not only improves the engineering properties of soil but also reduces the use of energy and greenhouse gases. Fly ash disperses the soil cement clusters into smaller clusters, thereby increasing the reactive surface for hydration and pozzolanic reactions. Due to these pozzolanic characteristics, the shear strength and bearing capacity of the organic soil can be increased by stabilizing it with fly ash. Fly ash reduces the plasticity index and shrinkage limit, which has a potential impact on the engineering properties of fine-grained soil . However, the effectiveness of the stabilization depends on the organic content present in the soil, which is not taken into account in the case of inorganic soil. Soil is a peculiar material. Some waste materials such Fly Ash, rice husk ash, pond ash may be used to make the soil stable. Addition of such materials will increase the physical as well as chemical properties of the soil. Some expected properties to be improved are CBR value, shear strength, liquidity index, plasticity index, unconfined compressive strength and bearing capacity etc. The objective of this study was to evaluate the effect of Fly Ash derived from combustion of sub-bituminous coal at electric power plants in stabilization of soft fine-grained red soils. California bearing ratio (CBR) and other strength property tests were conducted on soil. The soil is in range of plasticity, with plasticity indices ranging between 25 and 30. Tests were conducted on soils and soil-Fly Ash mixtures prepared at optimum water content of 9%. Addition of Fly Ash resulted in appreciable increases in the CBR of the soil. For water contents 9% wet of optimum, CBRs of the soils are found in varying percentages such that 3,5,6and 9. We will find the optimum CBR value of the soil is 6%. Increment of CBR value is used to reduce the thickness of the pavement, and increase the bearing capacity of soil [11, 12].

III. Materials & methodology used

Materials: The materials mostly used in the analysis are stated as expansive soil, and fly ash.

(i) Expansive Soil: Expansive soil or clay is considered to be one of the more problematic soils and it causes damage to various engineering structures because of its swelling and shrinking potential, when it comes into contact with water. Expansive soils behave differently from other normal soils due to their tendency to swell and shrink. As a part of this study, the Expansive Soil or Black Cotton Soil is acquired from the nearby areas of Bhilai, India.

(ii) Fly Ash: Fly ash is a fine powder that is a byproduct of burning pulverized coal in electric generation power plants. When used in concrete mixes, fly ash improves the strength and segregation of the concrete and makes it easier to pump. There are two common types of fly ash: Class F and Class C. Class F fly ash contain particles covered in a kind of melted glass. This greatly reduces the risk of expansion due to sulfate attack, which may occur in fertilized soils or near coastal areas. Class F is generally low-calcium and has carbon content less than 5 percent but sometimes as high as 10 percent. Fly ash is a byproduct of power generation with coal. The fly ash generated at National Thermal Power Corporation (NTPC) stations is ideal for use in the manufacture of cement, concrete, concrete products, cellular concrete products, bricks/blocks/ tiles etc Fly ash can be used to stabilize bases or subgrades, to stabilize backfill to reduce lateral earth pressures and to stabilize embankments to improve slope stability. The primary reason fly ash is used in soil stabilization applications is to improve the compressive and shearing strength of soils.

Methodology Adopted: the following are the various analysis concept have been used to obtain the stabilization effects: **Grain size Analysis:** Grain size analysis is done for Mechanical sieve and Hydrometer analysis. Expansive soil and for fly ash by using following procedures as per IS: 3104-1964. **Specific Gravity:** The specific gravity of soil was determined by using Pycnometer (volumetric flask) as per IS: 2720(part-III/sec-I) 1980. **Liquid Limit:** The liquid limit was determined in the laboratory by the help of standard liquid limit apparatus. About 120g of the specimen passes through a 425µ sieve. A groove was made by a groove tool an IS: 9259-1979 designates. A brass cup was raised and allowed to fall on a rubber base. The water content corresponding to 25 blows was taken as liquid limit. The value of liquid limit was found out for swelling soil and swelling soil with 20% fly-ash. **Plastic Limit:** The value of plastic limit was found for swelling soil and swelling soil with 20% fly-ash as per IS: 2720(part-V)-1986.

Optimum moisture content and maximum dry density: The Optimum moisture content and dry density of swelling soil with various percentages of fly ash (0%,10%,20%,30%,40%,50%) was determined by performing the "standard proctor test" as per IS: 2720 (part VII)1965. The test consists in compacting soil at various water contents in the mould, in three equal layers, each being given 25 blows of 2.6kg rammer dropped from a height of 31cm. The collar is removed and the excess soil is trimmed off to make it level. The dry density is determined and plotted against water content to find OMC and corresponding maximum dry density.

The specific apparatus used standard proctor test, while performing the experimentation of the expansive soil using fly ash are as follow:

[A] Apparatus: The specification or sizes of cylindrical mould of non corrodible material: Diameter = 100 mm; Height = 127.3 mm; Capacity = 1000 cc; Detachable base plate; Renewable extension color = 60 mm high; Metal Rammer: 50 mm diameter surface and weight 2.6 kg with arrangement for a free fall of 310 mm; Sample extractor, weighing balance, oven, Container, Measuring jar 500 cc, steel edge, mixing pan; Proctor penetration needle.

[B] Light compaction test (Standard Proctor Test): Volume of mould = 1000 cc; Weight of empty mould = 3.900 kg; Weight of Rammer = 2.6 kg; Fall of Rammer = 310 mm; No. of layer = 3; No. of blows per layer = 25; Specific gravity of soil (G) = 2.7.

IV. Result and Discussion

Based on above used apparatus and the light compact test, the various results have been evaluated and tabulated in table No. 3 to 14. Table 2 represent the liquidity and plasticity index test of soil.

Table 2: Liquidity and Plasticity Index Test of Soil

Mixture	Liquid limit	Plastic limit	Plasticity index
Only soil	65.6	35.8	29.8
Soil + 10% fly ash	61.2	34.6	26.6
Soil + 20% fly ash	58.8	33.2	25.6
Soil + 30% fly ash	56.4	31.5	24.9
Soil + 40% fly ash	51.8	28.67	23.13
Soil + 50% fly ash	49.2	26.3	22.9

Table 3: Standard proctor test for expansive soil with 0% fly ash considering water content (%)

S.No.	Empty container weight (g)	Wet soil + container weight (g)	Wet weight (g)	Dry weight (g)	Water weight (g)	Water content (%)
1.	6	60.3	54.3	50.40	9.02	17.9
2.	6	70.1	64.1	58.50	11.05	18.9
3.	6	66.3	60.3	54.90	11.41	20.8
4.	6	73.2	67.2	58.40	17.22	29.5
5.	6	75.1	69.1	60.80	15.74	25.9

Table 4: Standard proctor test for expansive soil with 0% fly ash considering dry density (g/cc)

S.No.	Weight of mould + compacted Soil (g)	Weight of Mould (g)	Weight of Compacted Soil (g)	Bulk Density (g/cc)	Water content (%)	Dry Density (g)
1.	5445	3900	1545	1.55	17.9	1.32
2.	5605	3900	1705	1.71	18.9	1.44
3.	5679	3900	1779	1.78	20.8	1.47
4.	5690	3900	1790	1.79	29.5	1.38

5.	5770	3900	1870	1.87	25.9	1.48

Table 5: Standard proctor test for expansive soil with 10% fly ash considering water content (%)

S.No.	Empty container weight (g)	Wet soil + container weight (g)	Wet weight (g)	Dry weight (g)	Water weight (g)	Water content (%)
1.	6	65.19	59.19	52.66	11.73	22.28
2.	6	68.25	62.25	54.05	14.68	27.17
3.	6	69.54	63.54	53.59	17.70	33.03
4.	6	77.60	71.60	59.86	20.62	34.45
5.	6	78.90	72.90	58.83	22.89	38.91

Table 6: Standard proctor test for expansive soil with 10% fly ash considering dry density (g/cc)

S.No.	Weight of mould + compacted Soil (g)	Weight of Mould (g)	Weight of Compacted Soil (g)	Bulk Density (g/cc)	Water content (%)	Dry Density (g)
1.	5560	3900	1660	1.660	22.28	1.357
2.	5770	3900	1870	1.870	27.17	1.470
3.	5725	3900	1825	1.825	33.03	1.371
4.	5685	3900	1785	1.785	34.45	1.327
5.	5655	3900	1755	1.755	38.91	1.263

Table 7: Standard proctor test for expansive soil with 20% fly ash considering water content (%)

S.No.	Empty container weight (g)	Wet soil + container weight (g)	Wet weight (g)	Dry weight (g)	Water weight (g)	Water content (%)
1.	6	58.65	52.65	48.78	9.56	19.61
2.	6	64.95	58.95	53.77	11.22	20.88
3.	6	87.06	81.06	71.52	15.87	22.19
4.	6	77.40	71.40	60.49	23.07	38.14

Table 8: Standard proctor test for expansive soil with 20% fly ash considering dry density (g/cc)

S.No.	Weight of mould + compacted Soil (g)	Weight of Mould (g)	Weight of Compacted Soil (g)	Bulk Density (g/cc)	Water content (%)	Dry Density (g)
1.	5555	3900	1655	1.655	19.61	1.392
2.	5690	3900	1790	1.790	20.88	1.480
3.	5765	3900	1865	1.865	22.19	1.526
4.	5665	3900	1765	1.765	38.14	1.277

Table 9: Standard proctor test for expansive soil with 30% fly ash considering water content (%)

S.No.	Empty container weight (g)	Wet soil + container weight (g)	Wet weight (g)	Dry weight (g)	Water weight (g)	Water content (%)
1.	6	63.98	57.98	52.76	9.61	18.22
2.	6	65.72	59.72	52.81	12.35	22.39
3.	6	64.90	58.90	51.18	14.01	27.50
4.	6	68.64	62.64	52.51	18.12	34.52

Table 10: Standard proctor test for expansive soil with 30% fly ash considering dry density (g/cc)

S.No.	Weight of mould + compacted Soil (g)	Weight of Mould (g)	Weight of Compacted Soil (g)	Bulk Density (g/cc)	Water content (%)	Dry Density (g)
1.	5535	3900	1635	1.635	18.13	1.384
2.	5630	3900	1730	1.730	23.39	1.402
3.	5725	3900	1825	1.825	27.50	1.431
4.	5650	3900	1750	1.750	34.82	1.298

Table 11: Standard proctor test for expansive soil with 40% fly ash considering water content (%)

S.No.	Empty container weight (g)	Wet soil + container weight (g)	Wet weight (g)	Dry weight (g)	Water weight (g)	Water content (%)
1.	6	57.86	51.86	47.60	8.42	17.70
2.	6	68.98	62.98	55.56	13.04	23.48
3.	6	69.47	63.41	54.92	15.36	21.97
4.	6	70.35	64.35	53.79	18.61	34.60

Table 12: Standard proctor test for expansive soil with 40% fly ash considering dry density (g/cc)

S.No.	Weight of mould + compacted Soil (g)	Weight of Mould (g)	Weight of Compacted Soil (g)	Bulk Density (g/cc)	Water content (%)	Dry Density (g)
1.	5485	3900	1585	1.585	17.70	1.346
2.	5610	3900	1710	1.710	23.48	1.384
3.	5690	3900	1790	1.790	21.97	1.398
4.	5645	3900	1745	1.745	34.60	1.296

Table 13: Standard proctor test for expansive soil with 50% fly ash considering water content (%)

S.No.	Empty container weight (g)	Wet soil + container weight (g)	Wet weight (g)	Dry weight (g)	Water weight (g)	Water content (%)
1.	6	65.30	59.30	54.90	7.64	13.91
2.	6	55.88	49.88	45.89	8.19	17.85
3.	6	62.68	56.68	50.33	12.15	24.16
4.	6	72.55	66.55	56.41	17.37	30.81
5.	6	80.49	74.49	60.34	23.09	38.27

Table 14: Standard proctor test for expansive soil with 50% fly ash considering dry density (g/cc)

S.No.	Weight of mould + compacted Soil (g)	Weight of Mould (g)	Weight of Compacted Soil (g)	Bulk Density (g/cc)	Water content (%)	Dry Density (g)
1.	5410	3900	1510	1.510	13.91	1.325
2.	5520	3900	1620	1.620	17.85	1.374
3.	5595	3900	1695	1.695	24.16	1.365
4.	5700	3900	1800	1.800	30.81	1.376
5.	5620	3900	1720	1.720	38.27	1.244

As based on the above results tabulated in the tables(s), the various graphs has been prepared between the dry density and water content in percentage, which responses in the Figs. from 5 to 12.

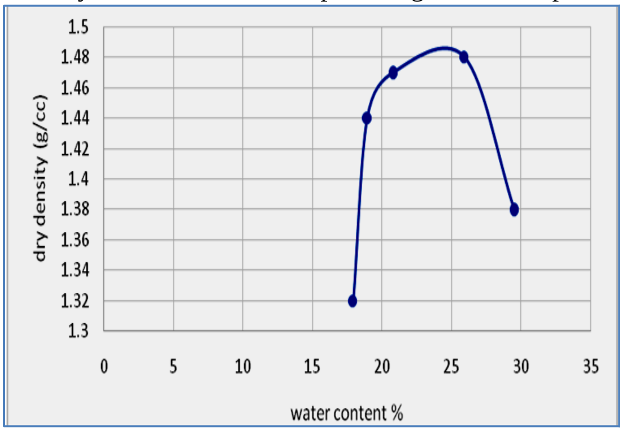

Fig. 5: Proctor test with expansive soil only

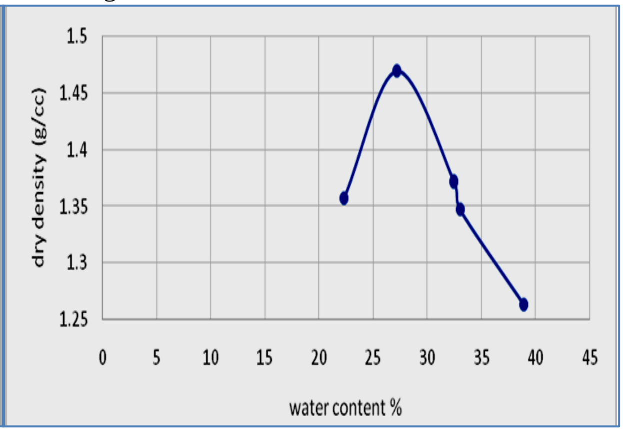

Fig. 6: Proctor test with expansive soil + 10% fly ash

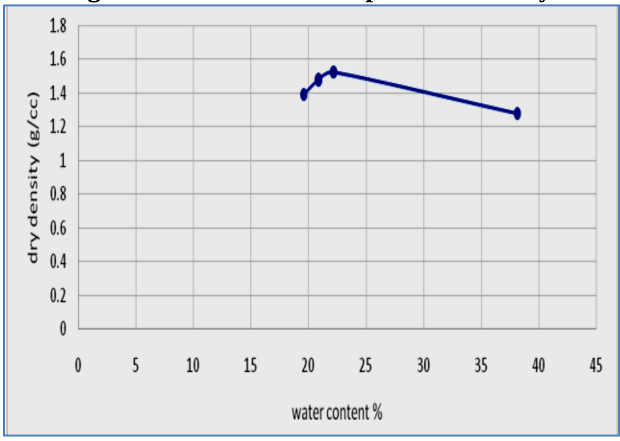

Fig. 7: Proctor test for expansive soil + 20% fly ash

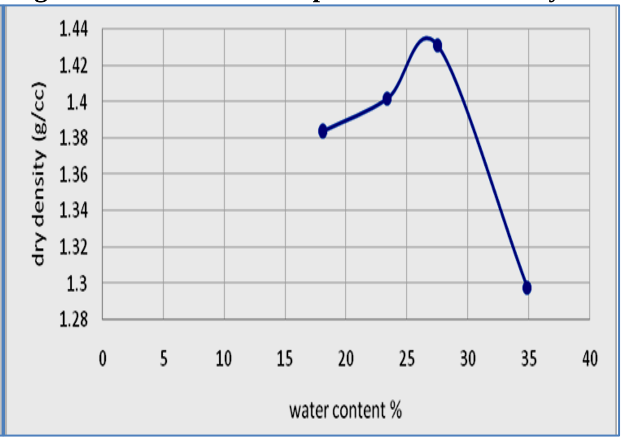

Fig. 8: Proctor test with expansive soil + 30% fly ash

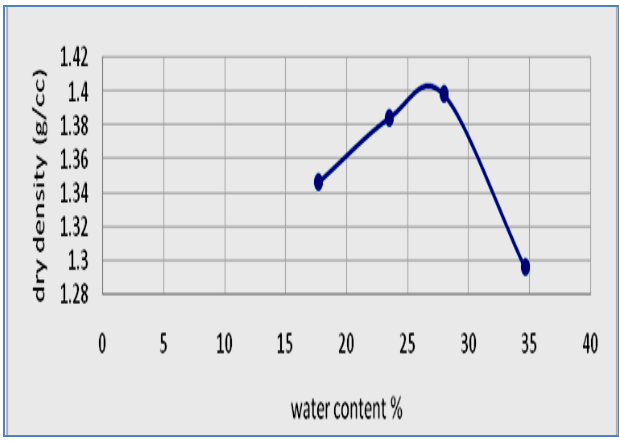

Fig. 9: Proctor test with expansive soil + 40% fly ash

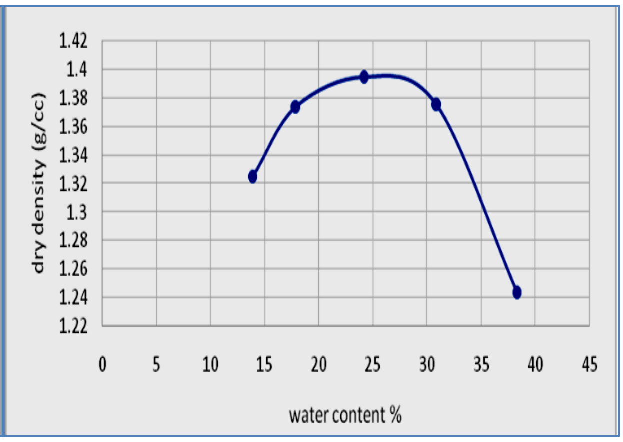

Fig. 10: Proctor test with expansive soil + 50% fly ash

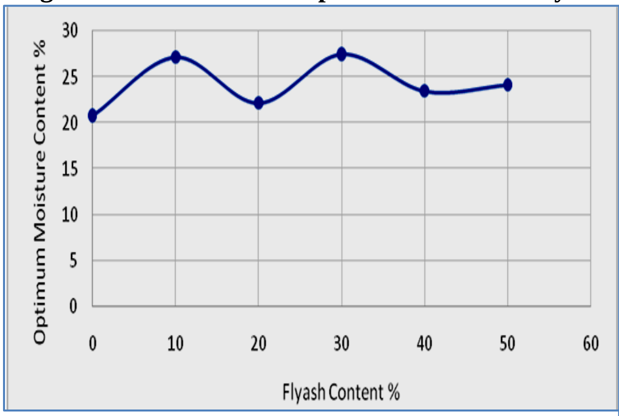

Fig. 11: Comparison of Optimum Moisture Content against Fly Ash Content

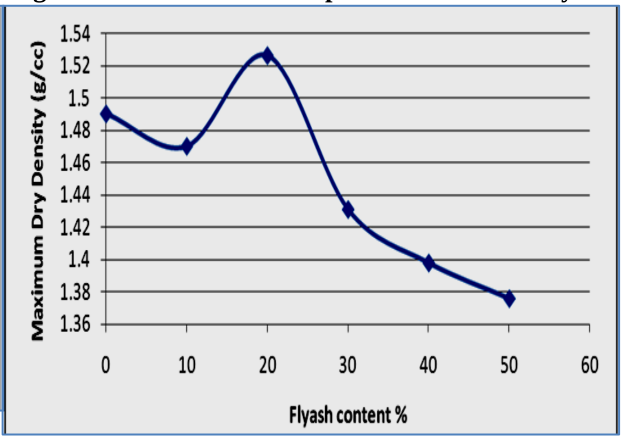

Fig. 12: Comparison of Maximum Dry Density against Fly Ash Content

Discussions: The effects and behavior of an additive on expansive soil, black cotton soil (or expansive soil) is mixed with fly ash, alternating its percentage (from 0% to 50%) using Standard Proctor Test and is Liquidity and Plasticity Index Test by weight, as shown in tabulation from table 4 to table 14. The liquid limit and the plastic limit of the soil-fly ash mixture varied with the changing fly ash content. Plasticity index values were computed from these experiments, which showed a consistent decreasing pattern with the increase of fly ash as shown in Figs. 5 to 12. The change observed in Standard Proctor Test of the soil - fly ash mixture with varying percentage of fly ash is taken. From the observation table and graph, it can be observed that 20% fly ash content gave the maximum dry density value for Standard Proctor Test.

References

[1]. Radhakrishnan, G., Kumar, M.A., and Raju, G.V.R.P., “Swelling Properties of Expansive Soils Treated with Chemicals and Fly ash”, American Journal of Engineering Research. Vol. 3, Issue 4, pp. 245-250, 2014.
[2]. Raut, J.M., Bajad, S.P., and Khadeshwar, S.P. , “Stabilization of Expansive Soils Using Fly ash and Murrum”, International Journal of Innovative Research in Science, Engineering and Technology. Vol. 3, Issue 7, 2014.
[3]. Satyanarayana P.V.V., Kumar, S.H., Praveen, P., Kumar, B.V.S., “A Study on Strength Characteristics of Expansive Soil-Fly ash Mixes at Various Moulding Water Contents”, International Journal of Recent Technology and Engineering. Vol. 2, Issue 5, 2013.
[4]. Senol, A., Etminan. E., and Olgun, C., “Stabilization of Clayey Soils Using Fly Ash and Homopolymerpolypropylene”, GeoCongress, pp. 3929-3938, 2012.
[5]. Sridharan, A., Pandian, N. S., and Rajasekhar, C., “Geotechnical Characterization of Pond Ash, Ash ponds and Disposal Systems, Narosa Publising House, New Delhi, India, pp. 97–110, 1996.
[6]. Xing, C., and Ji-ru, Z., “Stabilization of Expansive Soil by Lime and Fly Ash”, Journal of Wahan University of Technology – Mater. Sci. Ed., Vol. 14, Issue 4, pp. 73- 77, 2002.
[7]. Zha, F., Liu, S., Du, Y., and Cui, K., “Behavior of Expansive Soils Stabilized with Fly Ash”, Natural Hazards, Vol. 47, Issue 3, pp. 509-523, 2008.
[8]. Fly ash characterization with reference to geotechnical application: Author N.S. Pandian, Dept. of Civil Engg. IISC Bangalore
[9]. Expansive soils geotechnical engineering: Evaluation of soil and rock properties; Author(s) P.J. Sabatini, R.C. Bachus
[10]. Expansive soil in Highway Subgrades: Summary report No:FHWA-TS-80-236;Author Snethen.D.R.
[11]. www.sciencedirect.com
[12]. www.wikipedia.com