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Stabilization of Expansive Soils Employing Activated Fly Ash

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Abstract:

There are about 51.8 million hectares of land in India that are covered with a significant amount of soil (mainly Black Cotton soil). These expansive soils, in general, have the characteristic that when they are dry, they are fairly hard, but when they are wet, they lose all of their strength and become very brittle. This is because water causes the soil to lose its ability to hold together. All expansive soils have this characteristic in common with one another. Because expansive soils have this property, they are the cause of problems all over the world and present a challenge to geotechnical engineers who are tasked with finding solutions to these issues. The expansive nature of expansive soils makes it difficult for geotechnical engineers to do their jobs. Soil stabilization is often utilized for paving roads and creating the foundations of structures, making it one of the most important aspects of building construction. It is also considered to be one of the most important aspects of building construction. This form of stabilization regime strengthens the engineering qualities of the soil, such as the soil's volume stability, strength, and durability. As a result, this is why the situation is as it is. As a direct consequence of this, the circumstance is now in this state. At this point, the problematic soil is either removed totally or excavated and replaced with a new material of greater quality. If it is excavated, the problematic soil is replaced with material of higher quality. If the problematic soil cannot be removed, the soil in issue is either given a treatment with an additive or taken out entirely. Fly ash was collected from Sesa Sterlite in Jharsuguda, which is located in the state of Odisha in India. This fly ash was then used in the continuing research project to try to stabilise black cotton soil that was taken from Nagpur. The Sesa Sterlite factory in Jharsuguda was the source of this fly ash that was acquired. Expansive soils may be made more stable by putting this addition in the soil at a number of different concentrations, such as 10%, 20%, 30%, 40%, and 50%, respectively. The plasticity index (P.I.) of clay-fly ash mixtures shows a drop in value as the quantity of fly ash increases. This is because fly ash does not have any plastic characteristics of its own, hence the index value decreases. This is because fly ash does not possess any characteristics that are associated with plastic. In conclusion, the incorporation of fly ash into expansive soil lessens the soil's capacity for movement while at the same time enhancing the soil's capacity for manipulation. This is because the addition of the fly ash modifies both the particle size and the colloidal reaction of the soil, which leads to the occurrence of the aforementioned effect. Clay mixtures that included fly ash were placed through a series of wet and dry tests to evaluate their coefficients of frictional resistance (CBR). The results of these tests were analysed, measured, and compared to one another to arrive at their respective values. An investigation into the previously observed result suggests the possibility of using fly ash as an additive that has the potential to be employed for the purpose of boosting the engineering features of expansive soils. This possibility was suggested by the investigation into the previously observed result.

Keywords — **Expansive Soil, Fly Ash, Compressive, Shear, Split tensile, swelling characteristics, stabilization, fly ash, MDD, OMC, UCC.**

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1. INTRODUCTION

Due of its propensity to contract and expand in response to differences in the amount of moisture that is available, expansive soils are also known as swell-shrink soil. This is because of the soil's inclination to swell. This dual capability is provided to vast soils by their property. The variations in the soil cause severe discomfort in the soil, which is then followed by damage to the buildings that are located on top of the soil and are thus in direct contact with the soil. Certain types of soil are able to take in more water, which causes them to expand, and this ability is enhanced in environments with high levels of humidity, such as during the monsoons. Because of this expansion, the soils become more flexible, but they also lose part of their ability to hold water. This is a trade-off that must be made. On the other hand, when the environment is warmer and drier, such as in the summer, the moisture that is normally present in these soils evaporates, which causes the soil to become more compact. This may be seen as a negative effect on the soil's ability to support plant growth. This occurs because the soil loses its capacity to retain water when it dries out. If it is not properly managed, this specific kind of soil, which is common in arid and semi-arid regions of the world, is considered to be a potential natural hazard. If they are not handled correctly, these soils have the potential to not only result in the destruction of the buildings that have been constructed on top of them, but also the loss of human life. In addition, the destruction of the buildings that have been constructed on top of them could be avoided. These kinds of characteristics are often shown by soils in which the presence of montmorillonite plays a significant part in the creation of the overall composition of the soil. It is estimated that the huge damage to civil engineering facilities that these soils create would cost billions of dollars each year around the globe.

The bulk of the expansive soils on the Indian subcontinent are located over the Deccan trap, which is also known as the Deccan lava tract. Both of these names relate to the same geological feature. The Deccan trap has a few areas spread out over the state of Odisha in addition to the states of Maharashtra, Andhra Pradesh, Gujarat, and Madhya Pradesh. These sorts of soils are sometimes referred to as "Black Cotton soils" or "Regur soils," depending on the region in which they are found. In addition, the river basins of the Narmada, Tapi, Godavari, and Krishna all have soils that are similar to those mentioned in this article. In the upper portions of the Godavari and Krishna rivers as well as in the north-western part of the Deccan Plateau, the black cotton soil extends down to an exceptionally substantial depth. This is true even though the rivers are relatively shallow. These regions are found in the country of India. These are the soils that are left behind at the location of an event after different decomposition agents have used chemicals to break down rocks such as basalt. In a word, these are the soils that remain at the location where an event took place after it has concluded. Other processes, such as the cooling of volcanic eruptions (lava) and the weathering of igneous rocks, which are a different form of rock, also contribute to the development of a wide variety of soils. These are also examples of weathering processes. Igneous rocks and lava are both types of rocks that may be found. These soils have a high concentration of lime, alumina, magnesium, and iron, but they are deficient in nitrogen, phosphorus, and organic matter. However, they do have a high concentration of alumina. On the other hand, they do contain a significant amount of lime.

1.1. Classification of Fly Ash

The term "fly ash" refers to the ash that has been reduced to a fine powder before being collected from the flue gases by means of an electrostatic precipitator. After going through the pulverization process, this ash is what's left behind. Although fly ash, bottom ash, and pond ash are all formed of the same chemical, the particles that make up fly ash are the smallest of the three types of ash. Although the vast majority of the components that make up fly ash are made up of combustible particulate matter, it does include trace amounts of unburned carbon. The size of these particles often falls in between that of sand and that of silt. On the basis of the results of an experiment that investigates lime reactivity, the following four distinct kinds of fly ash have been distinguished from one another:

- Cementitious fly ash.
- Cementitious and pozzolanic fly ash.
- Pozzolanic fly ash.
- Non-pozzolanic fly ash

As it includes a sizable quantity of free lime but almost no reactive silica, this kind of fly ash is known as cementitious fly ash. Cementitious fly ash has use in the building and construction industry. Pozzolanic fly ash, on the other hand, is distinguished by its high concentration of reactive silica and its low levels of free lime. That is to say, it is a silica-rich reactive substance. Concentrations of reactive silica and free lime, two key components of both cementitious and pozzolanic fly ash, are highest. Reactive silica has both of these elements. There is no free lime or reactive silica in fly ash that has not been treated with pozzolanic acid. Both of these factors are now missing from the equation. Cementitious fly ash may be distinguished from pozzolanic fly ash by its brittleness upon contact with water, whereas pozzolanic fly ash does not become brittle until activated lime interacts with water. This quality makes it possible to differentiate between the two forms of fly ash. Because of this, a clearer distinction may be made between the two types of fly ash. This is the main difference between the two kinds of fly ash that may be bought nowadays. Cementitious and pozzolanic fly ash, together with pozzolanic fly ash, are the most accessible types of fly ash. Furthermore, it is possible to find fly ash with cementitious and pozzolanic properties.
Sub-bituminous type coal and lignite, both of which contain more than 20% calcium oxide, are the primary sources of Class C fly ash. Class D fly ash is also produced in this procedure. Class C fly ash, sometimes known as "dark grey" fly ash, may be easily recognised by its colour. Class F fly ash is created when anthracite and bituminous coals are burnt. It is widely agreed that this particular kind of fly ash is the most harmful to the environment. This fly ash contains less than 20% calcium oxide, which is a negligible amount. The chemical composition of fly ashes classified as C or F is shown in the following table.

Table-1: Fly ash classes C and F must meet certain chemical criteria (data source: ASTM C618-94a)

Particulars		Fly ash	
		Class F	Class C
$SiO_2 + Al_2O_3 + Fe_2O_3$	% minimum	70.0	50.0
SO_2	% maximum	5.0	5.0
MC	% maximum	3.0	3.0
LOI	% maximum	6.0	6.0

1.2. Utilization of Fly Ash

In the majority of instances, the applications of fly ash may be categorized into one of the three subsets that are elaborated upon in the following paragraphs:

- The Low Value Utilizations include a wide range of applications, including things like ash dykes, back filling, structural fills, road building, soil stabilization, embankment and dam construction, and other similar activities.
- The Medium Value Utilizations, which include things like grouting, cellular cement, pozzolana cement, bricks/blocks, soil amendment agents, prefabricated construction blocks, fly ash concrete, weight aggregate, and so on and so forth. These medium value utilizations include things like grouting, cellular cement, pozzolana cement, and so on and so forth. Examples of

High Value Utilizations are bricks and blocks, weight aggregate, and other items of a like kind.

- The High Value Utilizations encompass a wide variety of products and processes, such as acid refractory bricks, fly ash paints, the ceramic industry, the recovery of metals and other materials, distempers, and the extraction of magnetite, amongst many others.

1.3. Expansive Soil

It was necessary to be in possession of a large amount of the black cotton soil, which is also known by the word Khairi. This was necessary in order to accomplish the goals of this inquiry. Khairi is another name for the black cotton soil. Khairi might come from Pakistan in certain circumstances. It is very possible that this particular kind of pollution was first introduced into the environment in the city of Nagpur, which is located in the state of Maharashtra in India. Tamil Nadu is the name given to this particular state while it is in its native habitat in the southern part of the Indian subcontinent. You may find the area of India that is known as the state of Maharashtra inside of the land that is generally referred to as the nation of India. Following this method of collecting the soil from the black cotton plants, the material was placed in containers, transported to the laboratory, and subjected to further testing there. The outcomes of these examinations may be viewed at this location. After that, during the subsequent discussion, we are going to go through the findings of these tests in further depth. After a very minute quantity of soil was collected to serve as a representative sample, the soil was first weighed, then passed through a sieve with a mesh size of 4.75 millimetres, and then, after being allowed to air-dry, it was subjected to a second round of weighing. This process was repeated until the soil had reached the desired consistency. There were a total of three repetitions of this technique that were carried out. We were successful in accomplishing our goal of determining the natural percentage of water that is present in the soil by carrying out this experiment, which was the aim for why we carried it out. In the paragraphs that follow, a more in-depth examination of the numerous geotechnical properties that the acquired soil includes is offered. These paragraphs are ordered in the following order:

Table-2: Geotechnical properties of expansive soil

Sl. No.	Properties	Code referred	Value
1	Specific Gravity	IS 2720 (Part 3/Sec 1) - 1980	2.44
2	Maximum Dry Density (MDD)	IS 2720 (Part 7) - 1980	1.52 gm/cc
3	Optimum Moisture Content (OMC)	IS 2720 (Part 7) - 1980	22.65%
4	Natural Moisture Content	IS 2720 (Part 2) - 1973	7.28%
5	Free Swell Index	IS 2720 (Part 40) - 1977	105%
6	Liquid Limit	IS 2720 (Part 5) - 1985	65%
7	Plastic Limit	IS 2720 (Part 5) - 1985	37.08%
8	Shrinkage Limit	IS 2720 (Part 6) -: 1972	17.37%

2. THE STABILIZATION OF EXPANSIVE SOILS USING ACTIVATED FLY ASH.

The usage of fly ash that had been treated with alkli in order to stabilise the soil that is used for the production of black cotton resulted in the following outcomes, which were achieved: It is possible to calculate the necessary increase in strength by performing unconfined compression tests on samples after they have been cured for 3, 7, and 28 days, respectively, and comparing the results to the starting point. It was known for a fact that the length to diameter ratio would be 2:1 since the cast samples each had dimensions of 100 millimetres in height and 50 millimetres in diameter respectively. Due to the fact that it had already been agreed that the ratio would be 2:1, the potential of this occurring was not completely out of the question. The activator to total solid ratios in these samples vary from 15 to 25 percent, despite the fact that the weight percentages of fly ash range from 20 to 30 and even up to 40 percent based on dry mass. After the casting process, each specimen was vacuum-sealed for forty-eight hours in a container that was created to prevent the escape of air before having cling film put on top of it. After this, the specimens were stored in a container that was made to restrict the escape of air. This process was repeated a number of times until the desired results were achieved. After a total of forty-eight hours, the samples were taken out of the moulds and kept at an ambient temperature and humidity of between fifty and sixty percent relative humidity (RH) and thirty-two to thirty-five degrees Celsius. The samples were also kept in a dry environment. In addition, the relative humidity of the room where the samples were stored ranged from fifty to sixty percent. After all was said and done, the samples were then placed in storage after being sealed in plastic wrap using cling film. This treatment was carried out until the samples had reached their optimum, completely recovered state.

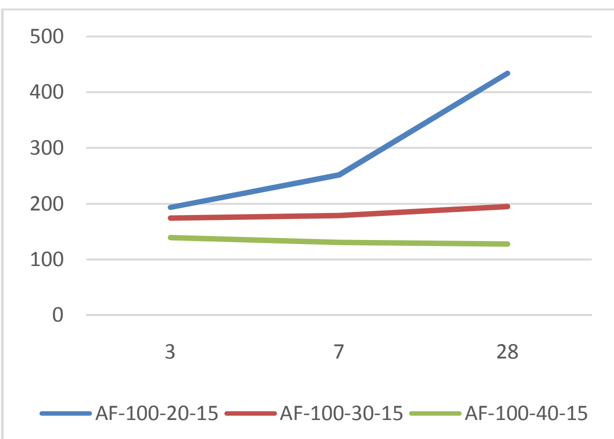

Figure-1: UCS results of AF-100-20-15, AF-100-30-15, AF-100-40-15.

2.1. Variation of MDD with Fly Ash

When fly ash is added to expansive soil or black cotton soil, the value of the maximum dry density is obtained when the percentage of fly ash in the expansive soil is around 28%. This is the case whether the fly ash is put to expansive soil or black cotton soil. This value may also be attained in black cotton soil with the use of fly ash. It is generally agreed that this value represents the "sweet spot" at which one may get the greatest potential dry density.

The following is the method in which the graph is presented:

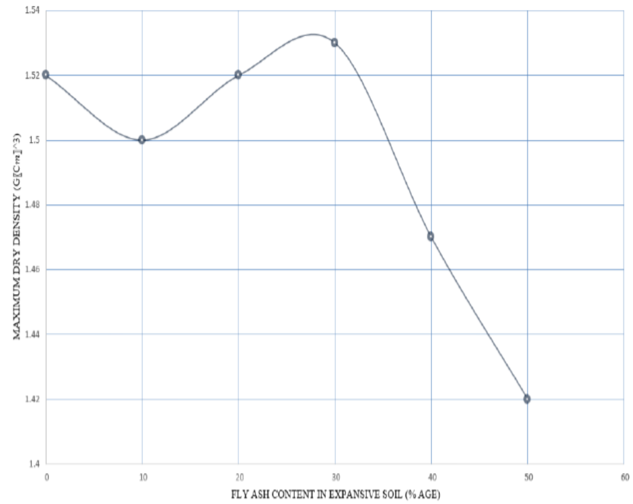

Figure-2: Variation of MDD values with different fly ash content in expansive soil

2.2. Variation of OMC with Fly Ash

The optimal moisture content of a soil is defined as the level of moisture in the soil at which the soil achieves its highest possible dry density (OMC). After the soil has attained its "Optimum Moisture Content," a measurement of its dry density is referred to as having reached its "Maximum Dry Density" (MDD). The OMC at different percentages of fly ash included in the soil is seen in the graph below:

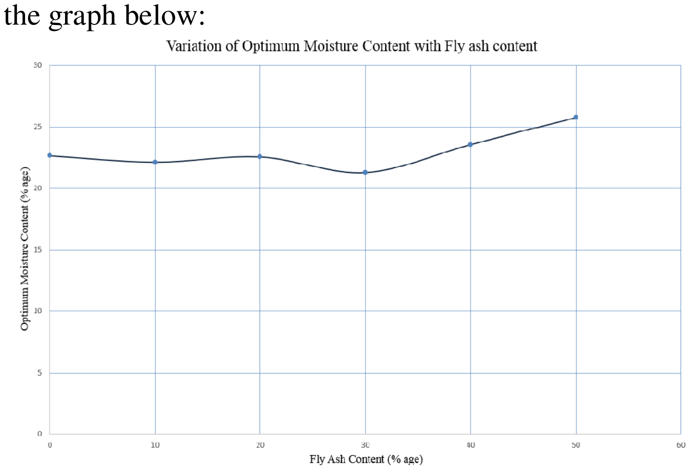

Figure-3: Variation of OMC values with different fly ash content in expansive soil

From the above graph of the variation of the optimum moisture content at the different percentage of the fly ash is maximum at the 50% amount of the fly ash added in the expansive soil.

2.3. Variation of UCS with Fly Ash

The "Unconfined Compressive Strength," sometimes abbreviated as "UCS," refers to the maximal axial compressive stress that a cohesive soil specimen is able to withstand when there is no restricting tension present. "UCS" stands for "Unconfined Compressive Strength." "UCS" is an abbreviation that stands for the phrase "Unconfined Compressive Strength." One of the methods that may evaluate the shear strength of clayey soil in the quickest and most cost-effective way possible is the unconfined compression test. This method is also one of the more common methods. Because there is no need for a restricted area in the unconfined compression test, this is the result.The graph of the variation of the UCS with different percentage of the fly ash in the expansive soil are given below:

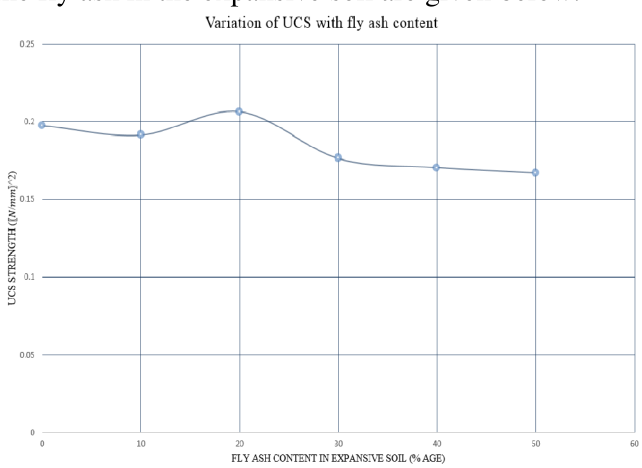

Figure-4: Variation of UCS values with different fly ash content in expansive soil

3. CONCLUSION

It is necessary to stabilize expansive soil in order to mitigate the detrimental effects that it has on components of the infrastructure, such as roads and buildings. This study revealed an innovative method for using activated fly ash as a soil stabilization agent in order to deal with expansive soil. As a chemical activator for the fly ash, the usage of sodium hydroxide and sodium silicate was used. The procedure for producing the sample, the amount of chemical additive, the curing of the sample, and changes in the basic geotechnical properties of expanding soil are all topics that are covered in this article. Following is a list of findings that may be drawn on the basis of the data that was acquired and its subsequent analysis:

- The chemical composition of the activated fly ash and the time of the curing process are discovered to impact the unconfined compressive strength of the soil.
- Samples with a molal concentration of 10 are more cost-efficient than those with a molal concentration of 12.5 or 15, due to the fact that their three-day and seven-day strengths are higher.
- It has been shown that samples with 12.5 molal are more durable.
- The greatest three-day strength that can be achieved by activated samples is 392.7 kPa, which is 3.25 times greater than the maximum three-day strength that can be achieved by fly ash-treated samples.
- Activated samples have a maximum 7-day strength of 546.88 kPa, which is more than twice as much as the maximum 7-day strength reached by samples that have been treated with fly ash. Activated samples have maximum 7-day strength of 546.88 kPa.

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