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Stabilization of Expansive Soils Employing Activated Fly Ash: A Review

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Abstract - *From the Egyptian pyramids to the current global twin tower, there is historical proof of changes taking place in the globe. This is because each change in structural development depends on a thorough examination of the soil's existing conditions by civil engineers. Expansive soil is a phrase used to describe any soil that has a high potential for shrinking or swelling owing to any change in moisture content. It is one of the troublesome soils. If expansive soils are found, it is important to recognise them and take the proper corrective action to either change the soil or lessen their negative impacts. The goal of this work is to enhance the expansive soil's qualities while also examining the impact of additives on the expansive soil's geotechnical features. The results of laboratory tests carried out at CSMRS for stabilising problematic soil in Subarnarekha Main Canal are provided in this study effort. Flyash from Parichha Thermal Power Station and hydrated lime were chosen as two additions and combined with the soil in varying proportions. The findings show that the expanding soil works well when combined with lime and fly ash.*

Key Words: Expansive soil, swelling characteristics, stabilization, fly ash, MDD, OMC, UCC.

1. INTRODUCTION

Significant structural and geotechnical issues may be presented everywhere in the globe by expansive soils (ES). Significant flaws may be introduced into lightweight construction as a result of the swelling and shrinking of the soil. When exposed to ES movement, lightweight structures often suffer from some kind of damage. It was pointed out in reference that the problems associated with ES are not the result of a lack of technical solutions; rather, they are the consequence of an inability to identify the existence and severity of swell/shrink of these soils in the early stage of the project. South Africa, Morocco, Mexico, Israel, Spain, Turkey, Iran, Great Britain, Ethiopia, Ghana, Australia, the United States of America, and Argentina are among the countries that have claimed economic losses as a result of ES. It is predicted that R100 million would be needed each year to cover the expense of repairing building damages caused by ES in South Africa. Damages caused by ES are estimated to amount to £400 million per year in the United Kingdom. According to estimates provided by the American Society of Civil Engineers, twenty-five percent of homes have some kind of damage that was caused by ES. Damages caused by ES result in an annual financial loss that is more than that caused by hurricanes, floods, tornadoes, and earthquakes combined. It was discovered that several geotechnical approaches may be used to produce soil stabilisation. These techniques change and enhance the condition of inappropriate ground in situations in which soil replacement is either not feasible due to technical and environmental factors or is not cost-effective. It has been reported that the cost of cut to spoil of ES during construction projects of airports, roads, and buildings has been steadily rising owing to the massive cost of removal and haulage, as well as the acute scarcity of spoil areas caused by the development of the city. In addition, the right materials to borrow keep on running out, and their locations keep moving a great deal farther away from the spot where they would be necessary. Because of this circumstance, research into practical techniques of ES improvement and application has been prompted. The purpose of the geotechnical process known as soil stabilisation is to maintain stability, improve engineering properties, limit water absorption capacity, and improve compressibility of the soil that has been treated. These goals can be accomplished through the use of mechanical, chemical, or other alternative treatment methods. According to the findings of other studies carried out by, the functions of soil stabilisation include increasing liquefaction resistance, filling voids, providing lateral stability, reducing imposed loads, controlling deformations, improving bearing limit, enhancing shear strength, increasing density, decreasing soil plasticity, and lowering the potential for swelling and shrinkage. The main goal is to investigate, characterise, and then report on the advantages and disadvantages of various mechanical and chemical treatment approaches. Nevertheless, the investigation will put additional emphasis on cost-effectiveness, geoenvironmental concerns, and standardisation issues.

1.1. Compaction

The primary objective of soil compaction is to produce a kind of soil that is capable of meeting the following three essential requirements: reduction in the following settling of soil material when it is subjected to living loads. Because of the decrease in permeability, earth dams will not experience a rise in the water stresses that cause liquefaction and will have a lower water content. Lastly, you should work to increase the soil material's shear resistance as well as its bearing limit. In addition, the impact that compaction has on the qualities of the soil is largely dependent on the structure that the soil achieves throughout the process of compaction.

The compaction curve is used to determine the optimal water content, also known as WOP, as well as the maximum dry unit weight, also known as dmax. For the purpose of determining the WOP and dmax of partly saturated fine-grained clay soils, a new mathematical idea that makes use of the differential function () and graphical approach was proposed. According to the findings, the values of WOP and dmax are both less than 0.5 percent and are considered to be inconsequential in classical soil mechanics. However, the soil moisture deficit values that are caused by WOP are very essential for soils that are only partly wet. An reliable evaluation of the compaction properties of partly saturated fine-grained clay soils may be obtained via the use of the mathematical technique. The values of the SS on the dry side of the WOP are greater than the values on the wet side, and compaction at the WOP may reduce the SS by as much as 15%. In addition to this, the swelling parameters and geotechnical index features have an effect on the SS of the compacted ES. Nevertheless, there is a significant influence that may be exerted on SS by the kind of clay material. The findings indicate that the shear strength of heaving soils greatly improves whenever the PL level is increased. The inquiry completed the SP of different compacted ES put at various starting water content (Wi), and the results demonstrate that the SP of compacted ES decreases as the beginning water content rises. The dry unit weight was also measured during the investigation (Wi). In addition, the research that was carried out on semi-empirical correlations for the SS of heaving soils in Barranquilla, Colombia, revealed that the SP of compacted ES decreases as the Wi rises. This was discovered as a result of the research that was carried out. Nevertheless, when you play at WOP, the SS will become higher whenever the Wi does. According to the findings, there was a positive exponential connection between the SS and the dry unit weight, however there was a negative exponential correlation between the SS and the moisture content.

1.2. Soil Replacement

Soil One of the mechanical soil stabilisation techniques that is used most often is called replacement. The active zone depth, soil profile, routine activities, and building requirements all play a role in determining the soil depth that has to be changed. Materials used as backfill have to be impermeable and stable, without any tendency to expand or contract. Additionally, backfill ingredients, particularly remodelled in-situ soil, need to be replaced and compacted using appropriate compaction criteria. If the material that is being used to replace the soil is porous, such as gravel or coarse sand, it will allow the surface moisture to be transmitted to the expanding clay layer and will cause differential movement that is similar to the surface. It is against the rules to use sand and gravel in place of soil resources in replacement projects. The most effective strategy, on the other hand, is to remove the problematic soil and replace it with a substance that has a greater ability to bear stresses. Last but not least, due to the greater costs associated with the replacement of some undesirable soils, such as swelling soils, the most cost-effective restoration approach can incorporate an effective stabilising technique.

1.3. Blending of Various Soils

During the process of mechanical stabilisation, the native soil and another soil with various concentrations are combined and stirred together. This is done in order to get the required intensity of the combined product at the end of the process. This stage may be carried out at the place of work or at an altogether other location before the mixture is delivered to the jobsite, distributed, and compacted to the required density. Alternatively, this step may be carried out at the jobsite itself. In addition, one method for stabilising soil is to combine it with a certain quantity of an additional product and then mix the two together. These additives have the ability to change the texture, gradation, shear stress, and flexibility of the soil, or they may function as binders for the process of soil cementation. Both of these outcomes are possible. Examining the impact of exchanging the ES for a combination of sandy-reused EP (extended polystyrene) is one of the things that is being done at the moment. It was shown that mixing the soils together decreased the swelling capacity while concurrently raising the compaction parameters (WOP, dmax) in response to an increase in the EP. This was the case even though the EP remained the same.

2. LITERATURE SURVEY

After studied the various research paper related to this topic, the summary of all paper are given below:

Parimala et.al: The investigation's main finding is that the liquid limit of expansive soil lowers as fly ash content rises. Additionally, the liquid limit of expansive soil falls with a fixed percentage of lime and an increasing percentage of fly ash. As the percentage of fly ash increased, the plastic limit of expansive soil fell. However, the 5 percent Lime Fly Ash addition initially raised the plastic limit. As a result, both soil fly ash and soil-lime and fly ash mix plasticity indices steadily reduced. Variable fly ash also affects the compaction properties of expansive soil; specifically, OMC of expansive soil increases with increased fly ash and MDD decreases with increased fly ash. Similar to how fly ash and constant lime alter compacting qualities of expansive soil, expansive soil's OMC increases with constant percent lime but its MDD decreases with constant percent lime. With rising fly ash, expanding soil's UCC value also rose. Additionally, the UCC value of expansive soil rises with an increase in fly ash content (5 percent lime). Conclusion: Waste materials like fly ash may be used efficiently in the building of civil engineering, but they become much more useful when lime is added in amounts greater than 5%. As the fly ash percentage rises, the swelling pressure falls. Additionally, swelling pressure was entirely abolished once lime was added to soil-fly ash samples.

Reshma et.al: The use of Alcofine and PPF in soil stabilisation is discussed in the paper. Alcofine-1101 is applied in a variety of amounts, including 0%, 5%, 10%, 15%, 20%, 25%, and 30% by weight of soil, with the amount of modified polypropylene fibre being constant at 1% for RS and BCS. The engineering qualities of soil are evaluated experimentally, and the UCS and CBR tests are used to ascertain the shear characteristics of the soil. The data show that adding admixtures improved all of the soil's characteristics and produced superior outcomes. According to the results of the Atterberg limit test, the water content decreases as the amount of admixtures increases. The chemical reactivity with soil and water is enhanced by an industrial waste including cementitious materials and lime. By doing so, the soil becomes less brittle and strengthens the connection between soil particles. The Atterberg limits and OMC are reduced as a result of this chemical reaction, which also absorbs the MC. MDD has consistently increased in value with an increase in admixtures, according to SPC strength tests, which demonstrated this. Additionally, OMC has reduced as admixtures have increased, indicating less water absorption. Alcofine increases the soil's rigidity and stability. This increases soil strength and significantly reduces volume change. The quantity of admixture has increased while UCS has improved. In RS and BCS, the maximum UCS at 20 percent alcofine is determined to be 132.64 kN/m2 and 106.87 kN/m2, respectively. The findings of the CBR test also demonstrated how the value of the compound increased as admixtures increased. Results of the wet CBR test four days later showed a higher value than the unsoaked CBR test. Unsoaked CBR value displayed maximum values of 26.28 and 19.24 percent, respectively, with higher Alcofine percentages in RS and BCS. Similary, with a 30 percent inclusion of acetoin in RS and BCS, the greatest value achieved after 96 hours of curing is 21.65 percent and 17.93 percent, respectively. The CBR value for both the soil and in both damp and unsoaked conditions has increased significantly, according to the results. We can state that 20% Alcofine has provided the best strength in both soil types, and strength gradually diminishes over 20%. We may thus deduce that 20 percent is the ideal Alccofine admixture concentration for soil stability. Future research might focus on the microstructural characteristics of soil, soil deformation, and the influence or impact of temperature on the soil. Additionally, the ability of the soil to withstand seismic vibration may be further investigated in order to address the issue of settlement and, as a result, prevent the destruction or collapse of buildings during disaster operations.

Anand: The best moisture content was achieved by adding bentonite to geopolymer with 20% fly ash and 10% alkali solution, while the best MDD was achieved when adding bentonite to geopolymer with 40% fly ash and 10% alkali solution (15 percent). The amount of fly ash and alkali solution was discovered to affect the UCS value of the geopolymer stabilised bentonite; the highest UCS value was observed at 40% fly ash and 10% alkali solution. According to a durability test, bentonite with 40% fly ash and 10% alkali solution had the highest resistance to loss in strength (RLS), which decreased when 15% solution was added. Based on the differential free swell test, it was shown that the swelling percentage significantly decreased when the proportion of alkali activated fly ash was raised. Bentonite + FA (20%) + S (10%) and bentonite + fly ash (20%, 30%, and 40%) + S (15%) required 3 days of cure before the swelling percentage decreased and the treated soil showed no swelling. Similar findings were found for bentonite + fly ash (20%, 30%, and 40%) + S (5%, 10%, and 15%) after 7 days of curing and for bentonite + fly ash (20%, 30%, and 40%) + S (5%, 10%, and 15%) after 14 days of curing. Bentonite was shown to be incredibly dispersive based on the results of the crumb test and double hydrometer test (84.87 percent). With the addition of more than 5% geopolymer, it stopped being dispersive. For dispersive soil, it was found that adding biopolymer caused OMC to rise while MDD to fall. However, the inclusion of biopolymer raised the UCS value. It was found that dispersive soil stabilised with guar gum had more strength than that stabilised with xanthan gum at the same gum content. According to the durability test, Xanthan gum (1%), along with guar gum, had the highest RLS (1 percent). RLS dropped when Xanthan gum percentage was raised, however the ideal RLS for guar gum was 1 percent. According to the crumb test and double hydrometer test, white soil was found to be very dispersive (89.57%) before becoming non-dispersive with the addition of biopolymer. It was noted that for pond ash, OMC increased and MDD reduced with the addition of biopolymer. However, the inclusion of biopolymer raised the UCS value. It was found that pond ash stabilised with Guar gum had more strength than that stabilised with Xanthan gum at the same concentration of gum. The sample stored indoors covered with film or wax has a lower UCS value than the sample that has been sun-dried.

Vikram et.al: Utilizing fly ash to stabilise weak expansive soil following alkali activation improves expansive soil's geotechnical characteristics and performance. Additionally, it offers the finest option for managing and disposing of fly ash by using it properly; otherwise, fly ash proves to be disastrous for people and the environment. The use of fly ash stabilised with alkali serves the dual purposes of improving the geotechnical properties of expansive soil and being environmentally friendly because fly ash would have otherwise been dangerous to people and the environment, according to the analysis of all the research conducted by various researchers. By being added to weak expansive soil in a variety of proportions to total solids at the ideal moisture level, alkali activated fly ash stabilises it. Utilizing fly ash to stabilise weak expansive soil following alkali activation improves expansive soil's geotechnical characteristics and performance. Additionally, it offers the finest option for managing and disposing of fly ash by using it properly; otherwise, fly ash proves to be disastrous for people and the environment. The use of fly ash stabilised with alkali serves the dual purposes of improving the geotechnical properties of expansive soil and being environmentally friendly because fly ash would have otherwise been dangerous to people and the environment, according to the analysis of all the research conducted by various researchers. By being added to weak expansive soil in a variety of proportions to total solids at the ideal moisture level, alkali activated fly ash stabilises it. Even after 28 days of curing, the cyclic, static, and dynamic tests for alkali activated fly ash used to support soil as a cementing material demonstrate an important gain in stiffness with curing. In contrast to cement-treated soil, the stiffness rise in alkali activated fly ash-treated soil is slow. From 28 to 90 days after treatment, the stiffness value doubles. Applying alkali activated fly ash to poor expansive soil improves its California bearing ratio value, allowing for a significant reduction in pavement thickness.

Yaseen et.al: When comparing the findings, it was found that the combined addition of 1% nano cement and 1% nano clay gave the test on peat soil the greatest strength (2 percent nano cement, 2 percent nano clay, and combined addition of 1% nano cement, 1% nano clay). The maximal strength of the soil was established by adding nanocement and nanoclay. Thus, it was determined that mixing both admixtures would yield the most strength (Nano cement and Nanoclay).

Zumrawi: A study was done to find out how fly ash activated by cement affected expansive soils' geotechnical properties in relation to their usage as pavement subgrade. Based on the findings and literature analysis, the key findings of this study are as follows: Fly ash coupled with cement is an efficient agent of soil stabilisation. In order to determine their impact on geotechnical qualities, expansive soil was treated with varied concentrations of fly ash (0, 5, 10, 15, and 20 percent) together with a set cement content of 5 percent. The expansive soil's inherent swelling values were dramatically decreased by the cement-fly ash stabiliser. With an increased proportion of fly ash mixed with 5% cement, the swell potential and swell pressure values reduced from 18.7 to 4.5 percent and from 175 to 75 KPa, respectively. It has been noted that adding 5% fly ash to 5% cement causes a significant drop in swell potential and swell pressure of roughly 60%, which then slowly decreases for every 5% fly ash addition. Cement-fly ash admixture treated soil showed a noticeable increase in strength. The majority of the strength increases occurred throughout the soaking phase, indicating that stabilising responses and strength increases were continuous. While the majority of the fly ash stiffness increases were attained relatively early in the curing phase with no further gains over time, soil treated with cement may be experiencing the development of extra inter-particle linkages over time. The soaked CBR rose with increasing fly ash up to a fly ash level of 15% before gradually decreasing for 5 percent cement content. With the addition of further fly ash, CBR values gradually changed after seeing a significant improvement at 5% fly ash and 5% cement. It is evident from the data that expansive soils treated with 5% cement and 15% fly ash have a significant increase in strength and a noticeable decrease in swelling. In order to stabilise expansive soils for use as road pavement, it is therefore cost-effective to use 5% cement and 15% fly ash.

Reddy: The following conclusions may be inferred from the study's results and comparisons, which include: Therefore, adding fly ash reduces swelling and boosts the stability of the black cotton soil. The results of the soil-fly ash mixture's standard compaction test changed as the fly ash content did. When fly ash was added, it was found that the ideal moisture content and Maximum Dry Density (MDD) initially declined. Then, as the amount of fly ash in the soil-fly ash combination increases, the optimal moisture content increases. Consequently, when the amount of fly ash in the soil-fly ash combination increases, the Maximum Dry Density (MDD) decreases. The greatest value reported was at a fly ash percentage of 25% by weight. Maximum Dry Density (MDD) was found to alter with different flyash content. Standard soil compaction tests with a combination of 25% fly ash and varying amounts of alkaline material were performed. Maximum Dry Density (MDD) was shown to rise with increasing alkaline material, whereas optimal moisture content was found to decrease with addition of alkaline material. The soil's Unconfined Compressive Strength (UCS) is measured. The graph compares the Black Cotton soil's stress-strain behaviour. 1.122 kg/cm2 is the highest value of UCS that could be measured with dirt. With the exception of the fact that the highest value was recorded for a fly ash concentration of 25% by weight, the Unconfined Compressive Strength (UCS) of the soil with change in fly ash content followed a similar trend to that of the MDD values. It is noted that the soil, 25 percent fly ash, and alkaline material with varied alkaline material contents all have altered unconfined compressive strengths (UCS). The graph displays how UCS varies with different alkaline materials. It was found that the UCS value increased as the amount of alkaline material increased.

Augustin et.al: This study work conducts a thorough evaluation of ES treatment employing mechanical and chemical approaches, and the final remarks are as follows: The features of ES are improved by the treatment of ES using mechanical stabilisation, chemical stabilisation, and other additions. Initially, stabilisation can be accomplished more affordably and fully than when repairs are required to maintain an unstable condition. The research is sparse on the behaviour of stabilised soils under repeated loads. There isn't much information in the literature about the use of artificial intelligence to forecast an optimum stabilisation strategy using combinations of stabilisers, such as neuro-fuzzy, artificial neural networks, and genetic programming. This study work conducts a thorough evaluation of ES treatment employing mechanical and chemical approaches, and the final remarks are as follows: The features of ES are improved by the treatment of ES using mechanical stabilisation, chemical stabilisation, and other additions. Initially, stabilisation can be accomplished more affordably and fully than when repairs are required to maintain an unstable condition. The research is sparse on the behaviour of stabilised soils under repeated loads. There isn't much information in the literature about the use of artificial intelligence to forecast an optimum stabilisation strategy using combinations of stabilisers, such as neuro-fuzzy, artificial neural networks, and genetic programming. The effects of stabilisation on the index properties, compaction characteristics, UCS, CBR, and swelling properties of ES have been explored by researchers. There aren't many research on the mechanical properties of treated soils, including their splitting tensile strength, shear strength, stiffness, hydraulic conductivity, and effect of matric suction. Future research on the mechanical and chemical methods of treating ES should be conducted keeping in mind the aforementioned comments.

Anil. Shekhar: For soil samples that contain a mixture of 20% FA and 25% RHA, the liquid limit is lowered to 55%. For a soil sample that has a combination of 20 percent FA and 25 percent RHA, the plasticity index is reduced to 86 percent. For a soil sample that has a mixture of 15% FA and 20% RHA, the differential free swell is reduced to 75%. The content of specific gravity decreases.

Khalid, Sachit: It has been discovered that the chemical content in the activated fly ash and the curing time affect the unconfined compressive strength of soil. The 10 molal samples are more cost-effective than the 12.5 and 15 molal samples since they provide superior strengths of 3 and 7 days. The long-term dependability is higher for 12.5 molal samples. The handicapped sample's overall 3-day intensity is 392.7 kPa, which is 3.25 times higher than the intensity of the samples treated with fly ash. The impaired sample's average daily intensity was 546.88 kPa, which is two twice the average daily intensity of the samples. The handicapped sample's average 28-day intensity is 977.09 KPa, which is 2.7 times higher than the average intensity of the samples treated with fly ash. The mechanical strength and the activator/ash ratio are highly correlated. According to the findings, increasing this ratio is advantageous since it improves intensity outcomes, which in turn improves overall cost. Because it includes a rise in the activator/ash ratio, reducing the viscosity of the grout mixes to levels that are comparable to cement grout might have a detrimental effect on the final strength. Therefore, if viscosity is a major issue for a particular application, it is advised that a compromise be made between an ideal degree of viscosity and the lowest feasible activator/ash ratio. To efficiently manage large soil areas, alkali-activated fly ash can be utilised as a chemical stabiliser.

Krishna: The unconfined compressive strength of the soil is observed to change with chemical content in the activated fly ash and curing time, according to the results and discussions of those results. In comparison to 12.5 and 15 molal samples, 10 molal samples have superior 3 and 7 day strengths, making them more cost-effective. The durability of 12.5 molal samples is greater. Maximum strength over 3 days for activated samples is 392.7 kPa, which is 3.25 times more than the maximum strength over 3 days for samples treated with fly ash. The maximum 7-day strength achieved by an activated sample is 546.88 kPa, which is double what samples treated with fly ash can achieve. The maximum 28 day strength achieved by an activated sample is 977.09 kPa, which is 2.7 times more than the maximum strength achieved by samples treated with fly ash.

3. CONCLUSION

As the percentage of binder material rises, the OMC value also rises. For virgin soil, the OMC value is 24.09 percent, which is the highest. As the percentage of binder material rises, the MDD value continues to fall. The MDD value drops as the OMC of the mix rises. It is possible to see that during 0 days of curing, the UCS value falls as the percentage of binder material rises. This can be because the MDD value has decreased. One may notice that as the curing period lengthens, the UCS value rises. This is a result of the binders placed into the soil having a sluggish pozzolanic response. Additionally, it can be shown that for all combinations, the UCS values rise as the binder content does as well. This is a result of the creation of C-S-H, C-A-H, and C-A-S-H gels as a result of the pozzolanic reaction between soil and fly ash and soil and corex slag, which fills spaces and binds the particles together.

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