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REVIEW ON PERFORMANCE OF FLY ASH ON THE STRENGTH PARAMETERS IN COHESIVE SOILS

Smt Shilpa Bhavesh Patel
Lecturer in Applied Mechanics, Applied Mechanics Department
Government Polytechnic, Himatnagar

Abstract: Fly ash produced during the combustion of coal for energy production is an industrial by-product which is recognized as an environmental pollutant. Fly ash applications must be widely adopted at various levels to minimize environmental contamination. Fly ash is generally gray, abrasive, mostly alkaline and refractory. Fly ash is often placed in Class F fly ash and Class C fly ash. The geotechnical properties of fly ash, such as specific gravity, permeability, internal friction and reinforcement properties, are suitable for road and embankment construction, structural fillers and especially clay soils. The purpose of this paper is to investigate the mineralogical analysis by X-ray diffraction (XRD) analysis or scanning electron microscopy (SEM), the geological evaluation of waste and the reuse of coagulated soil strength parameters for geological evaluation of waste will be. Fly ash split). Major soil strength tests conducted in this regard are Compression, California Bearing Ratio, Uncompressed Compressive Strength, and Triaxial Test. A systematic review of the literature on fly ash performance for viscous soil strength parameters has been described.

Index Terms - Fly ash, waste material, strength parameters, cohesive soil.

I. INTRODUCTION

A large amount of coal is burned every year in coal-fired power plants. This creates serious problems that create landfills and cause potential environmental pollution. Fly ash is defined as the material extracted from the flue gases of furnaces calcined with coal. Fly ash often consists of vacancies made of silicon, aluminum, iron oxide and unoxidized carbon. In addition, the nature of fly ash depends on the type and method of coal used to develop the power plant. Expansive soils expand and contract due to changes in water content and loose strength when contained in water. Clayey soil generally has undesirable engineering properties such as low bearing capacity, high shrinkage and swelling properties and high moisture sensitivity. Montmorillonite is the most common of all clay minerals in expansive clay soils. Montmorillonite minerals exhibit high shrinkage and swelling properties. Many additives such as lime, cement, fly ash, bitumen, calcium chloride, sodium chloride have been used for stabilization of this soil. Stabilization of mixed expansive soils controls the soil's potential for changes in volume and improves soil strength. Using fly ash as an additive reduces shrinkage compared to soft soils treated with lime or cement alone. When fly ash is mixed with expansive clay, cation exchange, the presence of free lime and the pozzolanic reaction provide the necessary effect to regulate the expansion and improve the strength of the expandable clay. High lime (Class C) fly ash with other active agents is a more economical alternative for a wide range of stabilization applications. The addition of fly ash reduced the compressive properties of the expandable clay. Fly ash reduces settling of structures built on improved soils and shortens the time required to reach final settlement. Fly ash can be used to improve shear strength, cohesion and bearing capacity in the soil. The fly ash method also reduced the plasticity and free expansion properties. It also binds the soil particles together to increase the CBR value of the improved soil. In addition, fly ash has favorable properties such as low specific gravity, low compressibility, high volume stability and pozzolanic reactivity. Using industrial byproducts such as fly ash as an additive to civil engineering building materials does not seriously affect the environment. Table 1 shows various studies on the performance of fly ash in viscous soil.

II. LITERATURE REVIEW

Edil et al. [1] evaluated the effect of fly ash for self-bonding to stabilize soft and fine soil. California bearing ratio (CBR) and elasticity modulus ($MMrr$) tests were performed on the mixture. Other soft fine soil such as mineral soil and organic soil and other fly ash were used. Two of the fly ash is of high quality grade C and the remaining ash is out of specification. Tests were conducted on soil and soil-fly ash mixtures prepared with optimal moisture content and different humidity of optimum moisture content. The results showed that the addition of fly ash significantly increased CBR and increased mineral soil. On the other hand, the CBR of the soil fly ash mixture generally increases with fly ash content and decreases as the compaction content increases. In addition, fly ash must be strengthened over time to increase the resistance of the packaging material. Organic soils generally have much lower CBR and $MMrr$ values in inorganic soils. However, in wet or more plastic particulate soils, the modulus of elasticity has increased further.

Cokca [2] was used in high calcium and low calcium Class C fly ash for the evaluation of expandable soils and for the evaluation of expandable soil-lime, expansive soil-cement and expandable soil-fly ash systems. Lime, cement and fly ash were added to the expandable soil in different proportions. The specimens were subjected to chemical composition, particle size distribution, consistency limits, and free expansion tests. In addition, specimens with fly ash were healed, after which they were subjected to an oedometer free swell test. It can be concluded that the expandable soil can be successfully stabilized by fly ash.

Also, the plasticity index, activity and swelling potential of the sample decreased with increasing ratio of stabilizer to cure time

Prasad and Sharma [3] evaluated the effect of sand and fly ash clay soils for soil stabilization. The purpose of this study is to find a solution for the proper disposal of fly ash and also to provide a good underground structure for the construction of the pavement. The results showed a substantial improvement in the compressibility and California bearing ratio of composites including clay, sand and fly ash. The swelling of the clay also decreased after stabilization. The maximum dry density of the clay-sand-fly ash mixture decreased with the addition of fly ash and the optimum moisture content increased. Thus, stabilized soils can be used for flexible pavement construction in low-traffic areas.

Bose [4] used fly ash to stabilize the plastic clay. The geotechnical properties such as atterberg limit, particle size distribution, linear shrinkage, free expansion index, well pressure, compression characteristics, undefined compressive strength and virgin clay CBR value were evaluated and stabilized by fly ash. Expansive soils were stabilized with varying proportions of fly ash. As a result, the plasticity index of the clay - fly ash mixture decreased with increasing fly ash content. Therefore, the addition of fly ash increases the workability by the colloid reaction and the change of particle size. As the fly ash content increased, the free swelling index and the expansion pressure of the expanded clay mixed with fly ash decreased. In addition, the addition of fly ash decreased the optimum moisture content, but increased the dry density and found that the uncompressed compressive strength of the clay-fly ash mixture was maximum. Therefore, we conclude that fly ash has the potential to improve the engineering properties of expansive soils.

Kumar and Sharma [5] have published studies on the efficacy of fly ash in improving the engineering properties of expansive soils. The experimental program evaluated the effect of fly ash on the free expansion index, expansion potential, expansion pressure, plasticity, compression, strength and hydraulic conductivity characteristics of expandable soils. The results show that as the fly ash content increases, the plasticity, water conductivity, and swellability of the mixture decrease and the dry unit weight and strength increase. The resistance of the mixture to penetration increased significantly with increasing fly ash content relative to a certain moisture content. The non - cohesive ($ccuu$) of measured and unpredicted non - sheared shear strength and expandable soils mixed with fly ash increased with fly ash content.

Kate sought the possibility of using fly ash with or without lime to stabilize the expandable soil and improve strength and volume changes. The Free Expansion Index, Expansion, Expansion Pressure and Uniaxial Compressive Strength tests were performed on expandable soils by mixing bentonite and kaolin clay in different proportions. As a result, the swelling properties such as free swelling index, maximum swelling and expansion pressure decreased with increasing fly ash ratio. This value is significantly reduced by adding a small amount of lime to the fly ash. A negligible change in the value of non-shear compressive strength was observed with an increase in fly ash ratio. On the other hand, the addition of lime greatly increases this value. Soil stabilized with fly ash alone did not show significant change in immediate strength. However, healing increased the intensity significantly. As a final result, soil with low expansibility can be stabilized at an appropriate rate of fly ash. However, medium to high expansion should be used in small proportions of lime and fly ash.

Kumar Pal and Ghosh [7] presented the strengthening and expansion properties of fly ash and montmorillonite clay blends. Several types of fly ash with different proportions of montmorillonite clay have been added to each sample. The specimens were compressed to the optimum moisture content and maximum dry density. A standard Proctor compression test was used in this regard. The influence of permeability, free swelling index and plasticity of the fly ash-montmorillonite clay mixture was also evaluated. As a result, immediate settlement of fly ash occurred during short periods of consolidation and second settlement was insignificant. There was no significant change in the vertical compression of the fly ash sample. The compression index ($cccc$) of fly ash and montmorillonite clay showed a fast strengthening and a large durability of the mixture. So soft soils can reduce fly settlement using fly ash.

Phanikumar and Sharma [8] studied the effect of fly ash on volume change of highly plastic expandable clay and non-expandable clay with low plasticity. The effects of fly ash on the free swelling index, swelling potential and swelling pressure of the expandable clay were evaluated. The compression index and secondary strengthening properties of the two clays were also determined. The results showed that when determined at a constant dry unit weight of the mixture, the swelling potential and the expansion pressure decreased and increased when determined by a constant weight of the clay. Compression index and secondary aggregation coefficient of the two clays were decreased by addition of fly ash. Therefore, settlement of structures built on this stabilized clay has been reduced and harmonization took place in a short time. Also, as the fly ash content increased, the maximum dry unit weight increased and the optimum moisture content decreased.

Lopes et al. [9] investigated the feasibility of applying ply and flooring to the pavement layer by mixing these ashes with non-regressive sand-siliceous soils, with or without lime intoxication. This study presented the physical and chemical properties and compression, elastic modulus and permanent deformation results after solubilization and elution of environmental tests. The results indicated that the soil was dependent on the pressure at the bed and contained the inclusion of fly ash and mixture, which increased the value of elastic modulus. On the other hand, poisoning of the flooring immediately increased the elastic modulus of the mixture. With the presence of bottom and fly ash, the mixture with or without lime showed compatible mechanical behavior with the requirements of low traffic volume packaging.

Lin et al. [10] studied two expansive soils at microscopic sites to better understand the cation exchange capacity, mineralogical and microstructural changes that occur during Class C fly ash stabilization. X-ray diffraction (XRD) was used to observe mineralogical changes and a scanning electron microscope (SEM) was employed to observe microstructural changes. Energy Dispersive X-ray Spectroscopy (EDXS) was used to evaluate the stabilizer distribution within the specimen. The CFA stabilization process decreased the measured water content of the plasticity index (PI), the clay size fraction, the percentage of expansion, the expansion pressure and the characteristic curve of the soil water, and increased the uniaxial compressive strength. The reaction between the soil and the fly ash resulted in a proven iron oxide coating with XRD and energy dispersive X-ray spectroscopy. The combined effect of coagulation and coating reduces the water retention properties of the stabilized soil, reduces the expansion potential, and increases the soil strength

Vizcarra et al. [11] presented the characteristics of MSW incineration ash and evaluated the ash content in road pavement by mixing ash with clay. Chemical, physical and mechanical tests on the pavement structure and mechanical-empirical design were performed on soil mixtures with pure soil and other ash content. As a result, fly ash decreased the material expansion and showed an increase in California bearing ratio (CBR) and modulus of elasticity values. In addition, ash content and form were important in the end results and demonstrated the efficacy of MSW fly ash in the primary road pavement.

Mir and Sridharan have studied how to add high calcium and low calcium fly ash in different proportions to very expansive black cotton soils. The purpose of this study was to investigate the effects of fly ash on the physical, compressive and swellability of black cotton soils reached from laboratory testing and use of waste materials without significant environmental impact. The results showed that the liquid limit, compressive properties and swelling potential of the expandable soil-fly ash mixture were greatly improved and improved. When fly ash is added to black cotton soils, the maximum dry unit weight of the mixture decreases as the optimum moisture content increases and may be due to improved grading of the fly ash. In addition, the addition of fly ash improves the compressibility of the expandable soil.

Misra et al. [13] studied the stabilization properties of clay soils mixed with self-splicing C-class fly ash and laboratory evaluation of residual self-splicing of spliced Class C fly ash. The stabilizing properties were evaluated by reaching uniaxial compressive strength stiffness and expansion potential. Thus, 12 sets of mixtures of kaolinite and montmorillonite, self-bonded fly ash, and clay soil with an appropriate amount of percentage were compressed and cured. For the swelling test, the cured sample was submerged using a one-dimensional urinal meter device. Also unrestricted compression and CBR testing was used. The results showed that the optimum moisture content varied due to the addition of fly ash. The samples quickly attained compressive strength and stiffness within 7 days of the curing period and showed the greatest increase in the day due to the feed water hydration of the fly ash. As the montmorillonite content increased, the strength of the sample increased significantly. Increased fly ash content can reduce the expansion potential of stabilized clay. CBR values have shown that voided Class C fly ash can be a good substitute for bass course material.

Zha et al. [14] includes particle size distribution, atterberg limit, specific gravity, compressive properties, free expansion, expansion potential, expansion pressure, expansion pressure, fluidity, shrinkage and uniaxial compressive strength. In this regard, we examined the effect of curing time on swelling potential, expansion pressure and uniaxial compressive strength. The relationship between the plastic index and the expansion - contraction properties of the soil was discussed. The results show that as the fly ash or fly ash-lime content increases, the firing index, activity, free swelling, swelling potential, swelling pressure, and shrinkage rate decrease. As the curing time of the treated soil increased, the expansion potential and the expansion pressure decreased. There was no significant change in the unrestricted compressive strength. However, after curing of the sample, the unrestricted compressive strength increased significantly. Also, as fly ash and lime fly ash content increases, optimum moisture content and maximum dry unit weight have been reduced.

Nalbantoglu [15] used cation exchange capacity values to demonstrate changes in mineralogy of the fly ash-soil mixture and explained the reduction of plasticity and absorption. Cation exchange capacity values were used to illustrate the effect of the pozzolanic reaction on particle size and swelling potential of the treated soil. As a result, it has been found that fly ash is effective in improving the structure and plasticity of the fly ash-soil mixture by reducing the content of clay-sized particles, the plasticity index and the expansion potential. However, the reduced cation exchange capacity value indicates that the fly ash improvement in the mineralogy of the improved soil changes and produces new minerals. These pozzolanic reactions cause the soil to be more granular and less water-absorbing.

Prabakar et al. [16] investigated the behavior of soils mixed with fly ash and improved soil intrinsic performance. Three different types of soil and fly ash were used. The aim of this study was to reach the usefulness of fly ash-soil mixture and to improve the engineering properties of soil with better strength. The study also addressed the cost effectiveness of fly ash for soil improvement and dealt with compression, settlement, California bearing ratio, shear strength parameters and swelling characteristics. As a result, the addition of fly ash has been shown to reduce soil dry density and soil unit weight. Porosity and porosity changed with increasing fly ash content in soils. The shear strength of the mixture was improved by the addition of fly ash and increased nonlinearly. The value of cohesion was increased by the addition of fly ash, and this change was linear. Improvement of soil CBR value by addition of fly ash. The results show that the shear strength and internal friction angle of soils mixed with fly ash exhibit better strength. The use of fly ash in the soil also reduces the swelling of the soil. Even fly ash improves shear strength, cohesion and bearing capacity. So, this mixture can be used as a base material for roads, back charging etc.

Temimi et al. [17] studied the addition of fly ash in clay soils. Other clay-fly ash samples were tested with the Odomedo test to determine the effect of fly ash on the mechanical properties of clay materials. It has been found that the inclusion of fly ash in clay materials improves the mechanical properties of clays such as compressibility and strengthening. So compressibility and settlement decreased and clay strengthening increased.

Senol et al. [18] used fly ash for self-bonding without any other activator for the stabilization of four different types of soft layers. Samples were prepared by mixing fly ash with varying moisture contents and different contents. Laboratory tests such as index properties, compression, uniaxial compressive strength and CBR test were used. To develop the moisture-strength relationship, the samples were applied to uniaxial compressive strength and California bearing ratio test after a cure time of 7 days. To evaluate the effect of compression delay, the sample was mixed with water and compressed after 2 hours. The results show that fly ash has increased uniaxial compressive strength and CBR value and can be replaced by highway mild steel. Therefore, stabilizing the soft ground at a certain moisture content and minimizing the compression delay can maximize the strength of the mixture.

Bin-Shafique et al. [19] conducted an empirical study to investigate the long-term performance of fly ash to improve two microparticulate soils and conducted this by focusing on the effects of weathering, such as wet drying cycles and freeze-thaw cycles . The specimens were generated from low-plasticized clay and high-plasticized expanded soil and improved to Class C fly ash. Samples were subjected to 12 cycles of wet-drying and freezing-thawing in controlled laboratory conditions where the soil properties of the weathering mixture were changed to understand the long-term performance. A wet drying cycle carried out with moisture and brine. Also, a plasticity index test, a uniaxial compression test and a vertical swelling test were used. Fly ash greatly increased the uncompressed compressive strength of fine soil and reduced the plasticity and swelling potential. The freeze-thaw cycle reduced the stabilized sample strength, but after this reduction the strength was still higher than that of the unstable sample. The wet drying cycle with saline reduced the firing but did not affect the strength. A slight decrease in vertical expansion was also observed after the wet-dry cycle using physiological saline. The freeze - thaw cycle did not change the plasticity of the stabilized soil but reduced the uncompressed compressive strength of the stabilized expandable soil. Also, the vertical expansion increases rapidly and then increases very slowly.

Mirsa [20] investigated clay stabilization with Class C fly ash. The physical and chemical properties of fly ash and the compressive and strength behavior of soils stabilized with Class C fly ash were discussed. The examples were prepared by blending a small amount of bentonite with kaolinite. Fly ash showed fast hydration characteristics. High density and strength were achieved when compression was performed with little or no delay. However, delayed compression provides low density and robustness. The stabilization characteristics were observed to be related to soil mineral type and firing. Laboratory studies have shown that the use of C-grade fly ash in soil stabilization depends on re-content, moisture content, compression delay, strength development and curing method over time, and type of clay minerals. Therefore, these Class C fly ash is particularly suitable for use as a soil conditioner.

III. OVERALL CONCLUSIONS

The creation of fly ash is more than its utilization. It can be used as an alternative to conventional materials in geotechnical engineering and infrastructure construction. Future studies of fly ash in soil stabilization may result in significant savings in material costs if the desired results are found. Fly ash, on the other hand, is a good material for use in geotechnical engineering. If the unit weight of fly ash is low, it can be installed on soft soil. The addition of fly ash changed the physical and compressive properties of the granular and agglomerated soils. Fly ash can improve the aggregation of dispersed clay particles by making cation arrangement more suitable than ionized condition. According to the cation exchange process, the effect of fly ash on the expandable soil results in a marked reduction of the plastic index, activity and swelling potential. In addition, its pozzolanic reaction results in the formation of bound bonds with high shear strength and low volume changes. The combination of soil and fly ash improves liquid limits, plastic limits and CBR values to an acceptable extent. Fly ash increases strength and reduces shrinkage deformation of expansive soils. It can be concluded that the fly ash treatment method can be used to stabilize the expandable soil. There are a few recommendations for the future listed in this regard:

- More research is needed on mechanisms that effectively make non-standard fly ash effective to stabilize organic soils.
- The use of fly ash as a stabilizer for expandable soils has not been investigated. On the other hand, there is a need to find new uses for this material and in this case less fly ash is used.
- Further laboratory work is needed to understand the long-term behavior of expanded clay treated with fly ash and the effect of alternative drying and wetting on the

expansion, expansion, expansion pressure, and strength properties of the expanded clay for practical testing.

- Extensive research is needed to understand the mechanism and geological engineering properties of expanded soils stabilized by fly ash.
- The two problems of expansion and contraction of this soil will cause a lot of damage to the structure.
- Further research is needed to gain a deeper understanding of the relationship between microscopic mechanisms and mechanical soil characteristics that arise during the Class C fly ash stabilization process. Understanding this connection is important for numerically modeling the mechanical behavior of stabilized expansive soils.
- Further research may be required by evenly distributing the fly ash in the soil to obtain a linear curve.
- Additional experimental studies should be performed on other treated expandable soils to assess the performance accuracy of the plasticity index method in predicting the expansion-shrinkage characteristics.
- Some articles discussed the impact of Class C fly ash on the engineering properties of expandable soils, but did not use shrinkage reduction as an indicator of appropriate additive content selection.
- Future studies should consider the combined treatment of soils using fly ash and fiber methods as stabilizers.
- The relationship between the expansion shrinkage characteristics and the plasticity index of the additive stabilized expandable soil has not been investigated.

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