Stabilization of Expansive Soil by Industrial Solid Wastes by using Fly ash and Corex Slag

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***Abstract*— Minimizing the cost of stabilization and improving the swell-shrink behavior & strength of expansive soils are major concerns to geotechnical engineers dealing with construction project over problematic soils. Expansive soil has tremendous strength but it become soft when came into contact with water, it expands during wet condition and shrinks in dry condition because of its mineralogical composition. The stability of structure is majorly influenced by expansive soils. Structures failures due to swell-shrink behavior of expansive soil are reported by many countries. This study is focused to improve the behavior of such soil by chemical stabilization using Fly Ash and Corex slag - industrial waste used to mitigate the problems associated with expansive soil, as well as to solve the disposal problem caused by this waste which is a big environmental issue now a days, considering sustainable approach. Corex Slag's use in the stabilization of expansive soil is very limited. Its use has been mainly applied to the field of concrete in order to increase its strength. However, study related to using Corex Slag in conjunction with Fly Ash is limited that is why an attempt has been made in this experimental work to study the effect on compaction properties, UCS, soaked CBR of an expansive soil stabilized with different percentage of FA-CS mixes. The primary goal of this experimental research is to examine the feasibility of Fly Ash and Corex Slag as a soil stabilizer to improve strength and reduce swell-shrink behavior at all set of possible combination. The experimental results showed better improvement in swell-shrink behavior, unconfined compressive strength, Tri axial (UU Test) and soaked California bearing ratio when combined with Fly Ash – Corex Slag. The findings of this study revealed that Fly Ash in combination with Corex slag could be used as a pozzolanic material in soil stabilization to reach the target strength for structures with improved swell-shrink behavior.**

Keywords*— Fly Ash, Corex Slag, Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), Tri axial (UU Test), Stabilization.

1. INTRODUCTION

Improving site soil's engineering properties is called soil stabilization. Soils containing significant levels of silt or clay, have changing geotechnical characteristics: they swell and become plastic in the presence of water, shrink when dry, and expand when exposed to frost. Site traffic is always a delicate and difficult issue when projects are carried out on such soils. In other words, the re-use of these materials is often difficult, if not impossible. Once they have been treated with flyash and corex slag combination, such soil can be used to create embankments or subgrade of structures, thus avoiding expensive excavation works and transport. Use of lime significantly changes the characteristics of a soil to produce long-term permanent strength and stability, particularly with respect to the action of water and frost. The mineralogical properties of the soils will determine their degree of reactivity with lime and the ultimate strength that the stabilized layers will develop. In general, fine-grained clay soils (with a minimum of 25 percent passing the #200 sieve (74mm) and a Plasticity Index greater than 10) are considered to be good for stabilization. Soils containing significant amounts of organic material (greater than about 1 percent) or sulfates (greater than 0.3 percent) may require additional or special construction procedures.

The expansive soil as base of a structure is one that is always to be avoided due to the nature of swelling and shrinkage that will give bad impact. On the ground level it would look deep in roughly polygonal crack patterns in the dry season. If there are buildings, the floor and walls will crack due to shrinkage and swelling. This phenomenon is also to be seen on the pavement structure in which the flexible pavement surface would look corrugated and cracked.

Improvement of expansive soil properties has been done by adding various kinds of additives such as lime, fly ash, gypsum, PC and others. Respectively additives contribute to reduced swelling and shrinkage properties of expansive soil and also increase in the strength in the same time.

Expansive soils presence in India is limited to region of south Uttar-Pradesh, south Gujarat, south Chhattisgarh, Madhya Pradesh, Maharashtra, Parts of Telangana, Andhra Pradesh, Karnataka, Kerala, Goa. Commonly known as Black Cotton soils, it covers approximately one-sixth of the total area of our country. Such soils exhibit extreme stages of consistency from very hard to very soft when saturated.

The CBRI investigations indicate that bagasse ash has to be considered as a pozzolanic material like fly ash or any other conventional pozzolana. High surface area is required to expose the grains which are coated with iron oxide and carbonaceous impurities. They suggested that the material may be used for preparing lime ash mixture to be used locally as a mortar, especially in rural areas where availability is high.

2. MATERIALS AND METHODS

Combination can likewise be utilized to enhance stabilization. One such combination includes the utilization of lime and cement, which has been considered widely. Extra rigidity is a good characteristic for the soil and combination techniques, which are used to accomplish this. This study deals with the study of Flyash and Corex slag

2.1. Soil

Based on the properties, the soil can be classified as CH soil. The test on this soil and the results yields that there is presence of Montmorillomite in it. Hence the soil can be identified as Black Cotton soil.

2.2. Fly Ash

The fly ash sample is to be collected from the Cement Factory or nearby thermal plant. Fly ash, which is a waste material of coal combustion in the thermal power plants, is produced in large quantities in many parts of the world. The annual production of fly ash in India is about 100 million tones posing serious problems of disposal as well as air, land and water pollution. Hence, research and development are being carried out to use fly ash because of its potential for manifold applications.

The large-scale utilization of fly ash is possible only in geotechnical engineering applications either alone or with soil as stabilizer. Fly ash, due to its pozzolanic property like lime and almost free of cost (being an industrial waste) availability, may be thought as prospective additive/alternative to lime for soil stabilization, mainly on economic considerations.

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal.

Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.

When used as a mineral admixture in concrete, fly ash is classified as either Class C or Class F ash based on its chemical composition. American Association of State Highway Transportation Officials (AASHTO) M 295 [American Society for Testing and Materials (ASTM) Specification C 618] defines the chemical composition of Class C and Class F fly ash.

- Class C ashes are generally derived from sub-bituminous coals and consist primarily of calcium alumino-sulfate glass, as well as quartz, tri calcium aluminates, and free lime (CaO). Class C ash is also referred to as high calcium fly ash because it typically contains more than 20% CaO.

- Class F ashes are typically derived from bituminous and anthracite coals and consists primarily of an alumino-silicate glass, with quartz, mullite, and magnetite also present. Class F, or low calcium fly ash has less than 10%CaO.

In my study, I am using Class C FS because of its self-cementitious property, it will be appropriate for sub grade and foundation uses as it will give higher strength compared to Class F FS.

2.3. Corex Slag

The Corex slag used in the experimental work is to be collected from Cement Factory.Corex Slag consists mainly of silica and alumina derived from iron oxide ore, and lime added as a fluxing agent. Rapid cooling of slag using water quenching produces a glassy material that is slowly reactive with water.

Slag is a latent hydraulic binder in that it hardens very slowly in water but is much more reactive when activated by alkalis, for example calcium hydroxide, one of the products of Portland cement (PC) hydration. The performance of slag as a cementitious material depends on the chemistry of the material, the glass content, and fineness of the ground slag.

The hydraulic reactivity of ground slag is influenced by the chemical and mineralogical composition of the material. Compounds that increase reactivity include CaO, MgO and Al2O3 while SiO2 reduces slag hydraulicity. Analysis showed that GGCS had higher CaO, Al2O3 and MgO concentrations than GGBS, and lower levels of SiO2.

These differences in composition indicate that GGCS should have higher hydraulic activity than GGBS of equivalent fineness, when compared based on most accepted hydraulic activity formulae.

TABLE 2.1 *Chemical constituents of Corex Slag*

Compounds	% by weight
CaO	37.20
SiO_2	30.80
Al_2O_3	16.00
MgO	13.70
TiO_2	00.51
Fe_2O_3	00.87
MnO	00.09
K_2O	00.35
Na_2O	00.12
SO_3	03.19

2.4 Mix proportions

The mixes may thus be named as M1, M2, M3, and M4. The virgin soil mix may be denoted as M0.

TABLE 2.2. *Proportioning of Soil- Fly Ash -Corex Slag*

Sr. No.	Soil (%)	Fly Ash (%)	Corex Slag (%)	Binder Content (%)	Remarks
1	100	0	0	0	M0
2	65	10	25	35	M1
3	60	20	20	40	M2
4	55	30	15	45	M3
5	50	40	10	50	M4

3. RESULTS AND DISCUSSIONS

In the present study an attempt has been made to determine the optimum quantity of Fly Ash, Corex Slag and Soil mix by studying their various geotechnical properties. The geotechnical properties tested includes MDD, OMC, UCS and CBR values.

3.1. Compaction Characteristics

Standard Proctor test (light compaction) conducted on various mixes of Fly Ash, Corex Slag and Soil by varying the proportion of water in every mix. OMC and MDD determined as per IS 2720 (Part 8)-1983 shows that with an increase in the binder content, the OMC value keeps on increasing as the MDD value keeps on decreasing.

3.2. UCS Tests

The UCS test results conducted for the virgin soil mix M_0 and the FA-CS stabilized mix M_1, M_2, M_3, M_4 are compared. Thus, the optimum mix for UCS is mix M_3 with 45% binder content. Thus, the optimum FA-CS mix is 30% Fly Ash and 15% Corex Slag.

3.3 CBR Tests

CBR values of all mixes M_0, M_1, M_2, M_3, M_4 were found out in soaked condition with 3 days curing and 4 days soaking. Thus, the optimum mix for CBR is mix M_2 with 40% binder content. Thus, the optimum FA-CS mix is 20% Fly Ash and 20% Corex Slag.

3.4 Tri-axial (Unconfined Undrained) Test

The angle of internal friction value depends upon the amount of slag which is present in the binder. Thus, values for mix M_1 is the highest with the values decreasing with the decrease in the slag content in the subsequent mixes. The angle of internal friction increases with the curing period.

4. CONCLUSIONS

Experimental studies were conducted on expansive soil stabilized by Corex Slag and Fly Ash for use in pavements. The conclusions drawn from the experimental work are stated below.

[1] The OMC value keeps on increasing with an increase in the binder content%. The OMC value is the highest for virgin soil which is 24.09%.
[2] The MDD value keeps on decreasing with an increase in the binder content%. As the OMC of the mix increases, MDD value decreases.
[3] It may be observed that for 0 days curing period, there is a decrease in the UCS value with an increase in the binder content %. This may be due to decrease in MDD value.
[4] It may be observed that the UCS value increases with the increase in the curing period. This is due to slow pozzolanic reaction of the binders mixed in the soil.
[5] It may also be observed that for all the mixes, with an increase in the binder content, there is an increase in the UCS values. This is due to the pozzolanic reaction between soil and fly ash & soil and corex slag which results in the formation of C-S-H, C-A-H and C-A-S-H gels which helps in increasing the strength as they fill the voids and binds the particles together.
[6] The UCS value at 28 days curing of mix M_3 is 261% more than that of the mix M_0 (virgin soil). Hence, mix M_3 is the optimum mix giving the highest value after 28 days curing period. Thus, the optimum FA-CS mix for UCS test is 30% Fly Ash and 15% Corex Slag. Hence, this mix can be used for ground improvement after feasibility study.
[7] CBR value of mix M_2 is the highest for all the mixes. Thus, for CBR, the optimum FA-CS mix is 20% fly ash and 20% Corex Slag. Its value is 8.98 which is sufficient enough for this mix to be used for flexible pavement sub-grade material.
[8] The value of cohesion increases with use of binders. As the binder content increases, there is an increase in the cohesion value. With increase in curing period, there is an increase in cohesion value.
[9] The angle of internal friction value depends upon the amount of slag which is present in the binder. As in my mixes, the slag value keeps on decreasing; there is a decrease in angle of internal friction. The angle of internal friction, however, increases with the curing period.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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