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SOIL STABILIZATION WITH FLYASH AND RICE HUSK ASH

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ABSTRACT

The objective of this paper is to upgrade expansive soil as a construction material using rice husk ash (RHA) and flyash, which are waste materials. Remolded expansive clay was blended with RHA and flyash and strength tests were conducted. The potential of RHA-flyash blend as a swell reduction layer between the footing of a foundation and subgrade was studied. In order to examine the importance of the study, a cost comparison was made for the preparation of the sub-base of a highway project with and without the admixture stabilizations.

Stress strain behavior of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the flyash content was increased from 0 to 25%. When the RHA content was increased from 0 to 12%, Unconfined Compressive Stress increased by 97% while CBR improved by 47%.

Therefore, an RHA content of 12% and a flyash content of 25% are recommended for strengthening the expansive subgrade soil. A flyash content of 15% is recommended for blending into RHA for forming a swell reduction layer because of its satisfactory performance in the laboratory tests.

KEY WORDS: *Construction Materials, Rice Husk Ash, Flyash.*

INTRODUCTION:

Clays exhibit generally undesirable engineering properties. They tend to have low shear strengths and to lose shear strength further upon wetting or other physical disturbances[1]. They can be plastic and compressible and they expand when wetted and shrink when dried. Some types expand and shrink greatly upon wetting and drying – a very undesirable feature. Cohesive soils can creep over time under constant load, especially when the shear stress is approaching its shear strength, making them prone to sliding. They develop large lateral pressures. They tend to have low resilient modulus values[2]. For these reasons, clays are generally poor materials for foundations[3]. The annual cost of damage done to non-military engineering structures constructed on expansive soils is estimated at $220 million in the United Kingdom and many billions of dollars worldwide[4].

Flyash[5-7] was successfully used for stabilizing expansive clays. The strength characteristics of flyash stabilized clays are measured by means of unconfined compressive strength (UCS) or California Bearing Ratio (CBR) values. Depending upon the soil type, the effective flyash content for improving the engineering properties of the soil varies between 15 to 30% [8-10]. Rice Husk Ash (RHA) is obtained from the burning of rice husk. The husk is a by-product of the rice milling industry. By weight, 10% of the rice grain is rice husk. On burning the rice husk, about 20% becomes RHA[11].

The objective of this paper is to upgrade expansive soil as a construction material using RHA and flyash, which are waste materials. The objective of this paper is to upgrade expansive soil as a construction material using RHA and flyash, which are waste materials. The soils used in this study are found in and around the Tri-state area (parts of Pennsylvania, New Jersey, and Delaware) of Philadelphia. No research has been done on these soils with the aforementioned additives. Therefore, the results will be of immense benefit to the design and field engineers of various infrastructure facilities in the Tri-state area near Philadelphia.

MATERIALS:

SOILS

The properties of the expansive clay used in this investigation are given in Table 1. As per the USCS classification system, the soil is a CH soil. A plasticity chart showing the location of the soil is shown in Fig. 1.

FLYASH

Class C flyash was used. Its constituents are listed in Table 2.

RICE HUSK ASH

In this investigation, RHA passing through No. 100 sieve (150 micrometers) was used. The chemical composition of RHA is listed in Table 3. The RHA had 90.2% silica content. This high amount provides good pozzolanic action.

EXPERIMENTS

UCS, CBR, compaction and swell-shrinkage tests were conducted.

TEST METHODS:

Compaction

The tests were performed in accordance with ASTM D 1557. The specimens were of 102mm diameter and 116mm height. The degree of compaction of soil influences several of its engineering properties such as CBR value, compressibility, stiffness, compressive strength, permeability, shrink, and swell potential. It is, therefore, important to achieve the desired degree of relative compaction necessary to meet the required soil characteristics.

UCS

The UCS tests were performed in accordance with ASTM D 2166. The sample sizes were of 40mm diameter and 80mm length. At the Optimum Moisture Content (OMC) and maximum dry unit weight values of the natural soil, the tests were performed.

CBR

The CBR tests were conducted in accordance with ASTM D 1883. The sample sizes were of 152mm diameter and 126mm length. At the OMC and maximum dry unit weight values of the natural soil, the tests were performed.

Swelling

Consolidation test (ASTM D 2435) setup was used for determining the cyclic swell-shrink behavior of the soil. The sample sizes were 76mm and 50mm in diameter and height respectively. The samples were prepared at Proctor's dry densities. The RHA was mixed with 15% flyash and compacted to dry unit weight of $5.5 kN/m^3$ at a moulding water content of 120%. The compacted admixture was cured for 14 days and placed over the expansive soil. The efficacy of RHA as a cushioning layer between the foundation and subgrade was also tested using the consolidation test.

TEST RESULTS AND DISCUSSION:

The optimum moisture content and the maximum dry unit weight of the untreated natural soil were 20% and $15.5 kN/m^3$ respectively.

The effect of flyash and RHA on Unconfined Compressive Strength for a curing period of 28 days of the soil is presented in Fig. 2. When the RHA content was increased from 0 to 12%, Unconfined Compressive Stress increased from 660 to 1300 kPa. Further increase in flyash decreased UCS, indicating that 25% is the optimum value of flyash. Conversely, at any flyash content, increase in RHA up to 12% increases UCS. Further increase in RHA decreases UCS, indicating that 12% is the optimum value for RHA. The following mechanism explains the obtained improvements. The chemical reactions that occur when flyash is mixed with clay include pozzolanic reactions, cation exchange[12], carbonation and cementation. These result in agglomeration in large size particles. This causes the increase in compressive strength[13]. Influence of flyash content on the UCS of RHA is presented in Table 4.

The influence of flyash on the stress strain behavior of the clay specimens in UCS test is shown in Fig. 3. The flyash content varied from 0 to 30%. When flyash was increased to 25%, failure stress increased from 330 to 680 kPa and failure strain increased from 6 to 9%.

The influence of RHA on CBR of clay-flyash mix is shown in Fig. 4. At any flyash content, addition of RHA up to 12% led to increases in CBR. Further increase in RHA decreased CBR, indicating that 12% is the optimum value of RHA. When the RHA content was increased from 0 to 12%, CBR improved from 1.5 to 10. RHA has 90% silicon dioxide. This high amount of silicon dioxide reacts with calcium for generating pozzolonic materials. The pozzolonic materials increase the strength of the clay-flyash blend.

Soils with larger clay content swell and shrink in rainy and summer seasons causing differential settlements under various structures. The swell decreased with an addition of flyash. The reason may be due to cation exchange in the flyash-soil mix during which the sodium ions in the soil are replaced by the calcium ions in the flyash. The percent swell is the ratio in percentage between the increased height to the original height of the sample. Fig. 5 shows the influence of number of cycles on swell percent. Swelling pressure is the pressure corresponding to zero volume change of the sample. The cured, stabilized RHA –flyash of the required thickness was placed over the compacted soil. Consolidation test was carried over for 4 cycles. The vertical movement of clay soils with cushioning material stabilizes after 3 cycles of swelling and shrinkage. The ratio of thickness of RHA-flyash layer to that of the soil was varied from 0 to 0.6. Fig. 6 shows the influence of swell reduction layer thickness ratio on percent swell for various surcharges. The percent swell under nominal surcharge of 5 kPa, 50 kPa and 100 kPa was determined after inundation with water.

Low cohesion makes RHA a poor cushioning and construction material. However, after stabilizing with flyash and curing for 28 days, RHA acquires better cushioning properties and hence it can be used as a construction material between the subgrade and foundations. At 15% flyash, for a 28 day curing period, the UCS is 94 kPa as shown in Table 4. As per Kate and Katti[14], this qualifies as a cushioning material at 15% flyash. Similar results were found by Sivapulliah et al.[15] for an RHA-lime mixture.

PRACTICAL IMPLEMENTATIONS:

In order to examine the importance of this study, a cost comparison was made for the preparation of the sub-base of a highway project with and without the admixture stabilizations. For this purpose, an eight lane, heavy duty highway for a design period of 20 years was considered as per the AASHTO design procedures[16-20]. The highway is to be constructed with the following materials: pavement-a 6 inch high stability plant mix; base-a 6 inch bituminous treated base; and subbase-crushed stone. The subgrade is treated with 25% flyash and 12% RHA. A transportation cost of 66 cents per mile and a distance of 50 miles were considered[21]. A subbase of 13 inch thickness can be eliminated by treating the subgrade with RHA and flyash. The savings in cost per mile over control group (with natural subgrade) is $ 1.4 million as shown in Table 5.

There are field implementation hurdles to be overcome for the successful utilization of admixtures in road construction[22]. For example, achieving uniform mixing of RHA mixture is important in order to achieve the laboratory strength values in the field. Moreover, dust issues will be significant in the areas where wind velocity is high. Hydration/pozzolanic reactions may be significantly disturbed in extreme weather conditions such as extreme low temperatures, snow and rain. These will be the focus of future research on the use of RHA as admixtures for stabilization of weak soils for road bases.

CONCLUSIONS:

1. Stress strain behavior of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the flyash content was increased from 0 to 25%.
2. When the RHA content was increased from 0 to 12%, Unconfined Compressive Stress increased by 97%.
3. When the RHA content was increased from 0 to 12%, CBR improved by 47%.
4. The optimum RHA content was found at 12% for both UCS and CBR tests.
5. The swelling potential of expansive soil decreases with increasing swell reduction layer thickness ratio.
6. The vertical movement of clay soils with cushioning material stabilizes after 3 cycles of swelling and shrinkage.
7. An RHA content of 12% and a flyash content of 25% are recommended for strengthening the expansive subgrade soil while a flyash content of 15% is recommended for blending into RHA to form a swell reduction layer.

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Table 1 Soil Properties

Properties	Soil
Specific Gravity	2.64
% Passing #200 sieve	40%
Liquid Limit	45
Plastic Limit	24
Plasticity Index	21
Free Swell Index	17%
USCS Classification	CH

Table 2 Constituents of Fly Ash.

Constituents	%
SiO_2	55.0
Al_2O_3	20.3
Fe_2O_3	6.3
CaO	12.0
MgO	3.5
Alkali	1.0
SO_3	1.5
Heavy Metals	trace

Table 3 Chemical Composition of Rice Husk Ash

Constituent	%
Silica – SiO_2	90.23
Alumina – Al_2O_3	2.54
Carbon	2.23
Calcium Oxide – CaO	1.58
Magnesium Oxide – MgO	0.53
Potassium Oxide – KaO	0.39
Ferric Oxide – Fe_2O_3	0.21

Table 4 Influence of flyash on UCS of RHA.

Flyash, %	Unconfined Compressive Stress, kPa	
	14 days curing period	28 days curing period
15	101	94
25	159	144
30	238	230

Table 5 Reduction in Design Thicknesses of Sub-base and Savings in Cost due to the addition of Admixtures.

Design Traffic Std. axles, Millions	Admixture % by weight	CBR, %	Soil Support Value	Weighted Structural Number	Sub-base thickness, inches	Savings in cost per mile over control group, $ millions
20	Control group	1.5	2.4	6.5	13	-
	25% Flyash + 12% RHA	10	6.1	4.4	2”	1.4

List of Figures:

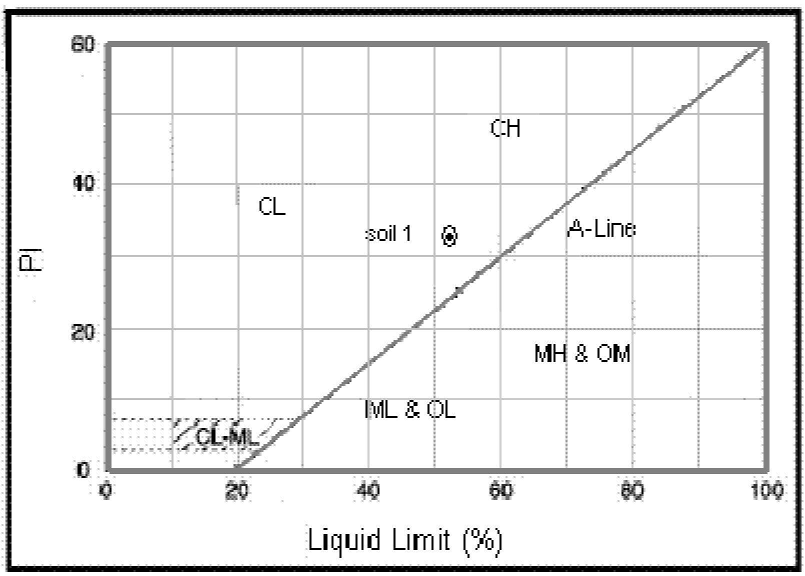

Fig. 1. Plasticity chart showing the soil.

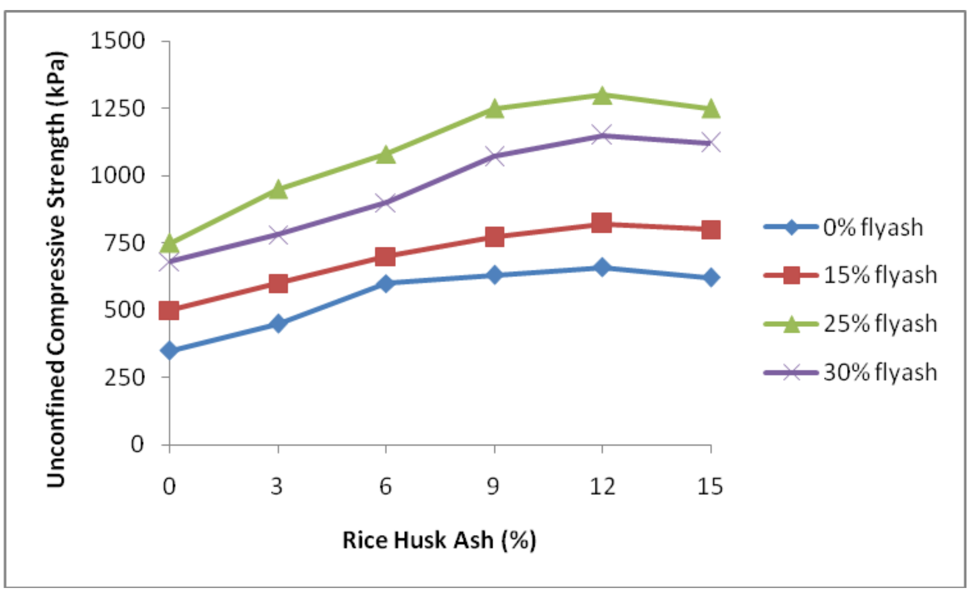

Fig. 2. Influence of RHA on UCS for clay-flyash mixture.

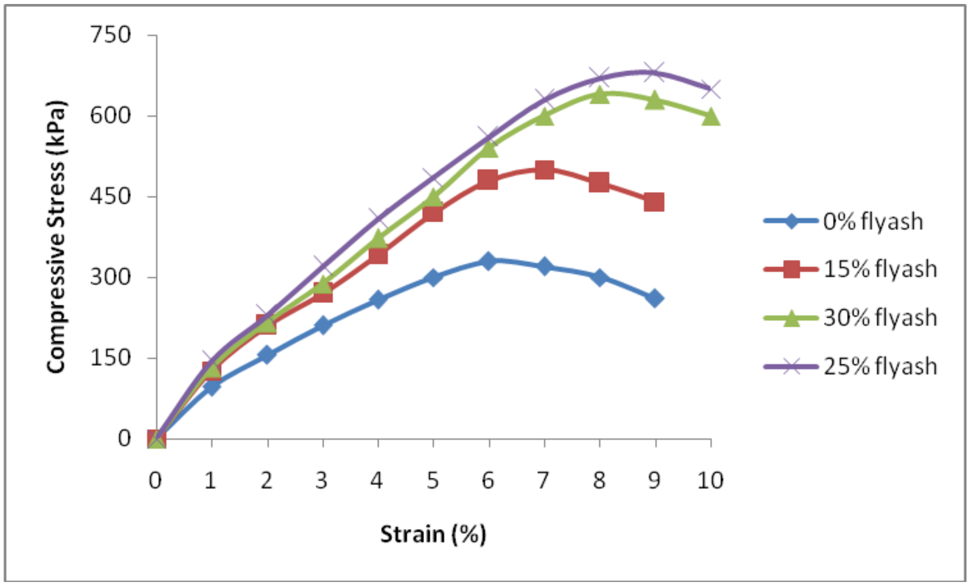

Fig. 3. Influence of flyash on the stress-strain behavior of the soil.

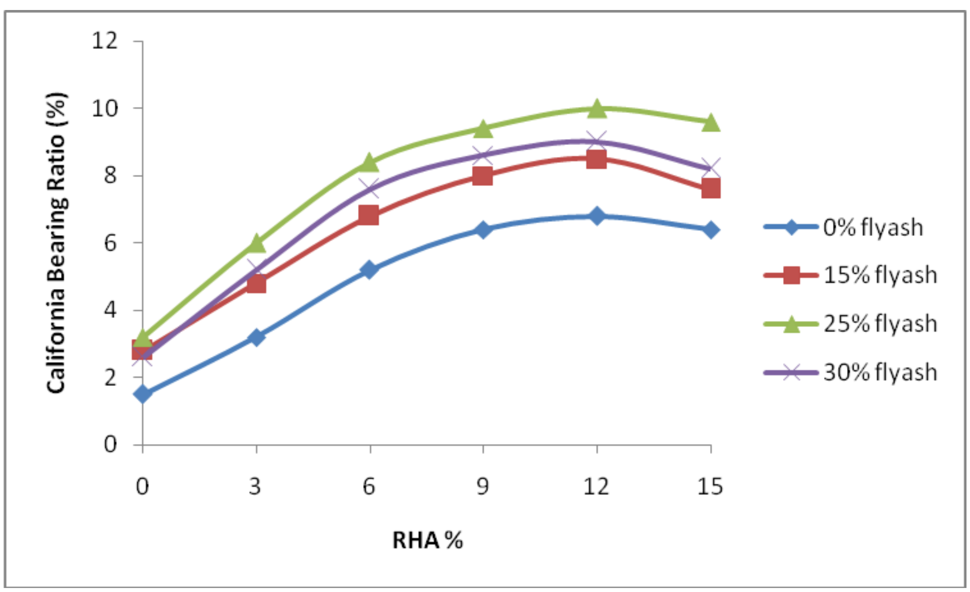

Fig. 4. Influence of RHA on CBR for clay-flyash mixture.

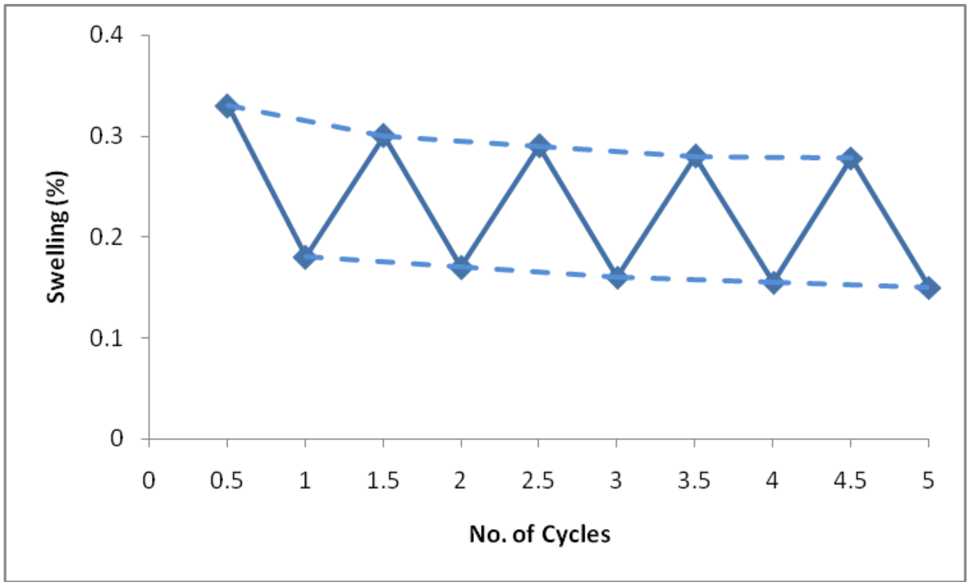

Fig. 5. Influence of number of cycles on swelling of 15% flyash and RHA blend under surcharge of 5kPa.

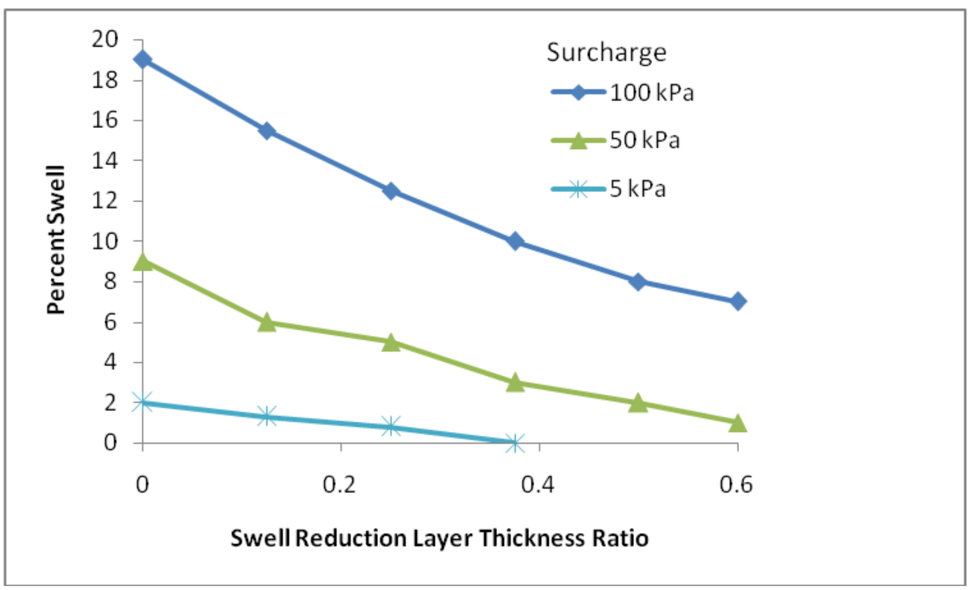

Fig. 6. Influence of Swell reduction layer thickness ratio on swell percentage of soil for various surcharges.