Stabilization of weak subgrade soil for road construction using fly ash and rice husk ash - Mahokanda, Sri lanka.

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Abstract: ***Roads construction projects require large quantities of suitable soils as a filling material. However, in urban areas, when roads are constructed, suitable filling soils have to be hired with enormous costs. Thus main objective of this research was to stabilize weak subgrade soils mixing with fly ash and rice husk ash. Weak sub-grade soil was obtained from Mahokanda construction site in Matara, Sri Lanka. Fly ash and rice husk ash were obtained from Lakvijaya power plant in Puttalam and rice mills in study area, respectively. Forty-eight weak subgrade soil samples were mixed with stabilizers (fly ash and rice husk ash) in different ratio and then 16 specimens were cured for 7 days while other 32 (2×16) samples were cured for 14 and 28 days, respectively. In order to find out maximum strength of each soil sample, different soil tests viz Atterberg Limits, Proctor Compaction, Swell Index (SI) and California Bearing Ratio (CBR) were carried out. Results revealed that maximum CBR value (36.01%) was obtained, when 70% of soil blends with 20% of fly ash and 10% of rice husk ash at 28 days curing period. Reason for the increment of CBR may be due to formation of cementitious compound in the mixture is due to chemical reactions of SiO2 in stabilizers and CaOH present in soils. Based on results, policy implications are discussed in relation to need of stabilizers in road construction projects in order to improve stabilizing weak subgrades while decreasing project cost and utilizing waste materials.***

Keywords: California Bearing Ratio, Fly Ash, Rice Husk Ash, Soil Stabilization.

1. Introduction

A roadway section consists of a complete pavement system (Figure 01) including its associated base course, sub-base course, sub-grade, and required system drainage components. The construction of long lasting, economical flexible pavement structures requires sub-grade materials with good engineering properties. The sub-grade should possess desirable properties to extend the service life of the roadway section and to reduce the required thickness of the flexible pavement structure. These desirable properties include strength, drainage, ease and permanency of compaction, and permanency of strength. (Yadav R.K. May 2014)

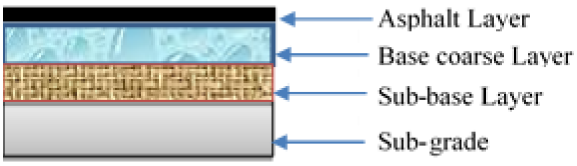

Figure 01: Road way cross section

A land-based structure of any type is only as strong as its foundation. For that reason, soil is a critical element influencing the success of a construction project. Soil is either part of the foundation or one of the raw materials used in the construction process. Therefore, understanding the engineering properties of soil is crucial to obtain strength and economic permanence. Geotechnical properties of problematic soils such as soft fine-grained and expansive soils are improved by various methods. Generally problematic soil is removed and replaced by a good quality material. In urban areas, borrow earth is not easily available which has to be hauled from a long distance. (Gandhi S.R. 2000)

Stabilization soils by using fly ash and mixture of lime or cement and fly ash is gaining more importance in recent times since it has widespread availability. This method is inexpensive and takes less time than other stabilization methods. Fly ash may be mixed with soil during excavation right in the field. Fly ash is a by-product produced during the combustion of pulverized coal in electric power plants. Coal ash contains 70 to 80 percent of fly ash and remainder is the bottom ash. Fly ash does not have any strength properties but together with water possess some cementation characteristics. The main minerals that can be found in fly ash are silica, alumina and secondary oxides of calcium, magnesium, iron and sulfur. Average diameter of particles is about 7 microns and is called as “pelerospheres”. Fly ash is similar to silt and has no plasticity properties. (Gaciarz R. May 2012)

An effective method for evaluating fly ash stabilization is to determine the moisture-density and moisture-strength relationship for the fly ash treated materials. This is accomplished by adapting American Society of Testing Materials (ASTM) C-593 (Standard specification for fly ash and other pozzolans for use with Lime). Stabilization of cohesive soils used for pavement sub-grades with self-cementing ashes can increase the California Bearing Ratio (CBR) by up to 20 times and increase the unconfined compressive strength by 3 to 12 times the untreated material. The increase in unconfined strength is influenced by the length of compaction delay and the hydration characteristics of the specific ash use for stabilization. (Nikil D. 2005)

The present investigation has been carried out with agricultural waste materials like Raw Rice Husk (RRH) and Rice Husk Ash (RHA) individually mixed with soil and also in combination with different percentage of hydrated lime with several mix proportions to study improvement of weak road subgrade. 5,10,15 and 20 percentages of RHA were mixed with soil stabilized with 3,6,9,12 and 15 percentage of lime in different combinations and also 2,3,4,5 and 6 percentages of RRH were mixed with soil stabilized with 6,9 and 12 percentage lime in several combinations and compacted at a water content of OMC+5% and tested for California Bearing Ratio(CBR) and Unconfined Compressive Strength(UCS) tests. The results show marked improvement in CBR & UCS values of the mixed soils in comparison with that of the original soil. The high percentage of siliceous materials present in RHA promises it to be used as a potential ground stabilizing/improving materials. The effect of curing of specimens was also investigated. It has been found that with increase in curing period UCS values as well as CBR value of lime RHA stabilized soil as well as lime RRH stabilized soil are increasing remarkably. (Biswas G. 2003)

Rice husk ash and Fly ash can be successfully used for stabilizing clayey peat soil. Fly ash and rice husk ash, which are waste materials comes from combustion of solid waste and rice husk. Rice husk ash attains good cushioning property when it is blend with fly ash and soil. Solid waste is generally defined as non-soluble material that is discarded in a solid or semi-solid form. This includes garbage, refuse, sludge and other discarded domestic materials, as well as waste from industrial, commercial, agricultural and mining operations and it has potential economic value. (Brooks R.M. December 2009)

Infrastructure projects such as highways, railways, etc. requires earth material in very large quantity. Laterite soil which is the product of borrow pit excavation is used as a sub-base and base course for construction of roads. In urban areas, borrow earth is not easily available which has to be hauled from a long distance. Quite often, large areas are covered with highly plastic and expansive soil, which is not suitable for such purpose. Soil stabilization is one of most important for the construction which improves the engineering properties of soil. Conventional method of concrete road construction consumes the natural resources like stone metal, sand, etc. and hence causes ecological imbalance.

The use of fly ash and rice husk ash (RHA) in concrete road construction will save such resources. Using fly ash and RHA, infrastructure development can be completed at lesser cost and will also help for environmental protection of our country. Thus main objective of this research was identify the best Soil:Fly-ash:Rice Husk Ash proportion to upgrade the bearing capacity of weak sub grade soil while other specific Objectives Reduce the construction cost of roads, Increase the durability of roads and reduce the maintenance cost, Reduce quantity of solid waste and reduce the environmental pollution.

2. Materials and Methods

<u>Materials used in the research</u>

Soil

Locally available sub-grade soil was used in the current study. Natural sub-grade soil was obtained from Mahokanda, the construction site which is located near to Matara, Sri Lanka. Soil was classified as fat clay (CH) according to the Unified Soil Classification System (USCS). The soil has approximately 52% particles passing the U.S. No. 200 sieve. It exhibits high plasticity. Plasticity Index of soil is 36.57. On visual inspection it was found to be grey clayey soil.

Fly Ash

The fly ash used in this study was high calcium Class C fly ash (12% CaO) obtained from Lakvijaya power Plant in Puttalam, Sri Lanka. The fly ash had a grayish color,
and a carbon content of 6-8%.

Rice husk Ash (RHA)

Rice Husk Ash (RHA) is obtained from the burning of rice husk. The husk is a byproduct of the rice milling industry. By weight, 10% of the rice grain is rice husk. On burning the rice husk, about 20% becomes RHA.

<u>Sample preparation and Testing method</u>

Forty-eight (48) soil samples were prepared. Each soil samples were sieved according to ASTM D 2216 over a #40 sieve to remove the larger particles. Weight of each sieved soil samples were 25 kg. In order to investigate the effect of fly ash and rice husk ash on engineering parameters of sub-grade clay soil, it was mixed with fly ash and rice husk ash in different ratio. For tests of specimens of mixed/stabilized soils, specimens were prepared by thoroughly mixing the required quantity of soil and stabilizers (Rice husk ash and Fly ash) in pre-selected proportion in dry state. All specimens were kept in desecrator after putting the specimens in sealed plastic bag for 7 days, 14 days and 28 days at room temperature before testing to investigate the effect of curing.

To study the plasticity of soil and fly ash mixes Liquid Limit and Plastic limit tests were made on Soil-Fly ash-RHA mixes as per ASTM D 4318-2009.

The compaction characteristics of soil-RHA-fly ash mixtures were studied using Standard Proctor Tests (ASTM D 698-2009). Standard compaction test uses a mold of volume 1/30 ft3 (945 ml) and the soil is compacted in 3 layers and each layer receiving 25 blows from a hammer of weight 5.5lbs (2.5 kg) with a free fall of 12 inches (305 mm).

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3. Results and Discussion

The Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI) of the untreated natural soil were 58.43%, 22.06% and 36.37% respectively. This shows that the soil is high plastic in nature. Whitlow states that if the LL of a soil sample is less than 35% it is a low plastic soil, between 50% and 70% high plastic soil, between 70% and 90% very high plastic soil, while greater than 90% is an extremely high plastic soil. According to the tabulated test results and the figures, on increasing Rice Husk Ash percentage in soil the Liquid Limit tends to decrease gradually. Lowest LL is 36.01%. It reported at 28 days curing period and corresponding Fly Ash:RHA:Soil ratio is 30:15:55. On increasing fly-ash and RHA percentage, the Plastic Limit tends to increase. The same follows when RHA content is on increasing with respect to certain percentage of Fly Ash. Highest PL is 39.83%. It reported at 28 days curing period and corresponding Fly Ash:RHA:Soil ratio is 30:15:55

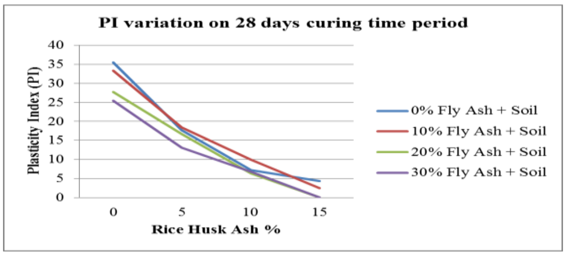

Figure 2: Plasticity Index (PI) variation on 28 days curing time period

On increasing Fly Ash percentage in soil, the Plasticity Index tends to decrease. Also on increasing RHA content, Plasticity Index tends to decrease gradually. The same follows when RHA content is on increasing with respect to certain percentage of Fly Ash. Lowest PI reported as 7.91% at 28 days curing period. Both 15 and 16 treatments indicate non-plastic behavior in 28 days curing period and corresponding Fly Ash:RHA:Soil ratios are20:15:65 and 30:15:55.Soil plasticity is a field indicator of slope stability. The engineering concept of soil plasticity has evolved to explain why some soils are more failure prone than others. Plastic soils exhibit clay-like behavior. Adding even modest quantities of water to such soils may cause unusually large and frequent slope failures. Naturally occurring tension and cracks have similar effects. At a high percentage of ash content, the soil lost most of its plasticity. Also by adding RHA soil lost its plasticity. This means that the soil behaves like a non-plastic material. This is undesirable since higher percentage of fly ash failed to render the Clayey soil the required binding properties. The fines present in the natural soil were non-plastic. However, it is well known that plastic fines play a major role in defining the strength of soil. Previous research indicated that the strength of fly ash-stabilized soil decreases with increasing plasticity index (PI), and Fly Ash is generally considered as a good activator when used for stabilization of granular soils.

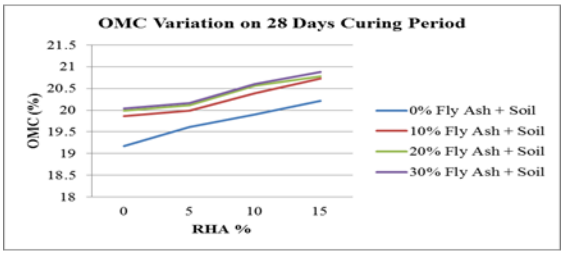

Figure 3: Optimum Moisture Content (OMC) variation on 28 days curing

The optimum moisture content (OMC) and the maximum dry density (MDD) of the untreated natural soil were 19.776% and 1.6802 g/cm3respectively. The pure soil sample has the highest maximum dry density (1.6802 g/cm3) at the lowest optimum moisture content (19.776%). The soil sample with highest fly ash content and highest RHA content exhibits the lowest maximum dry density (1.5201g/cm3) and highest optimum moisture content (21.384%).

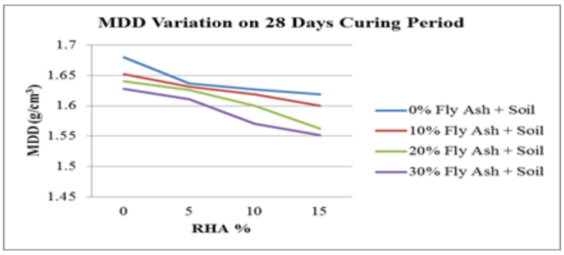

Figure 4: Maximum Dry Density (MDD) variation on 28 days curing time

When the fly ash content was increased from 0 to 30%, MDD decreased from1.6802 g/cm3 to1.5931g/cm3 in first seven days curing period. When the rice husk ash content was increased from 0 to 15%, MDD decreased from 1.6802 g/cm3 to 1.5913g/cm3in first seven days curing period and at any fly-ash content, increase in RHA up to 15% decreases MDD. Conversely, RHA increases up to 15% at any fly-ash content, and it causes to increase the MDD with the curing time period. When the fly ash content was increased from 0 to 30%, OMC increased from 19.776 % to 20.108% in 1st seven days curing period. When the rice husk ash content was increased from 0 to 15%, OMC increased from 19.776 % to 20.173%in first seven days curing period and at any fly-ash content, increase in RHA up to 15% increases MDD. Conversely, RHA increases up to 15% at any fly-ash content decreases OMC with the curing time period.

The decrease in the MDD can be attributed to the replacement of soil by the Fly ash and RHA in the mixture. Because of RHA and Fly ash have lower MDD values. The decrease in the MDD may also be explained by considering the Fly ash and RHA as filler (with lower specific gravity) in the soil voids. There is increase in OMC with the increase of Fly ash and RHA contents. This increase is due to the addition of Fly ash and RHA, which decreases the quantity of free silt and clay fraction and coarser materials with larger surface areas are formed. These processes need water to take place. This implies also that more water is needed in order to compact the soil-RHA-Fly ash mixtures.

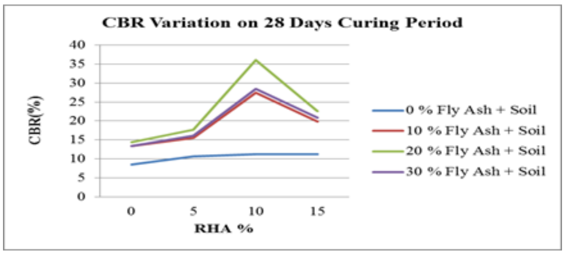

Figure 5: California Bearing Ratio (CBR) variation on 28 days curing time period

CBR value of the different admixtures with the original soil in varying proportion at OMC soaked conditions is shown in Table No 4.5.3Figure 4.5.4.1-4.5.4.3shows variation of CBR with Fly Ash and RHA combinations at OMC in Soaked condition.

California bearing ratio is the ratio of force per unit area required to penetrate into a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm /min. This test method covers the determination of the CBR of pavement sub-grade, sub base and base course materials from laboratory compacted specimens. The CBR value obtained in this test forms an integral part of several flexible pavement design methods.

For laboratory CBR tests, specimens were prepared in the CBR mould as per the standard practice. Immediately after preparation, specimen was submerged for four days for soaked tests. For every combination of soil and stabilizers, specimens were kept in closed dessicator after covering the same by plastic sheet for 7 days, 14 days and 28 days. Thereafter the specimens were tested for four days soaked tests to investigate the effect of curing.

As an indicator of compacted soil strength and bearing capacity, it is widely used in the design of base and sub-base material for pavement. It is also one of the common tests used to evaluate the strength of stabilized soils.

California Bearing Ratio (CBR) of the untreated natural soil sample was 8.5%. When the fly ash content was increased from 0 to 20%, CBR increased from 8.5 %to 13.37 % in 1st seven days curing period. Further increase in fly-ash decreased CBR, indicating that 20% is the optimum value of fly-ash. Conversely, at any fly-ash content, increase in RHA up to 10% increases CBR. Further increase in RHA decreases CBR, indicating that 10% is the optimum value for RHA. Also at any fly ash and RHA combination CBR increases with the curing time period. Maximum CBR value was obtained, when 70% of soil blends with 20 % of Fly ash and 10 % of RHA at any curing time period. The maximum CBR value is 27.94% in 1st seven days curing period. It increases up to 36.01 % in next 21 days curing period.
The reason for increment in CBR may be because of the gradual formation of cementitious compounds in the soil by the reaction between the Fly ash, RHA and some amounts of CaOH (Calcium Hydroxide) present in the soil. Fly ash and RHA have 57 % and 90% silicon dioxide respectively. This high amount of silicon dioxide reacts with calcium for generating pozzolonic materials. The pozzolonic materials increase the strength of the clay-flyash-RHA blend. The decrease in CBR at RHA content of 15% and Fly ash content 30% may be due to extra RHA and Fly ash that could not be mobilized for the reaction which consequently occupies spaces within the sample. This reduced the bond in the soil-RHA-Fly ash mixture.

According to clause 6201 of Federal Ministry of Works and Housing (F.M.W & H) Specification Requirement, the minimum strength of base course material shall not be less than 80% CBR (un-soaked) while minimum strength for sub-grade/fill shall not be less than 10% after at least 48 hours soaking. The sub-grade samples are good because they exhibit CBR (soaked) values that are even higher than what is stipulated in the specification.

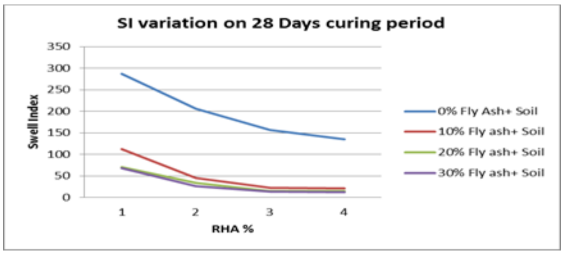

Figure 6: Swell Index (SI) variation on 28 days curing time period

Swelling percentages of the samples decreased considerably with increasing stabilizer percentages. The swelling percentage of soil is diminished by 56.04% after 7 days curing by adding 10% of fly ash. Reduction is continued with increasing fly ash percentages. The amount of reduction is decreased as fly ash additions increased. Adding 20% and 30% fly ash around 73%decreased the swelling percentage of Soil nearly by the same amount (72.81% and 73.74% respectively).5% rice husk ash (RHA) addition is caused a reduction of 44.35% in the swelling percentage of soil. A gradual reduction is continued up to 10% RHA addition. Reduction nearly slowed down thereafter. 10% RHA addition reduced the swelling percentage of soil by 44.21%, and 15% RHA addition resulted in a reduction of 52.32%. The swell index (SI)and swelling percentage are decreased gradually, when RHA content is on increasing with respect to certain percentage of Fly Ash as per calculated results and Figure 4.3.4.1, 4.3.4.2 and 4.3.4.3. This gradual reduction is continued up to Soil:FlyAsh:RHA combination of 70:20:10.Reduction nearly slowed down thereafter.

7 days, 14 days and 28 days curing provided considerable reductions in the swelling percentages of the samples. Reductions were gradual for each of the stabilizer additions. Swell Index (SI) value of each sample was the highest for 28 days curing and lowest for 7 days curing. That is each sample followed the order below:
(SI) 28 days curing > (SI) 14 days curing > (SI) 7 days curing
Curing helps the moisture to be distributed uniformly in the mixture, and by providing the time necessary for the development of pozzolanic reactions it encourages self-

hardening with time. The resulting cementitious soil matrix provides extra resistance against swelling and cause further reduction in swelling percentage.

Statistical Analysis using sas 10.1

According to the result P value is 0.0001 and it is smaller than the alpha value (0.05). Therefore, H_o is rejected. That means all the mean values of 16 treatments are not equal. And according to the result highest mean value is obtained from 11th treatment. Therefore 11th treatment is the best mixture for soil stabilization. The best ratio of fly ash + RHA+ Soil is 20: 10: 70.

4. Conclusions

Results suggest that maximum California bearing Ratio (CBR) value was obtained, when 70% of soil blends with 20 % of Fly ash and 10 % of RHA. The Plasticity Index (PI) and Swell Index (SI) of this proportion are good because they exhibit values that are even better than what is stipulated in the specification. Therefore, the best Soil-Fly Ash-Rice Husk Ash proportion for strengthening the weak sub-grade soil is 70%-20%-10%. Also Strength properties of treated soil increase with curing.

5. Other recommendations

In this study, the geotechnical performances of fly ash and rice husk ash (RHA) in stabilizing the weak sub-grade were presented. However, fly ash and rice husk ash (RHA) can contain materials like heavy metal that are harmful to the natural environment. The risks imposed on the environment by possible geotechnical applications of fly ash and rice husk ash (RHA) must be carefully weighed against creating new pollution sources elsewhere. Therefore, to define more clearly the conditions for a safe application from an environmental point of view this research must be extended by performing leachate analyses of the samples used in this study.

It should identify the field application of this method, by using suitable technology. Also cost-benefit analysis should be made to evaluate the effectiveness of this technology.

Only two types of stabilizers, Fly Ash and Rice Husk Ash, were used as a stabilizing agent in this study, further research could be done with wide range of chemical stabilizers.

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