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Stabilization of soil using Rice Husk Ash

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Abstract:

In today scenario, lack of stable ground for development of infrastructures is very common. In view of this, construction of buildings on unsuitable ground is unavoidable and making a suitable ground before constructions is real challenging issue for Geotechnical Engineers. To overcome the difficulties experienced with problematic soil in geotechnical applications on one side and safe disposal of solid wastes on the other side, an attempt is made in this investigation to explore the possibilities of utilizing solid wastes to improve the engineering behavior of problematic soil. In this, in this present investigation the type of solid waste namely Rice Husk Ash for stabilization is selected to study the effects of same on the index and engineering characteristics of problematic soil. The rice husk ash is mixed with soil in various proportions like 5%, 10%, 20%, 30%, 40%, 50% and 80%. The various tests were conducted on these proportions and optimized proportion is arrived.

Keywords: *Stabilization, Alluvial soil, clay, Rice husk ash, Index properties, Shear strength and California bearing ratio*

I. Introduction

Disposal of solid waste on the land fill can be minimized if the waste is having desirable properties such that they can be utilized for various geotechnical application viz. land reclamation, construction of embankment etc. There are several methods used for improving geotechnical properties of problematic soils that includes densification (such as shallow compaction, dynamic deep compaction, pre-loading), drainage, inclusions (such as geosynthetics and stone columns), and stabilizations. Chemical stabilization of the problematic soils is especially significant in concerning with the treatment of soft fine-grained, expansive soils, and collapsible loess deposits. Soil stabilization is the process which is used to improve the engineering properties of the soil and thus making it more stable. Soil stabilization is required when the soil available for construction is not suitable for the intended purpose. It includes compaction, preconsolidation, drainage and many other such processes. For instance, fly ash is solid waste from thermal power plant which is used for various civil engineering applications like manufacturing of cement and bricks and other geotechnical construction works. In present investigation the type of solid waste namely RICE HUSK ASH (RHA) is selected to study the effects of the index and engineering characteristics of problematic soil. In order to utilize the rice husk ash for the improvement of problematic clay a detailed program has been formulated and index, compaction, shear strength and CBR tests have been conducted on problematic clay and alluvial soil with increasing % of solid wastes.

II. Materials:

2.1. Natural Soil

The natural soil sample 1 (clay soil) was collected from a site in Kodambakam area at 1.5m depth from the ground level by making open trench. Soil Sample 2 (alluvial soil) was collected from a site in Thungachatram nearby Chennai at 1.5m depth from the ground level by making open trench. The soil samples thus collected were labeled properly and stored in laboratory. The collected soil then air dried at room temperature and there after soil lumps will be powered and sieved through 425micron sieve before the same are used for laboratory tests. The physical properties of natural soils were identified and classified.

2.2. Rice Husk Ash (RHA):

The rice husk ash was collected from Kamakshi rice mills Chennai, Tamil Nadu. In the form of ash which is a solid wasted which is disposed in the empty barren land as a solid waste. Rice Husk Ash is by-product material produced from the process of manufacturing puffed rice, contains large amount of iron oxide and silicate. It has higher density, stay in the top layer and then transported to a water basin with a low temperature for solidification. The end product is a solid, hard material that goes to the crusher for further processing. Annually 60,000 tons of rice husks are produced in India. It is chemically stable and its physical properties are similar to that of natural sand. The high angularity and friction angle (up to 530) of rice husk contribute to excellent stability and load bearing capacity. With specific gravities ranging from 2.8 to 3.8, rice husk aggregates are decidedly heavier than conventional granular material. Rice husk aggregate tend to free drying and are not frost susceptible. The constituents of Rice Hush Ash are listed in **Table 1**.

Table 1. Composition of Rice Husk Ash (RHA)

Constituent	Composition (%)
SiO_2	67.3
Al2O3	4.9
Fe2O3	0.95
CaO	1.36
MgO	1.81
Loss On Ignition (LOI)	17.78

2.3. Sample Preparation:

The sample for testing was prepared as per the requirement of the tests. The pulverized soil sample was first sieved through the required sieve for a particular test. The required quantum soil was weighed out for the test. The material to be added to the soil was also sieved through the required sieve, for the particular test and then the required quantum was weighed out on the weight basis as per the percentage to be added to the soil for test. The soil and the material were then mixed together in dry conditions thoroughly before testing. The mixed sample was then used for performing the various tests.

III. EXPERIMENTAL STUDY:

To study the effect of Rice Husk Ash on soil, the various proportions like 5%, 10%, 20%, 30%, 40%, 50% and 80% were mixed with natural soil. And laboratory tests were conducted to study the index and engineering properties.

3.1. Index properties tests:

The various index properties test like Specific gravity, Liquid limit test, Plastic limit test, Free swell index and Standard proctor compaction tests were conducted on natural soil and soil with various proportions like 5%, 10%, 20%, 30%, 40%, 50% and 80% of Rice Husk Ash.

3.2. Engineering properties tests:

The various Engineering properties test like Direct Shear test and California Bearing Ratio tests were conducted on natural soil and soil with various proportions like 5%, 10%, 20%, 30%, 40%, 50% and 80% of Rice Husk Ash.

IV. Results and Discussion:

The liquid and shrinkage limit, free swell index, compaction characteristics, shear strength parameters and CBR values were determined for clay soils and alluvial soils increasing the percentage of rice husk ash. The results are analyzed and discussed below.

4.1. Effect of RHA on Index properties:

Understanding of plasticity soils of fine grain soils are playing vital role not only for soil classification and also they are very much useful to predict engineering property like Shear strength, permeability and compressibility and also swell ability of clay through empirical relationship. The liquid limit and plastic limit are governed by both physical and physio-chemical mechanisms. In montmorillonide mineral enriched clays, the plasticity behavior is governed by physio-chemical mechanism and whereas for kaolinite mineral enriched clays, it the physical force governing the same. Further in the presence of coarser fraction the plasticity characteristic of clay are significantly influenced and the operating mechanism may be physical are physio-chemical, which essentially depends on the percentage of coarser fractions in clays.

4.2. Effect of Rice Husk Ash on Liquid Limit:

Liquid limit is referred as generalized state parameter which has been given greater attention compared to plastic limit. The liquid limit is largely influenced by type and amount of clay content, and also literature shows that ion concentration ionic valency also largely influences the liquid limit of clay soil Figure 1. Shows the variation of liquid limit soil with increasing percentage of RHA .The liquid limit values are tabulated in Table 2. It can be seen that at any percentage the liquid limit continuously decreases for RHA. Liquid limit reduces from 57% to 30.5% for soil +80% RHA for alluvial soil and reduces from 60% to 26.5% for soil +80% RHA for clay soil

In general reduction in the liquid limit is the indicative of reduction in the compressibility and swelling characteristics. From the change in liquid limit it may be inferred that there is an overall Improvement in the behavior of problematic clay and alluvial soil on the addition of RHA.

Table 2. Effect of RHA on Liquid Limit behavior

DESCRIPTION	ALLUVIAL SOIL (%)	CLAY SOIL (%)
Soil alone	54.00	57.00
Soil + 5%	51.25	54.80
Soil + 10%	48.50	51.30
Soil + 20%	44.30	48.20
Soil + 30%	43.00	47.50
Soil + 40%	38.54	44.00
Soil + 50%	36.00	37.50
Soil + 80%	30.50	26.50

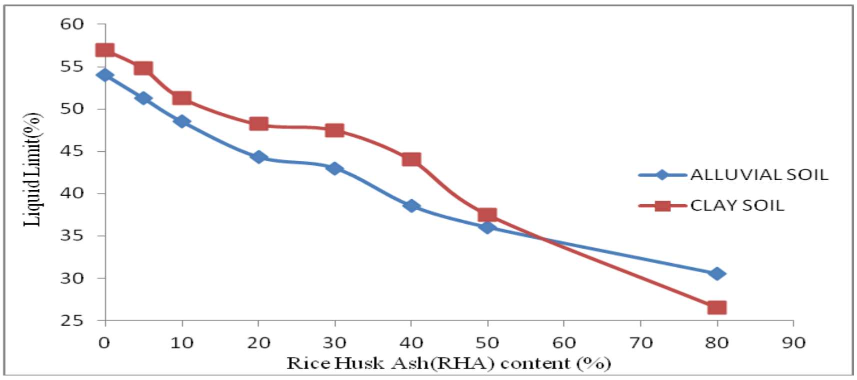

Figure 1. Effect of RHA on liquid limit behavior of Natural soil

4.3. Effect of RHA on shrinkage limit:

Shrinkage limit is one of the important index properties, which will give an idea about the shrinkage and swell potential. In general the clayey soil which shrinks more will have high shrinkage and swelling potential and such soils have low shrinkage limit, provided if there is no influence of soil structure. The addition of sand sized particles to shrink. Figure 2 shows the variation in shrinkage limit on addition to soil. The values are tabulated in table 3. Shrinkage limit increased from 12% to a maximum of 24% for soil+80% RHA for alluvial soil and from 12% to 24% for soil+80% RHA clay soil, the increase of shrinkage limit is 2 times higher than that of soil alone at soil +80% RHA. The increase of shrinkage limit for soil with the addition of RHA only indicate that shrinkage and swelling potential of expansive clay, reduce with percentage of RHA which is an improvement over the existing properties of clays and alluvial soil, At any percentage of RHA clay soil compared to soil + alluvial soil. This may be due to the fact that alluvial soil is inert granular particle where clay soil is having calcium oxide varying between 36 and 39%. Presence of divalent ca^{2+} might have induced the suppression of double layer, in turn resulted in flocculated structure. Generally, soil with flocculated structure results in low plasticity characteristics and high shear strength .hence increase may be mainly due to the physic-chemical interaction between the soil particles and RHA.

Table 3. Effect of RHA on Shrinkage Limit Behavior

DESCRIPTION	ALLUVIAL SOIL (%)	CLAY SOIL (%)
Soil alone	12.00	14.32
Soil + 5%	12.72	13.50
Soil + 10%	13.71	15.20
Soil + 20%	15.29	15.89
Soil + 30%	16.20	17.10
Soil + 40%	18.50	19.56
Soil + 50%	21.20	22.50
Soil + 80%	23.71	24.19

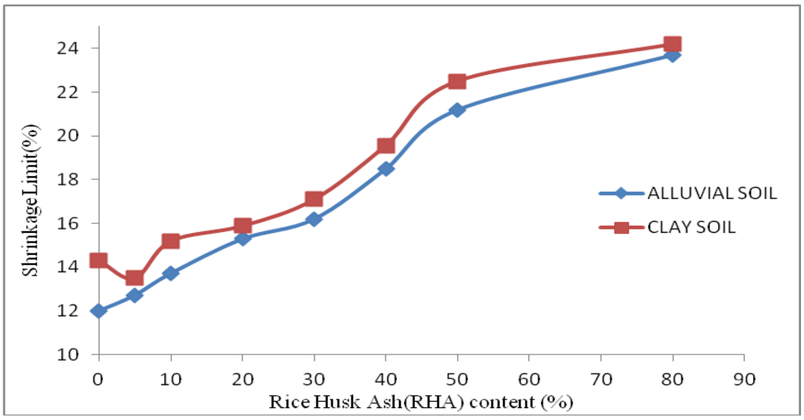

Figure 2. Effect of RHA on Shrinkage limit behavior of Natural soil

4.4. Effect of RHA on free swell index:

Free swell index (FSI) is an indicative swelling nature of expansive clays. Figure 3 shows the variation of FSI with increasing % of solid wastes. The values of FSI are tabulated in Table 4. The free swell index decreases from 59% to 19% for soil + 80% copper slag and from 59 to 14% for soil + 80% of RHA. The reduction and free swell index is varying from 67 to 76%. The reduction in FSI indicates that the addition of RHA particle reduces the swelling nature of the soil. Earlier, Dayakare T. Al(2004)have shown a reduction in FSI varied from 70% to 80% when solid waste like quarry dust and marble powder are used in problematic soil. At any percentage, the reduction in RHA is high in alluvial soil and clay soil. The reason is mainly attributed to the presence of the free CAO in RHA which react clay properties because of physiochemical interactions. In the case of CS, because of the replacement of swelling by non-clay CS, the swelling decreases. The variation FSI in the case of soil CS is due to the physical forces generated between the particles.

Table 4 Effect of RHA on Free Swell Index

DESCRIPTION	ALLUVIAL SOIL (%)	CLAY SOIL (%)
Soil alone	59.00	60.00
Soil + 5%	56.25	48.50
Soil + 10%	50.00	27.27
Soil + 20%	45.26	25.20
Soil + 30%	42.86	22.72
Soil + 40%	37.93	20.83
Soil + 50%	32.74	18.18
Soil + 80%	19.23	13.63

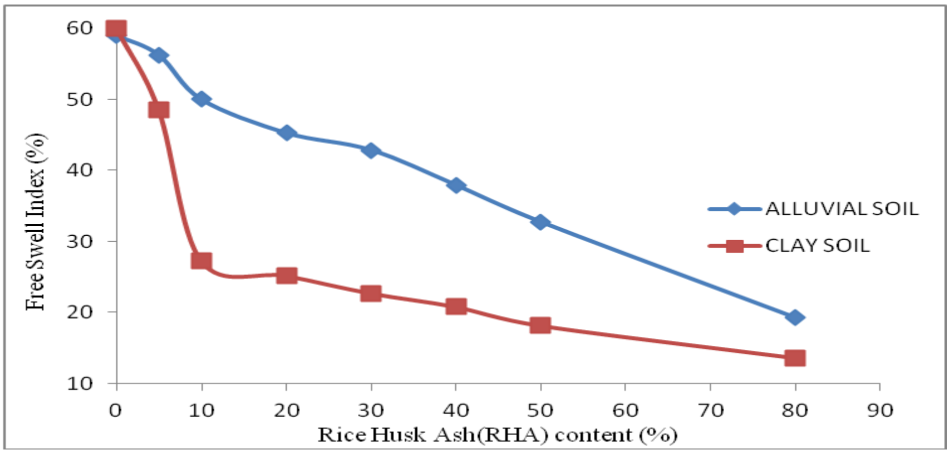

Figure 3. Effect of RHA on Free Swell Index behavior of Natural soil

4.5. Effect of Solid Waste on Compaction Characteristics:

In order to study the waste of solid waste on the compaction characteristics of alluvial and clay soil standard Procter compaction on test was conducted on soil with increasing percentage of RHA by weight basis. The results were obtained for soil with 0, 10, 20, 30, 50 and 80% of RHA along with clay and alluvial soil and listed in Table 5 and variations are shown in Figure 4 and 5.

Table 5 Effect of RHA for Natural soil on OMC and $\gamma_{d,max}$

DESCRIPTION	ALLUVIAL SOIL		CLAY SOIL	
	OMC (%)	$\gamma_{d,max}$ (kN/m^3)	OMC (%)	$\gamma_{d,max}$ (kN/m^3)
Soil alone	17.80	16.39	17.80	16.39
Soil + 10%	16.60	18.25	17.40	17.20
Soil + 20%	16.40	18.75	16.30	17.70
Soil + 30%	16.00	19.38	15.80	17.98
Soil + 50%	14.00	20.25	14.20	18.32
Soil + 80%	13.25	20.95	13.70	19.47

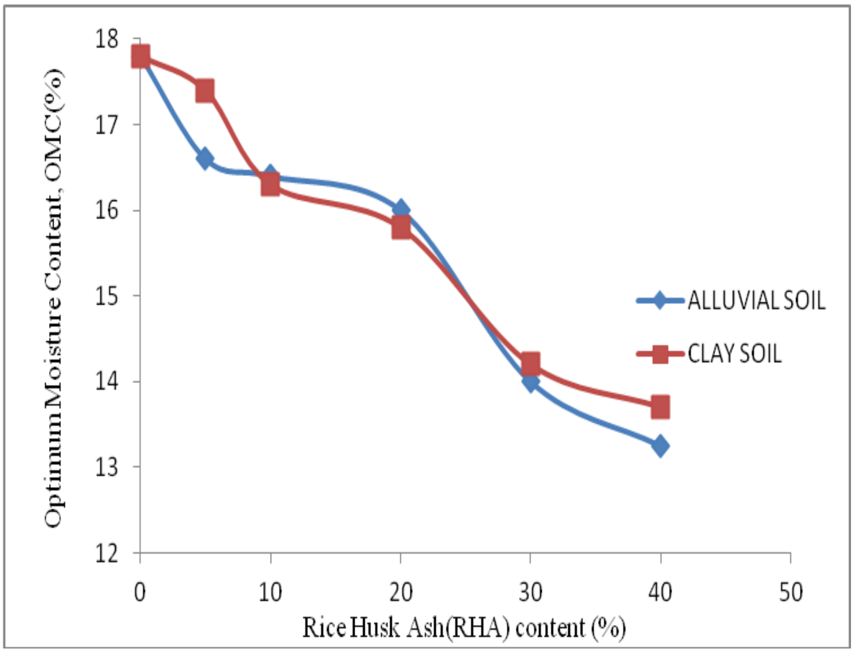

Figure 4. Effect of RHA on Optimum Moisture content (%) of Natural soil

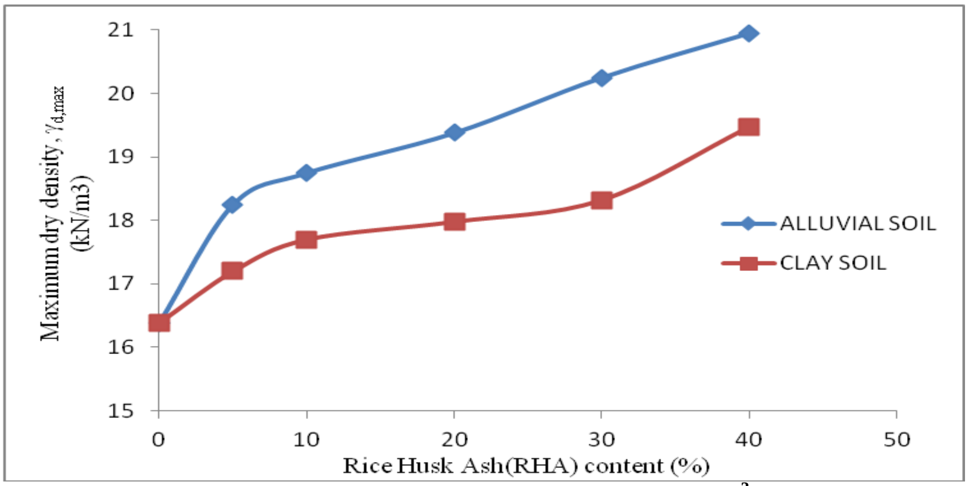

Figure 5. Effect of RHA on Maximum dry density $\gamma_{d,max}$ (kN/m^3) of Natural soil

4.6. Effect of RHA on Shear Strength Parameters (Direct Shear Test):

In order to study the effect of RHA on the shear strength parameters of the clayey soil and alluvial soil, direct shear unconfirmed compressive test is conducted. As the result obtained from UCC test, not implies the actual shear strength parameters of the soil added. Hence, alternatively direct shear test is conducted on soil with increasing % of RHA on weight basis results of stress-strain characteristics were obtained for soil with 0,10,20,30,50, and 80% of alluvial soil and clay soil with 0,10,20,30,50 and 80% the direct shear tests is discussed and results are listed in Table 6. The variation in the shear strength parameters C and ϕ for clayey soil and alluvial soil are shown in Figure 6 and 7.

Table 6 Effect of RHA for Natural soil on Shear Strength Parameters (C and ϕ)

DESCRIPTION	ALLUVIAL SOIL		CLAY SOIL	
	COHESION (kN/m^2)	ϕ	COHESION (kN/m^2)	ϕ
Soil alone	60	17°50'	60	17°50'
Soil + 10%	50	21°	50	26°
Soil + 20%	45.23	27°	47.50	29°
Soil + 30%	37.5	31°	40	33°
Soil + 50%	30	35°	37.50	35°
Soil + 80%	20	39°	30	38°

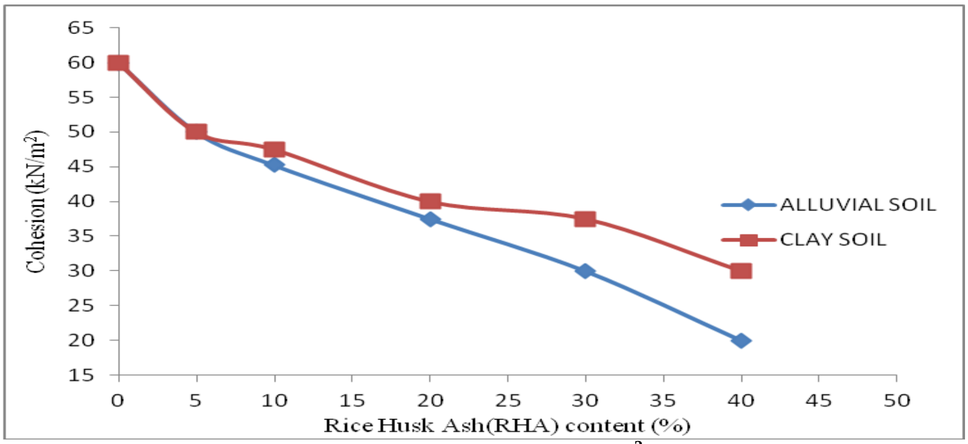

Figure 6. Effect of RHA on Cohesion (kN/m^2) of Natural soil

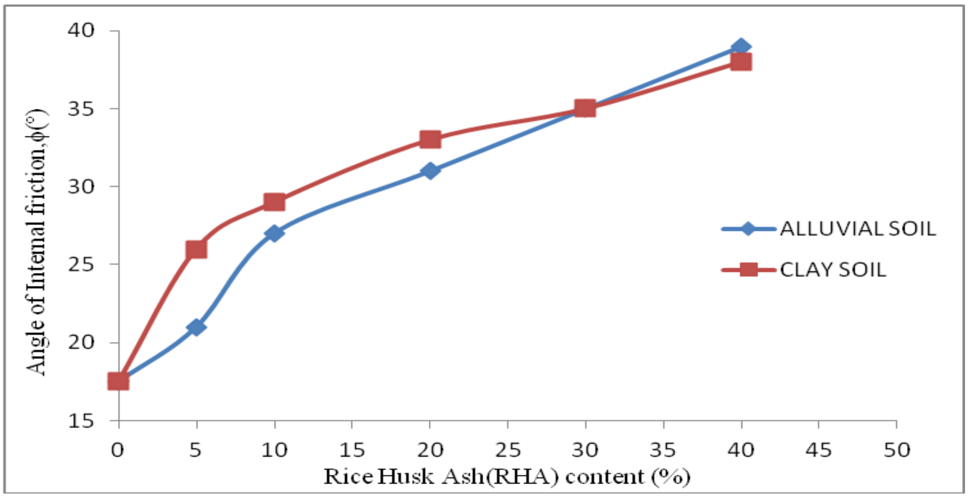

Figure 7. Effect of RHA on Angle of Internal Friction, ϕ (°) of Natural soil

4.7. Effect of RHA on CBR Values:

The thickness of the flexible pavement is a primary function of strength of sub grades in other words its CBR values. From the compaction tests, it is clear that, $\gamma_{d,max}$ of soil keeps increasing consistently with % of RHA for Alluvial soil and Clay soil and OMC decreasing with the same which imply that the strength of such soil also would be relatively increasing. CBR tests for both soaked and unsoaked conditions were conducted for soil with 0, 10,20,30,50 and 80% of RHA. Figure 8 & 9 show that the comparison of RHA on CBR values. The unsoaked and soaked CBR value for RHA mixed with Alluvial soil is slightly high when compare to RHA mixed with Clay soil. In graph, up to 30% there is not much difference in unsoaked and soaked CBR values, beyond 30% the difference seems clearly. The unsoaked CBR value for soil mixed with 80% RHA for alluvial soil is 12 and Clay soil is9 respectively. And the soaked CBR value for soil mixed with 80% RHA for alluvial soil is 6.4 and Clay soil is 4.35.

Table 7 Effect of RHA for Natural soil on CBR values

DESCRIPTION	ALLUVIAL SOIL		CLAY SOIL	
	UNSOAKED CBR VALUE	SOAKED CBR VALUE	UNSOAKED CBR VALUE	SOAKED CBR VALUE
Soil alone	3.27	2.42	3.60	2.80
Soil + 10%	6.27	2.58	6.01	2.58
Soil + 20%	6.69	2.67	6.47	2.70
Soil + 30%	7.30	3.40	6.73	3.28
Soil + 50%	8.80	4.22	7.50	3.58
Soil + 80%	12.19	6.40	9.30	4.35

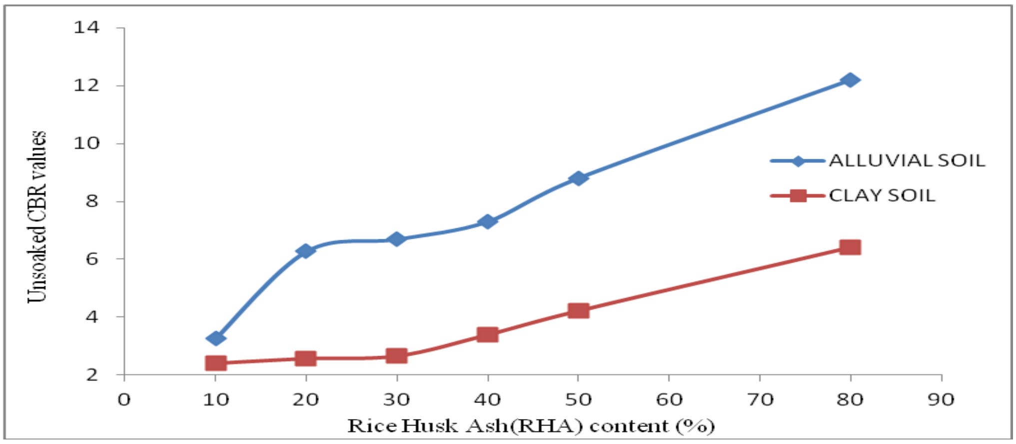

Figure 8. Effect of RHA on Unsoaked CBR values of Natural soil

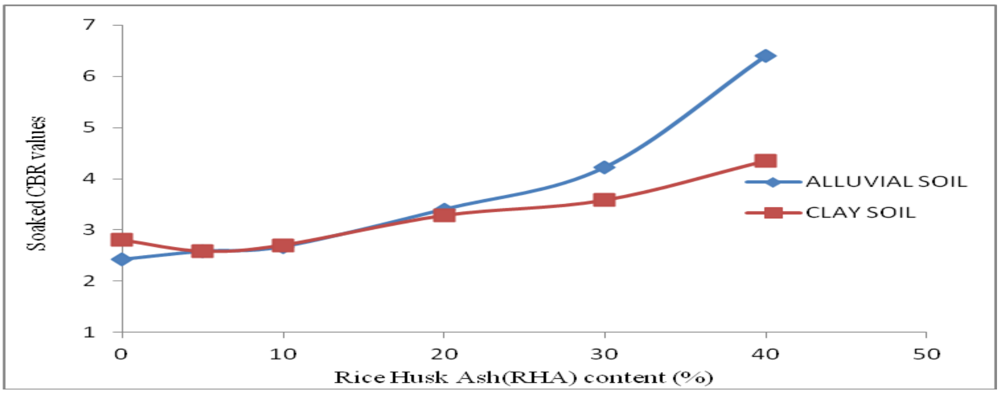

Figure 9. Effect of RHA on Soaked CBR values of Natural soil

V. RESULT:

The effect of solid wastes namely Rice husk ash in alluvial soil and clay soil on the variation of index properties, compaction characteristics, shear strength and CBR values were analyzed. From the results the following conclusion may be drawn.

1. The liquid limit and the FSI of the soil decreased steeply with the increase in the % of RHA .In case of alluvial soil the liquid limit decreased from a value of 59% to 19.2% for the same quantum of addition of RHA. The decrease in the free swell Index was from 59% to 13.6%. The shrinkage limit of soil increased to 23.7 and 24.2% respectively for alluvial soil and clay soil from 12% initially for virgin soil.
2. The Maximum dry density increased from 16.39KN/m3 to 20.95kN/m^3 in case of addition of 80% RHA to alluvial soil the soil. The maximum and minimum dry density of alluvial soil is 21.8kN/m^3 and 18.4kN/m^3 respectively. The Optimum moisture content decreased steeply with % RHA 17.8% to 13.25%. The Optimum moisture content decreased steeply with 80% RHA for clay soil from 17.89% to 13.25% and maximum dry density increased from 16.39kN/m^3 to 19.5kN/m^3.
3. The undrained cohesion value of soil mixed with alluvial soil decreased from 60kN/m^2 to 20 kN/m^2 and angle of internal fraction value increased from 17°5' to 39°. The undrained cohesion value of the soil mixed with RHA for clay soil decreased from 60 kN/m^2 to 30 kN/m^2 and angle of internal friction value increased from 17°5' to 38°.
4. The unsoaked CBR value of the soil increased from 3.2% to 12% whereas soaked CBR value from 2.4% to 6.4% only in the case of addition of RHA to alluvial soil. The unsoaked CBR value in the case of addition of RHA to clay soil increased from 3.2% to 9.3% and the soaked CBR value 2.4% to 4.4%.

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