EFFECT OF RICE HUSK ASH ON LIME STABILIZATION

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The focus of the paper is to evaluate the effectiveness of using rice husk ash (RHA) as a puzzuolanae to enhance the lime treatment of soil. The paper presents the influence of different mix proportions of lime and RHA on compaction, strength properties, CBR values and durability characteristics of soil. The results show that addition of RHA enhances not only the strength development but also the durability of lime stabilized soil.

Keywords: *Rice husk ash, Compaction, Unconfined compressive strength, CBR, Durability*

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INTRODUCTION

Many procedures have been developed to improve the physical behaviour of soil by incorporating a wide range of stabilizing agents, additives and conditioners. Undoubtedly the most widely applied methods involve the use of inorganic cementing agents. The effectiveness of such agents relies on the formation of cementing bonds between the particles in the soil system. The two most common cementing stabilizing agents are cement and lime. Soil stabilization has been widely recommended for developing countries for the construction of various elements of the pavements[15, 18]. The reasons usually put forward are that the use of locally available materials will lead to lower costs. An understanding of local conditions is of paramount importance while developing any soil stabilizing technique for a given country. Climatic conditions can affect the behaviour of stabilized soil materials as well as construction procedures.

Lime as an additive, brings several beneficial changes in the engineering properties of soil such as decrease in soil plasticity and shrink swell potential apart from improving strength characteristics. Stabilization of soil by lime is achieved through cation exchange, flocculation and agglomeration, lime carbonation and pozzolanic reaction. Cation exchange and flocculation agglomeration reaction takes place rapidly and brings immediate change in soil properties, where as, pozzolanic reactions are time dependent. These reactions involve interaction between soil silica and (or) alumina and lime to form various types of cementing agents thus enhancing the strength. The chemical processes modify the soil structure whereby larger grain aggregates are formed, leading to several advantage in the suitability of soil in road construction[3]. Certain natural substance, such as volcanic ash reacts to the lime addition much better than do the ordinary soil types. If such materials are added to soil, the efficiency of lime stabilization may be greatly increased. The characteristics of compacted soil, if improved, resulting from residue utilization like flyash, blast furnace slag, rice husk ash etc mostly brings environmental and economic benefits. However on a comparative scale the use of rice husk ash has found limited application.

Rice husk is a major agriculture byproduct obtained from the food crop of paddy. For every 4 tons of rice 1 ton is of rice husk is produced. The husk is disposed of either by dumping it in an open heap near the mill site or on the roadside to be burnt. Burning rice husk (RH) generates about 15-20% of its weight as ash. The ash being very light is easily carried by wind and water in its dry state. It is difficult to coagulate and thus contributes to air and water pollution. Cumulative generation of ash requires a large space for disposal. Utilization of rice husk ash by exploiting its inherent properties is the only way to solve the environmental and disposal problem of the ash. A number of researchers have studied the physical and chemical properties of rice husk ash. Rice husk ash cannot be used alone for stabilization of soil because of the lack of cementitious properties. The high percentage of siliceous material in rice husk ash indicates that it has potential pozzolonic properties[5]. The normal method of conversion of husk to ash is incineration. The properties of rice husk depend whether the husks have undergone complete destructive combustion or have been partially burnt. The rice husk ash has been classified into high carbon char, low carbon ash and carbon free ash[6]. This paper brings out the results of an experimental programme carried out to evaluate the effectiveness of using RHA as a puzzuolanae to enhance the lime treatment of soil.

MATERIALS AND METHODS

Materials used

The materials used in the present study were RHA, hydrated lime and locally available soil. The composition along with the physical properties of the materials used is outlined in Table 1, Table 2, Table 3 respectively.

Table-1.1- Composition of Rice Husk Ash used

S. No.	Component	% in Rice Husk
1	SiO_2	93.2 %
2	Al_2O_3	0.59
3	Fe_2O_3	0.22
4	CaO	0.51
5	MgO	0.41
6	K_2O	2.93
7	Loss on Ignition	1.91

Table-1.2- Properties of Rice Husk Ash used

S. No.	Property	Value
1	Specific gravity	1.95
2	Maximum dry density (KN/m^3)	8.5
3	Optimum moisture content (%)	31.8
4	Angle of internal friction (degrees)	38
5	Unsoaked CBR (%)	8.75
6	Soaked CBR (%)	8.15

Table-2 Composition of hydrated lime used

S. No.	**Characteristics**	**Value**
1	Minimum assay (%)	90
2	Chlorides (%)	0.04
3	Sulphates (%)	40
4	Aluminum. Iron and Insoluble matters (%)	1.0
5	Arsenic (%)	0.0004
6	Lead (%)	0.004

Table-3- Physical properties of soil

S. No.	Characteristics	Value
1	Specific gravity	2.69
2	Particle Size distribution (%) a) Sand b) Silt c) Clay	 12 58 30
3	Liquid limit (%)	61.2
4	Plastic limit (%)	34.5
5	Plasticity index (%)	26.7
6	Classification of soil	MH
7	Maximum dry density (KN/m^3)	16.2
8	Optimum moisture content (%)	24.4
9	Unconfined Compressive Strength (Mpa)	0.21
10	Unsoaked CBR (%)	3.65
11	Soaked CBR (%)	2.40

Specimen Preparation

The soil collected from the site was pulverized with wooden mallet to break lumps and then air-dried. Subsequently it was sieved through 2.36 mm IS sieve and then dried in an oven at 105^0C for 24 hours. Processing of RHA was done on the similar line as that of soil. The following procedure was used to mix the rice husk and lime into the soil. Required quantity of soil was first weighed and poured into a mechanical mixture. Then the required quantity of lime (slurry form) was mixed into the soil in small increments to ensure uniform coverage. Now desired quantity of rice husk ash was added in the soil lime mix. This mixture was mixed using a ‘two bladed mortar mixing bit’, powered by an electric drill. Due care was taken to ensure a uniform soil-lime RHA mixture. Test specimens were prepared as per normal practice of Indian Standard specification. All desired tests were conducted as per IS methods. In order to improve reproducibility of the test results, tests were conducted in triplicate for a given soil-lime RHA composition. The results reported are the average of three test results.

Compaction and strength tests

In the compaction tests, the soil was thoroughly mixed with various moisture contents and allowed to equilibrate for 24 hours prior to compaction. The dry density- moisture content relationship was determined using the standard compaction method as per IS specifications.

One of the popular methods of evaluating the effectiveness of stabilization is the unconfined compressive strength[15]. As a general rule, for a given type of stabilization, the higher the compressive strength, the better is the quality of the stabilized material. Each specimen used in unconfined compression tests was compacted at optimum moisture content and maximum dry density. Specimens were cured in groups of three in a thermostatically controlled incubator set at (30 $\pm$ 2)^{o} C before being tested in compression. Curing times adopted were 7, 28 and 56 days and at least three specimens were tested for each case.

CBR tests

Composite strength- stiffness parameters are employed for the subgrade, where the pavement section and subgrade have to resist repetitive loads with very low deformation tolerance. California bearing ratio is more commonly used to describe the composite strength-stiffness parameters. As reported in the literature development of strength of lime-flyash-soil mix depends on curing period, moisture content and temperature. The higher the curing temperature, the greater will be the strength development. The strength after 7 days curing at 38^{o}C is usually considered to be the same as for 28 days curing at 20^{o}C and the strength after 7 days at 55^{o}C is about the same as one-year strength at 20^{o}C. To evaluate the suitability of soil-lime-RHA mix in base and subgrade course of flexible pavements, CBR tests were conducted as per IRC 1981. Test samples were prepared at optimum moisture content and maximum dry density. Curing time adopted for test samples were 7 days at 38^{o}C, which was then soaked for 96 hours. Tests were conducted for both soaked and unsoaked samples.

Durability tests

The wet dry test was used to evaluate the durability of the specimens. For these tests, specimens were prepared at the designated density and optimum moisture content and then moist cured for a specific number of days. Subsequently, specimens were air dried for 24 hours at room temperature and then completely immersed in distilled water for 24 hours. This completed one cycle of drying and wetting. The durability indices of the specimens were obtained by the determination of compressive strength after 12 wetting and drying cycles and dividing the figure thus obtained by the compressive strength of a sample produced simultaneously, but stored under wet conditions during the entire test period[7].

RESULTS AND DISCUSSION

Compaction parameters

For a given RHA content in the compaction tests, addition of lime decreased the maximum dry density of the stabilized soil but increased the optimum moisture content [Figure-1(a) and 1(b)]. Earlier studies had also observed that the addition of lime leads to an immediate decrease in the maximum dry density of soil and an increase in the optimum moisture content, for the same compactive effort. The decrease in the maximum dry density of the treated soil is reflective of increased resistance offered by the flocculated soil structure to the compactive effort[13]. The increase in optimum moisture content is probably a consequence of additional water held within the flocculated soil structure resulting from lime interaction. This trend does not change even after the addition of RHA. Figure-1 clearly shows that an increase in RHA content results in a decrease of maximum dry density and increase in optimum moisture content. RHA, which has a low specific gravity, when present in excess of the amount required for reaction with the available lime may have reduced the dry density. Increase in moisture content is probably due to additional water being absorbed by the excess RHA.

Unconfined Compressive Strength

The effects of adding RHA on the unconfined compressive strength of lime soil mixture after 7, 28 and 56 days of curing are shown in Figure 2. A general pattern is observed in which the strength develops rapidly with addition of RHA until an optimum condition is reached, beyond which the increase in strength is either nominal or there is marginal decrease in strength. The optimum RHA content is observed to be about 12 % in all the cases. Further it is also observed that curing period has marked influence on the unconfined compressive strength and for a given lime content, optimum unconfined compressive strength increases with increasing curing period. Although treatment with lime improves the strength characteristics of soil, but addition of 12 % of RHA further improves the strength of the lime-stabilized soil. For example, for 7 % lime content and 28 days curing period, the maximum strength of RHA treated sample is about 1.77 times that of without RHA. Figure-2 also shows that a sample with 5 % lime and

6 % RHA has strength of 1.37 times that of a sample with 7 % lime and no RHA after 56 days curing. This indicates that in a lime – RHA – soil mixture, a lesser amount of lime is required to achieve a given strength as compared with lime – soil mixture. The gain in strength of lime–stabilized soil is primarily a result of pozzolanic reactions between silica and (or) alumina from the soil and lime to form various types of cementing agents. By introducing RHA to the soil, additional amounts of silica are available for reaction with lime resulting in further increase of strength. Presence of RHA in the soil lime mix beyond the optimum value does not lead in strength development. The reason may be attributed to the insufficient availability of lime for pozzolanic reaction.

Since RHA is much cheaper than lime, addition of rice husk ash in lime-soil mix can result in cost reduction of construction. In tropical countries where rice husks are abundant and considered as waste material, use of RHA in the construction of roads, airfields and other earthworks may particularly become attractive, because of reduced construction costs, reduced disposal costs and environmental damage and conservation of high grade construction materials.

Figure 3 shows the variation of unconfined compressive strength with curing period. It can be seen that addition of RHA produces not only higher strength but also higher rate of initial strength development. RHA contents with the optimum values (12%) produced the best results. It can also be observed from figure 3 that for all cases, the rate of strength increase reduced at the later stage. Earlier research also indicated that for lime stabilized soil, the strength increases rapidly at first, notably during the first seven days of curing, followed by a reduced and more or less constant rate for about 15 weeks[9]. This supports the view that cementitious products are formed at an early stage, that is, as soon as flocculation is completed due to lime-clay reaction[10]. It was also reported that the increase in strength tailed off within 1 or 2 years and that no changes took place, even in active clays, after 7 years[4]. The dependence of strength development on curing period provides a considerable factor of safety for design based on 7, 28 or 56 days strength.

Effect of Temperature

To study the influence of curing temperature on unconfined strength, mixture containing 5 and 7 % lime were moist cured in an oven for 28 days where forced air circulation was maintained at 60^{o}C. Samples cured at 60^{o}C developed more than twice the strength of those samples cured at 30^{o}C (Fig. 2) and showed a significantly higher rate of strength development (Fig. 4). Earlier studies on lime treatment of soil had also indicated that higher temperatures accelerated curing, with improvement in strength. Many other researchers subsequently confirmed this. It is interesting to note that the increase in temperature results not only in development of higher strength of lime treated soil, but also enhancement of strength development when RHA is added. Temperature and humidity are relatively high in tropical countries therefore the use of rice husk ash for soil stabilization is well suited to these regions.

California bearing ratio

Figur-5 shows the result of CBR versus RHA content at a given lime content both for unsoaked and soaked condition. It can be observed from the figure 5 that addition of lime increases the CBR value considerably, which increase further under soaked condition.

Information available from literature indicates that CBR value of soil under soaked condition increased significantly after the addition of lime[16]. Addition of RHA further enhanced the CBR value. The increase in CBR value after addition of lime is due to the formation of various cementing agents due to pozzolanic reaction between silica present in soil and lime. When RHA was added, additional amount of silica became available for reaction with lime, which further increased the CBR value. Therefore the efficiency of lime stabilization may be greatly increased by the addition of RHA. For all the three lime contents considered in the study, 12% addition of RHA was found to be optimum for maximum improvement in CBR. Similar improvements in CBR value were reported in Indonesia when RHA and lime was added in soil [12]. Sridharan et al (1996)[17] also reported that even addition of material like mooram improves the CBR value considerably. A considerable increase in CBR value was reported when lime was added in Flyash –soil mix[11]. Results of tests conducted at IIT Delhi using lime and flyash to stabilize silt shows considerable improvement in CBR values [14].

Durability

A stabilized soil should have the ability to retain its strength under “In-Situ” conditions. The determination of the durability of a stabilized soil is a problem because of the difficulty to simulate field conditions in the laboratory. Many test procedures have been developed for this purpose, e.g., heating and cooling, freezing and thawing, wetting and drying. For tropical regions only last two are relevant. The results of durability test after 12 cycles of wetting and drying are presented in table-4, the results indicate reduction in unconfined compressive strength of the specimen, compared to the strength of the specimens moist cured for the same period. The period adopted for moist curing was 28 days for the determination of durability index in the present investigation. It can also be observed from the table that average strength retention lies in the range of 59 to 69% of the original strength of specimen after 12 cycles of wetting and drying containing RHA and moist cured for 28 days. The sample with 12 % RHA content retained the highest strength after wetting and drying.

Similar findings have been reported earlier also[2]. Al-Rawi (1981)[1] reported a loss of over 50% due to saturation for lime- stabilized soil. Durability index determined after 4 and 8 cycles, though not reported here showed that there was drastic reduction in strength of specimen after first cycle but it regained the strength in subsequent cycles. Reason for reduction in strength may be due to the combination of factors induced during

Table 4 : Reduction in unconfined compressive strength of Soil-Lime-RHA mixing

Mix proportion Soil:Lime:RHA	UCS^1 (Mpa)	UCS^2 (Mpa)	UCS^1 / UCS^2
97:3:0	0.18	0.54	0.32
91:3:6	0.40	0.72	0.55
85:3:12	0.45	0.75	0.59
79:3:18	0.49	0.79	0.61
95:5:0	0.22	0.59	0.37
89:5:6	0.64	0.95	0.67
83:5:12	0.69	0.98	0.70
77:5:18	0.62	0.90	0.69
93:7:0	0.27	0.69	0.39
87:7:6	0.59	0.89	0.66
81:7:12	0.76	1.09	0.69
75:7:18	0.70	1.02	0.68

UCS^1 – Unconfined Compressive Strength (UCS) of specimen moist cured for 28 days and subjected to 12 wet dry cycles

UCS^2 – Unconfined Compressive Strength of specimen moist cured for 28 days

Wet-dry cycles and the gain in strength subsequently is due to curing effects. Thompson (1966)[19] also reported that the ratio of soaked and unsoaked strength were approximately in the range of 0.7-0.85, when the lime stabilized soil was subjected to prolonged exposure to water.

In general the addition of RHA produces not only stronger but also durable samples as compared with those treated with lime only. This implies that maintenance costs for roads, airfields etc. will be reduced considerably.

CONCLUSIONS

Addition of lime and RHA to soil increases the optimum moisture content and reduces the maximum dry density. Adding RHA enhances the development of unconfined compressive strength of lime-stabilized soil. The optimum rice ash husk ash content is 12 % in line: RHA: Soil mixture. Curing period and temperature has a significant effect on development of unconfined compressive strength, when RHA is added in lime-stabilized soil. As the curing time and temperature increases, the rate of strength increase is intensified by addition of RHA. Durability of lime- stabilized soil is enhanced by addition of RHA. Addition of RHA increases the CBR value considerably for both soaked and unsoaked condition.

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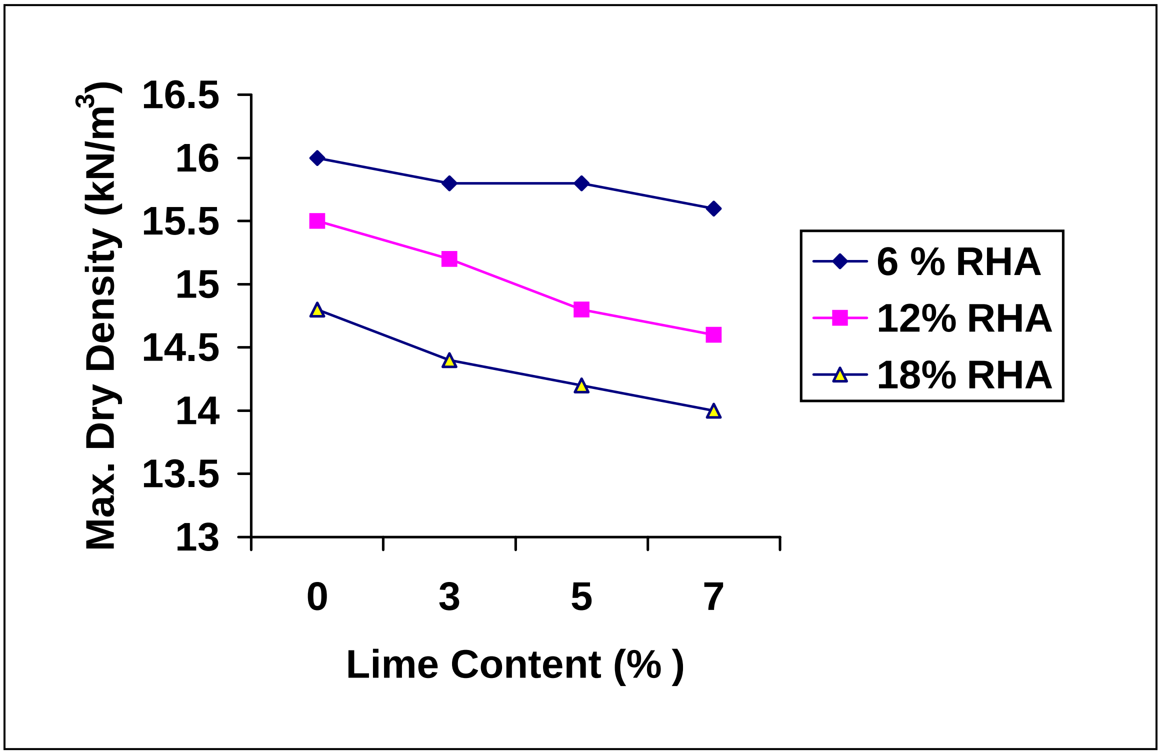


Figure-1(a)

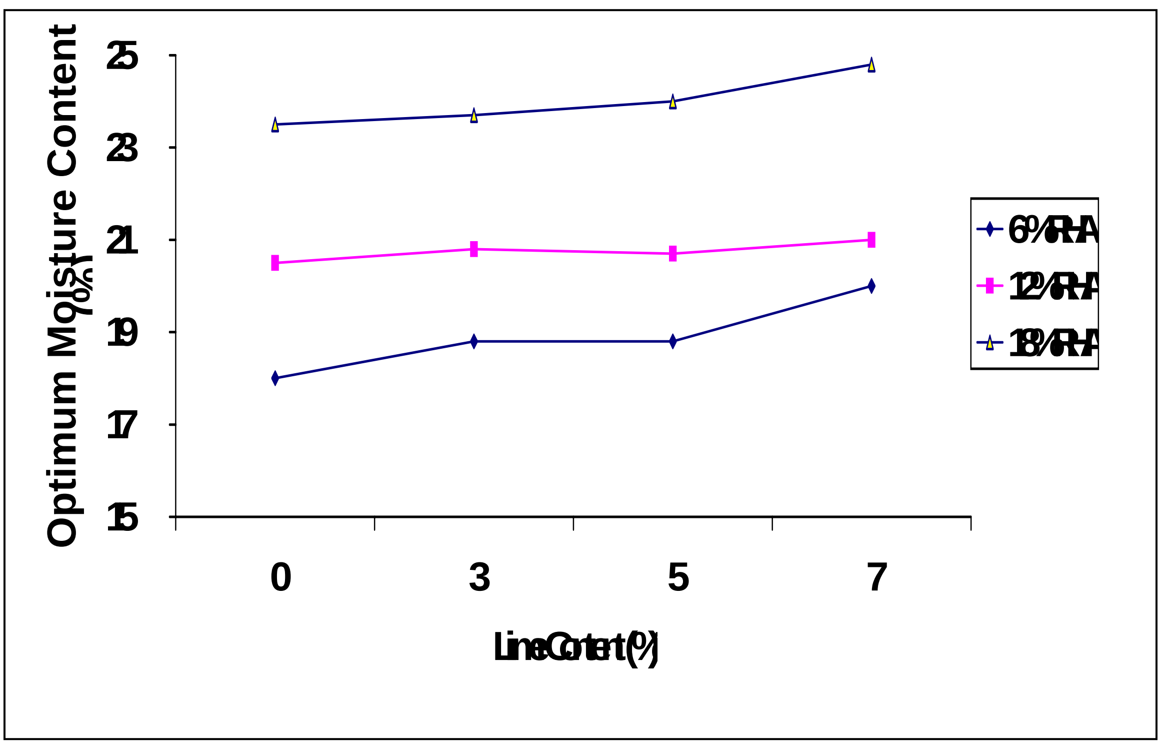


Figure –1(b)

Fig.-1. Variation of compaction characteristics of soil with lime – RHA content

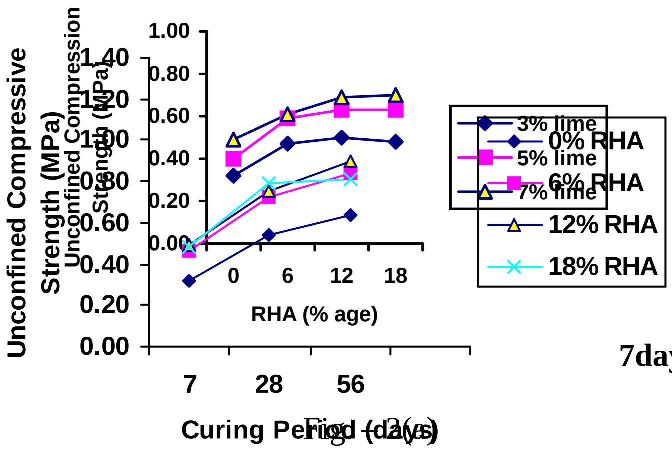
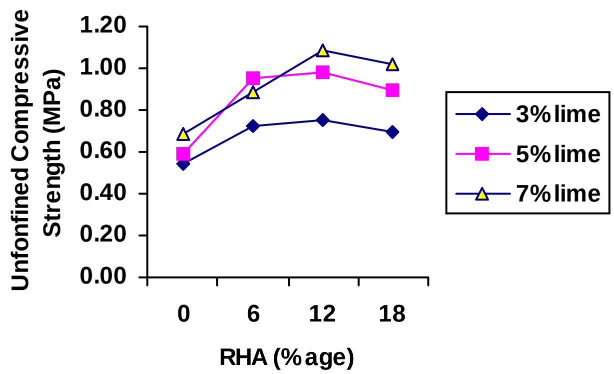


Fig. – 2(a)

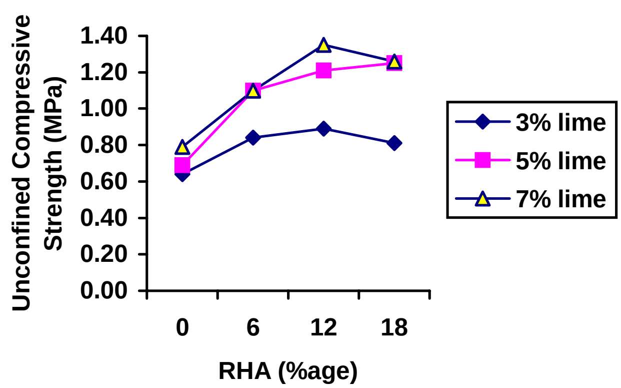
7days

3% Lime



28 days

Fig. – 2(b)

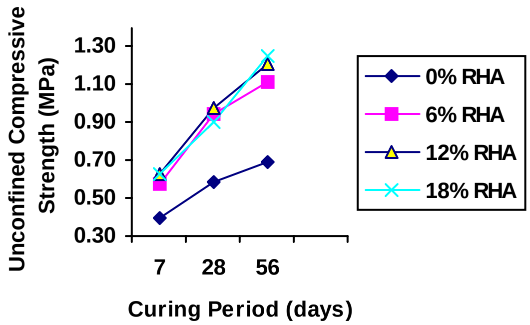


56 days

Fig. – 2(c)

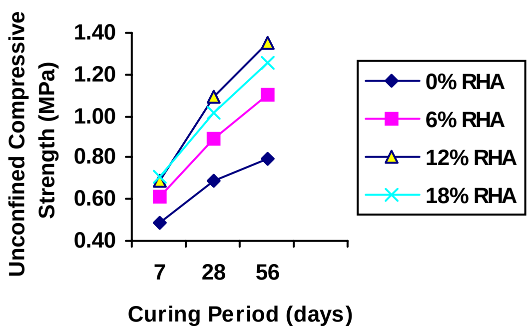
Fig.-2. Variation of unconfined compressive strength of soil with lime-RHA content

Fig.-3(a)



5% Lime

Fig.-3(b)



7% Lime

Fig.-3(c)

Figure-3. Variation of UCS of lime-RHA-soil mix with curing day

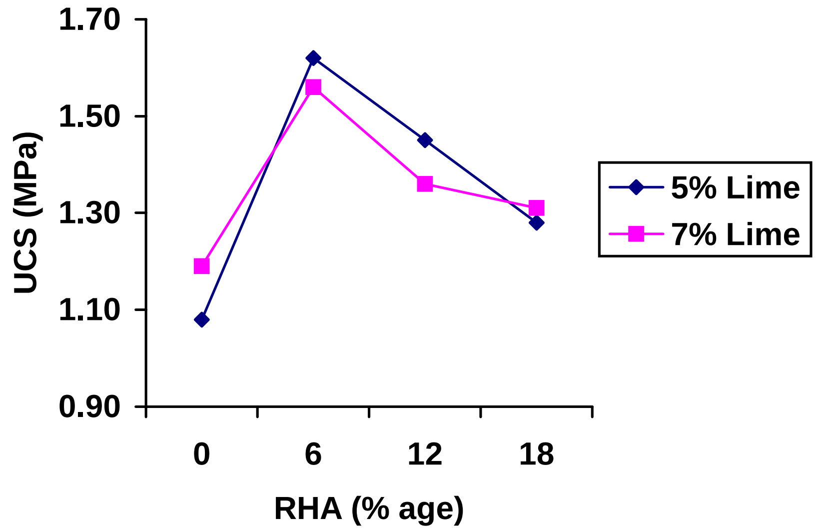
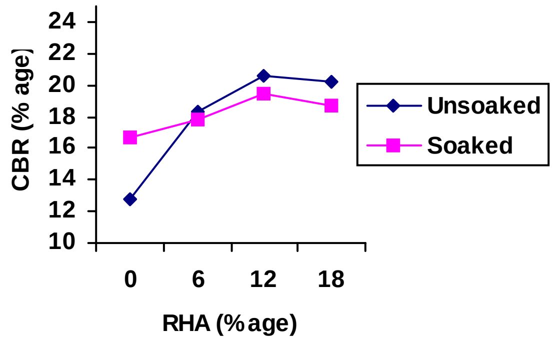
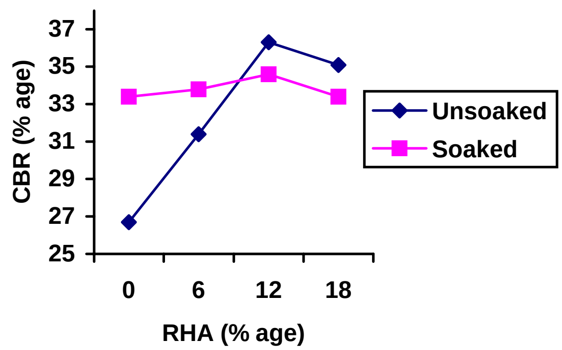


Figure 4 – Variation of UCS of lime-RHA-soil mix cured at 60^0C with RHA content



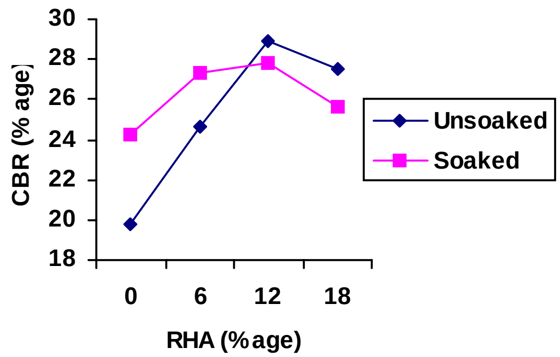
3% Lime

Fig.-5(a)



5% Lime

Fig.-5(b)



7% Lime

Fig.-5(c)

Fig.5- Variation of CBR for lime-RHA-soil mix with RHA content