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Use of Various Agricultural and Industrial Waste Materials in Road Construction

Aditya Kumar Anupam[a], Praveen Kumar[b1] and G D Ransinchung R N[b]

a Assistant Professor, Civil Engineering Department, Graphic Era University, Dehradun, India
b Professor, Civil Engineering Department, IIT Roorkee, India

Abstract

The main objective of the present investigation is to assess the usefulness of agricultural and industrial waste as a soil admixture, and focused to improve the engineering properties of soil to make it capable of lower layer of road construction. Present investigation describes the behavioral aspect of soils mixed with industrial waste materials viz. fly ash (FA), rice husk ash (RHA) & bagasse ash (BA) and agricultural waste material rice straw ash (RSA) to improve the load bearing capacity of the soil. Clayey soil has been considered using four different types of stabilizer viz. FA, BA, RHA & RSA ranging from 5 to 35% by weight of soil. The physical and chemical properties of these stabilizers were ascertained and compared. Admixing of all these stabilizers improve soaked CBR values substantially and dramatic reduction in dry density was observed.

Keywords: Agricultaural Waste; Industrial Waste; Baggasse; Fly Ash; Rice Husk Ash; Rice Straw

1. Introduction

India produces an enormous amount of different types of waste materials as byproducts from different sectors like industrial, agricultural, etc. These waste materials if not deposited safely it may be hazardous. The amount and type of waste generated increases with increase in population. These wastes remain in the environment for longer duration since it is unused. The waste disposal crisis arose due to the creation of non decaying waste materials. One solution to this crisis lies in recycling waste into useful products. Research into new and innovative uses of waste materials is continually advancing. In India, research is currently underway to examine the potential for use of some locally available wastes in road construction.

[1] * Corresponding author. Tel.: Tel.: +91 1332 285470; fax: +91 1332 273560.
E-mail address: pkaerfce@iitr.ernet.in

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Indian coals, though low in sulfur, contain higher amount of ash (about 35-45%), resulting in huge quantities of fly ash in India. The annual generation of fly ash has increased as shown in figure 1 (Kumar V. et. al., 2005). Fly ash can provide an adequate array of divalent and trivalent cations (Ca_2^+, Al_3^+, Fe_3^+, etc.) under ionized conditions that can promote flocculation of dispersed clay particles. Thus, expansive soils can be potentially stabilized by cation exchange using fly ash (Kumar, A. et al. 2007).

Rice husk is huge available in rice producing countries like China, India, Indonesia, Bangladesh, Brazil and South East Asia. Rice husk is mainly used as a fuel in industries in boilers for process energy requirements and for power generations. Rice husk is a fuel having high ash content, varying from 20-25% of rice husk and content having 80-90% of silica. In the majority of rice producing countries much of the husk produced from the processing of rice is either burnt for heat or dumped as a waste. India alone produces around 120 million tons of rice paddies per year, giving around 24 million tons of rice husk and 4.4 million tons of RHA every year (Govindarao, 1980).

About 1711.087 MMT of sugar cane is produced annually throughout the world and india produces 292.3 MMT in 2010 (FAOSTAT). India has just over 500 sugar mills, with nine states (Uttar Pradesh, Bihar, Punjab and Haryana in the northern region; Maharashtra & Gujarat in the western region and Andhra Pradesh, Tamil Nadu and Karnataka in the southern region, holding 95 % of them (National Federation). Indian sugar mills are currently self-sufficient in energy, already using bagasse to meet their steam and power requirements. As only 20-30% of all bagasse is used for these purposes, this suggests that the remaining 2/3 of bagasse is currently being “wasted”, and which is mostly used as a captive boiler fuel other than its minor use as a raw material in the paper industry.

Rice is a staple food in the diet for much of the world. Production of rice was 696.32 MMT in the world and India stands second largest in the production with 142 MMT (FAOSTAT). The quantity of agricultural residues produced differs from crop to crop and is affected by seasons, soil types, and irrigation conditions.

Indian clayey soils can be problematic for direct utilization of subgrade construction. Clayey soil applies to soils that have the tendency to swell when their moisture content is increased. Soils containing the clay mineral montmorillonite generally exhibit these properties. The clayey soils have a low bearing capacity in the presence of water and more shrinkage cracking in dry condition. Admixing some percentage of cement or cementitious material with soil improves the bearing capacity but crack formation due to shrinkage cannot be minimized. Hence, highway engineers are putting constant efforts in finding material which are really potential to improving the bearing capacity as well as for shrinkage cracking control. In the present study, an effort has been made in the similar direction, by selecting RHA as an admixture to improve the strength properties of selected clayey soil.

2. Previous Research Works

Fly ash is a non-crystalline pozzolanic and slightly cementitious material. Dhawan, P. K. et al. (1994) explored the feasibility of ash utilization in bulk for road construction. They considered three types of ashes as fly ash, bottom ash & pond ash admixed with different types of soil. The result CBR values indicated that improvement of CBR values of the soil with the coal ash from thermal power station and FA can be used as sub base materials, subgrade & embankment. Prabakar, J. et al. (2004) studied influence of fly ash on soils and reported that the addition of fly ash reduced the dry density of the soil due to the low specific gravity and unit weight of soil and improved the shear strength. Kumar, P. et al. (2008) evaluated the strength parameters of four locally available materials for their use in the sub base course of a pavement. Fly ash had the lowest CBR of 9%, but its behaviour under dynamic load is better than that of stone dust, which has shown the maximum value of CBR.

Cordeiro (2009) obtained the important parameter for the production of SCBA with pozzolanic activity. The SCBA produced with air calcination at 600°C for 3 hr. with a rate of heating of 10°C/min presents amorphous silica, low carbon content and high specific surface area. The sample produced with these characteristics presents considerable pozzolanic activity according to both mechanical and chemical methods of evaluation. Goyal et al. (2007) reported that SCBA with high specific surface area, high contents of amorphous silica and calcium oxide fulfilled the principal requirements of a pozzolanic material. Ganesan et al. (2007) studied on the use of bagasse ash (BA) as partial cement replacement material in respect of cement mortars. Up to 20% of ordinary portland cement can be optimally replaced with well-burnt bagasse ash without any adverse effect on the desirable properties of concrete.

Several studies have been carried out on the effectiveness of clay stabilization by RHA admixing. In this context, Basha, E.A. et al. (2005) studied the stabilization of residual soils by chemically using cement and RHA. In general, 6–8% of cement and 10–15% RHA show the optimum amount to reduce the plasticity of soil. CBR value determined maximum at 4% cement and 5% RHA mixtures with soil. According to compressive strength and PI, 6–8% of cement and 15–20% RHA showed the optimum amount to improve the properties of soils. Jha, J. N. and Gill, K. S. (2006) evaluated the effectiveness of RHA to enhance the lime treatment of soil.

Han, Y. W. and Anderson, A. W. (1974) analyzed the problem of waste rice straw which more than half of the dry matter of straw consists of cellulose and hemicellulose. The rest is comprised of lignin, nitrogenous compounds, and ash – mostly silica. Ranasinghe and Arjurna, P. (1993) reported about the ash and silica content of some of the plants derivatives. It has been seen that rice straw have 14.65% ash after burning, thus for every 1000 kg of rice straw burnt 146.5 kg ash are produced having about 82% of silica content.

3. Materials

3.1. Soil

Clay of medium compressibility (A-7-6) soil is used for this study. The index properties such as liquid limit, plastic limit, plasticity index and other important soil properties as per AASHTO and United States soil classification systems are presented in Table 1. Fig. 1 presents the grain size distribution curves of the soil.

Table 1. Physical properties of soil

Properties	Values
Optimum moisture content (%)	17
Dry density (gm/cm^3)	1.71
Specific gravity	2.74
Liquid limit (%)	46
Plastic limit (%)	21
Plasticity index	25
Unified soil classification	CL
AASHTO soil classification	A-7-6
Type of soil	Clay of medium compressibility

3.2. Fly Ash (FA)

The fly ash used in the study was brought from National Thermal Power Station situated at Ghaziabad which was available free of cost. Fly ash is classified as silts of low compressibility (ML). The chemical, physical and engineering properties of ash depends on the type and source of coal used, method and degree of coal preparation, cleaning and pulverization, type and operation of power generation unit, ash collection, handling and storage methods etc. So the properties of fly ash vary from plant to plant and even within the same plant. The physical and chemical properties of fly ash tested in laboratory are given in Table 2.

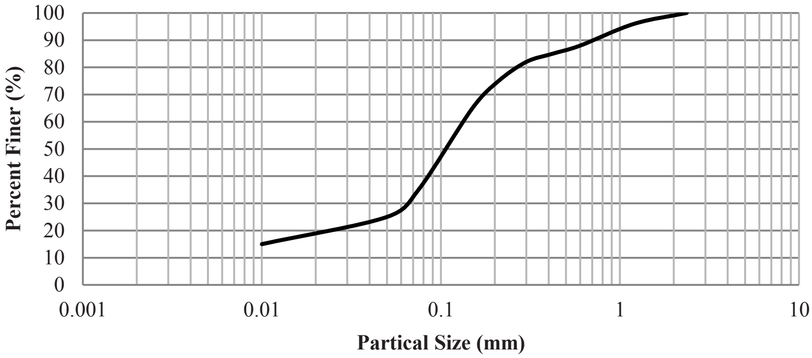

Fig. 1. Grain size distribution of soil

Table 2. Properties of fly ash

Physical properties		Chemical properties	
Properties	Test value	Constituents	% by weight
Specific Gravity (G)	2.24	SiO_2	58.78
Liquid limit	47	Fe_2O_3	9.31
Plastic limit	Non-plastic	Al_2O_3	26.92
Proctor OMC (%)	25.0	CaO	1.77
Maximum dry density (g/cm^3)	1.4	MgO	0.68
Lime Reactivity (kg/cm^2)	28	Ignition Loss (%)	0.72

3.3. Bagasse Ash (BA)

The bagasse ash used in the study was brought from Uttam Sugar Mill, Deoband near Roorkee. The ash was obtained from this mill at a boiler temperature of 750-800°C. The bagasse ash produced at the plant was about 2-2.5 % of the bagasse used in boiler. The physical and chemical properties of BA tested in laboratory are given in Table 3.

Table 3. Properties of bagasse ash

Physical properties		Chemical properties	
Property	Value	Constituents	% by weight
Specific gravity	2.38	Ignition loss	2.11
Liquid limit	41	SiO_2	65.27
Plastic limit	Non-plastic	Al_2O_3	3.11
Optimum moisture content (%)	48	Fe_2O_3	2.1
Maximum dry density (g/cm^3)	1.27	CaO	11.16
Lime Reactivity (kg/cm^2)	32	MgO	1.27

3.4. Rice Husk Ash (RHA)

Rice husk ash is a predominantly siliceous material obtained after burning of rice husk in a boiler or an open fire. Lime reactivity test conducted on this ash indicate the fully burned RHA exhibits greater reactivity. This waste material having pozzolonic properties can be utilized in the stabilization for road construction. For this study, RHA was obtained from paddy mill, Roorkee. It was fine grained siliceous in nature light weight and grey in color. The physical and chemical properties of RHA tested in laboratory are given in Table 4.

Table 4. Properties of rice husk ash

Physical properties		Chemical properties	
Property	Value	Constituents	% by weight
Specific gravity	2.17	Ignition loss	6.2
Liquid limit	78	SiO_2	72.2
Plastic limit	Non-plastic	Al_2O_3	5.4
Optimum moisture content (%)	75	Fe_2O_3	2.1
Maximum dry density (g/cm^3)	1.9	CaO	4.1
Lime Reactivity (kg/cm^2)	25	MgO	1.7

3.5. Rice Straw Ash (RSA)

Rice-straw ash used was procured from agricultural field of Roorkee (U.K.). This is waste material for farmers. The specific gravity was 1.81 and colour was light grey. The physical and chemical properties of RSA tested in laboratory are given in Table 5.

Table 5. Properties of rice straw ash

Lime Reactivity (kg/cm^2) 28 MgO 5.12

Physical properties		Chemical properties	
Property	Value	Constituents	% by weight
Specific gravity	1.81	Ignition loss	9.4
Liquid limit	NA	SiO_2	62.75
Plastic limit	NA	Al_2O_3	2.4
Optimum moisture content (%)	64	Fe_2O_3	24.18
Maximum dry density (g/cm^3)	1.3	CaO	2.76
Lime Reactivity (kg/cm^2)	28	MgO	5.12

4. Laboratory Investigation and Interpretation of Results

4.1. Material combination for soil stabilization

The influence of FA, BA, RHA and RSA on the geotechnical characteristics of different types of soil were investigated by conducting various laboratory tests viz. shrinkage limit, standard proctor and California bearing ratio (CBR) test. The tests were performed for various combinations of soil-FA, soil-BA, soil-RHA and soil-RSA mixtures as presented in Table 6. In the present study, manual mixing method was employed intentionally so as to simulate better the field working conditions. Initially subgrade soil was dried and pulverized properly with the help of small crowbar and spatula to make lumps free soil. For FA–soil mixtures, FA was admixed @ 5 percent equal intervals up to 35% by part replacing the subgrade soil. Similar procedure was adopted for soil-BA, soil-RHA and soil-RSA mixtures. In order to ensure proper mixing, initially a layer of subgrade soil was spread on mixing tray then on top of which a layer of FA was spread then after; dry hand mixing was performed from one end so as to intermix the entire materials thoroughly. This step was repeated for another five to six times till mixtures show uniform colour. There was no any problem to obtain uniform mix even when using the method of adding 5% at a time. Same mixing operations were maintained for all mixtures.

Table 6 Combinations of soil and ash

Combinations	Soil (% by total dry weight)	FA (% by total dry weight)	BA (% by total dry weight)	RHA (% by total dry weight)	RSA (% by total dry weight)
1	100	0	0	0	0
2	95,90, 85, 80, 75, 70, 65	5,10,15,20, 25,30, 35	0	0	0
3	95,90, 85, 80, 75, 70, 65	0	5,10,15,20, 25,30, 35	0	0
4	95,90, 85, 80, 75, 70, 65	0	0	5,10,15,20, 25,30, 35	0
5	95,90, 85, 80, 75, 70, 65	0	0	0	5,10,15,20, 25,30, 35

4.2. Shrinkage Limit (SL) test

Shrinking is the opposite to swelling of soil. Soil swells with increase in moisture content and will shrink with decrease in moisture content. Soil shrinkage can cause serious distress to a foundation/structure. The mechanism is the same as the expansive, but in the opposite direction. When wetter than the SL, the soil is fully saturated, but when drier, the soil becomes unsaturated. The soil changes to a lighter color at the SL due to the water receding within the pores. In fact, the volume does continue to decrease on drying beyond the SL as soil is dried below the plastic limit it shrinks and gets brittle until finally all the particles are in contact and the soil can shrink no further. This point is called the shrinkage limit. The soil still has moisture within it but if any of this moisture is lost by further drying, air has to enter the soil to replace it. This test was conducted as per IS 2720 (Part VI). Fig. 2 shows the variation of shrinkage limit in respect of the soil sample on admixing of FA, BA, RHA and RSA.

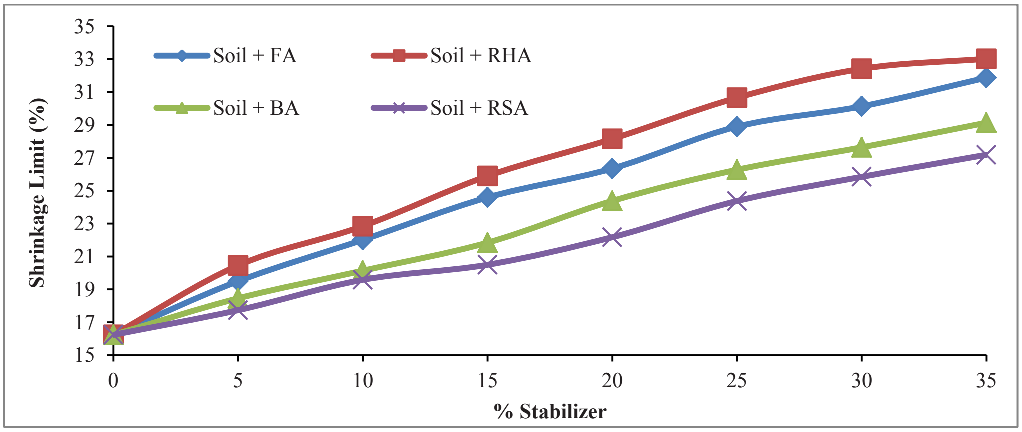

Fig. 2. Shrinkage limit for admixed soil

Admixing of FA, BA, RHA and RSA increases the shrinkage limits remarkably. This increase was more pronounced for RHA and FA admixed with soil samples. This phenomenon is mainly attributed to the flocculation of clay particles caused by the free lime present in the RHA and FA resulting in the reduction of friction between the particles. Similarly, another possible reason for having higher shrinkage limits on admixing of stabilizers was due to the substitution of finer particles of clayey soil by relatively coarser FA and RHA particles. Similar behavior was also observed for soil admixed with BA and RSA.

4.3. Standard Proctor test

The geotechnical properties of soil are dependent on the moisture and density at which the soil is compacted. Generally, a high level of compaction of soil enhances the geotechnical parameters of the soil, so that achieving the desired degree of relative compaction necessary to meet specified or desired properties of soil is very important. The aim of the Proctor test (moisture-density test) was to determine the optimum moisture contents (OMC) and maximum dry densities (MDD) of both untreated compacted and treated stabilized soil-mixtures. In order to obtain these parameters, heavy compaction test was employed for the mentioned mixture proportions as per IS: 2720 (Part 8). The results for OMC and MDD for soil stabilized with FA, BA, RHA and RSA are as shown in Fig. 3 and Fig. 4 respectively.

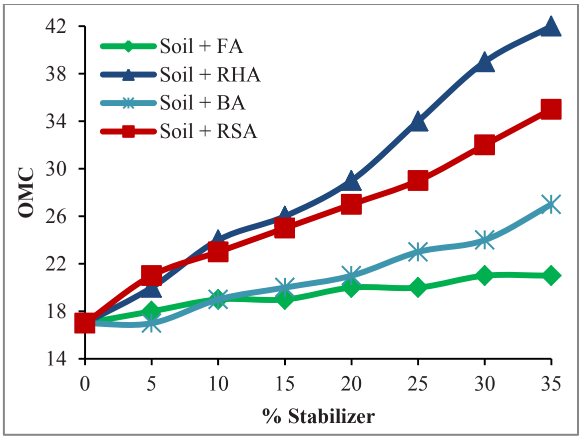

Fig.3. OMC for admixed soil

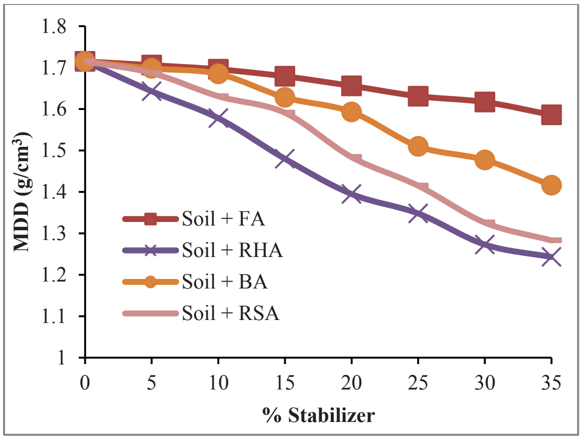

Fig. 4. MDD for admixed soil

As shown in Fig. the OMC for soil increases with increase in percentage content of FA, BA, RHA and RSA. This increase was more pronounced for RHA admixed soil-mixtures in comparison to that of other types stabilizers of used. This phenomenon was mainly due to, RHA being material containing more percentage of silica and CaO than that of FA, BA and RSA which subsequently influenced the hydration effect and the affinity for more moisture during chemical reaction process. The dry density for the soil samples decrease with increase in the percentage of FA, BA, RHA and RSA (Fig. 4). Decrease in density was directly attributed to the flocculation/aggregation and the formation of cementitious products. This decrement was more pronounced for RHA to that of other stabilizers.

4.4. California Bearing Ratio (CBR) test

It is in essence a simple penetration test developed to evaluate the strength of road subgrades. We are determining the resistance of the subgrade, (i.e. the layer of naturally occurring material upon which the road is built), to deformation under the load from vehicle wheels. Even more simply put, "How strong is the ground upon which we are going to build the road". Higher the CBR reading shows stronger the subgrade and less thick it is necessary to design and construct the road pavement, this gives a considerable cost saving. Conversely low

CBR reading indicates the subgrade is weak and we must construct a suitable thicker road pavement to spread the wheel load over a greater area of the weak subgrade in order that the weak subgrade material is not deformed, causing the road pavement to fail. The samples of soil admixed with FA, BA, RHA and RSA content varying from 0% to 35% were cured for 3, 7, 14 and 28 days. This test was conducted on these samples after soaking in water for four days as per IS 2720 (Part 16). The results for average CBR values of each three samples for soil-FA, soil-BA, soil-RHA and soil-RSA are as shown in Figure 5 to Figure 8 respectively.

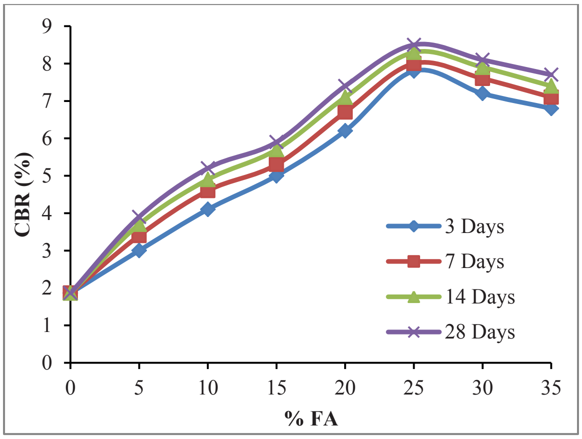

Fig. 5. CBR for admixed soil with FA

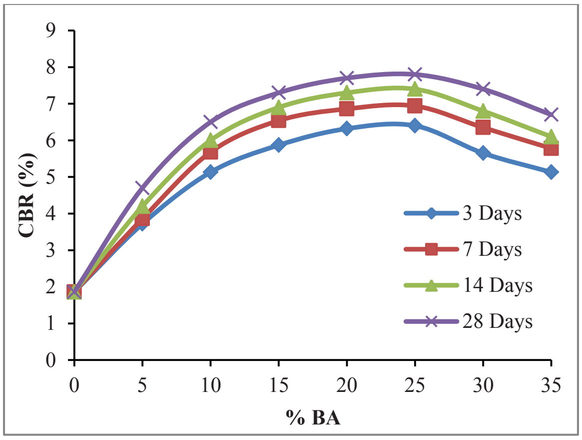

Fig. 6. CBR for admixed soil with BA

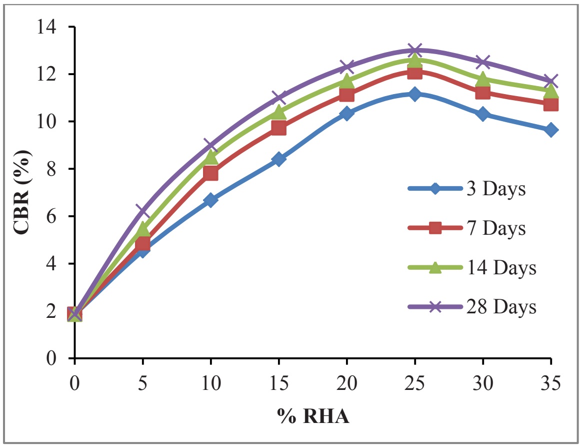

Fig. 7. CBR for admixed soil with RHA

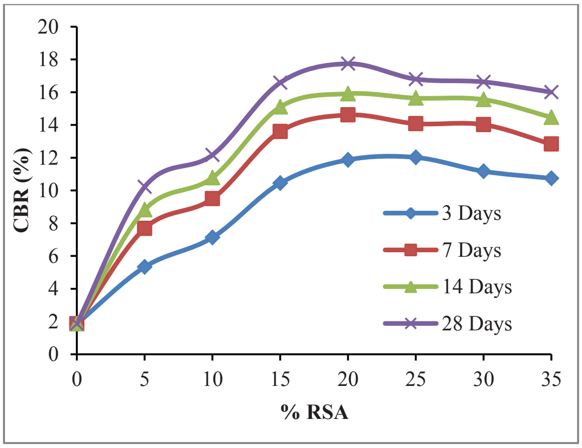

Fig. 8. CBR for admixed soil with RSA

The soaked CBR value of the soil increases with the addition of FA and BA up to a 25 % of FA and RHA and thereafter these values start decreasing (Figs.5 & 6). The trend of increase of CBR values with the percentage content of FA is approximately linear upto 20% admixing. Abrupt increase in CBR values were also noticed between 20% & 25 % FA admixing. Also it was found that the CBR increased from 7.8 to 8.5% with the curing period from 3 to 28 days at 25% of FA admixed with soil. In case of BA, CBR improves progressively upto 25% after this decrease with further addition of BA. This behavior was more pronounced for FA-soil in comparison to

BA-soil. These trends clearly depicted that FA is more effective between 20 and 25% admixing. At 25% of BA content, the CBR increased from 6.4 to 7.8% with the curing period from 3 to 28 days. Whereas, RHA admixing improves the CBR values substantially upto 25% replacement level (Fig.7). The trend of increase of CBR values were gradual and more consistent in comparison to that of FA admixed soil samples. The soaked CBR values obtained while admixing RHA were much higher than that of FA and BA admixing. The percentage increase of CBR value were more for higher percentage RHA admixed soil samples with respect to FA and BA admixed soil samples. The increase in curing period from 3 to 28 days increased the CBR from 11.15 to 13% at 25% of RHA content. The increase of soaked CBR value for RSA admixed soil sample showed linear relationship with the ash content up to 20% after which this increase is slackened with increase of RSA (Fig. 8). The CBR value of soil admixed with 20% RSA were much higher than that of 25% FA, 25% BA and 25% RHA admixing. The positive effect of curing period from 3 to 28 days was observed for RSA admixed with soil at 20% RSA content, which increased the CBR from 11.87 to 17.74% respectively. The low CBR of the clayey soil (as compared to clayey soil-stabilizers mixes) is attributed to its inherent low strength which is due to the dominance of the clay fraction. In overall, the improvement observed on soaked CBR values on admixing of stabilizers were due to the frictional resistance contributed from the FA, BA, RHA and RSA.

5. Conclusions

In the present study performance of various agricultural and industrial waste materials in road construction are studied through laboratory investigation. The soil admixed with FA, BA, RHA and RSA samples were cured up to 28 days before testing. Various tests like shrinkage limit, CBR, UCS, and triaxial test were conducted. The following conclusions have been drawn from these laboratory tests:

- Marked improvements in shrinkage limits were observed for soil admixed with FA, BA, RHA and RSA. This improvement was more pronounced for 30% RHA admixing.
- Admixing of FA, BA, RHA and RSA made to have higher optimum moisture content as the dosages of stabilizers increased. This increase was more pronounced for RHA admixed soil-mixtures in comparison to that of other stabilizers. But dry densities were decreasing with increasing in the percentage of FA, BA, RHA and RSA. This decrement was more pronounced for RHA to that of other stabilizers.
- Admixing of FA, BA and RHA upto 25% and RSA upto 20% increased CBR values of clayey soil at all curing days. The CBR value of soil admixed with 20% RSA were much higher than that of 25% FA, 25% BA and 25% RHA admixing. The positive effect of curing period from 3 to 28 days was observed for RSA admixed with soil at 20% RSA content, which increased the CBR from 11.87 to 17.74%.
- Based on the present study, all stabilizers viz. FA, BA, RHA and RSA attains its optimal strength after 28 days curing period. It is suggested that these can be utilized as an effective soil stabilizer if available in abundant quantity. The results are based only on laboratory investigations and hence it is further recommended that the viability and long-term performance in field, of this material should be determined in actual highway construction projects.

References

Basha, E. A., Hashim, R., Mahmud, H. B. and Muntohar, A. S. (2005). Stabilization of residual soil with rice husk ash and cement Stabilization of residual soil with rice husk ash and cement. *Construction and Building Materials, Vol. 19*, 448–453.

Cordeiro, G. C., Toledo Filho, R. D., Fairbairn, E. M. R. (2009). Effect of calcinations temperature on the pozzolanic activityof sugar cane bagasse ash. *Construction and Building Materials. Vol. 23*, 3301–3303.

Dhawan, P. K., Swami, R. K., Mehta, H. S., Bhatnagar, O. P., and Murty, A. V. R. S. (1994). Bulk utilization of coal ashes from road works. *Indian highways, Vol. 22 (11)*, 21-30.

FAOSTAT, http://faostat.fao.org/, accessed on 10 September, 2012.
Ganesan, K., Rajagopal, K. and Thangavel, K. (2007). Evaluation of bagasse ash as supplementary cementitious material. *Cement & Concrete Composites, Vol. 29*. 515–524.
Govindarao, V. M. H. (1980). Utilization of rice husk - a preliminary analysis. Journal of *Science and Industrial Research, 39(6)*. 495-515.
Goyal, A., Anwar, A.M., Kunio, H., Hidehiko, O. (2007). Properties of sugarcane bagasse ash and its potential as cement - Pozzolana binder. *Twelfth International Colloquium on Structural and Geotechnical Engineering*, 10-12 Dec. Cairo – Egypt. 1.
Jha, J. N. and Gill, K. S. (2006). Effect of rice husk ash on lime stabilization. *Journal of the Institution of Engineers (India), Vol. 87*, 33-39.
Kumar, A., Walia, B. S. and Bajaj, A. (2007). Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil. *Journal of Materials in Civil Engineering, 19(3)*. 242–248.
Kumar, P. and Singh, S. P. (2008). Fiber-reinforced fly ash subbases in rural roads. *Journal of Transportation Engineering ASCE, 134(4)*. 171-180.
Osinubi, K. J., Bafyau, V, and Eberemu, A. O. (2009). Bagasse Ash Stabilization of Lateritic Soil. *Appropriate Technologies for Environmental Protection in the Developing World, Springer*, 271-280.
Prabakar, J., Dendorkar, N. and Morchhale, R. K. (2004). Influence of fly ash on strength behavior of typical soils. *Construction and Building Materials, Vol. 18*. 263–267.
Ranasinghe and Arjurna, P. (1993). Use of Rice Straw as Pozzolana. *Master Thesis No. St-85-1*, Asian Institute of Technology.