Review on Suitability of Rice Husk Ash as Soil Stabilizer

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Abstract. Modern era is an era of sustainable development. To utilize industrial waste for development works is an essential principle of sustainable development. Around 70 million hectare area of central India has black cotton soil, so there is a deficiency of stable construction site in these areas. Making these sites suitable for construction activities is a challenging task for geotechnical engineers. India is the second largest rice producer in the world. Around 24 million tons of Rice Husk and 4.4 million tons of Rice Husk Ash (RHA) are produced annually in India. The effective disposal of such huge quantity is cumbersome, thus their use in some other fields must be looked into.

The use of RHA as a soil stabilizer not only intensifies the required soil properties but also provides an effective way of its safe disposal. RHA contains rich amount of silica which have capability to replace the exchangeable ions present in clay minerals, thus reducing the shrinkage and swelling behavior of black cotton soil.

The present study describes the available knowledge on use of RHA in soil stabilization purposes. The effect of RHA on various index and engineering properties of soil is also discussed based on previous researches in this field.

Keywords: Black cotton soil, Rice Husk Ash, Solid waste, Stabilization

1 Introduction

Roads are the most vital component for the economic and social development of any country. Its importance further increases if the economy of a country is based on agriculture. India has a total road network of 6 million kilometers of which 79% consist of rural roads [1]. In India more than 20% land area is covered with soils having low California Bearing Ratio (CBR) and shear strength values [2]. The pavement constructed over such poor subgrade soils will deteriorate significantly under heavy wheel load. So in order to overcome such situations, some soil reinforcement techniques have to be adopted which includes chemical, mechanical and physical methods [3].

Soil stabilization by addition of RHA and lime is quite suitable for road pavements since it leads to cheaper construction and lesser maintenance costs, prevents environmental degradation and preserves good quality aggregate materials which are available in limited quantity [4]. India is one of the largest producers of rice in the world.

The major use of rice husk is in refractory brick industry, cement and steel industry as a fuel, which ultimately produces rice husk ash as a solid waste.

This paper reviews and describes the available state of the art knowledge on use of RHA for soil stabilization purpose.

2 Rice Husk Ash

Rice husk is a by-product of the rice milling. About 110 million tons of husk per year are produced across the world. Due to its abrasive character, it is not suitable as animal feed. High lignin and ash content make it unacceptable for paper manufacturing. During milling of paddy, around 75% is obtained as rice and bran and rest 25% as husk [4]. The husk obtained is used as fuel for processing paddy in rice mills and for producing energy through direct combustion. Upon burning, 25% of husk gets converted into ash and remaining is volatile matter. This RHA is a great threat to the environment which can damage surrounding area and land where it is dumped. For its effective disposal it can be used as pozzolanic material in concrete production, absorbents for oils and chemicals and for soil stabilization [5**]**. Table 1 and Table 2, respectively, shows the chemical composition and physical properties of RHA [6].

Table 1. Chemical Composition of RHA

Constituent	Percentage (%)
Silica (SiO_2)	87.12
Aluminium Oxide (Al_2O_3)	3.27
Ferric Oxide (Fe_2O_3)	1.45
Calcium Oxide (CaO)	2.79
Magnesia (MgO)	0.63
Loss in Ignition	4.50

Source: Subrahmanyam et al.

Table 2. Physical Properties of RHA

Property	Value
Grain Size Distribution (% Finer than)	
4.75mm	100.00
2.8mm	97.21
2mm	95.45
1.18mm	93.87
600µ	89.63
300µ	79.42
150µ	46.56
75µ	17.90
Specific Gravity	2.07

3 Classification of RHA

Based on the carbon content, rice husk ash has been classified into two types [4].

a) Low carbon RHA
b) High carbon RHA

a. Low Carbon RHA

The burning of rice husk at high temperature and shorter duration or low temperature and longer duration in controlled atmosphere produces low carbon RHA. Currently various techniques including fixed bed reactor, fluidized bed reactor, rotary tube furnace etc. have been developed for burning rice husk under controlled atmospheric conditions. The RHA thus produced contains amorphous silica and low graphite carbon content. Fig. 1 shows the low carbon RHA.

Fig. 1. Low Carbon RHA

b. High Carbon RHA

When burning temperature and duration both are high as in case of open heap burning of rice husk, the ash thus produced contains crystalline silica and high graphite carbon content. High carbon RHA is used less as open heap burning is prohibited in various countries due to production of hazardous gases resulting in severe health issues. Fig. 2 shows the high carbon RHA.

Fig. 2. High Carbon RHA

The index properties of RHA are shown in Table 3.

Table 3. Index Properties of RHA

Particulars	Description
Liquid Limit (%)	Non-Plastic
Plastic Limit (%)	Non-Plastic
Maximum Dry Density (KN/m^3)	6.90
Optimum Moisture Content (%)	42.20
CBR (%)	16.12
Colour	Grey
Shape Texture	Irregular
Mineralogy	Non-Crystalline
Odour	Odourless
Appearance	Very Fine

4 Review of Literature

This section presents the state of art knowledge about use of RHA in soil stabilization.

Rao et al. (2012) studied the effect of RHA, lime and gypsum on the index and engineering properties of marine clay. The soil sample was classified as clay of high compressibility (CH) as per Indian standard classification system (ISCS). The soil sample was mixed with 5% lime, RHA (10-40%) and gypsum (2-5%) and tested at various curing periods (4 to 28 days). The optimum mix was found to be 5% lime + 20% RHA + 3% gypsum at 28 days curing, where maximum improvement in soil properties are obtained. Maximum improvement in UCS and CBR was 548% and 1350% respectively. It was concluded that utilization of industrial wastes like RHA, lime and gypsum is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries.

Sabat (2012) studied the effect of polypropylene fiber on geotechnical properties of RHA and lime stabilized expansive soil. The soil sample was classified as clay of high compressibility (CH) as per ISCS. As percentage of polypropylene fiber increases in the RHA-lime stabilized soil, MDD decreases and OMC increases. The UCS and CBR of the RHA-lime stabilized soil increased up to 1.5% addition of polypropylene fiber and decreases with further increase in fiber content. The hydraulic conductivity of RHA-lime stabilized soil increases as the percentage of fiber increases, whereas swelling pressure decreases. The optimum proportion of soil: fiber: lime: RHA was found to be 84.5: 1.5: 4: 10 where maximum improvement was reported.

Rao et al. (2012) studied the effect of adding potassium chloride (KCI) and RHA on the strength and swelling properties of clayey soil. The soil sample was collected from Amalapuram, East Godavari district, Andhra Pradesh and was classified as clay of high compressibility (CH) as per ISCS. The KCI content varies from 0 to 3%, whereas RHA content varies from 0 to 16%. The maximum reduction in plasticity index; swell potential; swelling pressure and improvement in UCS was observed at 1% KCI and 12% RHA content. The UCS of expansive soil has increased by 515% at

28 days curing as compared to unreinforced specimen. It was concluded that utilization of industrial wastes like RHA is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries.

Kuity and Roy (2013) studied the effect of using waste material and geogrid on the strength behaviour of poor subgrade soil. The soil sample was collected from BESUS, West Bengal and classified as clay of low compressibility (CL) as per USCS. The waste materials; pond ash (PA) and rice husk ash (RHA) and lime as additive was mixed in different proportions with soil. Geogrids are placed at middle of mold in single layer and at one-third height from both top and bottom of mold. It was found that soaked and unsoaked CBR values of mix increased by 1.22 to 3.72 times and 1.16 to 2.06 times respectively by adding PA, RHA and lime. For single layer of geogrid in soaked and unsoaked condition improvement varies from 7.76 to 12.84 and 1.91 to 7.88 times respectively. For double layer of geogrid in soaked and unsoaked condition improvement varies from 7.49 to 18.21 times and 2.16 to 9.29 times, respectively in comparison to virgin soil. It was concluded that use of geogrid in soil subgrade enhanced the CBR value significantly.

Anupam et al. (2013) studied the effect of mixing fly ash (FA), bagasse ash (BA), rice husk ash (RSA) and rice straw ash (RSA) on the shrinkage limit, OMC-MDD and soaked California bearing ratio (CBR) value. The soil sample was classified as clay of low compressibility (CL) as per USC system. Waste materials were mixed in increment of 5% upto 35% by part replacing the subgrade soil. It was found that shrinkage limit increased with increase in percentage of waste material. Heavy compaction test showed an increase in OMC and decrease in MDD with increase in percentage of waste material in the mix. Soaked CBR test conducted at different curing periods (i.e. 3, 7, 14 and 28 days) showed an increase in CBR value upto 25% for FA, BA, RHS and upto 20% for RSA and beyond that it decreased. Thus there will be considerable reduction in the thickness requirement of pavement leading to cost savings.

Shrivastava et al. (2014) studied the effect of adding lime and RHA on various geotechnical properties of Black cotton soil. The soil sample was collected from Bilhari area of Jabalpur (Madhya Pradesh). The RHA content varies from 5% to 20%, whereas lime content was kept constant at 5%. The test results indicate significant improvement in California bearing ratio (CBR) and Unconfined compressive strength (UCS), whereas differential free swell decreases with increase in RHA content. Maximum improvement of 287.5% and 30% in CBR and UCS, respectively, was reported corresponding to 20% RHA content. It was concluded that silica present in RHA reacts with lime to form a binding material and enhances the soil properties considerably.

Kumar and Preethi (2014) studied the effect of RHA and lime addition on strength properties of clayey soil. The soil sample was classified as clay of intermediate compressibility (CI) as per ISCS. The RHA (5 – 15%) and lime (3 – 9%) are mixed in soil sample individually and in various combinations and tested for CBR and UCS for different curing periods (4, 7 & 14 days). It was found that 6% addition of lime shows maximum improvement in the CBR and UCS as compared to other combinations for 14 days curing. Maximum increase of 89% in UCS and 378% in CBR with respect to uncured sample is obtained. It was concluded that lime addition changes the soil condition from poor to excellent, thus significantly reducing the thickness requirement of pavement.

Roy (2014) studied the effect of RHA and cement on the strength properties of clayey soil (CH). The soil sample was mixed with (5-20%) RHA and 6% cement. It was found that with increase in RHA content, reduction in maximum dry density (MDD) and increase in optimum moisture content (OMC) is reported. The CBR and UCS shows maximum improvement of 106% and 90%, respectively, at 10% RHA and beyond that it decreases. It was concluded that silica present in RHA reacts with the lime present in cement, thus forming binder material and improves the engineering properties of poor subgrade soil.

Akinyele et al. (2015) studied the effect of adding RHA in various percentages (i.e. 2, 4, 6, 8 & 10%) on the index and shrinkage properties of poor lateritic clayey soil. The soil sample was collected from Buruku, Nigeria and is classified as clay of low compressibility (CL). It was found that as the percentage of RHA increases, reduction in plasticity index and linear shrinkage is reported. It was concluded that the RHA is an effective stabilizing agent for subgrade in road construction and for backfilling in retaining wall, but the mix should be controlled not to exceed 10%.

Kumar and Gupta (2015) studied the effect of adding pond ash (PA), rice husk ash (RHA), polypropylene fibers and cement on the compaction and strength behaviour of clayey soil. The soil sample was collected from Jalandhar, Punjab and was classified as clay of low compressibility (CL) as per USCS. Pond ash and rice husk ash content varies from 30-45% and 5-20% respectively whereas fibers and cement content varies from 0 to 1.5% and 0 to 4% respectively. To study the effect of curing, specimens are cured for 7, 14 and 28 days. Modified compaction, unconfined compressive strength (UCS) and split tensile strength (STS) tests are conducted. It was found that OMC increased and MDD decreased with increase in RHA content. Fiber addition increased the UCS and STS values with reduction in post peak strength loss and crack formation. The optimum value of pond ash and rice husk ash content in mixture was found as 40% and 10% respectively. Thus it was concluded that admixtures can be used as light weight fill materials.

Raj et al. (2016) studied the effect of RHA addition in various proportions (i.e. 5%, 10%, 20%, 30%, 40%, 50% & 80%) on the engineering properties of clayey and alluvial soil. As the RHA proportion increases, reduction in liquid limit, free swell index and OMC is observed whereas; significant improvement in MDD, CBR and angle of internal friction was reported for both soils. Maximum increase of 160% and 55%, respectively, in CBR was observed for alluvial soil and clayey soil when mixed with 80% RHA.

Prakash et al. (2017) studied the effect of adding RHA in various percentages (i.e. 5%, 10%, 15% & 20%) on strength properties of poor subgrade soil. As the percentage of RHA increases, reduction in liquid limit and MDD was reported, whereas

OMC increases. The CBR value increases upto 10% RHA content and beyond that it decreases. It was concluded that silica present in RHA is capable to replace the exchangeable ion present in clay mineral, thus can reduce shrinkage and swelling property of clay minerals.

Ghutke et al. (2018) studied the effect of RHA addition on index and strength properties of black cotton soil. The RHA was mixed in various percentages by weight of soil (i.e. 4%, 8%, 12% & 16%). It was found that liquid and plastic limit first increases upto 4% RHA addition and then start decreasing. Specific Gravity and MDD decreases as the percentage of RHA increases. CBR value increase up to 12% RHA content and beyond that it decreases. It was concluded that optimum ash content in soil was 12% where maximum improvement in properties are occurring.

5 Conclusions

The Rice Husk Ash is a pozzolanic material which contains large amount of silica with little or no cementious properties. From the previous research on the potential of RHA as a soil stabilizer we can conclude that RHA is generally not used alone as a soil stabilizer, but can be used with small amount of cement or lime. Lime reacts with silica present in RHA and forms cementious compounds and hence enhances the geotechnical properties of expansive soils. The RHA can also be used with small amount of soil reinforcing materials such as polypropylene and waste coir fibres. The optimum amount of stabilizer with the combination of different materials is as follows:-

1- 10% RHA with 6% cement gives maximum improvement in CBR and UCS values of soil.
2- 10% RHA with 6% Lime results in maximum increase in CBR and shearing properties of the soil.
3- 20% RHA and 10% stone dust results in maximum improvement in the strength characteristics in soil.
4- 8% RHA and 1% core fibre results in maximum improvement in shearing characteristics of soil.

Thus it can be recommended to use RHA as soil stabilizer which not only reduces construction cost of pavement due to significant improvement in CBR, but also provide its safe disposal, which otherwise may cause substantial environmental degradation. However, more research work is required to fully understand the working mechanism of such agricultural wastes for soil stabilization. Hence it’s time to support Rice Husk Ash for the sake of better environment.

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