PERFORMANCE OF RICE HUSK ASH AND CEMENT AS SOIL SUBGRADE STABILIZING AGENTS

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ABSTRACT

Soil stabilization is a critical technique for enhancing the engineering performance of weak and expansive soils, particularly for road and pavement construction. Expansive clays, characterized by high swell potential, low shear strength, and poor bearing capacity, pose significant challenges for infrastructure development, as observed along the historic Mughal Road connecting Kashmir valley to Poonch–Rajouri. In this study, locally available soils with inherently low strength were stabilized using rice husk ash (RHA), an agricultural by-product, and cement in varying proportions. Laboratory investigations, including compaction characteristics, optimum moisture content (OMC), maximum dry density (MDD), and California Bearing Ratio (CBR) tests, were performed to assess improvements in soil properties. Results revealed that the addition of RHA and cement significantly increased soil strength and stability, with CBR values improving from 1.88 to 7.03 as RHA content increased from 0% to 7%. The optimum stabilizer combination was identified as 10% RHA by dry weight of soil, providing notable strength gains while promoting sustainable use of agricultural waste. Literature studies corroborate these findings, highlighting the synergistic effects of RHA with lime, gypsum, and other admixtures. Overall, the study demonstrates that RHA-based stabilization offers a cost-effective, eco-friendly solution for upgrading weak soils and ensuring durable road infrastructure.

Keywords: Subgrade, Rice Husk Ash, Cement, Stabilizing Agents, Soil

INTRODUCTION

Civil engineering projects located in areas with soft or weak soils have traditionally incorporated improvement of soil properties by using various methods. Soil Stabilization is being used for a variety of engineering works, the most common application being in the construction of road and pavements, where the main objective is to increase the strength or stability of soil and to reduce the construction cost by making best use of the locally available materials. Over time, rice husk ash is the material used for stabilizing soils. Thus the use of Agricultural waste (such as rice husk ash - RHA) will considerably reduce the cost of Construction and as well reducing the environmental hazards they cause. Rice husk is an agricultural waste obtained from milling of rice. About 108 tons of rice husk is Generated annually in the world. Hence, use of RHA for upgrading of soil should be encouraged. Because expansive clays are characterized by excessive compression, dispersion, collapse, low shear strength, low bearing capacity, and high swell potential, such soils are unsuitable for road sub grade layer construction. Expansive clays usually experience large volume changes depending on the amount of water contained in the soil voids. Such soils can form deep cracks in drier seasons and expand dramatically when wet. Such instability affects the strength performance of soil as a construction material. Volume changes involving shrinkage and swelling cause deformation of the road surface, whereas increased moisture content in 0expansive clay soils significantly reduces soil bearing strength. Soils with low-bearing capacity can be strengthened economically for building purposes through the process of "soil stabilization" using different types of stabilizers.

The soil used for the stabilization was collected from various locations from the historic Mughal road connected to link Kashmir valley to various parts of Poonch Rajouri areas through an indirect way. The soil present there is very loose with a low bearing capacity and less requisite strength. Various tests with different percentages of both RHA and Cement were added to the soil itself and subsequent checks were made in improvement of soil and its strength like OMC, MDD, CBR, etc

Soil stabilization is a general term for any physical, chemical, biological, or combined method of changing a natural soil to meet an engineering purpose. Improvements include increasing the weight bearing capabilities, tensile strength, and overall performance of in- situ sub soils, sands, and other waste materials in order to strengthen road surfaces.

Some of the renewable technologies are: enzymes, surfactants, biopolymers, synthetic polymers, co-polymer based products, cross-linking styrene acrylic polymers, tree resins, ionic stabilizers, fiber reinforcement, calcium chloride, calcite, sodium chloride, magnesium chloride and more. Some of these new stabilizing techniques create hydrophobic surfaces and mass that prevent road failure from water penetration or heavy frosts by inhibiting the ingress of water into the treated layer.

However, recent technology has increased the number of traditional additives used for soil stabilization purposes. Such non-traditional stabilizers include: Polymer based products (e.g. cross-linking water-based styrene acrylic polymers that significantly improves the load-bearing capacity and tensile strength of treated soils), Copolymer Based Products, fiber reinforcement, calcium chloride, and Sodium Chloride.

Traditionally and widely accepted types of soil stabilization techniques use products such as bitumen emulsions which can be used as a binding agents for producing a road base.

However, bitumen is not environmentally friendly and becomes brittle when it dries out. Portland cement has been used as an alternative to soil stabilization. However, this can often be expensive and is not a very good "green" alternative. Cement fly ash, lime fly ash (separately, or with cement or lime), bitumen, tar, cement kiln dust (CKD), tree resin and ionic stabilizers are all commonly used stabilizing agents. Other stabilization techniques include using on-site materials including sub-soils, sands, mining waste and crushed construction waste to provide stable, dust free local roads for complete dust control and soil stabilization.

Soil Stabilization Methods with Different Materials:

The following are the list of materials which are responsible for the stabilization of soils and also the various methods required to process them:-

Soil Stabilization with Cement

Cement stabilization of soil is done by mixing pulverized soil and Portland cement with water and compacting the mix to attain a strong material. The material obtained by mixing soil and cement is known as soil-cement. The soil cement becomes a hard and durable structural material as the cement hydrates and develops strength. Cement stabilization is done while the compaction process is continuing. During the compaction process we use some amount of cement. Some void space can be found in soil particle.

Cement is just like paw, so cement can fill the void space of soil easily. As a result, void ratio of soil may reduce. After this primary tasks, when we add water in the compaction the cement reacts with water and become hard. So unit weight of soil is also may increased. Because of the hardening of cement, shear strength and bearing capacity will be increased. Because of the stabilization, permeability of soil may decrease.

The appropriate amounts of cement needed for different types of soils may be as follows:

Gravels – 5 to 10%

Sands – 7 to 12%

Silts – 12 to 15%, and

Clays – 12 – 20%

Stabilization Mechanisms

Portland cement is composed of calcium-silicates and calcium-aluminates that, when combined with water, hydrate to form the cementing compounds of calcium-silicatehydrate and calcium-aluminate-hydrate, as well as excess calcium hydroxide. Because of the cementitious material, as well as the calcium hydroxide (lime) formed, portland cement may be successful in stabilizing both granular and 0fine-grained soils, as well as aggregates and miscellaneous materials. A pozzolanic reaction between the calcium hydroxide released during hydration and soil alumina and soil silica occurs in fine-grained clay soils and is an important aspect of the stabilization of these soils. The permeability of cement stabilized material is greatly reduced. The result is a moisture- resistant material that is highly durable and resistant to leaching over the long term.

Advantages of Cement Stabilization

- It is widely available.
- Cost is relatively low.
- It is highly durable.
- Soil cement is quite weather resistant and strong.
- Granular soils with sufficient fines are ideally suited for cement stabilization as it requires least amount of cement.
- Soil cement reduces the swelling characteristics of the soil.
- It is commonly used for stabilizing sandy and other low plasticity soils. Cement interacts with the silt and clay fractions and reduces their affinity for water.

Soil Stabilization using Lime

Slaked lime is very effective in treating heavy plastic clayey soils. Lime may be used alone or in combination with cement, bitumen or fly ash. Sandy soils can also be stabilized with these combinations. Lime has been mainly used for stabilizing the road bases and the subgrade. Lime changes the nature of the adsorbed layer and provides pozzolanic action.

Plasticity index of highly plastic soils are reduced by the addition of lime with soil. There is an increase in the optimum water content and a decrease in the maximum compacted density and the strength and durability of soil increases.

Normally 2 to 8% of lime may be required for coarse grained soils and 5 to 8% of lime may be required for plastic soils. The amount of fly ash as admixture may vary from 8 to 20% of the weight of the soil.

Literature review

- **Koteswara (2011)** used rice husk ash, lime and gypsum as additives to the expansive soil which resulted in considerable improvement in the strength characteristics of the expansive soil. It was found that rice husk ash can potentially stabilize the expansive soil solely (or) mixed with lime and gypsum. The utilization of industrial wastes like RHA, lime and gypsum is an alternative to reduce the construction cost of roads particularly in the rural areas. It was observed that the liquid limit of the expansive soil has been decreased by 22% with the addition of 20% RHA+5% lime. It was noticed that the free swell index of the expansive soil has been reduced by 88% with the addition of 20% RHA + 5% lime. The unconfined compressive strength of the expansive soil has been increased by 548% with addition of 20% RHA+5% lime + 3% gypsum after 28 days curing.
- Mtallib and Bankole (2011) carried out experimental study on lime stabilized lateritic soils using rice husk ash as admixture. The index property tests classified the soils as (A-7-6) under the AASHTO soil classification scheme. Index and geotechnical properties tests conducted on the soil containing lime and rice husk ash combinations showed significant improvement in properties. The Atterberg limits were significantly altered with lime and rice husk ash combination; the plasticity of the soils were significantly reduced from 18.10 to 6.70 for sample A and 26.6 to 5.92 for sample B at 6 % lime and 12.5% RHA combination. In terms of compaction characteristics, addition of lime and rice husk ash decreased the maximum dry density and increased the optimum moisture content. At 8% lime and 12.5% RHA, the values of MDD for samples A and B were 1.27 and 1.22 Mg/m3 respectively. The California bearing ratio values peaked at 50% unsoaked values for 8 % lime and 10 % RHA combinations for sample A while that of sample B was 30% at 6% lime and 12.5% RHA combinations. This paper presents the results of experimental study carried out on three different soils improved with different percents of rice husk ash.
- Brooks (2009) made a trial to upgrade expansive soil as a construction material using rice husk ash and fly ash, which are waste materials.Remolded expansive clay was blended with RHA and fly ash and strength tests were conducted. The potential of RHA-fly ash blend as a swell reduction layer between the footing of a foundation and subgrade was studied. In order to examine the importance of the study, a cost comparison was made for the preparation of the sub-base of a highway project with and without the admixture stabilizations. Stress-strain behavior of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the fly ash content was increased from 0 to 25%. When the RHA content was increased from 0 to 12%, unconfined compressive stress increased by 97% while CBR improved by 47%. Therefore, an RHA content of 12% and a fly ash content of 25% were recommended for strengthening the expansive sub grade soil. A fly ash content of 15% was recommended for blending into RHA for forming a swell reduction layer because of its satisfactory performance in the laboratory tests.
- Kumar and Singh(2008) tried different admixtures of polypropylene fiber and fly ash on soil. It was observed that the addition of fiber to soil satisfies all the geotechnical parcels to meet the conditions of sub base subcaste. Bijayanandaetal.(2011) conducted a series of laboratory soaked and unsoaked CBR tests on aimlessly acquainted fiber corroborated and unreinforced samples of muddy soil, compacted at OMC and MDD. Coir fiber has been used as a buttressing material to probe its salutary use in pastoral road subgrade soil. From CBR test results, the engineering performance of coir fiber addition was examined. The results indicated that the addition of coir fiber enhanced the CBR strength of the soil samples significantly. Muddy soils mixed with filaments showed noticeable increase in the CBR strength in comparison with the same soils without fiber eliminations. That is, aimlessly acquainted separate fiber mounts in muddy sub grade offered advanced resistance to penetration than unreinforced one, under analogous lading conditions.

- Shankar etal.(2012) studied on lithomargic complexion mutated with different probabilities of beach and coir, and enhancement in nearly all parcels was observed. The CBR both in soaked and unsoaked conditions, increased as the chance of beach increased from 0 to 40 and coir from 0 to0.5. With the increase in the sand content, the UCS values of blended soil for both light and modified compaction densities increased up to a certain limit, whereas, the increase of coir content resulted in a continuous increase in UCS. According to Ramaswamy and Aziz (1989), its strength and condition beyond a period of one year after placement should not be of any concern, as by that time the coir would have already played a very important role in providing a self-sustaining subgrade for most of the soil types. The loss of strength of the coir with time can be well compensated by the gain in strength of the subgrade within the same time frame.
- Sarbaz (2014) on soil specimens reinforced with palm fibers and bitumen coated fibers showed that palm fibers significantly increased the CBR strength of the sand specimens. Maheshwari et al. As per the Indian Road Congress (IRC) standard IRC 37-2012, the flexible pavement sections resting on fiber reinforced soil for traffic volumes of 1 to 150 msa were designed and modeled using finite element software Plaxis 2D. Considerable reduction in deformation was obtained on the top of sub-grade due to reinforcing of sub-grade soil using fibers.
- Geiman (2005) carried out a study on traditional and non-traditional stabilizers against three Virginia soils. The selected stabilizers were: quicklime, hydrated lime, pelletized lime, cement, lignosulfonate, synthetic polymer, magnesium chloride, and RBI 81. The RBI 81 was observed to be more effective in increasing the strength of soils tested. Cementitious stabilizer may be useful in situations where workability of the soil rather than strength of the soil is a priority. The majority of strength gain for samples treated with lime, lignosulfonate, synthetic polymer, and RBI 81 occurs within 7 days of curing period. Resource center for Asphalt and Soil Training Academy (2008) conducted laboratory studies on properties of soils treated with RBI
- Yoder and Witczak (1975) define two types of pavement distresses, structural and functional failures. In structural failure a collapse of the entire structure or a breakdown of one or more pavement components makes the pavement incapable to sustain the loads imposed on the surface. Functional failure occurs when the pavement is unable to execute its purpose without causing discomfort to drivers or passengers or imposing high stresses on vehicles. These failures may be due to inadequate maintenance, excessive loads, climatic and environmental conditions, poor drainage leading to poor subgrade conditions, disintegration of the component materials, surface fatigue and excessive settlement, volume change of subgrade soils due to wetting-drying and freezing-thawing, etc.
- Hveem and associates developed the first empirical methods using CBR method during 1930's. In 1972, the American Association of State Highway Officials (AASHO) developed an empirical pavement design guide based on an equation (prediction model) with coefficients that were statistically obtained from the AASHO test road. The main drawback of empirical methods were, they are restricted to a particular extent of pavement and traffic loads only, and they are insufficient to account a new material or different traffic loads outside the range considered (Lav et al. 2006). This leads to the development of mechanistic empirical methods for pavement design. In this method, the pavement structure and load configuration are assumed. Generally the pavement structure is simplified to three distinct layers (Dormon and Edwards 1968).
- Allam and Sridharan 1981, Shihata and Baghdadi 2001, Al-Obaydi et al. 2010). Khoury and Zaman (2002, 2007) determined the effect of FT and WD cycles on cylindrical specimens of stabilized aggregate soil. For soil stabilized with 10% Class C FA, resilient modulus and UCS values of 28-days cured specimens were observed to be increasing up to 12 FT cycles, and beyond which a reduction was experienced. The same soil specimens with 15% Cement Kiln Dust (CKD) and 10% class C FA (or fluidized bed ash) were cured for 28 days and then subjected to WD cycle prior to testing for resilient modulus and the values were observed to be decreasing after 30 cycles. Among different durability test procedures used by Zhang and Tao (2008) on cement stabilized samples, the tube suction test showed promising results as an alternative to the regular soil durability test. Ibrahaim et al. (2011) observed that the expansive soil stabilized with 4 and 6% lime become more durable against the cycles of wetting and drying.
- Arun et al. (2013) used lime with different purity levels for stabilization and observed that low purity lime can be

used for silty soil but in the case of clayey soils, it did not show much structural strength improvement. Amadi (2014) conducted a series of durability tests on BC soil with CKD and quarry fines, and the results observed for higher dosage of these stabilizers satisfied the durability criteria. Effect of purity of lime on strength and durability of three selected soils viz. silty soil, BC soil and clayey soil were evaluated in the laboratory.

- Yadu et al. (2011) presented the laboratory study of black cotton soil stabilized with fly ash (FA) and rice husk ash (RHA). The samples of these soils were collected from a rural road located in Raipur of Chhattisgarh state. The soil was stabilized with different percentages of FA (i.e., 5, 8, 10, 12, and 15%) and RHA (i.e., 3, 6, 9 11, 13, and 15%). The Atterberg limits, specific gravity, California bearing ratio (CBR), and unconfined compressive strength (UCS) tests were performed on raw and stabilized soils. Results indicated that addition of FA and RHA reduces the plasticity index (PI) and specific gravity of the soil.
- Rao., Pranav , Anusha et.al (2012) has conducted a detailed study on expansive soils with the addition of RHA, lime and gypsum on properties of expansive soil such as Atterberg's limits, compaction, strength, CBR and free swell index. It was observed that the liquid limit of the expansive soil has been decreased by 22% and Free Swell Index by 88% with the addition of 20% RHA+5% Lime. The improvement of 548% in UCS and remarkable increase in CBR value was also observed on addition of 20% RHA+5% lime + 3% Gypsum. Roy et.al (2014) has studied the effect of blended mixture of cement & RHA on properties of soil such as optimum moisture content, maximum dry density, California bearing Ratio (CBR) and Unconfined Compressive Strength (UCS). The paper studied the soft soil which was identified as clay of high plasticity (CH) according to IS Soil Classification System. It had very low CBR value (1.46) and UCS was found to be 70 KN/m2. The soil was required to be stabilized before doing any construction work. After the study it was revealed that, treatment with RHA and a small percentage of cement showed a general decrease in the Maximum Dry Density (MDD) by 10% and increase in Optimum Moisture Content (OMC) by 15% with increase in the RHA content. There was also an improvement in the un-soaked CBR (106% at 10% RHA content) compared with the CBR of the natural soil. A similar trend was obtained for UCS. The UCS value was at its peak at 10% RHA (90.6% improved). For maximum improvement in strength, soil stabilization using 10% RHA content with 6% cement is recommended as optimum amount for practical purposes

Conclusion

Many of the engineering properties of soils can be enhanced by addition of RHA. The properties of such soil-RHA mixtures vary and depend upon the type of soil as well as the concentration of lime. In this study, a series of experiments were performed on Mughal Road soils through variation of parameters, based upon which the following conclusions were drawn:

1. The soil is of GM-ML character as evident from the results of liquid limit and plastic limit tests in association with plasticity index Curves.
2. The compaction characteristics of the concerned soils vary significantly at low additive (RHA and CEMENT) content. The maximum dry density increases with their increased content.
3. The resistance or strength to penetration of the soils is determined by CBR test. As the concentration of RHA is increased from 0% to 7%, the value of CBR of the soil increases from 1.88 to 7.03.
4. After going through the detailed experimentation of the soil under this study, the tabulated data and corresponding plots reveal one point of inflexion named to be optimum lime content and is decided as 10% RHA content to dry weight of the soil.

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