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A Review On The Soil Stabilization With Waste Materials

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Abstract
Soil stabilization means alteration of the soils properties to meet the specified engineering requirements. Methods for the stabilization are compaction and use of admixtures. Lime and Cement was commonly used as stabilizer for altering the properties of soils. Earth reinforcement techniques with commonly used with mild steel rods, geo synthetics etc. From the recent studies it is observed that, solid waste materials such as rice husk ash and waste tyres are used for this intended purpose with or without lime or cement. Disposal of these waste materials is essential as these are causing hazardous effects on the environment. With the same intention literature review is undertaken on utilization of solid waste materials for the stabilization of soils and their performance is discussed.

Keywords – Rice husk ash, RHA, Waste tyre rubber, Shreds and Soil stabilization

I. Introduction

Solid waste term includes all those solid and semi-solid materials that are discarded by the community. Improper management of solid wastes causes adverse effects on the ecology which may lead to cause possible outbreak of diseases and epidemics. Solid wastes are broadly classified in to three group's namely Industrial waste, Agricultural waste, and Municipal waste apart from other categories of wastes. In this paper previous researches are discussed on rice husk ash waste from paddy grain and waste tyre use in geotechnical works. Rice is the primary source of food for billion peoples across the world. In 2013 around 107 million tons of paddy produced in India [32]. India is second largest producer of rice next to china. One ton of rice paddy produces 220 kg rice husk [33]. Rice husk is the shell produced during de-husking of paddy. Rice husk being agricultural waste dumped near the mills or burnt in open fields. Numerous problems arises from rice husk disposal such as, methane generation due to fermentation of RHA with microorganisms, being light and fine particles causing breathing problems, bad effect on the health are reported such as acute and chronic effect affecting eyes, skin and upper respiratory tract and allegoric response such as nasal catarrh, asthma and limitation of RHA because of low nutritious value, long periods required for decompose are not appropriate for composting of manure. Thus, proper and safe disposal of rice husk is again a big problem. Different ways are available in for enhancing the engineering performances of soils are soil stabilization, soil reinforcement, etc. Admixtures like lime, cement were used traditionally for stabilization purposes. Recent studies shows RHA alone or in combination with lime or cement can be used for effective stabilization of weak soils to a great extent. Disposal of recycling tyre poses a major problem worldwide. A lot of research work is going on worldwide to cope up with this problem. Waste tyres have characteristics that make them not easy to dispose, and potentially combustible. Huge stockpiles and uncontrolled dumping of tyres, throughout the countries, is a threat to public health and environment. One of the alternative ways of disposing of waste tyre is to use them for geotechnical applications, due to following advantages: (1) It will help in not only saving huge spaces occupied by waste tyre and tubes, but the environmental health hazards will also be reduced. (2) The consumption of natural soil will be reduced, there by rendering cost saving benefits. (3) The various soil properties such as bearing capacity, shear strength, drainage etc. can be improved by reinforcing it with waste tyre rubber. (4) With the introduction of waste tyre rubber in soil its capacity to absorb and dissipate energy will be enhanced drastically. (5) Non-biodegradable and thus more durable. (6) Inexpensive compared to other lightweight reinforcing materials for granular soils. Reinforced earth technique has been gaining popularity in the field of geotechnical engineering due to its highly versatile and flexible nature. The application of waste tyres in various forms has been recently developed in reinforcing soil for a variety of geotechnical applications ranging from retaining structures and earth embankments, asphalt pavement and paving system, foundation beds and other applications. Therefore, using recycled materials, particularly wastes tyres when mixed/combined with soil is becoming more popular due to the shortage of natural mineral resources and increasing waste disposal costs. However, with increasing the use of waste tyres in geotechnical applications, a need for further understanding of the behavior of rubber–soil mixture/combination is required. Many researchers have investigated the use of recycled tyre products for soil stabilization, bearing capacity improvement and for reduction of settlement. This may found to be economical treatment methods for soils and solution will definitely found beneficial for the developing countries like India where economy is the prime concern for adopting any new method or technique.

II. RHA Soil Stabilization

Rice husk is a major agriculture byproduct obtained from the food crop of paddy. For every 4 tons of rice around 1 ton is of rice husk is produced. Burning of rice husk generates about 15-20% of its weight as ash. RHA being very light is easily carried by wind and water in its dry state. RHA is difficult to coagulate and thus contributes to air and water pollution. Additionally cumulative generation of ash requires large space for its disposal. On the basis of studies carried out on physical and chemical properties of rice husk ash suggested that RHA cannot be used alone for stabilization of soil because of the lack of cementing properties and some additive used by some researcher are given in table 2. The high percentage of siliceous materials in rice husk ash indicates it has potential pozzolonic properties. The normal method of conversion of husk to ash is incineration. Properties of RHA depend upon, whether the husk have undergone complete destructive combustion or have been partially burnt. RHA has been classified into high carbon char, low carbon ash and carbon free ash. On the basis of temperature range and burning duration crystalline or amorphous form of silica are obtained from husk ash. Different factors influencing ash properties are incineration condition (temperature and duration), rate of heating, geographic location, fineness, color and crop variety and year of crop production. Research studies have shown that physical and chemical properties of ash are dependent on the soil chemistry, paddy variety and climatic conditions. Studies have also shown that difference may be due to fertilizers applied during the cultivation. The chemical composition of RHA from the various location given in following Table 1 shows that the variation in chemical composition especially silica content is high (range 85%-95%) [12]. All other constituents are available in small range. Color changes are associated with the completeness of combustion process as well as structural transformations of silica in the ash. Ash of white color is an indication of complete oxidation of the carbon, which is also an indication of availability of large portion of amorphous silica in the ash. At high temperature strong interaction between potassium and silica ion cause the formation of potassium polysilicate combined with carbon resulting in grey color ash.

Table 1: Comparison of chemical properties of RHA from various locations [12]

Constituent	Weight (%)			
	India	Iraq	USA	Canada
Silica as SiO_2	90.70	86.80	94.50	87.20
Alumina as Al_2O_3	0.40	0.40	-	0.15
Iron as Fe_2O_3	0.40	0.19	-	0.16
Calcium as CaO	0.40	1.40	0.25	0.55
Potassium as K_2O	2.20	3.84	1.10	3.68
Magnesium as MgO	0.50	0.37	0.23	0.35
Sodium as Na_2O	0.10	1.15	0.78	1.12
Sulphur as SO_3	0.10	1.54	1.13	0.24
Loss on Ignition	4.80	3.30	-	8.55

Table 2: RHA used for soil with some additives for soil stabilization reported by some researchers

Additive material used in soil	Reference
RHA	1, 2, 3, 4, 9, 10
RHA Lime sludge	11
RHA + Lime + Gypsum	5
RHA + Lime	7, 13 & 14
Soil + RHA + Cement	15, 16, 17, 18

The review of literature [1]-[18] shows that one of the prominent uses of RHA is in improvement of soil performance. The geotechnical characteristics of RHA-soil mixtures were studied by different investigators to evaluate their suitability as stabilizer. Summary of the literature review carried out for the application of RHA as stabilization for soil and are presented here.

2.1. Soil stabilization process by (RHA)

RHA content used from 0 to 12% for UCS and CBR tests [1]. RHA content for CBR tests used as 0% to 12.5% [2]. RHA content was increased from 0 to 12% [3]. The soil was stabilized with different percentages RHA (i.e., 3, 6, 9 11, 13, and 15%). Based on UCS tests, the optimum amount of RHA was found to be 9% [4]. RHA was varied from 10 percent to 40 percent by dry weight of soil in steps of 10 percent with 5 % of lime for curing period of 4, 7 and 14 for CBR and 4, 7 and 28 days for UCS tests [5]. RHA was varied from 5 percent to 20 percent by dry weight of soil in steps of 5 percent. Standard Proctor Compaction tests, UCS tests, were conducted. For studying, the effect of Marble dust on expansive soil stabilized with optimum percentage of RHA, the Marble dust was added from 0 to 30% at an increment of 5% [6]. RHA addition is considered up to about 40%. Lime is added in the range of 3 to 5% and curing period 7, 14 and 28 days [7]. Series of laboratory tests like soaked and un-soaked CBR have been performed to evaluate the effects of the foreign materials on virgin soil [8]. RHA content for the soil to its maximum at RHA between (6 – 8) percent was used for CBR test [9]. One-dimensional consolidation tests were conducted to determine the compressibility characteristics of untreated clay and clay stabilized with rice husk ash to evaluate its effect in reducing compressibility of the soil. Specimens of parent clay and clay treated with 4, 8, 12, 16 and 20% by weight of rice husk ash passing 425 micron IS sieve [10]. RHA was added to soil from 5 to 20% at an increment of 5%. Lime sludge was added to soil stabilized with optimum percentage of RHA was from 0 to 15% at an increment of 5%. UCS, CBR, consolidated undrained triaxial compression tests and consolidation tests were conducted at 0, 7 and 28 days of curing [11]. Laboratory evaluation of the characteristics of rice hush ash (RHA) stabilized reclaimed asphalt pavements (RAP) subjected to British Standard light; BSL (standard Proctor), determine the compaction characteristics and CBR values was carried out [15]. Compressive strength investigation carried out to propose use of RHA in to the cement stabilized rammed earth system [16].

2.2. Strength of soil after stabilization using (RHA)

The improvement in the un-soaked CBR (18.5% at 6% RHA content) compared with the CBR of the natural soil (8.5%) and soaked CBR also improved [1]. CBR increased from 22.05% to 80.14% with increase in RHA content from 0% to 10% respectively and subsequently reduced with further addition of RHA. The reason for increment in CBR may be because of the gradual formation of cement compounds in the soil by the reaction between the RHA and some amounts of CaOH present in the soil [2]. RHA content was increased from 0 to 12%, Unconfined Compressive Stress increased by 97%. RHA content was increased from 0 to 12%, CBR improved by 47%. The optimum RHA content was found at 12% for both UCS and CBR tests [3]. Based on CBR and UCS tests, the optimum amount of FA as 12%.The optimum amount of FA increased the soaked CBR by approximately 190%. The UCS of the soil stabilized with optimum amount of FA has been found to be approximately 200% higher compared to raw soil [4]. 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. It was observed that the UCS of the expansive soil has been increased by 548% with addition of 20% RHA+5% lime + 3% Gypsum after 28 days curing and CBR was increased by 1350% with the addition of 20% RHA+5% lime + 3% Gypsum after 14 days curing[5]. For stabilization the optimum proportion of Soil: Rice husk ash: Marble dust was found to be 70: 10: 20. The UCS of the RHA and CBR stabilized expansive soil increased up to 20% addition of Marble dust. There is 228 % increase in UCS and 293% increase in soaked CBR of virgin soil [6]. Addition of rice husk ash along with 3% lime shows steep increment in unconfined compressive strength for 20% ash for curing period of 14 days. Further curing of samples has not shown much marginal improvement in strength. Samples cured up to 14 days have shown continuous increment and strength increased from 310 KPa to 567 KPa for 20% addition of ash and 3% of lime [7]. Addition of RHA with soil, a very little amount of lime improves the soil property to a great extent [8]. There is enormous increase in the UCS with increase in RHA content for the soil to its maximum at RHA between (6 – 8) percent [9]. The use of rice husk ash lowers the slope of virgin compression curves. It has been observed that rice husk ash is helpful in reducing compression index and hence decreasing the consolidation settlement of the parent soil [10]. The optimum percentages of RHA and lime sludge for stabilization of expansive soil are 10% and 15% respectively. CBR, increases at the optimum percentages of the stabilizers [11]. The RHA stabilized RAP mix proportions with 89.25% RAP/1.5% cement content, and 89% RAP/2% cement content with CBR values of 73 and 79% (soaked for 24 hours) can be used as sub-base or sub-grade materials in road construction [15]. For sandy soil, when partially replaced by the maximum ash content 7.5% and stabilized with 10% cement, proved to be promising alternative material [16]. These are results for the soil improvement with RHA in past few years.

III. Waste tyre soil stabilization

Scrap tyres can be managed as a whole tyre, a slit tyre, a shredded or chipped tyre (300 - 460 mm, 100 - 230 mm, (100-150 mm in length) and crumb rubber particle size (4.75 mm - 0.075 mm) used as asphalt modifier (0.15 - 0.6 mm). In civil engineering works tyre applications of waste tyre are as (1) Embankment construction with shredded or chipped tyres. (2) Rubber as a fine aggregate substitute in asphalt pavements. (3) Crumb rubber as a modifier for the asphalt cement binder in a process in which the rubber is blended with asphalt binder. (4) Retaining walls construction with whole and slit tyres. (5) Reinforcement in earth works. Some properties of waste tyre are given in table 3 by some of the researchers.

3.1. Physical Properties

Shredded/Tyres are basically flat, irregularly shaped. The average compacted density ranges from 650 kg/m^3 to 840 kg/m^3. Tyre chips are more finely and uniformly sized than tyre shreds. The compacted density of tyre chips probably ranges from 570 kg/m^3 to 730 kg/m^3. Tyre chips have absorption values that range from 2.0 to 3.8 percent. The specific gravity of crumb rubber is approximately 1.15 [31].

3.2. Chemical Properties

Tyre chips and tyre shreds are nonreactive under normal environmental conditions. The principal chemical component of tyres is a blend of natural and synthetic rubber, but additional components include carbon black, sulfur, polymers, oil, paraffin, pigments, fabrics, and bead or belt materials [31].

3.3. Mechanical Properties

Limited data are available on the shear strength of tyre chips, although the shear strength characteristics of tyre chips vary according to the size and shape of the chips, internal friction angles were found to range from 19^o to 26^o, while cohesion values ranged from 4.3 kPa to 11.5 kPa [31].

Table 3: Waste tyre rubber properties used by different researchers

Shape	Size (mm)	Gs	Reference
Irregular	12-50	1.12	19
Square and Rectangular	10×10, 10×20, 10×30	-	20
Irregular	4 and 750μm tyre powder	1.1	21
-	4.75-2, L=20	1.05	22
Strips	L=25, Ar=12.5	1.03	23
-	5-9, 10-20	1.16	24
Rectangular	B=10 L=30-50		25
Rectangular	65×300	1.02-1.27	26
Angular	3.5	1.14	27
Square	50×50	-	28

3.4 Soil stabilization process using waste tyre rubber

Numerous experiments including index tests, compaction tests, pullout tests, and large-scale direct shear tests were conducted. Tyre chip–sand mixtures with mixing ratios of 0:100, 30:70, 40:60, and 50:50 by weight were used as fill materials [19]. A program of standard Proctor tests, unconfined compression tests and California bearing ratio tests was carried out on specimens of the cohesive soil-tyre mixtures, by varying tyre chips content from 5% to 20% by weight of the soil. Vibratory compaction tests and direct shear tests were conducted on the cohesionless soil-tyre mixtures by adding tyre chips varying from 10% to 50% by weight [20]. Repeated loading consolidated drained triaxial were performed. The bauxite residue sand is mixed with three different amounts (by weight) of tyre grains (i.e. 10%, 30% and 40%) and tyre powder (i.e. 6%, 9% and 12%) [21]. Fly ash and waste tyre rubber fibers were used to modify the clayey soil at four different percentages of fly ash content (0%, 20%, 35%, 50%) and at three different percentages of fiber content (0%, 5%, 10%) [22]. The plate load tests and triaxial tests were performed on waste tyre-fiber reinforced sand at relative densities of 70%, 80% and 90% with different fiber contents of 0%, 0.25%, 0.50%, 0.75% and 1.0%. The samples were tested under drained conditions with cell pressures of 0.1MPa, 0.2MPa and 0.4MPa [23]. In this research, tyre chip mixed randomly with various percentages by weight up to 30% of sand and two different sizes of tyre chip. Soil type is SP according to Unified Soil Classification System (USCS). Laboratory California Bearing Ratio (CBR) was performed [24]. The relative density of sand in tank was 66%. Plate load test performed for load settlement behaviour for different samples of sand with varied rubber content, thickness of rubber soil layer and soil cap [25]. The soil has been reinforced with the rubber shreds at various relative densities of 50%, 60%, 70% and 80% provided at different depths of 0.5B, 1.0B, 1.5B and 2.0B. The plate load test was conducted on the sandy soil [26].

3.5. Strength of Soil after Stabilization by using waste tyre rubber

The mixture at the mixing ratio of 30:70 by weight or 50:50 by volume was found to be the most suitable fill material compared to other mixing ratios. The pullout resistance and the pullout interaction coefficients of geogrid A were slightly higher than those of geogrid B. In contrast, in the direct shear resistance, the direct shear interaction coefficients, and the efficiency values of geogrid B were slightly higher than those of geogrid A. Since geogrid B has the needed uniaxial reinforcement properties and its sufficient interaction characteristics with tyre chip–

sand mixture, the geogrid B was utilized. The interaction coefficients between the tyre chip–sand backfill with 30:70 mixing ratio by weight were found to be 0.71 in pullout mode and 0.92 in direct shear mode for geogrid B [19]. Cohesive clayey silt and cohesionless fine sand were used. The results showed that 13% and 30% chip contents, respectively by weight, were optimum for composite strength of the two reinforced soil mixtures [20]. Adding 30% tyre-grains to bauxite residue sand seems to lead to satisfactory geotechnical engineering properties for stability of embankments. Using the bauxite residue sand with 30% tyre grains as a sub-base material for pavement design appears to decrease the maximum and residual vertical stresses on top of sub-grades and is thus desirable, although compressibility increases so sand-tyre crumb mixtures have a good potential for use as lightweight fill material in geotechnical engineering applications [21]. Due to addition of rubber fibers, the deformation behaviour of the clayey soil-fly ash mix changes significantly and becomes ductile [22]. There is reduction in settlements with the addition of waste tyre-fibers up to fiber content of 0.75% [23]. The addition of tyre chip increase the CBR strength of the sand significantly, it's about 29% for size (5-9) mm and 19.5% for size (10-20) mm at the tyre chip percentage of 20%, improved the bearing capacity and modifies the load-settlement behavior of the footing. The used of tyre chips reduced settlement about 22 % [24]. For the optimum value of rubber content of 5% at footing settlement level of 5%, the maximum improvement in bearing capacity of rubber- reinforced bed was obtained as 2.68 times of the unreinforced bed. This value of improvement was achieved using the optimum thickness of reinforced layer of 0.5 times of footing width and the optimum thickness of soil cap of 0.25 times of footing width [25]. BCR (Bearing Capacity Ratio) can be increased up to1.78 at a relative density of 50% and depth of reinforced layer at 0.5B. A minimum SRF (Settlement Reduction Factor) of 0.24 has also been observed at same Relative Density and depth of reinforcement [26].

IV. Conclusion

On the basis of literature survey carried out RHA and waste tyre can effectively use. Rice husk ash an agricultural waste can be effectively used for stabilization of soils using cement or lime as additive. Rice husk ash is source of silica has numerous applications in silicon based industries. Addition of RHA to the soil in general increases optimum moisture content and reduces the maximum dry density. RHA and lime/cement improves plasticity index and swelling potential of expansive soils. Using waste tyres in geotechnical engineering applications may be feasible to consume the scrap tyres. Waste tyre can use for improvement of bearing capacity soil upto optimum rubber content and. Tyre waste can effectively use as soil reinforcement beneath footing, embankment and retaining wall. Findings lead to overall saving in soil material costs and recycling of tyres waste and RHA waste.

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