Study of expansive soil stabilized with agricultural waste

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Abstract. During any construction on soil surface such as construction of road and airport pavements, compaction of the soil is required and soil stabilization plays a vital role. Various characteristics of soil should be optimized with different factors. Expansive soil has property of swelling when moisture content increases and shrinking when water gets evaporated. Rice husk is a major agricultural waste that is easily available in India and is generally burnt to get rice husk ash (RHA). This study has been aimed to get dual benefit, first to stabilize expansive soil by addition of RHA and second to effectively utilize RHA, the agricultural waste. It has been observed that at 12% RHA in presence of 5% cement can be effectively used to improve plasticity of soil and CBR value resulting in effective soil stabilization. Thus, the research demonstrates that agricultural waste has efficient use in soil stabilization.

Keywords: Expansive soil, Rice husk ash, Liquid limit, OMC, MDD, CBR.

1. Introduction

The performance of road transport is rapidly deteriorating due to the proliferation of large vehicles with heavy load. Today, we need technology that can help us save money, improve road efficiency, and substantially decrease construction costs, while also minimizing overlapping public road networks and increasing construction-related air pollution [1,2]. Sustainable construction practices demand the control of cost, safety and performance [3–5]. The greatest impediment to completing the net function of the road network in developing nations such as India is the scarcity of money available to build roads using conventional techniques [6]. Additionally, it is critical to use one of the appropriate low-cost road construction methods to meet the growing demand for road transport. Costs of development may be significantly reduced by using local resources, especially local expansive soil, for the development of the surface's lower levels, such as the sub-base level. If the local soil's resilience is insufficient to support loads, soil stabilization methods may improve the performance [7].

Expansive soils are fine-grained soils generally consisting of disintegrated rock particles that exhibit dramatic volume changes in response to moisture content variations due to wetting and drying. The increased likelihood of swelling-shrinkage at the ground surface that is strongly influenced by changes in season and environmental conditions is another concern [8]. The majority of serious damage is caused by the absorption of univalent cations by the montmorillonite clay. Fabrication on expansive soil is extremely speculative in that resulting in cracking of structural elements of these structures [9].

Stabilization of soil is the process of altering the characteristics of a locally useable soil in order to increase its engineering efficiency, such as strength, stiffness, compressibility, permeability,
workability, and sensitivity [10]. The idea of soil-stabilized road construction necessitates the efficient use of indigenous soils and other appropriate stabilizing chemicals. Stabilization is utilized in a variety of infrastructure projects, the most common being the construction of road and airport pavements [11]. Commercial road construction, bridge upgrades, unpaved highway maintenance, highway rebuilding, road development, parking lots, air strips, and bulk fills are more examples with use of soil stabilization. Stabilization of soil may be done physically or by inclusion of additives to enable the stabilized soil to fulfil its role as a construction component material [12].

Lime and cement are the primary components utilized in the stabilization [13]. However, Lime and cement manufacturing process is costly and with increasing demand of these materials in construction industry, the need of alternatives has garnered the interest of researchers [14,15]. With consideration of sustainable techniques, use of locally available and cost-effective raw materials is an economically viable option [14,16]. In this concern, research interests have been focused on the improvement and strengthening of the soil by utilizing waste products from industries such as fly ash, polypropylene fibres, recycled carpet fibres and agriculture such as husk, ash and fibres of sugarcane [17], palm [6], jute [18], rice husk [19], coconut [20] etc. Medina et al. have used residues of various types from crops for stabilization of degraded soil [15]. Oluwatuyi et al. have used milled eggshell [10] while Vodounon et al. have used fibres from pineapple leaves as soil stabilizer [9]. Soil stabilization using agricultural waste is desirable because of its ease of availability, minimal cost, pozzolanic action and as a tool of waste minimization [21]. Rice husk cannot be directly used as raw material because it decomposes in soil with time. However, rice husk ash (RHA) contains a significant content of silica with pozzolanic action that can bind soil particles and provide much strength. Small amount of cement is needed to add in it to get optimum stabilization. This research bases its findings on the use of RHA to stabilize expansive soil. Index and engineering properties of soil have also been assessed with regard to the effect of adding RHA.

2. Materials and methods
OPC (43 grade) was purchased from local supplier and expansive soil was collected from nearby site. Table 1 summarises the characteristics of soil. RHA was obtained from a nearby mill as a by-product produced from the manufacturing of puffed rice. RHA contains large amount of iron oxide and silicate. RHA is chemically stable and its physical properties are similar to that of natural sand. It contributes to excellent stability and load bearing capacity. The sieve size of RHA was made up to size of soil particles (0.07 mm).

The effect of incorporating RHA in soil as a soil stabilizer was studied by using various proportions with soil (6%, 12%, 18%, 24% by weight of soil mass) at constant cement content (5%). The specimens were completely blended by employing a mechanical mixer and tested further with standard compaction in agreement with IS: 2720(Part 7). Atterberg’s limit (liquid limit) and CBR (California Bearing Ratio) were analyzed in agreement with IS: 2720 (Part-5)-1985 and IS: 2720(Part-16) respectively.

Table 1. Characteristics of expansive soil

| Parameter            | Value     |
|----------------------|-----------|
| Plastic Limit        | 30%       |
| Liquid limit         | 65%       |
| Particle Density     | 35%       |
| Shrinkage Limit      | 11        |
| OMC                  | 30        |
| Specific Gravity     | 2.6       |
| MDD                  | 1.7 g/cm² |
| UCS                  | 85 KPa    |
| CBR (unsoaked)       | 1.4       |
| Free swell Index     | 50%       |
3. Results and discussion

3.1. Liquid limit

Figure 1 illustrates the effect of addition of RHA in varying dosages on the liquid limit (LL) of the used soil. It can be seen that with addition of RHA, the LL continuously decreases (5.30% to 15.43%). The variation in LL highly affects the compressibility and swelling characteristics of soil i.e. reduction in LL means reduction in the compressibility and swelling. During ash stabilization of soil, a reduction in the LL and surge in the plastic limit has been reported in the literature [14]. Figure 1 displays the effect of addition of RHA in varying dosages on the LL of soil. It can be noticed that with addition of RHA, the LL continuously decreases from 5.30% to 15.43%. The decrease in LL specifies that the incorporation of RHA improves the overall behaviour of the soil. The overall reduction in LL for all specimens owes to the formation of cementitious compounds namely, calcium silicates by interaction of silica particles present in RHA with soil particles [22].

![Figure 1. Variation of Liquid limit](image)

3.2. Standard Proctor Compaction Test

Figure 2 displays the variation in optimum moisture content (OMC) on adding RHA in different proportion. OMC was observed to enhance when RHA dosage increased and soil content decreased. This may be attributed to increasing percentage of coarser materials in the mix with consumption of water, as a result of the inclusion of RHA thereby decreasing clay and free silt [10]. This implies that more water is required for compaction of the mixture. The change in maximum dry density (MDD) due to the incorporation of RHA in various proportions is shown in Figure 3. The MDD is found to decrease with increase in RHA content for all the specimens. The reduction in MDD may be ascribed to the soil particles being replaced by RHA particles in the mixture. RHA particles have lesser special gravity than the soil particles and act as filler in the soil voids [13].
3.3. CBR Test

Figure 4 illustrates that the comparison of unsoaked CBR values at a penetration of 2.5 mm and 5 mm with varying dosage of RHA in the mixture. It can be seen that, there is an enhancement in CBR values up to 12% dosage of RHA and after that a decrease is observed. The rise of unsoaked CBR with addition pf RHA from 0-24% may be attributable to the calcium silicates formation following a soil-silica reaction [23]. The later on decrease in the unsoaked CBR indicates that surplus of silica does not react with soil particles and negatively influence the binding of the particles [24,25].
4. Conclusion
The primary aim of this investigation was to assess the effect of incorporating an agricultural waste, rice husk ash (RHA) on the various properties of soil. During the result analysis, it was deduced that adding RHA to the expansive soil, in presence of cement, decreased the value of the liquid limit and MDD with an increase in OMC. Silica particles in RHA, are not only capable of replacing the exchangeable ion found in clay minerals, but also participate in strength enhancement resulting in a lower shrinkage and swelling behaviour for clay minerals. The 12% addition of RHA to the expansive soil was found to provide the maximum CBR value indicating the optimized content that can be used for stabilization of the soil under study. Thus, the study confirms the utilization of agricultural waste in soil stabilization as sustainable practices.

References
[1] Liu Y, Su Y, Namdar A, Zhou G, She Y and Yang Q 2019 Utilization of cementitious material from residual rice husk ash and lime in stabilization of expansive soil Adv. Civ. Eng. 2019
[2] Jayasree P K, Balan K, Peter L and Nisha K K 2015 Volume Change Behavior of Expansive Soil Stabilized with Coir Waste J. Mater. Civ. Eng. 27 04014195
[3] Garg R and Garg R 2020 Performance evaluation of polypropylene fiber waste reinforced concrete in presence of silica fume Mater. Today Proc. 43 809–16
[4] Garg R R and Garg R R 2020 Effect of zinc oxide nanoparticles on mechanical properties of silica fume-based cement composites Mater. Today Proc. 43 778–83
[5] Heidari A R, Parsakhooh A, Nasiri M and Habashi H 2021 Effect of the Curing Time and Combination of Corncob (Zea Mays L.) Ash With Swelling Clay on Mechanical Properties of Soil in Forest Road J. Sustain. For. 40 346–56
[6] Onyelowe K, Bui Van D, Igboayaka C, Orji F and Ugwuanyi H 2019 Rheology of mechanical properties of soft soil and stabilization protocols in the developing countries-Nigeria Mater. Sci. Energy Technol. 2 8–14
[7] Soltani A, Deng A, Taheri A and Mirzababaei M 2018 Rubber powder-polymer combined stabilization of South Australian expansive soils Geosynth. Int. 25 304–21
[8] Fadele O A and Ata O 2018 Water absorption properties of sawdust lignin stabilised compressed laterite bricks Case Stud. Constr. Mater. 9 e00187
[9] Vodounon N A, Kanali C and Mwero J 2018 Compressive and Flexural Strengths of Cement
Stabilized Earth Bricks Reinforced with Treated and Untreated Pineapple Leaves Fibres

[10] Oluwatuyi O E, Adeola B O, Alhassan E A, Nnochiri E S, Modupe A E, Elemile O O, Obayanju T and Akerele G 2018 Ameliorating effect of milled eggshell on cement stabilized lateritic soil for highway construction Case Stud. Constr. Mater. 9 e00191

[11] Yadav J S and Tiwari S K 2017 Effect of waste rubber fibres on the geotechnical properties of clay stabilized with cement Appl. Clay Sci. 149 97–110

[12] Soltani A, Taheri A, Khatibi M and Estabragh A R 2017 Swelling Potential of a Stabilized Expansive Soil: A Comparative Experimental Study Geotech. Geol. Eng. 35 1717–44

[13] Cheng Y, Wang S, Li J, Huang X, Li C and Wu J 2018 Engineering and mineralogical properties of stabilized expansive soil compositing lime and natural pozzolans Constr. Build. Mater. 187 1031–8

[14] Kumar Yadav A, Gaurav K, Kishor R and Suman S K 2017 Stabilization of alluvial soil for subgrade using rice husk ash, sugarcane bagasse ash and cow dung ash for rural roads Int. J. Pavement Res. Technol. 10 254–61

[15] Medina J, Monreal C, Barea J M, Arriagada C, Borie F and Cornejo P 2015 Crop residue stabilization and application to agricultural and degraded soils: A review Waste Manag. 42 41–54

[16] Garg R, Garg R, Thakur A and Arif S M 2021 Water remediation using biosorbent obtained from agricultural and fruit waste Mater. Today Proc.

[17] James J and Pandian P K 2018 Bagasse Ash as an Auxiliary Additive to Lime Stabilization of an Expansive Soil: Strength and Microstructural Investigation Adv. Civ. Eng. 2018

[18] Wang Y-X, Guo P-P, Ren W-X, Yuan B-X, Yuan H-P, Zhao Y-L, Shan S-B and Cao P 2017 Laboratory Investigation on Strength Characteristics of Expansive Soil Treated with Jute Fiber Reinforcement Int. J. Geomech. 17 04017101

[19] Rahgozar M A, Saberian M and Li J 2018 Soil stabilization with non-conventional eco-friendly agricultural waste materials: An experimental study Transp. Geotech. 14 52–60

[20] Ikeagwuani C C, Nwonu D C, Eze C and Onuoha I 2018 Investigation of shear strength parameters and effect of different compactive effort on lateritic soil stabilized with coconut husk ash and lime Niger. J. Technol. 36 1016

[21] Hasan H, Dang L, Khabbaz H, Fatahi B and Terzaghi S 2016 Remediation of Expansive Soils Using Agricultural Waste Bagasse Ash Procedia Eng. 143 1368–75

[22] Shukla R P and Parihar N S 2016 Stabilization of Black Cotton Soil Using Micro-fine Slag J. Inst. Eng. Ser. A 97 299–306

[23] Okeke C A U 2020 Engineering behaviour of lime- and waste ceramic dust-stabilized expansive soil under continuous leaching Bull. Eng. Geol. Environ. 79 2169–85

[24] Akinwumi II and Aidomojie OI 2015 Effect of Corncob ash on the geotechnical properties of lateritic soil stabilized with Portland cement Int. J. Geomatics Geosci. 5 375–92

[25] Atahu M K, Saathoff F and Gebissa A 2019 Strength and compressibility behaviors of expansive soil treated with coffee husk ash J. Rock Mech. Geotech. Eng. 11 337–48