ISSN: 0974-5823 Vol. 6 No. 3 December, 2021

International Journal of Mechanical Engineering

Effect of Various Organic Waste Ashes in the Modification of Soil

Sandhya Rani R.[1] and Shiva Chandra V.[2]

[1]Asso. Professor, Dept. of Civil Engg., Maturi Venkata Subba Rao Engg. College, Hyderabad – 501510,

[2]Asst. Professor, Dept. of Civil Engg., Maturi Venkata Subba Rao Engg. College, Hyderabad – 501510,

Abstract: Clayey soils exhibit specific problems due to its volume change, lower value of strength, plasticity etc. and environmental issues prompted human to use waste materials in soil modification for better mechanical behaviour. In this research, the attempt is to use organic waste ashes in soil modification to improve its properties, eliminate environmental issues and contribute to the economy. The organic waste ash admixtures used here are Coconut coir ash (CCA), Coconut shell ash (CSA), Rice husk ash (RHA), Sugarcane bagasse ash (SBA) and Wood ash (WA) to check their potential in modifying the clay soil. Various proportions of these admixtures in combination with small percentage of lime have been mixed with clay soil and cured for 7 days, 14 days and 28 days. The unconfined compressive strength of clay soil was improved with the addition of 10 to 15% organic waste ash admixtures and also with curing period.

Keywords: Coconut coir ash, Coconut shell ash, Rice husk ash, Sugarcane pulp ash, Wood ash.

Introduction:

Soil is a natural resource, one of the most complex materials in civil engineering and when it comes to designing in soil, the uncertainty is very high as it involves many risks. Various factors have to be considered in the soil analysis because even a small mistake results in higher design values and it leads to failure of the structure. Clay is a fine-grained natural soil formation that contains clay minerals in abundance. Clays become plastic while wet due to a film of water surrounding the clay particles, but they become hard, brittle, and non– plastic when dry or burnt.

Abandoned sites are increasing substantially as a result of low bearing capacity of soil, resulting in land scarcity and increased demand for natural resources. In most geotechnical projects, in-situ soil modification is required to meet the design criteria. To achieve the design standards, there is a need to adjust the engineering qualities of the in-situ soils.

Soil modification is a method of altering the properties of natural soil such that it satisfies the design requirements and can be accomplished by several methods. Mechanical and chemical stabilisations are the two major categories in which all of these approaches reside. Mechanical stabilisation can be done through physical processes such as induced vibration and/or compaction, or by inducing additional features such as nails and barriers, which modify the physical composition of native soil particles. It is not the primary focus of this study and will not be discussed further. Chemical stabilisation depends mostly on chemical reactions between the stabiliser (cementitious material) and the soil minerals (pozzolanic materials). It is associated with the modification of soil properties using chemically active materials. The stabilized soil materials have a higher shear strength, lower permeability & compressibility and controlled shrink-swell properties than the native soil. It also increases the soil's load-bearing ability, allowing pavements and foundations to be supported. Soil stabilisation is critical in the construction industry, particularly during the design and construction of foundations.

Understanding the material qualities involved in the mixture and the outcome after mixing is critical in soil stabilisation. As a result, judgments can be made about which materials to use and what percentages to use. Soil stabilisation can be accomplished using a variety of procedures or materials. Researchers have spent many years developing novel additions such as lime, cement kiln, and fly-ash to improve the physical qualities of soil. However, in recent years, the cost of using these stabilisers in the soil stabilisation process has increased. This challenge necessitates the use of an alternative stabiliser to lower the cost of soil stabilisation. The use of diverse organic waste ashes as a stabiliser reduces the cost and eco-friendly. This technology also helps in the resolution of different social issues such as waste reduction, the production of valuable materials from non-useful waste materials, and so on.

Background Information:

The organic waste materials and by-products of industrial origin have potential applications in reducing the swelling capacity and the improvement of mechanical capacities of an expansive soil. The higher swelling reductions and strength improvements obtained when these materials were combined with lime or cement. Rice husk fly ash in combination with lime or magnesium oxide (Seco et al., 2011), Palm oil fuel ash in combination with cement (Shahram Pourakbar et al., 2015) results in the reduction of plasticity index and obtained the best mechanical properties. The findings show the technological, economic and environmental benefits of using this agricultural waste as a partial alternative for Cement/Lime in stabilising soils, especially soft clays, which typically require large amounts of stabiliser to achieve adequate results.

Previous studies demonstrated that fly ash can be used as a construction material and a soil stabiliser. A laboratory investigation on the efficiency of fly ash cement-improved Singapore marine clay was reported by Huawen Xiao et al. (2017), and the results showed that the effectiveness of stabilisation was dependent on cement & water content, and also on curing period.

The CBR values used in road infrastructure design are critical because they determine the suitability of soil materials for use as different layers of road pavement (Imoh Christopher Attah et al., 2021). The stabilization potential of periwinkle shell ash and cement kiln dust (David Ufot Ekpo et al., 2021), sewage sludge ash (Adekemi L. Ayodele et al., 2016), oyster shell ash (Roland Kufre Etim et al., 2020) was investigated in treating lateritic soils and significant improvement was observed with increased strength, dry density and CBR values.

Harshil Bhatt et al. (2021) stabilized the expansive soil with Kota Stone Slurry (KSS) powder and coir fibre. The slurry powder developed by the kota stone industries during the cutting and finishing process is an industrial waste. This waste is produced in slurry form and it is dumped into the lands and it becomes powder in dry state and then it is easily transported by air and other medium. This waste is hazardous for land fertility as well as for human health. The purpose of using KSS powder is to reuse the waste in an efficient way. The index as well as engineering properties of expansive soil can be improved by mixing it with various percentages of Kota stone slurry and coir fibre.

Ishola et al. (2019) provide a review of the use of pozzolanic agricultural waste (Bagasse ash, Palm oil fuel ash, Locust bean waste ash, Rice husk ash, Corn cob ash, Banana leaf ash, Coconut shell ash, Bamboo leaf ash, Palm kernel shell ash and Cassava peel ash) in geotechnical engineering applications. Agricultural waste with pozzolanic qualities increases the engineering properties of soil, according to findings from several researchers.

Because of the potential of employing waste materials in soil amelioration procedures, waste residue has attracted a lot of interest in the field of geotechnical engineering as a result of environmental concerns. This shows the necessity of present study to deal with the utilization of organic waste ashes in enhancing the mechanical performance of clayey soil.

Materials:

The materials collected to use in this study are Clay soil, Lime, Coconut coir ash, Coconut shell ash, Rice husk ash, Sugarcane pulp ash and Wood ash. Soil samples were made by adding lime and organic waste ashes in different proportions and tests were conducted to determine the effect of admixtures on soil strength.

Clay

Clay has been collected from Adibatla village, Hyderabad from a depth of 2 m to obtain true representative samples. The soil collected was transported to the laboratory under disturbed condition. The sample was air dried and broken down to avoid lumps.

Lime

Lime was bought from the local market in hyderabad. Lime is a better option for short term modification of clay having moderate to high plasticity. Clay is modified when cations provided by hydrated lime replace cations ordinarily found on the clay minerals surface, which is promoted by the lime-water system's high pH environment. The addition of lime to soil reduces its swelling behaviour and increases its strength. Lime reduces swelling and imparts strength to the soil by pozzolanic reaction. Lime is used in the form of hydrated lime or quick lime for soil modification. Hydrated lime was used in this study to control the swelling behaviour of clay.

Coconut Coir Ash

Coconut Coir was obtained from locally available temples of Hyderabad. Coconut coir is cellular fibrous waste product after usage. It is used as a fuel and as a raw material in the preparation of gunny bags. When this coconut coir is burnt, the resultant residue is coconut coir ash. It contains amorphous silica, which has cementing capabilities and can help to form strong bonds between soil grains for increased shear strength.

Coconut Shell Ash

This is the waste reproduced from burning of coconut shells in the air for a minimum of three hours. This was used as a pozzolana in concrete production to partially replace cement. This is rich in amorphous silica and can be used to increase the strength. Coconut shells were also collected locally.

Rise Husk Ash

Rice milling produces rice husk, which is a by-product that surrounds the paddy grain. Approximately 78% of the weight of paddy is received as bran, broken grains and rice during milling. Remaining 22% of weight is accounts up as husk. About 220kg (22%) of husk is produced for every 1000kg of paddy milled, and when burned in the boilers, about 55kg (25%) of rice husk ash is produced (Koteswara Rao et al., 2012). Rice husk used is collected from a locally available Rice mill, Hyderabad.

Sugarcane Bagasse Ash

Sugarcane bagasse is a by-product of sugar industry that is used as a fuel source for boilers after the sugarcane is extracted. The ash generated from the bagasse burning in sugar industry is termed as sugarcane bagasse ash.

Wood Ash

This is the residue left over after wood has been burned. Wood ash contains appreciable amounts of plant nutrients and makes it a valuable fertilizer to increase the yields of crop. Locally available fire wood has been obtained to prepare wood ash.

Coconut coir, Coconut shell, Rice husk, Bagasse and Fire wood are agricultural wastes produced abundantly across the globe and poses risk to environment. Thus their effective and eco-friendly utilization has always been a challenge. All these organic waste products were collected and dried under the sun initially to remove moisture. They were then exposed to uncontrolled open-air combustion and permitted to cool. The burned ash was sieved, collected and being stored for future use.

Experimental Investigation:

Preliminary tests were performed on clay to determine specific gravity, atterberg’ s limits and classification. Standard proctor and unconfined compression tests were also performed as per guidelines of IS 2720. Tests were conducted in the laboratory to determine the chemical composition of various ashes.

Various blends were prepared for each ash type with 1% of lime and 5, 10, 15 & 20% of ash combinations. Nominal amount of lime (say 1%) was added to reduce the swelling characteristics of clay soil. However lime also helps in imparting strength to soil. The samples were cured for seven days, fourteen days, and twenty-eight days. Unconfined compressive strengths of each sample before and after curing were determined to investigate the effect of various ashes as a stabilising agent.

Results and Discussion:

The engineering properties and index properties of clay soil obtained are listed below in Table 1. Soil was classified as high compressible clay according to Indian Standard Classification system.

Table 1: Properties of clay

S. No.	Soil Property	Value
1	Specific Gravity (G)	2.81
2	Liquid Limit (w_L)	52%
3	Plastic Limit (w_P)	24%
4	Plasticity Index (I_P)	28%
5	Maximum Dry Density (MDD)	1.82 g/cc
6	Optimum Moisture Content (OMC)	16%
7	Unconfined Compressive Strength	2.05 kg/cm^2
8	IS Classification	CH

Chemical composition of various organic waste ashes used in this study is shown in Table 2. The chemical compounds predominantly present in these ashes include silicon dioxide, calcium oxide, magnesium oxide, iron oxide, aluminium oxide and potassium oxide. The materials having these chemical compounds are treated as pozzolanas (ASTM C618, 2014).

Table 2: Chemical Composition of Organic Waste Ashes

S. No.	Constituent	Composition (%)				
		Coconut Coir Ash	Coconut Shell Ash	Rice Husk Ash	Sugar Cane Bagasse Ash	Wood Ash
1	SiO_2	18.8	36.64	85.54	73.38	40.6
2	MgO	5.16	1.32	2.57	3.85	1.62
3	CaO	12.4	4.26	1.3	2.54	25.34
4	Fe_2O_3	1.15	16.39	1.9	5.57	5.9
5	Al_2O_3	2.24	24.21	1.5	8.67	7.46
6	Na_2O	0.40	0.85	0.26	1.15	1.54
7	K_2O	37.24	1.01	2.05	2.56	2.39
8	P_2O_5	9.52	0.64	7.44	4.01	0.12
9	SO_3	3.34	0.75	0.23	1.08	0.15

The variation in unconfined compressive strength values for different ash percentages (0, 5, 10, 15 and 20) and curing periods (0, 7, 14 and 28 days) are shown in Figure 1 to 5. It has been observed that unconfined compressive strength increases with curing period from 0 days to 28 days by about 20 to 50%.

It has been further observed that the maximum increase in strength has been obtained at 10% of wood ash followed by Coconut coir ash at 15%. The maximum increase in strength has been observed at 10% of ash content for Wood ash, Bagasse ash & Coconut shell ash and at 15% of ash content for Coconut coir ash & Rice husk ash. Ca^{2+} ions in the ash reacting with metallic ions in the clay microstructure led in flocculation and agglomeration of the clay particles, resulting in increased unconfined compressive strength values (Ijimdiya et al, 2012). The finely divided silica in ash can combine with calcium in presence of water to form stable compounds that have cementitious properties (Raheem and Kareem, 2017).

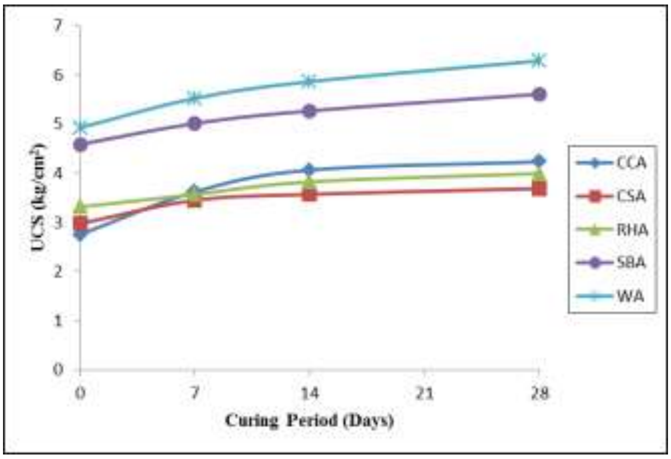

Figure 1: Unconfined Compressive Strength Vs Curing Period at 5% Ash Content

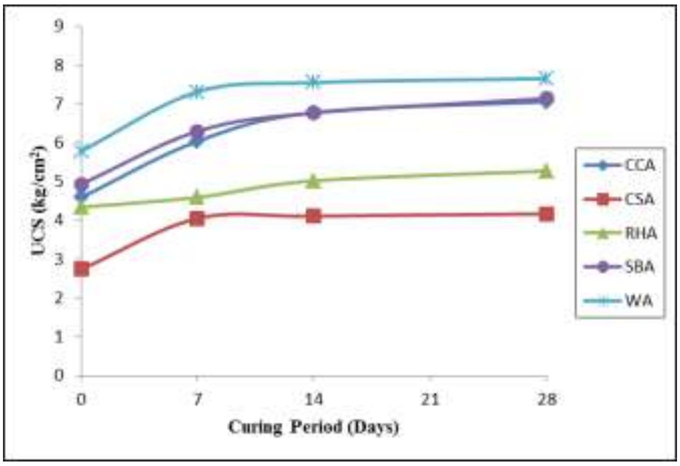

Figure 2: Unconfined Compressive Strength Vs Curing Period at 10% Ash Content

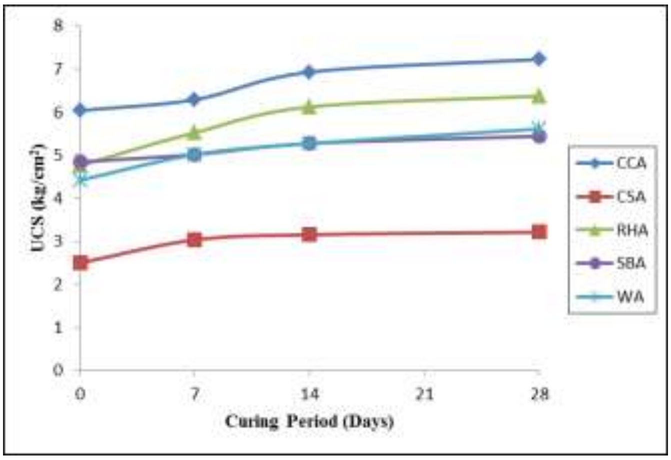

Figure 3: Unconfined Compressive Strength Vs Curing Period at 15% Ash Content

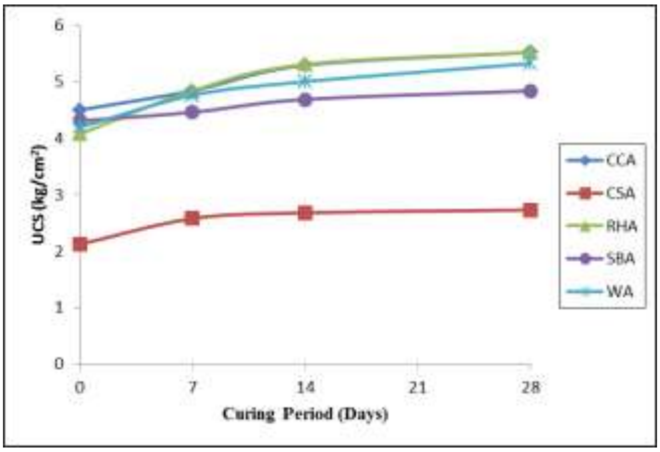

Figure 4: Unconfined Compressive Strength Vs Curing Period at 20% Ash Content

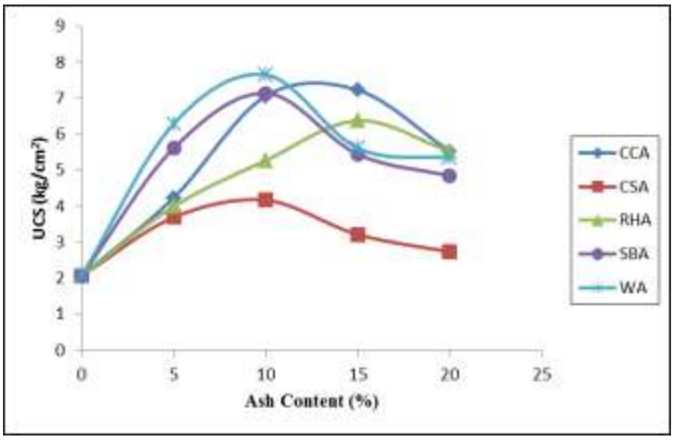

Figure 5: Unconfined Compressive Strength Vs % Ash Content at 28days Curing

The increase in percentage of ash content increases unconfined compressive strength with due to ion exchange/pozzolanic action. The maximum strength was obtained for 10% or 15% of ash contents. As the percentage of ash increases, the strength decreases. This strength decrease may be because of replacing of heavy soil with lightweight ash. The amount of lime added also contributes towards strength. The increase in strength recorded was marginal after 14 days of curing.

Conclusions:

The introduction of various organic waste ashes with small amount of lime improves the strength of clay soil. This work exposes organic waste ashes as an admixture for soil modification in economical way. The following conclusions were drawn.

- Addition of nominal amount of lime has been responsible for controlling of swelling behavior of soil.
- The maximum increase in strength is obtained at 10% of wood ash followed by 15% Coconut coir ash for 28 days curing.
- The accepted percentage of all five ash types to achieve maximum strength was found to be 10 to 15% and at 28 days of curing.
- The strength achieved was because of high calcium content and pozzolanic properties of various admixtures used which are difficult to dispose.
- The unconfined compressive strength of clay increases with increase in curing period.
- Further increase in strength is achieved, if admixed with appreciable amount of conventional stabilizers such as Portland cement and lime.
- Organic waste ashes have a good potential in soil modification and greatly reduce the stabilization cost & adverse effects on environmental.

References:

1. **Seco** A., **Ramírez** F., **Miqueleiz** L and **García** B. (2011), " **Stabilization of expansive soils for use in construction" ,** Applied Clay Sciences, Elsevier, Volume 51, Issue 3, Pages 348-352, https://doi.org/10.1016/j.clay.2010.12.027.
2. **ShahramPourakbar**, **AfshinAsadi**, **Bujang B.K.Huat** and **Mohammad Hamed Fasihnikoutalab** (2015), " **Stabilization of clayey soil using ultrafine palm oil fuel ash (POFA) and cement" ,** Tranportation Geotechnics, Elsevier, volume 3, Pages 24-35, **https://doi.org/10.1016/j.trgeo.2015.01.002**.
3. Huawen Xiao, Wei Wang and Siang Huat Goh (2017), " Effectiveness study for fly ash cement improved marine clay" , Construction and Building Materials, Elsevier, Volume 157, pp. 1053-1064.
4. **Imoh Christopher Attah**, **Fidelis Onyebuchi Okafor** and **Onuegbu Okoronkwo Ugwu** (2021), " Optimization of California bearing ratio of tropical black clay soil treated with cement kiln dust and metakaolin blend" , **International Journal of Pavement Research and Technology**, **volume** 14, **pages** 655– 667.
5. **David Ufot Ekpo**, **Adeyemi Babayemi Fajobi** and **Adekemi Loretta Ayodele** (2021), " Response of two lateritic soils to cement kiln dust-periwinkle shell ash blends as road sub-base materials" , **International Journal of Pavement Research and Technology**, **volume** 14, **pages**550– 559.
6. Adekemi L. Ayodele, Adedayo O. Adebisi And Muraino A. Kareem (2016), " Use of Sludge Ash in Stabilising Two Tropical Laterite" , International Journal of

Scientific & Engineering Research (IJSER), Volume 7, Issue 8, pg:104-108.

7. **Roland Kufre Etim**, **Imoh Christopher Attah** and **Paul Yohanna** (2020), " Experimental study on potential of oyster shell ash in structural strength improvement of lateritic soil for road construction" , **International Journal of Pavement Research and Technology volume** 13, **pages**341– 351.
8. Harshil Bhatt, Kuldeep Singh Kulhar and Ajay Pratap Singh Rathor (2021), " Experimental Study on Locally Available Expansive Soil by using Kota Stone Slurry with Coir Fibre" , Design Engineering, Issue: 5, Pages: 1970 – 1980.
9. Ishola K., Olawuyi O. A., Bello A. A., Etim R. K., Yohanna P. and Sani J. E. (2019), " Review of Agricultural Waste Utilization as Improvement Additives for Residual Tropical Soils" , Arid Zone Journal Of Engineering, Technology & Environment Azojete, Vol. 15(3), 733-749.
10. Koteswara Rao, D., Rameswara Rao, G.V.V. and Pranav, P.R.T. (2012), " A Laboratory study on the affect of Rice husk ash and Lime on the propertiws of Marine clay" , International Journal of Engineering and Innovative Technology(IJEIT), Volume 2, Issue 1, 345-353.
11. ASTM C618-12a (2014), Standard Specification for Fly Ash and Raw and Calcined Natural Pozzolan for Use in Concrete, ASTM International.
12. Ijimdiya, T. S., Ashimiyu, A. L. and Abubakar, D. K. (2012), "Stabilization of Black Cotton Soil using Groundnut Shell Ash", Electronic Journal of Geotechnical Engineering, Vol. 17, 3645-3652.
13. Raheem A. Akeem and Kareem A. Mutiu (2017), " Chemical Composition and Physical Characteristics of Rice Husk Ash Blended Cement" , International Journal of Engineering Research in Africa, Trans Tech Publications, Switzerland, Vol. 32, pp 25-35.