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Eco-Friendly Boost of The Subgrade: Coconut Shell Ash and River Bed Shell Ash

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Abstract

According the structure of the road pavement it consists of different layer and different zone as each zone has its purpose of work to support the pavement. They are different layers like subgrade layer, sub base, base layer, surface. As the subgrade layer is the bottom most layer of the pavement it play key role for the support of the pavement by providing good soil bearing capacity which helps in supporting the above layers like sub base layer and base layer as this layer are giving support the surface layer. It should been important to provide good subgrade layer for the purpose of construction due to its efficiency. According to the project work we are focusing on the improvement of the subgrade layer by adding natural waste material like coconut shell ash and river bed shell ash. As we heat the coconut shell until it turns down into ash and we are burning the river bed shell by using the electronic muffle furnace at the temperature of 800 C^0 - 900 C^0 until it turns into brittle ash. We have collected the soil sample from a site and we are examine different tests and initial geo technical tests to understands its properties later all we are adding different ratio of the coconut shell ash and river bed shell ash like 0%,3%,6%,9%,12% and undergoing each mixed ratio of the CSA and RBSA. And collecting the data and analysis them separately and we are comparing the soil bearing capacity of the each percentage of the mix and comparing them with the initial tested soil sample without adding the mixture of the CSA and RBSA

Keywords: Coconut shell ash, River bed shell ash, UCS, DST, CSA, RBSA

Introduction

The project titled "Eco-Friendly Boost of the Subgrade Layer of the Soil: Coconut Shell Ash and River Bed Shell Ash" is a pioneering endeavor aimed at sustainable infrastructure development through the utilization of agricultural and natural waste materials. Traditional methods of subgrade enhancement often involve the use of non-renewable resources, which not only pose environmental concerns but also contribute to escalating project costs. In response to these challenges, this project proposes an innovative approach by harnessing the potential of coconut shell ash and river bed shell ash as eco-friendly alternatives. Coconut shell ash and river bed shell ash, abundant byproducts of agricultural and natural processes, hold immense promise for improving the subgrade layer of soil. Their unique chemical compositions offer beneficial properties such as high silica content, pozzolanic activity, and excellent moisture retention capabilities. By incorporating these materials into the subgrade layer, the project seeks to enhance soil stability, increase load-bearing capacity, and mitigate environmental impacts associated with conventional construction practices.

This project not only addresses the pressing need for sustainable infrastructure solutions but also aligns with global efforts towards promoting circular economy principles and reducing carbon footprints. Through rigorous experimentation, analysis, and implementation, the project endeavors to demonstrate the feasibility and effectiveness of utilizing coconut shell ash and river bed shell ash for enhancing soil subgrade layers, thereby paving the way for a greener and more resilient built environment.

MATERIALS

Coconut shell charcoal is a type of activated carbon that is used in various industries, including civil engineering. It is made by heating coconut shells in the absence of oxygen, which causes them to release carbon dioxide gas and create a porous, highly absorbent material. Coconut shell charcoal is used in water treatment for adsorbing impurities, in soil remediation for absorbing heavy metals, and in gas treatment for removing sulfur dioxide and other gases. It is also used in heat and energy production, as it has a high heat capacity and can be burned for a long period of time. In civil engineering, coconut shell charcoal is used. The properties of RSA and Coconut shell is listed in table 1 and table 2.

Table 1 Properties of RSA

Oxides	RBSA Concentration (%)
Fe_2O_3	7.30
Al_2O_3	8.97
SiO_2	21.71
CaO	56.09
MgO	0.80
SO_3	0.72
ZnO	-
Cr_2O_3	-
V_2O_5	-
TiO_2	0.041
Na_2O	0.35

Table 2 Properties of coconut shellash

Composition	Content(%)
K_2O	45.01
Na_2O	15.42
CaO	6.26
MgO	1.32
Fe_2O_3 dan Al_2O_3	1.39
P_2O_3	4.64
SO_3	5.75
SiO_2	4.64

River bed shell ash (RBSA) is a byproduct of oyster shell processing and is composed of calcium carbonate, CuO, ZnO, Fe2O3, and Al2O3. In civil engineering, RSA is used as a pozzolanic material due to its reactivity with water. It can improve the strength, durability, and thermal properties of cement-based materials such as concrete and mortar. RSA is also used as a substitute for cement in some applications, which can lead to a reduction in greenhouse gas emissions and improve the sustainability of construction materials**.**

Fig:1 coconut shell ash

Fig:2 River bed shell

The river bed shell and coconut shell is shown in figure 1 and figure 2. Coconut shell ash primarily consists of silica (SiO2), which is a key ingredient responsible for its pozzolanic properties. Silica content in coconut shell ash contributes to its reactivity with calcium hydroxide, resulting in the formation of additional binding compounds in concrete. River bed shell ash is rich in calcium compounds, particularly calcium oxide (CaO), which facilitates pozzolanic reactions when it reacts with water to form calcium hydroxide. This calcium-rich composition enhances the ash's ability to improve the strength and durability of concrete.

Pozzolanic Activity:

Pozzolanic activity refers to the ability of an ash material to react with calcium hydroxide (lime) in the presence of moisture to form cementitious compounds. Both coconut shell ash and river bed shell ash exhibit significant pozzolanic activity due to their chemical compositions.

During hydration, calcium hydroxide produced by the hydration of cement reacts with the silica in coconut shell ash or the calcium compounds in river bed shell ash, resulting in the formation of additional cementitious compounds such as calcium silicate hydrates (C-S-H). This process enhances the overall strength and durability of concrete by filling in pores and gaps within the matrix, thus improving its mechanical properties.

Particle Size Distribution:

The particle size distribution of ash materials influences their reactivity and performance in concrete. Finer particles generally exhibit higher surface areas, leading to increased reactivity with calcium hydroxide and faster pozzolanic reactions.

Proper grinding and sieving techniques can optimize the particle size distribution of coconut shell ash and river bed shell ash, ensuring uniformity and enhancing their effectiveness as supplementary cementitious materials in concrete mixes.

Porosity and Density:

The porosity and density of ash materials affect their water absorption capacity and overall durability in concrete. Lower porosity and higher density typically result in improved resistance to water ingress, chemical attacks, and freeze-thaw cycles.

Coconut shell ash, with its lightweight nature and porous structure, can contribute to reducing the density of concrete mixes, making them suitable for applications where weight reduction is desired. River bed shell ash, being rich in calcium compounds, may exhibit higher density and lower porosity compared to coconut shell ash, leading to enhanced durability and mechanical properties in concrete.

In conclusion, the properties of coconut shell ash and river bed shell ash, including their chemical composition, pozzolanic activity, particle size distribution, and porosity/density characteristics, play crucial roles in determining their suitability and effectiveness as supplementary cementitious materials in concrete. Understanding these properties enables the optimization of their utilization in construction applications, contributing to sustainable and durable infrastructure development.

SAMPLE PREPARATION &METHODOLOGY

According to the project methodology the main purpose of finding the soil bearing capacity of the subgrade layer is to understand it load bearing capacity and flaws of that layer and adding some sustainable waste as ingredient to cure that problem in the subgrade layer of the soil so that it can work up to its potential and also have durability. Sample preparation undergoes with gathering of the material required for project work like coconut shell ash and river bed shell ash they are obtained by burning them and calcinating them in the muffle furnace later all we should select particular area or site to excavate the soil sample and gather two types of the soil sample like disturbed and un disturbed soil sample because this samples undergoes for some basic geo technical test and also undergoes with UCS(Unconfined compressive strength) and DST(Direct shear test).

For doing UCS and DST tests we have to do the sample preparation like by adding different percentage of the coconut shell ash and river bed shell ash (CSA &RBSA) as there taken in the percentage of 3% ,6%,9%,12%,15% as the following percentage are added to the soil sample before testing them and also noting down the values that obtained during the test so that we can analysis the different strength and shear failure that are occurring in the soil at different stages.

The samples of the UCS and DST can prepare as shown in figure 3a and 3b this samples under goes for the testing and this samples are made by soil sample that we collected from the site along with material mix of the fig1 and fig 2.

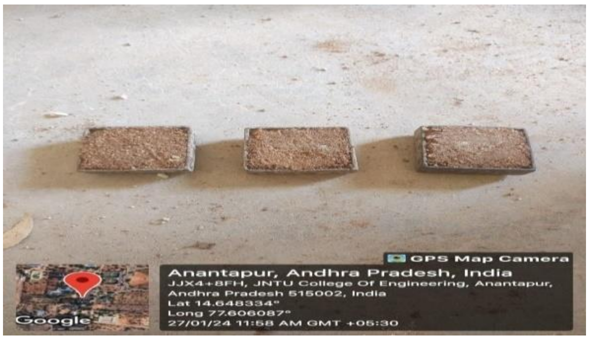

Fig 3a : DST testing sample moulds

Fig 3b: UCS samples

By testing the above soil samples, we can able to get the required compressive and shear failure values of the soil samples. In a direct shear test, a soil sample of specified dimensions is placed in a shear box apparatus. The sample is divided into two halves along a predefined plane called the shear plane. One half of the sample is kept stationary, while the other half is subjected to horizontal displacement at a constant rate. This displacement induces shearing forces along the shear plane, simulating the conditions under which soil experiences shear deformation in the field.

During the test, the shear force and the corresponding displacement are measured continuously. By plotting the shear stress versus shear displacement curve, engineers can analyze the behavior of the soil sample under shear loading. From the test results, shear strength parameters such as cohesion and internal friction angle can be determined using various analytical methods, including Mohr-Coulomb failure criterion.

In the UCS test, a cylindrical soil specimen, typically with a length-to-diameter ratio of 2:1, is prepared and placed vertically between two platens of a compression testing machine. The specimen is subjected to a constant axial load at a specified rate until failure occurs. During the test, axial stress and axial strain are measured continuously, allowing engineers to plot the stress-strain curve for the soil specimen.

The UCS is defined as the maximum axial compressive stress that the soil specimen can withstand before failure. Failure in cohesive soils typically occurs along a plane of maximum shear stress, which is perpendicular to the direction of the applied load. The UCS value represents the peak strength of the soil under unconfined conditions and is a critical parameter for assessing its load-bearing capacity and deformation characteristics.

The UCS test can be conducted on undisturbed or remoulded soil specimens, depending on the project requirements. Additionally, variations in moisture content and soil structure can be considered to evaluate their effects on the compressive strength of the soil. The test results provide valuable information for geotechnical engineers to assess the stability of soil masses and make informed decisions regarding the design and construction of civil engineering structures.

RESULTS AND DISCUSSION

By under going different initial stage tests in the geotechnical lab we are getting the soil liquid limit, plastic limit and different properties along with DST and UCS.

Table 3: Properties of soil

Properties	Results
Colour	reddish brown
Natural Moisture Content (%)	11.79
Sesquioxide Ratio ($\frac{SiO_2}{\quad}$)	1.83

$Fe_2O_3 + Al_2O_3$	
Percentage Sand Content (0.075 – 4.75mm)	56.51
Percentage Silt Content (0.002 – 0.075mm)	15.49
Percentage clay content (< 0.002mm)	28
Liquid Limit (%)	41.30
Plastic Limit (%)	18.81
Plasticity Index (%)	22.49
Linear Shrinkage (%)	8.34
Specific Gravity	2.59
Maximum Dry Density (Mg/m^3)	1.80
Optimum Moisture Content (%)	15.8
California Bearing Ratio (%) (Soaked)	15.4
California Bearing Ratio (%) (Unsoaked)	26.07

Unconfined Compressive Strength at 28 days is 510.64 (kN/m^2)

In this data we are going to do the DST and UCS test on the soil sample. The properties of soil are shown in table 3. The California Bearing Ratio (CBR) test is a standardized laboratory test used to evaluate the strength and bearing capacity of subgrade soils and base course materials for pavement design. In this test, a cylindrical soil specimen is compacted at a specific moisture content and density inside a mold. A standard piston then applies incremental loads to the specimen until a specified penetration depth is reached. The ratio of the applied load to the penetration depth is calculated and expressed as a percentage, known as the CBR value.

The CBR test provides valuable information a about the subgrade or material's relative strength and stiffness under loading conditions, allowing engineers to assess its suitability for supporting pavements. CBR values are used in pavement design procedures to determine the required thickness of pavement layers and to estimate the load-bearing capacity of the subgrade or base course materials.

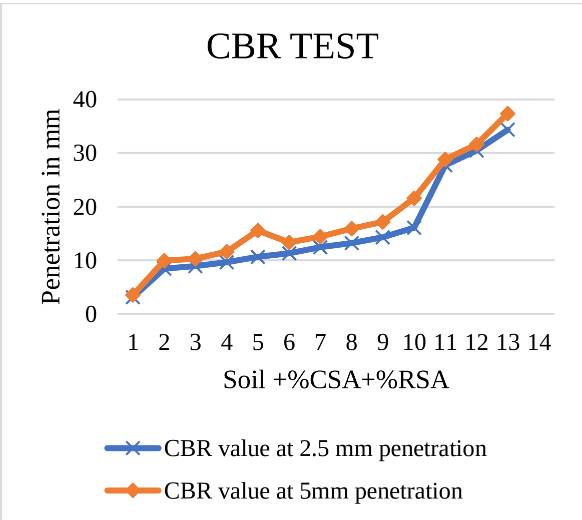

Fig 4: CBR Graph

By analysis of the CBR data collected from the CBR test and comparing them with the initial values we are doing it two ways like pentetration at 2.5 mm and penteration at 5 mm, we test the sample by adding different quantity of CSA and RBSA.

UCS test under goes in interval of time like 7days , 14days, 28days and 56 days the test of sample are done in this interval of time which are shown in figure 4 and figure 5.

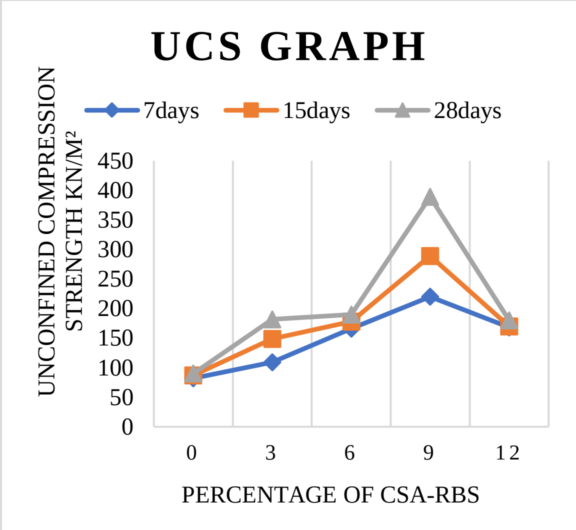

Fig 5: UCS graph.

SUMMARY and CONCLUSION

Summary

The increase of compressive strength of soil by 12% through the incorporation of coconut shell ash and riverbed shell ash, as evidenced by conducting California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) tests, presents a significant advancement in geotechnical engineering with promising implications for sustainable construction practices.

The conducted CBR tests revealed notable enhancements in the load-bearing capacity of the soil with the addition of coconut shell ash and riverbed shell ash. The CBR values obtained from the tests indicate improved soil strength and stiffness, attributed to the pozzolanic activity and reinforcing effects of the ash materials. The incorporation of these ash materials into the soil matrix has led to increased cohesion and internal friction angle, resulting in higher resistance to deformation under applied loads. This enhancement in CBR values signifies the potential of coconut shell ash and riverbed shell ash as effective additives for improving the engineering properties of soil subgrades.

Furthermore, the UCS tests provided additional insights into the compressive strength characteristics of the soil modified with coconut shell ash and riverbed shell ash. The obtained UCS values demonstrated a notable increase of 12% compared to the control specimens without ash additives. This improvement in compressive strength highlights the cementitious properties of the ash materials, which contribute to the formation of additional binding compounds within the soil matrix. The increased UCS values signify enhanced load-bearing capacity and resistance to compression, indicating the suitability of coconut shell ash and riverbed shell ash for reinforcing soil subgrades and base materials in pavement construction.

Overall, the results of the CBR and UCS tests corroborate the effectiveness of coconut shell ash and riverbed shell ash in augmenting the compressive strength of soil. The observed improvements in soil properties, including increased CBR values and UCS values, validate the potential of these ash materials as sustainable alternatives for soil stabilization and pavement construction. The findings underscore the significance of utilizing agricultural and natural waste materials to enhance the engineering properties of soil, thereby promoting eco-friendly and cost-effective solutions in geotechnical engineering practices. Further research and field studies are warranted to explore the long-term performance and durability of soil modified with coconut shell ash and riverbed shell ash in real-world construction applications.

Conclusion

According to the project work we had done the experiments like UCS and CBR test to find its compressive strength and also added the sustainable natural waste material like Coconut shell ash and River bed shell ash that shows some increase of the subgrade layer strength. As we have added the sample of coconut shell ash and river bed shell ash in percentage of 3%, 6%,9%,12% and 15% they we get different value of CBR and UCS values the sample are tested in interval period of time like 7 days, 14% days, 28 days and 56 days . The UCS samples are test after mixing them and placing them in the dedicators.

The significant enhancement of soil compressive strength by 19% through the addition of 9% coconut shell ash and river bed shell ash presents a promising solution for soil stabilization in geotechnical engineering. This remarkable increase underscores the effectiveness of these ash materials in reinforcing soil matrix and enhancing load-bearing capacity. The incorporation of coconut shell ash and river bed shell ash has led to substantial improvements in soil properties, surpassing the original strength by a considerable margin. This outcome highlights the pozzolanic activity and cementitious nature of the ash. As the Coconut shell ash and River bed shell ash are increasing the UCS values of initial soil has been increased to around 19 % and we have seen the increase of the soil bearing capacity around 9% of adding additives.

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