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Strength Analysis of Heat Treated Clay and Rice Husk Mixture

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Abstract: The strength analysis of Heat Treated Clay and Rice Husk Mixture was to ascertain the threshold temperature and the strength of the sample for construction work. The strength of the material was analysed to determine the threshold temperature to produce a satisfactory construction material from Rice Husk Ash and clay. The materials used in this study include rice husk, clay, sieve shaker kiln, mould, muffle furnace, compression machine and Schmidt hammer. The rice husk was collected from the rice mill and dried under the sun and burnt in kiln at the temperature of 500º Celsius to 700º Celsius to become white grey and sieved with sieve shaker 15m to obtain smooth and fine ash and mixed with clay in different ratios of 500 : 500, 600 : 400, 700 : 300, 800 : 200 and 900 : 100 in grams, ash and clay respectively, and the mixture was introduced into moulds and was taken to unconfined compressive machine to determine the untrained strength and the stress-strain characteristic of the sample after that, the samples was left for four days to dry under room temperature and weigh before it was heated in the furnace to ascertained the rate of water moisture in each of the samples. From the furnace, the samples were reweighed to ascertained the water contain if at all there is, and at what rate. Schmidt hammer was applied for impact test in mega paschal (Mpa) after heating. It was noticed that the mixture ratio of 900g ash: 100g clay gave the optimum strength for building and construction work. From the test results, compressive test sample E with the mixture of 900g ash and 100g clay shows that crushing load of 30.46Kn, strength of the material proves to be 3.33Nmm^2, density of the material is 1245gm^3, impact test result 22.7Mpa.

Keywords: Rice Husk, clay, strenght analysis, crushing load**,** material

I. Introduction

The construction industry is continuously seeking innovative and sustainable materials to meet the demands of modern infrastructure development while minimizing environmental impact. One such avenue is exploring the potential of clay-based materials and agricultural waste byproducts. This research proposal aims to investigate the strength properties of a composite material composed of heat-treated clay and rice husk mixture, with the goal of understanding its feasibility for structural applications. Davidovites, (2020).

Rice husk are the heard protecting covering of grains of rice in addition to protecting rice during the growing seasons. Rice hulls are part of the chaff of the rice. Rice husk can be put to use as building materials, fertilizer, and insolation material or as fuel. Lee et al, (2008).

Rice husk (RH) is a residue generated during the rice production. The main problem related with this residue it's that exists in large quantities leading to management problems, as well as its high volume. After incineration, it is obtained only 20 wt% of rice husk ash (RHA) but has a high silica content. This high silica content makes the residue very interesting for a variety of different applications. The understanding of the influence that the thermal and chemical treatments have in the properties and silica content of the RHA is crucial. Neville, (2020).

The primary objectives of this research are as follows:

- To assess the effect of incorporating rice husk into clay and subjecting the mixture to heat treatment on the strength properties of the composite.
- To determine the optimal mixture proportions of clay and rice husk for achieving desirable mechanical strength.

II. Literature Review

According to Pius, (2017); Clay bricks are more popular in building constructions than the cement/concrete bricks because of Eco-friendly and low cost. These bricks have been made from clay, since they found. However, the quality of the bricks can be upgraded by doping with the agricultural natural waste materials. Rice husk (RH) is a most common and hugely abundant wastes that consist of SiO2 percentage is RHA. In the present study, eight sets of brick were manufactured and each set consists of three bricks. These bricks were doped with RHA of ratio 0 to 30% of the total weight of mixture with a step of 5%. These bricks were allowed to dry for 3 days and fired in the brick kiln, which the traditional method is still used to burn bricks in Sri Lanka. The physical and mechanical properties of the burnt bricks were tested and compared with Sri Lankan Standard Specifications (S.L.S) as well as the British Standard Specifications (B.S.S) and compared with the commercially available brick made purely from clay. The bricks doped with RHA are obviously superior to the commercially available brick in the Eastern region of Sri Lanka. However, the brick doped with 5% RHA has higher compressibility of 3.7 N.mm -2 and the water absorption of 15.8% that satisfy the S.L.S and B.S.S.

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Subashi (2021) investigated effect of waste RHA, residual ash generated from rice husk fuelled brick kilns, on strength, durability and thermal performances of mortar was investigated. Cement in the mortar was replaced by 0%, 5%, 10%, and 20% of waste RHA. Compressive strength, bulk density, water absorption, porosity, sorption rate, sulfate, acid and alkaline resistance, thermal performance, and microstructural analysis of specimens were examined. Bulk density of control (i.e. 0%) and 20% waste RHA mortar were 2033 kg/m ^{3} and 1821 kg/m ^{3}, respectively, promising a lightweight mortar by blending waste RHA into the mixture. At 56 days, Strength activity index (SAI) was achieved to be 95% and 85% for 5% and 10% waste RHA mortar, respectively, indicating better compressive strength achievement with waste RHA added mortar. The expansion due to sulfate exposure was reduced by 54% and 70%, for 5% and 10% waste RHA mortar, respectively. Weight loss due to acid exposure was reduced by 45%, 40%, and 25% for 5%, 10%, and 20% waste RHA specimens, respectively. The weight loss due to alkaline exposures was reduced from 3.13% to 2.41% with rising waste RHA level from 0% to 5%. Mortar with 20% waste RHA had a higher temperature difference than the control mortar, indicating that RHA contributed to the reduced thermal conductivity. At 5% waste RHA sample, high counts of CSH was formed, micro-voids were filled, making it a dense structure, which is favorable to achieve improved strength and durability performances.

Pornkasem et, al. (2018) investigated the potential and efficiency of the use of Rice husk Ash (RHA) to add up partially which replaced Portland cement in deep cement mixing technique are examined. A series of unconfined compression tests on cement - RHA-stabilized clay was conducted to investigate the influence of RHA on the mixture properties. Special attention also was paid to its efficiency for increasing the strength by partial cement replacement to obtained high strength soil cement, and also it was compared with fly ash. The tested result indicated that up to 35% of RHA could be advantageously added up to enhance the strength if the cement contain in the mixture is larger than 10%. The RHA enhanced the strength of cement-admixed clay by larger than 100% at 28 days. For curing time of 14 and 28 days, the RHA exhibited higher efficiency on Portland cement replacement when the cement and overall cementations contents are not less than 20 and 35%, respectively. The optimum condition for high strength mixture is achieved with addition of RHA of about 20% cement content mixture. When compared with fly ash of similar grain size, the efficiency of RHA is higher when the content added is greater than 15%. This indicates the suitability of RHA for used in high-strength soil-cement.

Joel, 2011 investigated the effect of rice husk ash (RHA) on the burnt properties of the clay brick 2 to 10% RHA was blended with the clay. Atterberg limits specific gravity, compressive strength and water absorption test were conducted on each admixture. In addition, X-ray diffraction and geochemical tests were performed on the soil and rice husk ash respectively. X-ray diffraction studies shows that the Ibaji soil was mainly kaolinite. The results showed that the plasticity index reduced gradually and had a minimum value at 6% RHA. The compressive strength and water absorption attained a maximum value of 18.64MN/m^2 and a minimum value of 14.8% respective at 2%RHA additive led to a significant improvement in the properties of Ibaji burnt clay brick.

2.1 Theoretical Background

This study is material science which is a branch of solid state physics. Materials science is interdisciplinary field where other field of studies are combined together. The termed materials science and engineering, covers the design and discovery of new materials, particularly solids. The intellectual origins of materials science stem from the Enlightenment, when researchers began to use analytical thinking from chemistry, physics, and engineering to understand ancient, phenomenological observations in metallurgy and mineralogy. Hegazy, (2012). Materials science still incorporates elements of physics, chemistry, and engineering. As such, the field was long considered by academic institutions as a sub-field of these related fields.

2.2 Shear Modulus of Rigidity

Shear modulus also known as Modulus of rigidity is the measure of the rigidity of the body, given by the ratio of shear stress to shear strain. Often denoted by G sometimes by S or μ.

Shear Modulus of elasticity is one of the measures of mechanical properties of solids. Other elastic moduli are Young’s modulus and bulk modulus. The shear modulus of material gives us the ratio of shear stress to shear strain in a body.

Shear modulus formula:

$$G = \frac{Txy}{\gamma xy} = \left(\frac{F / A}{\Delta x / l} \right) = \frac{Fl}{\mathrm{A}\Delta x} \qquad (1)$$

Where :

T= T x y F/A = Is the shear stress

F= force acting on the object

A is the area on which the force is acting

Y x y Δx/l is shear strain.

Bulk modulus is a modulus associated with a volume of strain when a volume is compressed.

The formula for bulk modulus is bulk modulus = -(pressure applied /fractional change in volume)., where

K= bulk modulus

P = pressure

V = initial volume of the substance

$$k = -V \frac{dp}{dv} \qquad (2)$$

Bulk modulus is used to measure how incompressible a solid is. Besides, the more the value of K for a material, the higher is its nature to be incompressible. The unit of bulk modulus is the same as that of pressure N/M^2The reciprocal of Bulk modulus is called *compressibility*

Young modulus =

$$Y = \frac{longitudinalstress}{longitudinalstrain} \; Y = \frac{F/A}{l/L} = \frac{FL}{la} \qquad (3)$$

The unit for young modulus is $Y = N/M^2$

Mechanical Testing: Conduct comprehensive mechanical tests on the heat-treated composite specimens, including:

- Compressive Strength (σ_c): The compressive strength of the composite will be determined using the formula: σ_c = AP. Where P is the maximum load applied and A is the cross-sectional area of the specimen.
- Tensile Strength (σ_t): The tensile strength will be calculated using the equation: $\sigma_t = A_F$ Where F is the maximum tensile load applied and A is the cross-sectional area.

  Source: [kedsarin, (2001); Kute, (2003); and Dondi, (2009)]

3.0 Materials

The following materials were used in the study

i. Rice husk ash
ii. Clay
iii. Sieve Shaker
iv. Kiln
v. Mould
vi. Weighing Balance
vii. Muffle furnace
viii. Unconfined compression machine
ix. Compression machine
x. Schmidt hammer

III. Method

Rice husk used for this study was collected from Akpet rice mill in Biase Local Government Area of Cross River State Nigeria. The rice husk was stacked in heaps near the mill. Samples were collected from different spots at the heap site. The sample were dried under the sun.

The rice husk was burned at 700^o C for 6 hours in a kiln. The ash was left to cool inside the kiln and removed the next day. The ash was then sieved using sieve shaker of a 150µm to achieve a degree of fineness of the sample (RHA) was weighed with the weighing balance in the ratio of 500 :500, 400 :600, 300 : 700, 200 :800, and 100g clay: 900g Ash respectively into five different portions and the sample was mixed with water for moulding and was taken for compression with unconfined compression machine to ascertained the shear stress and strain.

The sample was weighed to ascertain the weight of the sample and kept for solidification 4 days in room temperature after that the brick was put in a muffle furnace for a temperature between 900 – 1200 degree Celsius to achieve crystalline like nature (vitrification). The brick was left in the furnace to cool the next day it was removed weighed after heat to ascertain its weight before exposed to impact factor test and compression test to ascertain the hardness of each of the samples.

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IV. Results and Discussion

4.1 The table below shows the result of Compression test. Cylindrical shape Dimension of the sample, height 9cm, and diameter 5cm The sample was measured in gram ratio Ash and clay

Area of a cylinder, A= πr^2 (4)

Volume of a cylinder, V = $\pi r^2 h$ (5)

Density of the sample, ,

where D = density (6)

Strength of the sample, stress = $\frac{load}{Area}$ (7)

Table 4.1: Compressive Test Results

Mixed samples	Weight of sample before dry (g)	Age (days)	Weight of sample after dry (g)	Density (g/m^3)	Crushing load (KN)	Strength N/mm^2
500g ash 500gclay **A**	250	4 days	132	0.746	3.32	1.69
600g ash 400gclay **B**	258	4 days	129	0.739	2.52	1.28
700g ash 300gclay **C**	264	4days	110	0.621	4.10	1.87
800g ash 200gclay D	300	4 days	199	1.000	7.88	2.09
900g ash 100gclay **E**	340	4 days	275	1.245	30.46	3.33

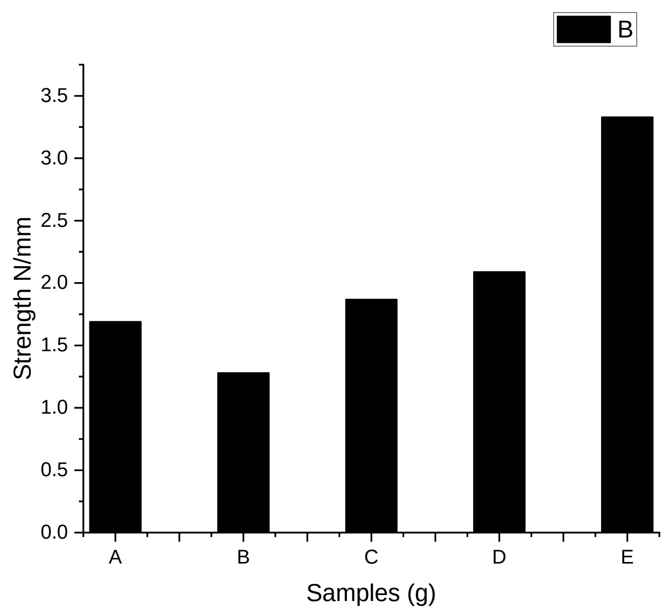

Fig.4.1. The bar chat shows the strength of the sample

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V. Discussion of the Results

From table 4.1 compressive test result of the crush load, the strength and the bulk density of different samples were determined based on the mixture ratio of each sample A, B, C, D and E with 900g ash: 100g clay, shows high strength of the material with 30.46 kN, 3.33Nmm^2 and 1245g/m^3. The test result shows that pozzolans can complement ordinary portl and cement for building. From the bar chart shown in figure 4.1, that shows the strength of the material, sample E has the highest strength followed by sample D. Then C and A. With this result, pozzolans can substitude Portland cement for construction of culvert and pavement in general the optimum of the material is ascertained. With the mixture of 900g ash and 100g clay.

From the findings, it is observed that pozzolans of this mixture 900g ash and 100g clay which the unit strain and stress of the sample prove that it can replace Portland cement for construction work and also shows the *optimum* strength of the material for construction of concrete. The percentage or ratio of mixture of the sample shows that addition of RHA to clay gives high strength of the material which is suitable for building and construction.

VI. Conclusion

The analysis of heat treated clay and Rice Husk mixture can sub stitude the ordinary Portland cement for building and construction works with the strength sample of 900g ash and 100g clay as shown. Secondly Rice Husk Ash with clay of this mixture can withstand load in term of strenght. The outcomes of this research provides valuable insights into the feasibility of utilizing such composites in structural applications, leading to more eco-friendly and efficient construction practices.

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