RICE RUSK ASH-AN ALTERNATIVE TO GYPSUM IN POP BOARD

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ABSTRACT

Rice husk ash (RHA) is a good substitute for gypsum, the popular white cement with trade name of molda 3 used in producing plaster of Paris (POP) ceiling boards. The research showed how rice husk (RH), an industrial waste materials is optimized by substituting it for gypsum used for producing ceiling board, hence converting waste to wealth. Gypsum is an expensive material used for manufacturing POP boards. RH is an industrial waste that pollutes the environment and causes enormous difficulty of disposing appropriately without causing any form of occupational health, safety and environmental hazard. Its organic property is converted to inorganic pozzolanic substance when burned at a very high temperature. The ashes exhibited an inorganic pozzolanic property that makes it to behave like cement and hence a good substitute for gypsum. 10%, 20%, 30% and 40% of the molda 3 was replaced with RHA and tested for setting time, hardness and compressive strength at each substitution. Each new percentage mix was used in the production of POP-RHA boards. The crushing strength of each mix was determined in 7, 14, 21, and 28 days respectively and the result compared to that of 0% RHA control mix. The results showed a correspondingly steady increase in strength according to the percentage mix. The density of the POP-RHA boards reduced as the percentage of the RHA increased. The aesthetics was relatively good. Improved resistance to fire, chloride and sulphate attacks are expected. The setting time of the new mix increased with increase in RHA content. Ultimately, minimization of cost and resources to maximise profit is achieved from the industrial waste materials.

Keywords: Rice husk ash, Plaster of Paris, gypsum, compressive strength, setting time, molda 3.

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1. Introduction

The research investigated the possibility of producing POP-RHA boards. The method was to produce the board type using the normal constituent materials to serve as control and then to replace the essential material with RHA. A mixture of RHA and molda 3 at determined percentages was used to produce the boards. The crushing strength of each percentage mix was determined in the laboratory and compared with the control to determine the optimum RHA percentage suitable for the purpose.

The research optimises the waste material for aesthetics and structural benefit thus enhancing its economic viability and usage. Rice husk ordinarily is an environmental nuisance both at milling point and at point of open burning which is the normal practice [1] .

The research aims at producing the best of ceiling board with good aesthetics and designs of the different components of the POP, namely POP board, rosette and conies with RHA as alternative/ substitution material. Durability, strength and aesthetics, reduced porosity, resistance to fire, chloride and sulphate attacks, should be reasonably high to achieve economic aims [2], [3].

1.1 Plaster of Paris (POP)

POP is a white cementicious powder which set to a hard solid when mixed with water. Large deposits were originally found outside Paris in France, hence its name. When gypsum is heated to about 150^0C it losses water and produces the powder used in making POP. During the heating process, there is usually evolution of heat which generates a large amount of steam, leaving the residue which is ground to powder [4]. The chemical equation is as follows:

$$2CaSO_4{\cdot}2H_2O \longrightarrow \longrightarrow \text{heat} \quad 2CaSO_4{\cdot}\tfrac{1}{2}H_2O + 3H2O \qquad (1)$$

Addition of water to Plaster of Paris results in production of Gypsum

$$2CaSO_4{\cdot}\tfrac{1}{2}H_2O + 3H_2O \longrightarrow 2CaSO_4{\cdot}2H_2O + \text{heat} \qquad (2)$$

The chemical formula for plaster of Paris is $CaSO_4 \cdot ½H_2O$

Many authors [5], [6],[7], [8], and [9]. have discussed the benefits of POP ceiling.

1.2 Rice husk ash

RHA is the after-mill waste product of rice found in large quantities in south-eastern Nigeria and some parts of Nigeria's middle-belt where rice is milled. In Niger State, Nigeria, about 96,660 tonnes of rice grains were produced in year 2000 [10]. Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world. Globally, approximately 600 million tons of rice paddy is produced each year. On average 20% of the rice paddy is husk, giving an annual total production of 120 million tones [12]. In majority of rice producing countries much of the husk produced from processing of rice is either burnt or dumped as waste. Burning of RH in ambient atmosphere leaves a residue, called rice husk ash [11]. For every 1000 kg of paddy milled, about 220 kg (22 %) of husk is produced, and when this husk is burnt in the boilers , about 55 kg (25 %) of RHA is generated [12], [1]. RHA is a source of Silica and Silicon compound [13], [14]. It is actually a Super-Pozzolan having about 85% to 90% silica content. A good way of utilizing this material is to use it for making 'High Performance Concrete', which means high workability and very high early strengths and long-term durability of the concrete. Compressive strength of concrete can be increased by up to 30%, Water permeability, chloride penetration, and heat of hydration can be reduced by up to 60%, and 25 % respectively with 10 % replacement of cement in concrete, [13] [15]. During heat treatment of RH in inert atmosphere, organic compounds decompose and partly change to H_2O, CO, CO_2, and volatile compounds, leaving carbon and SiO_2 [16]. The technological trend towards waste utilization and cost reduction in industrial processing has attracted use of Rice Husk as a value added material. Rice Husk Ash (RHA) has been found suitable for wide range of domestic as well as industrial applications. Considering the importance and increasing demand of this material, a systematic study based on properties and industrial applications has been carried out [12].

[3], [1] discussed the following physical and chemical properties of RHA

Table 1. Parameters and their values

S. No	PARAMETERS	VALUES
1	Fineness passing 45 micron	96%
2	Specific gravity	2.06
3	Specific surface (nitrogen absorption) m^2/ kg	27400
4	Silicon dioxide (SiO_2)	87.20%
5	Aluminium oxide (Al_2O_3)	0.15%
6	Ferric oxide (Fe_2O_3)	0.16%
7	Calcium oxide (CaO)	0.55%
8	Magnesium oxide (MgO)	0.35%
9	Sulphur trioxide (SO_3)	0.24%
10	Carbon (C)	5.91%
11	Loss on ignition	5.44%
12	Pozzolanic activity	84%
13	Particle size (μm)	7

Test conducted by [3] on rice husk ash with concrete showed that rice husk used as a replacement for cement results in the following:

1. Increase in compressive strength.
2. Decrease in chloride iron penetration as a result of reduction in the volume of large pores.
3. Low permeability when mixed with a super plasticizer.
4. Improved resistance to sulphate and alkali attack due to the presence of high amount of silica.
5. High resistance to acid attack.

Tested as an alternative to silica fume, RHA possesses a small particle size that lowers the porosity of concrete and is a highly reactive pozzolan[17]. However, previous experience has shown that silica fume decreases the initial set time of concrete and increases the amount of shrinkage in the mix. Rice husk ash does not possess these undesired characteristics. Furthermore, RHA has a greater amount of surface area per unit weight than silica fume, helping to increase the overall strength of the mix [18]. Research showed that RHA has High silica content when burnt at 650^0c-700^0c that it reduces its carbon content and increases its surface area [1].

Research into the possibilities of improving residual soil properties by mixing RHA and cement in suitable proportions as stabilizing agents has shown positive results [19].Rice husk ash has been widely used in various industrial applications such as processing of steel, cement, ceramic and other refractory industries, silica source, etc [12], [20], [1].

2. Materials and Method

The rice husk ash was obtained from rice mill in Abakaliki, capital of Ebonyi state in south eastern Nigeria. Burning heap was dug open to obtain a well burnt layer of fine ash. Other materials and equipment used, include molda 3, babutine, filler, latior oil, wood saw, paint brush, water, measuring tape and cylinder. The laboratory tests carried out include setting time and crushing tests and the equipment used were the vicat apparatus and crushing machine. The size of the POP-RHA specimen produced were précised to enable the production of the required number of varying percentages of rice husk ash that can be crushed for the seventh, fourteenth, twenty-first and twenty-eighth day strength test. The percentage of rice husk ash added to the molda 3 used for the POP ceiling board production ranged from zero percent to forty percent. A POP specimen of 180mm x 180mm x 25mm was produced by preparing mould of a desired shape and design. The measurement was by percentage volume. The volume of molda 3 to produce a board of 180mm x 180mm x 180mm was measured out. 10, 20, 30, and 40 percent respectively of the measured volume was replaced with equal volume of RHA and the portion was well mixed. The zero percent RHA mix was used as control.

3. Results and Analysis

3.1 Setting time

The setting time of the new compound increased with a corresponding increase in the percentage of RHA content present in the specimen as shown in Table 1.0 and Fig 1.0. This implies that it takes a longer time for the specimen with a higher proportion of RHA content to set compared to specimen with zero percent used as control. This result is attributed to the quantity of Tricalcium Aluminate (C_3A) present in RHA being relatively small compared to the quantity removed in the process of replacement. However, with the passage of time the new compound attained its final setting time.

Table 2. Summary of setting time

S/N	% OF RHA	Initial setting time(min)	Initial penetration (mm)	Final setting time (min)	Final penetration (mm)
1	0	4.00	45	7.00	3
2	10	4.30	34	8.30	1
3	20	5.00	40	11.00	4
4	30	6.00	39	11.00	5
5	40	7.00	29	15.00	3

3.2 Compressive strength

The results of the compressive strength tests revealed that the zero percent RHA mix developed the highest strength for the seventh, fourteenth, twenty-first and twenty-eighth day crushing test. There was initial drop in strength for the various percentage RHA content in the mix. Then there was a steady rise in strength proportional to the various percentages of RHA content. The increase in strength was observed in all mixes for the seventh, fourteenth, twenty-first and twenty-eighth day crushing test with the 40% RHA content mix developing the highest strength. The 10% RHA content dropped in strength as a result of reduced concentration of Tricalcium silicate C_3S in RHA. The high proportion of Silica present in RHA gives it an unusual ability to develop strength much better than molda 3. Tables 2.0 and 3.0 and figures 3.0 and 4.0 show that the higher the percentage of RHA in the specimen, the higher the strength gained with time. Research has shown that the strength will develop further with time until it exceeds that of the control mix by up to thirty percent [15].

Table 3: Results of load at varying percentage of rice husk ash content

S/NO	% OF RHA	LOAD			
		DAY 7	DAY 14	DAY 21	DAY 28
1	0	12.1	52.3	62.4	65.6
2	10	5.3	6.8	12.4	22.7
3	20	6.0	7.0	16.0	24.0
4	30	6.0	14.0	21.0	31.0
5	40	31	31.1	32.0	42.0

Table 4: Results of stress at varying percentage of rice husk ash content

S/NO	% OF RHA	STRESS			
		DAY 7	DAY 14	DAY 21	DAY 28
1	0	0.040	0.160	0.193	0.202
2	10	0.020	0.020	0.038	0.070
3	20	0.020	0.020	0.050	0.074
4	30	0.020	0.040	0.064	0.096
5	40	0.096	0.096	0.099	0.130

4. Conclusion

It has been established experimentally that RHA is a good alternative to Gypsum. The various percentages of rice husk ash introduced into the molda 3 in their varying proportions showed that the higher the RHA content the higher the initial and final setting time and the lower their initial penetrations respectively. The result of the final penetration is not conclusive. The initial and final setting time and their respective penetrations are higher than that of ordinary Portland cement. However, maximum hardness is achieved with time. The inference from the result showed that 40% RHA developed the highest strength and with time will exceed the strength of the 0% mix. The strength of the RHA can exceed that of molda3 by up to 30% [15]. The aesthetics of the products are reasonably good. Fire resistance is expected to improve and porosity reduced. The addition of rice husk ash results in increased resistance to chloride and sulphate attacks. A mixture of RHA and molda 3 gives a better board strength-wise and hence higher durability than that of standard molda3 alone. It is obvious that a new, more economical and stronger ceiling board has been produced without compromising aesthetics.

5. Appendices

Plate 1: POP-RHA after production

Plate 2: POP-RHA on Weighing Balance

Plate 3: POP-RHA in a Compressive Strength Machine

Plate 4: POP-RHA after Crushing

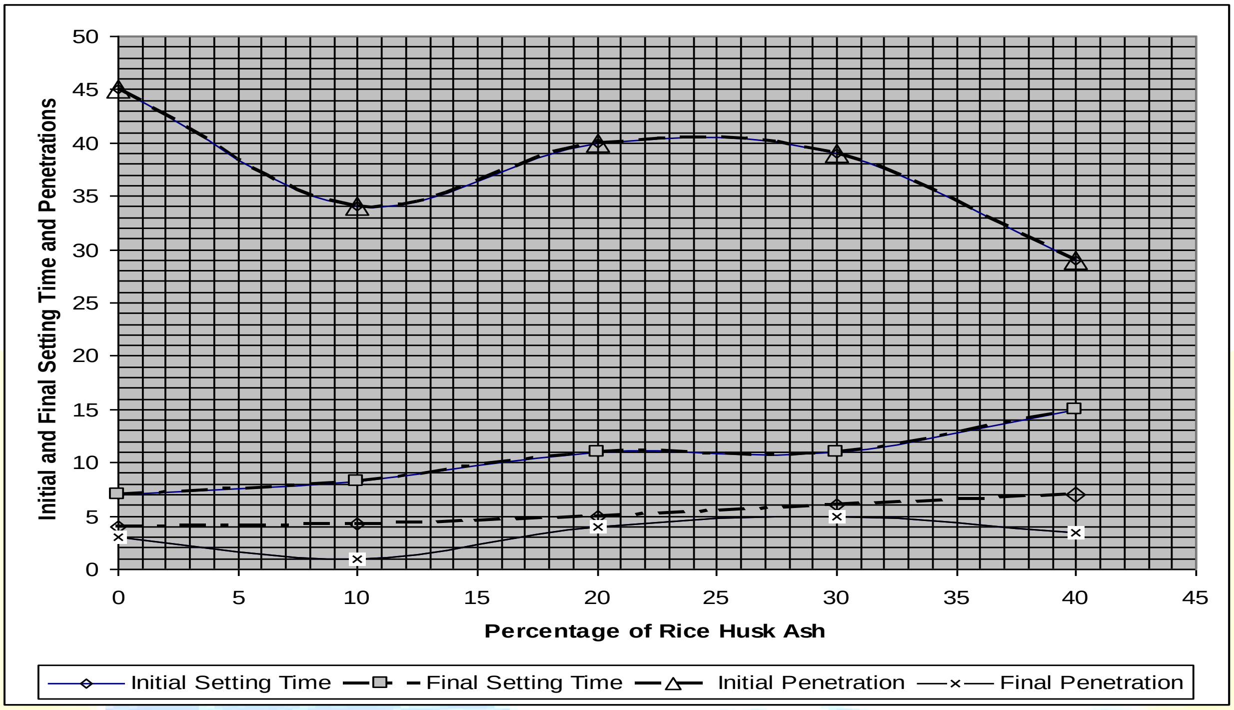

Figure 1: Graphical representation of initial and final setting time and penetration

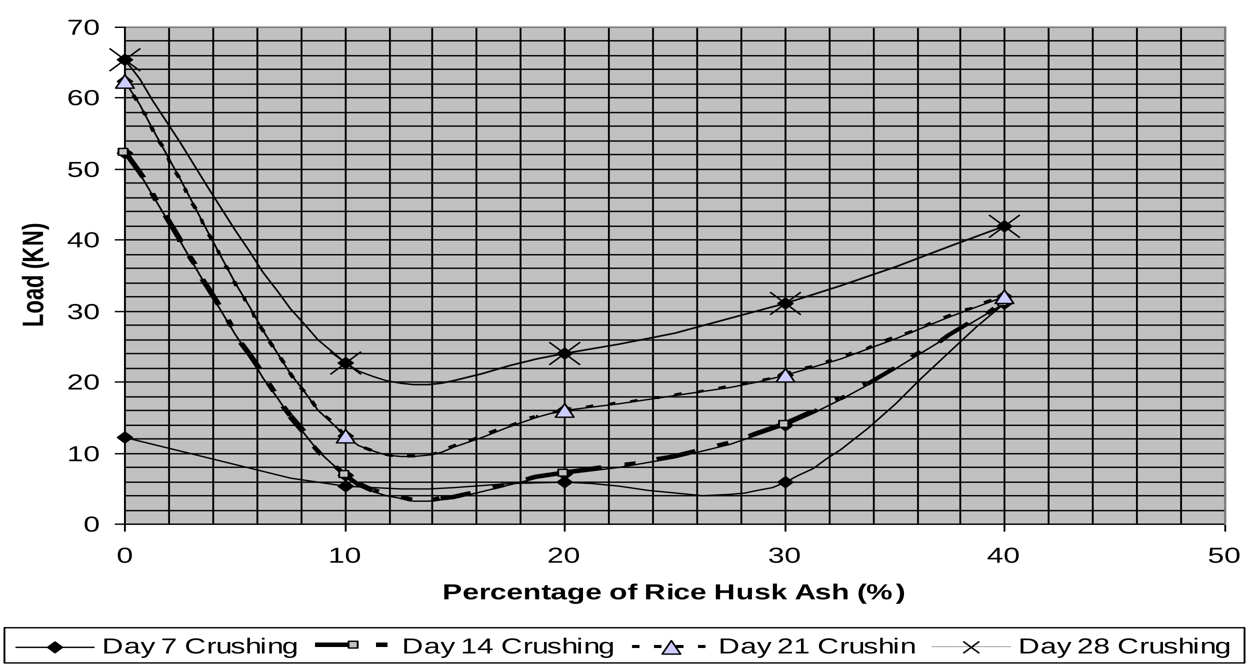

Figure 2: Graphical representation of load (KN) against percentage (%)

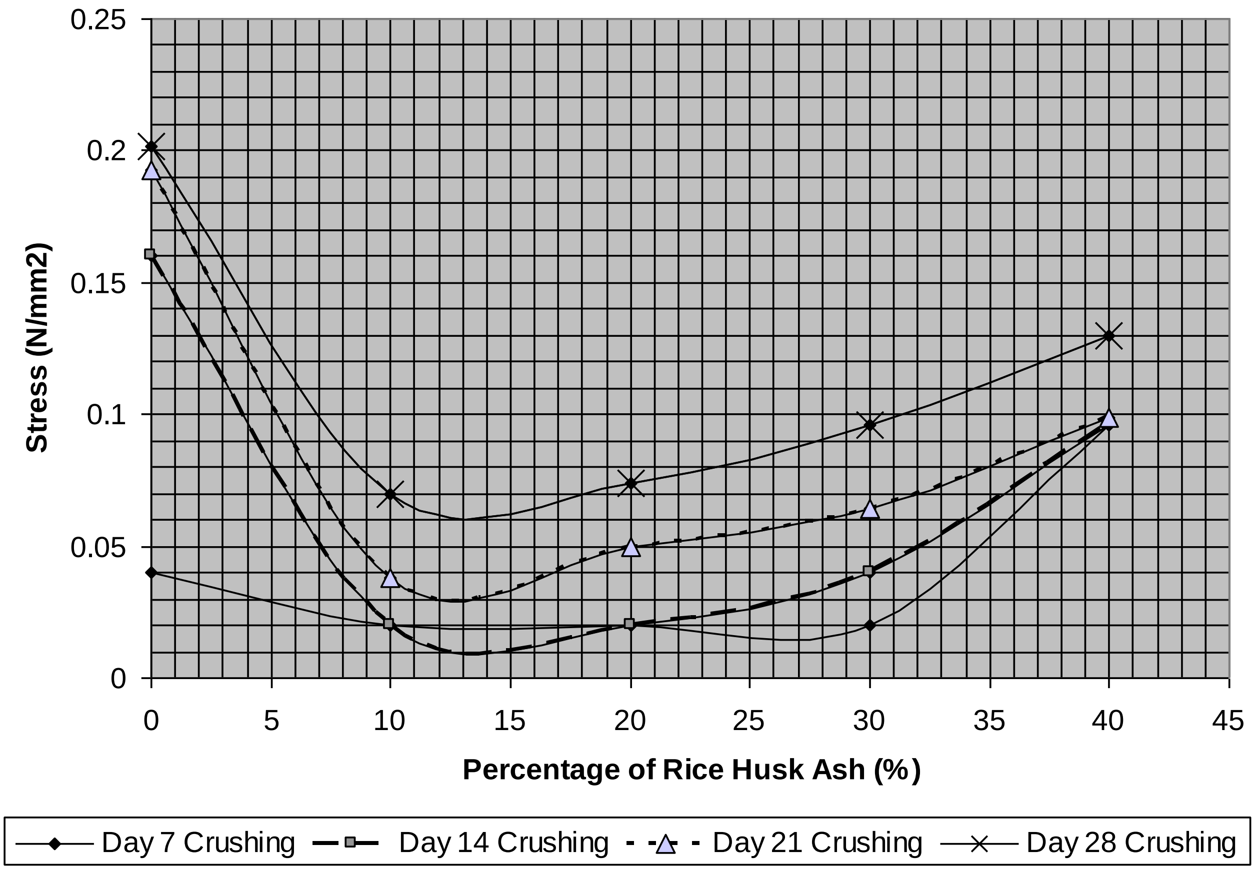

Figure 3: Graphical representation of stress (n/mm^2) against percentage (%)

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