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SUITABILITY OF STABILIZED RICE HUSK CEILING BOARD AS AN ALTERNATIVE CEILING MATERIALS FOR RURAL SCHOOLS IN BENUE STATE, NIGERIA

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ABSTRACT

The purpose of this study is to investigate the suitability of stabilized rice husk ceiling board as alternative ceiling materials for rural schools in Benue State, Nigeria. Three research questions were set to guide the investigation. The study employed true experimental design and the physical-mechanical properties of the rice husk were assessed for manufacturing ceiling boards with potato starch and gum Arabic as adhesives. The rice husk ceiling boards were produced in the following four mix ratios: 0.75: 0.15: 0.10, 0.75: 0.20: 0.05, 0.60: 0.25: 0.15 and 0.65: 0.25: 0.10 composition of rice husk, potato starch and gum Arabic respectively. For most parameters, the ceiling boards produced exclusively with mix ratios I-III showed similar performance to mix ratio IV. The major findings of the study include that mix ratio IV (0.65:0.25:0.10) was found to be the suitable ratio for the production of rice husk ceiling board as proved by the physical-mechanical property tests which showed better quality than other mix. Rice husk ceiling board showed better fire resistance abilities and relatively fine moisture penetration resistivity. The study among others recommends that Federal and State Ministries of education and works should adopt the use of rice husk ceiling board in rural schools as it has high fire and water resistance ability.

Key Words: ***Rice Husk, Adhesives, Rural schools, Benue State.***

INTRODUCTION

In Nigeria, variety of waste is generated in different forms, shape and texture. The agricultural wastes tend to be hazardous and threatening the environment and the society living nearby. Various researches have been done on this waste material to either degrade or to utilize them in other ways. Abayomi, Temitope, Olawale and Oyelayo (2015) stated that perhaps one such hazardous waste generated by industrial process is Rice Husk. There is a need for the utilization of these wastes to reduce the risk and danger in waste generation. Rice husk ceiling

board is therefore one such material which may be considered as potential substitutes for POP, plastic or wood based board products. According to Johnson and Yunus, (2009) the medium-density range of the material is widely used for construction, furniture, and wall ceiling paneling. The production of sheet products from agricultural residues is important considering the increase level of waste from processing the farm products.

Bhatnagar (1994) said, rice husk is quite fibrous by nature, hence requires little energy input to prepare the husk for board manufacture. Whether it is climate change or simply daunting energy bills, there is increased demanding for more efficient, greener new buildings. Insulation is therefore a hot topic. Rice husk density is less than 500kg/m^3. Low density ceiling boards possess better thermal insulation properties which are highly needed in hot-weather region of North Eastern Nigeria. The ceiling board to be produced will efficiently serve the purpose in tropical environment characterized by dry and hot season and short period of rainy season. Bronzeoak (2003) noted that rice husk can be used as a superior siliceous material for the manufacture of calcium silicate heat-insulating material with a good thermal durability of 1000^{o}C. This indicates that rice husk is resistant to heat. Opera (2007) in a study of chemical composition of rice husk revealed that rice husk is fire resistant. The study showed that rice husk recorded zero percent ignition loss.

Convenient and comfortable buildings are expected to serve the following functions as outlined by Miller (1999); provision of sufficient sound insulation, offer adequate resistance to fire, provide adequate thermal insulation and aesthetics. The harsh weather in Northern Nigeria with particular reference to Benue State has called for buildings materials that can more efficiently insulate heat. Strictly, buildings protect its occupants and content of the building from adverse weather effects by preventing the penetration of wind, rain and extreme of weather such as heat.

Most rural areas within Benue State lack basic amenities such as electricity which further compound the threat of heat on building dwellings. Rice husk posses' low density with the potentials of better thermal insulation compared to medium-density ceiling boards will be cost effective for rural schools in Benue State. Benue State rural schools needs cost effective building materials as most depends on the communities for structural development. According to Davis, & Sumara, (2010) inadequacy of these infrastructures constitutes another source of frustration and disillusionment among teachers.

This scenario has prompted the prospect of locally made building materials like rice husk ceiling boards and many others alike. Rice husk has been known to be very light in weight. The weight of a building material is a very important factor in construction industries. One of the biggest problems in the construction industry today is how to

reduce the weight of individual elements and at the same time achieve a high strength capacity. It is also noted that rice husk is resistant to corrosion and chemical attacks. In support of the fact that rice husk is water resistant, Ndazi, Karlsson, Tesha and Nyahumwa (2007) reported that rice husk is coated with cuticle, a biological membrane which is resistant to water passage. This study therefore, is based on how these natural fibres can be used in the production of ceiling boards in order to reduce cost and as well reducing over-dependence on foreign ceiling boards. Federal and state ministries of education will benefit from the resulting board as a versatile substitute for ceiling materials in a wide range of applications especially as ceiling boards in rural schools.

STATEMENT OF THE PROBLEM

Conventional ceiling boards are becoming more expensive beyond the reach of lower earners especially for rural housing. In Benue State most rural schools are funded partly by the communities hence required more cost reduction building materials. These materials incorporated in the building should provide a conducive teaching and learning environment. The rapid urbanization is creating a shortfall of conventional building construction materials due to limited availability of natural resources. On the other hand energy consumed for the production of conventional building construction materials pollutes the air, water and land.

With the Federal Government directive on non-importation of rice, there is bound to be more indigenous production of rice which in turn produces rice husk. The components of this rice husk are determined by the milling method employed (Patel, 2005). This might be having environmental effects on the inhabitants through waste generation. The only possible way to dispose the waste is to dump it on barren lands or to use it in the construction industry through production of ceiling boards.

This research work therefore will make use of the locally available rice husk from the local milling industry within Benue state in Nigeria, the properties of the raw material input will be determined in relation to the ceiling board requirements. Because of the reliant of ceiling board production on adhesives used as a binder, adhesives therefore account for up to 32% of manufacturing costs in the glued-wood composites industry (Sellers, 2000). The use of a cheap binder is therefore imperative. For this research work, starch will be used as adhesives or binder in the production of the ceiling board this is not unconnected to its cheap abundant nature. In this way what is regarded as wastes will be converted to wealth.

PURPOSE OF THE STUDY

The purpose of this study is to investigate the suitability of stabilized rice husk ceiling board as alternative ceiling materials for rural schools in Benue State, Nigeria. The specific objectives are to:

- Establish the suitable mix ratio of stabilizer to Rice Husk for the production of Rice Husk ceiling board.
- Determine the extent of fire resistance of the rice husk ceiling board,
- Determine the rate of moisture penetration of the rice husk stabilized and compressed ceiling board for rural schools.

CONCEPTUAL FRAMEWORK

A ceiling board is a horizontal slab covering the upper section of a room or internal space, it is generally not a structural element but is a shell concealing the details of the structure above. However, Sellers (2000) said the ceiling might be holding up building materials such as heat or sound insulation. In modern buildings, electric lights, smoke detector, security cameras and signage are commonly attached to ceilings.

The ceiling creates a division between the roof and room space in a building structure. The ceiling structure is mainly used in order to serve these functions; effective thermal control, sound proofing and efficient reflection of lighting system (Giaccio, Sensale & Zerbino, 2007). The common types of materials used for ceiling structures are gypsum board, Metal ceiling panels, fibre boards, plaster of paris (POP) and plywood. These are further categories into; gypsum ceiling boards, acoustical ceiling boards, gypsum fibre ceiling boards, cement fibre-ceiling boards.

Ceiling boards are grouped in accordance to the raw materials used for the production. Gypsum ceiling boards are produced from gypsum, Acoustical ceiling boards are obtained from mineral wool, gypsum and small amount of paper and starch. Gypsum fibre ceiling boards are produced from gypsum and fibre to reinforce the ceiling board. This study however will be based mainly on the production of rice husk ceiling boards.

In the past, ceiling boards were produced using Asbestos a fibre present naturally in rocks. It was used because of its high tensile strength, poor heat conductivity and high fire resistance. However, asbestos causes asbestosis, which leads to cancer (Ekpunobi, Ohaekenyem, Ogbuagu and Orjiako, 2015). As a result of this problem, manufacturers of ceiling boards went into research to find out substitutes that can be used in the production of ceiling boards. This substitute includes shredded wood, cellulose fibre agricultural waste among others. Rather than industrial products (glass-fibre, iron fillings) and man-made materials, the fibres best suited to

the socio-economic circumstances of developing countries are natural fibres.

Generally all ceiling materials are weak in compressive strength with test result ranging from 0.45-0.27N/mm^2. However, when used especially in suspended ceiling where it is subjected to heavy weight of load, the ceiling boards or chipboards could crack and expire in structural composition at unscheduled period of time after it has been used (Mukaila, 2011). The nails also may not hold the boards and structure tight when the composition expires. According to Folorunso and Anyata (2007) chipboard produced from agricultural waste such as rice husk, saw dust additive and cassava glue has higher tensile strength of 32N/M^2 over only the rice husk boards with 23.5N/M^2. They further state that rice husk product and commercial boards' water absorption rate has confirmed that rice husk shell has similar standard with the manufactured conventional boards. However, Mathur (2006) investigated the potential of sisal and jute fibres as reinforcements to systematically overcome their well-defined problems of moisture absorption. The performance of polymer composites made from these natural fibres and unsaturated polyester.

METHODOLOGY

This study was an experimental research work which investigates the potentiality of rice husk in the production of ceiling boards using potato starch (*Solanum tuberosum*) and Gum Arabic as adhesives. The laboratory procedures that were carried out include mixing, moulding, drying, weighing and testing. The study was carried out in Mechanical and Civil Engineering Departments' Laboratories, Adamawa State Polytechnic, Yola Adamawa State and Physics Department Laboratory in Federal University of Agriculture, Makurdi Benue State. All the procedures presented by British standard institution (BS EN 520:2004+A1:2009) for particle board, plaster board ceiling board and related non-structural materials production specification were strictly observed which also specifies the standard equipment required for boards production. The reliability of the instruments was ensured by trying and testing each instrument twice on separate occasions and comparing the result with the previous by the same equipment.

All materials were sourced from Benue State, Nigeria, where they are available and accessible to the researchers. The weighing scale was used to weigh the rice husk, potato starch, and Gum Arabic. There were four mix ratios adopted for this study 0.75: 0.15: 0.10, 0.60: 0.25: 0.15, 0.75: 0.20: 0.05 and 0.65: 0.25: 0.10. These were thoroughly mixed manually by using wooden stick as a stirrer. Thereafter, the mixtures were poured into a wooden mould of rectangular cross - section measuring 600 X 450 X 5mm, then pressed using hydraulic press in two (2) uniform compacts. Subsequently the ceiling boards were tested for ceiling properties.

RESULT AND DISCUSSION

Research Question One

What is the suitable mix ratio of potato starch to rice husk for the production of rice husk ceiling board?

Table 1: Suitable Mix Ratio of Potato Starch to Rice Husk for the Specimens Produced

Specimen		Mix Ratio I (0.75:0.15:0.10)		Mix Ratio II (0.75:0.20:0.05)		Mix Ratio III (0.60:0.25:0.15)		Mix Ratio I V (0.65:0.25:0.10)	
		Weight (kg)	**Density kg/m^3**	**Weight (kg)**	**Density kg/m^3**	**Weight (kg)**	**Density kg/m^3**	**Weight (kg)**	**Density kg/m^3**
A	1.1	0.41	304	0.41	304	0.40	296	0.41	304
	1.2	0.53	393	0.35	259	0.53	393	0.51	378
	1.3	0.72	533	0.36	267	0.71	526	0.62	459
	1.4	0.62	459	0.32	237	0.67	496	0.52	385
	1.5	0.49	363	0.49	363	0.51	378	0.59	437
B	1.1	0.41	304	0.35	259	0.48	356	0.41	304
	1.2	0.35	259	0.46	341	0.47	348	0.35	259
	1.3	0.36	267	0.52	385	0.65	482	0.36	267
	1.4	0.32	237	0.48	356	0.39	289	0.32	238
	1.5	0.49	363	0.49	363	0.59	438	0.49	363
C	1.1	0.40	297	0.56	415	0.64	475	0.40	296
	1.2	0.53	393	0.71	526	0.71	526	0.53	393
	1.3	0.71	526	0.49	363	0.49	363	0.31	230
	1.4	0.67	496	0.48	356	0.63	467	0.66	489
	1.5	0.51	378	0.65	482	0.48	356	0.51	378
D	1.1	0.41	304	0.61	452	0.58	429	0.41	304
	1.2	0.53	393	0.48	356	0.57	422	0.53	393
	1.3	0.72	533	0.49	363	0.36	267	0.29	215
	1.4	0.62	459	0.67	497	0.48	356	0.62	459
	1.5	0.49	363	0.63	467	0.63	467	0.49	363

Table 1 presents result of the suitable mix ratio of potato starch to rice husk for the production of rice husk ceiling board, it shows the weight and density. Twenty specimen with labels A(1.1-1.5) to D(1.1-1.5) were produced for the respective mix ratios. Research question two was to establish suitability of mix ratio of potato starch to rice husk for the production of rice husk ceiling board. Density of mix ratio I range from 237-533kg/m^3 as the highest, mix ratio II ranges from 237-526kg/m^3, while ratio IV has lowest density ranging from 215-489kg/m^3. This indicates that an increase in starch content augment density of the board. Therefore both mechanical test and

physical observation shows that mix ratio IV is the suitable mix ratio of potato starch to rice husk plus wood glue (gum Arabic) for the production of rice husk ceiling board. It is thus concluded that specimen B (1.3) of mix ratio IV stand suitable for ceiling board production from the result of both physical and mechanical tests.

Figure 1: Presents Result of the Deflection from Flexural Strength Test with Applied Load from 5N-10N.

Load (N)
Deflection (mm)

Figure 1 Load deflection curves for boards made with different mix ratios

The figure above show that the highest flexural strength value 0.31 N/mm^2 achieved on the board specimen with mix ratio I. Other values are 0.25 N/mm^2, 0.18 N/mm^2 and 0.14 N/mm^2 for specimen produced from mixes II, III and IV respectively. It was found that the specimen under mix ratio I failed on the application of more than 9N load, mix ratio II failed after the load applied was more than 8N, mix ratio III was at load more than 7N and mix ratio IV failed on the application of load more than 6N.

Research Question Two

What is the extent of fire resistance of the rice husk ceiling board?

Table 2: Results of Fire Resistance of the Rice Husk Ceiling Board Produced for Different Mixes I, II, III and IV

Mix Ratios	Specimen	Fire resistance (hr:min:sec) per distance intervals		
		5cm	**10cm**	**15cm**
Mix Ratio I	1.1	00:12:05	00:19:37	00:42:18
	1.2	00:06:04	00:16:23	00:41:10
	1.3	00:08:31	00:13:09	00:50:53
	1.4	00:12:44	00:28:49	00:52:58
	1.5	00:17:53	00:43:12	00:51:48
Mix Ratio II	1.1	00:11:09	00:19:59	00:50:45
	1.2	00:07:04	00:15:07	00:39:49
	1.3	00:07:57	00:14:42	00:37:57
	1.4	00:06:04	00:16:23	00:41:10
	1.5	00:08:31	00:13:09	00:39:53
Mix Ratio III	1.1	00:12:05	00:19:37	00:42:18
	1.2	00:11:24	00:16:23	00:41:10
	1.3	00:14:31	00:13:09	00:50:53
	1.4	00:11:43	00:28:49	00:52:58

	1.5	00:09:58	00:43:12	00:51:48
Mix Ratio IV	1.1	00:12:34	00:41:32	00:54:08
	1.2	00:14:31	00:28:58	00:59:52
	1.3	00:03:54	00:34:29	01:45:39
	1.4	00:05:31	00:21:59	00:48:59
	1.5	00:06:49	00:30:47	01:20:32

Table 2 presents the extent of fire resistance of the rice husk ceiling board for mix ratios, it shows the ignition time at distance intervals of 5cm, 10cm and 15cm. In this research question, the result shows that at distance 5cm, specimen 1.5 of mix ratio I (0.75:0.15:0.10 i.e 0.75 of rice husk, 0.15 of potato starch and 0.10 of gum arabic) had taken longer time to ignite the board. Mix ratio II indicated low fire resisting ability ranging from 6mins 4sec to 11mins 9sec time to ignite at distance 5cm. At 15cm distance away from the fire frame, mix ratio II also show least time to ignition hence regarded as mix ratio with the specimens has poor fire resistance. At distance 5cm mix ratio IV took about 6mins 49sec to 14mins 31sec to ignite which indicate better fire resistance compare to the other three mix ratios. At 10cm and 15cm distance away from the fire frame mix ratio IV also showed a better fire resistance with longer time to ignite.

This shows that the specimens can serve the purpose of ceiling board as they are not prone to close range fire frame. Result revealed that mix ratio IV with the corresponding specimens have taken longer time to ignite fire frame in all the three distance intervals which makes it a better fire resisting board. The variation in time taken to ignite may be caused by the amount of starch in the particular specimen, this is because rice husk alone does not ignite frame quickly due to its cuticle shells. This is unconnected to moisture content as the specimens were all dried in 6 days.

Research Question Three

What is the rate of moisture penetration of the rice husk ceiling board?

Figure 2: Presents Result of Percentage Water absorption Per Time of Immersion for the Four Mixes.

% water absorption
Mix ratios

Figure 2: Percentage water absorption verses mix ratios

The ASTM C 473 standard specification on time intervals for water immersion was employed. All the mix ratios with their respective specimen have bearable moisture absorption percentage but at altering degree of

absorption as shown in Figure 2. Based on the results shown, it is noted that the mixing proportion has significant effect on the average percentage water absorption. This indicates that more water is absorbed with increasing quantity of starch. Hence, there is a need for pretreatment of starch to be used in ceiling boards in order to reduce its affinity for water. Result shows that mix ratio IV has highest percentage of water absorption of 6.13% whereas mix ratio I indicate the lowest percentage of 3.88%. These results indicate that the more rice husk content the less absorption of water which translate to rate of moisture penetration.

FINDINGS OF THE STUDY

The following are the major findings of the study:

- Mix ratio IV (0.65:0.25:0.10 i.e 0.65 of rice husk, 0.25 of potato starch and 0.10 of gum Arabic) was found to be the suitable ratio for the production of rice husk ceiling board with flexural strength of deflection failure at load 10N. From the physical observation and mechanical tests mix ratio IV was stable.
- The fire resistance test reveals that rice husk ceiling board has good fire resisting ability with average of 48mins; 24 sec at distance 15cm which is within permissible range according to BS 476: Part 5 fire resistance test for the time taken to ignite boards.
- Result of water absorption test reveals that all the mix ratios with their respective specimen have bearable moisture absorption percentage but at altering degree of absorption according to ASTM C 473.

CONCLUSION

It is concluded that rice husk waste can be utilized in the manufacture of ceiling board. The use of potato starch, a biodegradable adhesive reduced the use of the more expensive synthetic adhesive based on petroleum resources. The test results showed that the rice husk, potato starch and gum Arabic combination provides results which have high potential to be used in the production of ceiling board. The observations from the physical tests conducted showed that the densities and the percentage absorptions of the immersed ceiling board increases with increasing time of immersion. Since the construction industry is a growing industry, the use of renewable resources such as rice husk can reduce the strain on forest resource and form excellent replacement for wood and wood based composite materials.

The ever increasing cost of building materials makes the search for cheap ones non optional. In Nigeria and many other developing countries, asbestos products are dominant in the building industry, with its health hazards. In this study efforts have been made to convert rice husk and potato starch into the production of ceiling boards. It

is therefore concluded that rice husk which is regarded as waste can be used for the production of ceiling board using appropriate technologies. This will provide local ceiling board and in turn eradicate over dependence on foreign building materials.

RECOMMENDATIONS

Based on the findings the following recommendations have been proffered:

- The mix ratio of 0.65:0.25:0.10 rice husk, potato starch and gum Arabic is adequate and suitable therefore should be uphold for the production rice husk ceiling boards.
- In case of fire, swift action should be taken within the resistivity time of 48minute to prevent the rice husk ceiling board from igniting.
- Rice husk ceiling board should strictly be used where moisture does not exceed the bearable percentage of 3.88% (see fig. 2).

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