Economy of RHA (Rice Husk Ash) in Concrete for Low-Cost Housing Delivery in Nigeria

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Abstract: Delivery of housing units in adequate quantity and quality has been the pursuits of individuals and successive governments in Nigeria. Still, the gap between demand and supply is becoming wider on daily basis due to exorbitant cost of building materials that is beyond the reach of average Nigerians. Concrete being the most acceptable construction material is expensive due to high cost of cement. Efforts made to reduce the cost of cement were to no avail, thus there is need to look elsewhere. Past researches showed that substituting cement with 15% of RHA (rice husk ash) in concrete improves the performance of concrete and reduces global warming as a result of emissions from cement production. This paper looks into the effect of using RHA as partial substitute of cement on the cost of a low-cost housing unit. Results showed that cement based construction materials are responsible for 82.58% of the total cost in which cement is responsible for 42%. When 15% RHA was used to substitute cement over N90,000 was saved, amounting to about 7% of the total cost of the building. In addition, depletion of natural resources was reduced.

Key words: Housing delivery, pozzolan, rice husk ash, global warming, low-cost housing.

1. Introduction

Acquiring a befitting housing unit at an affordable cost is the desire of every man, irrespective of his location and social status. Housing serves as shelter and haven against unfavorable weather conditions, protection from dangerous animals and affords us the opportunity of raising our family. To others, it serves as one of the best indicators of a person’s standard of living and his or her place in the society [1]. These features and others have made the demand for housing to skyrocket.

The limiting factors to owning a home includes some of the following: cost of land acquisition, construction cost, style, design, purpose and use. These however, have little or no effect on the desires of the elites, the rich and the well-to-do in the society on developing and owning property. In recent years, home ownership for the middle and low income earners of the society is turning into a mirage as building materials, construction costs and other factors have constantly put housing development at a very high cost.

In Ref. [2], Mabogunje assesses housing situation in Nigeria and put existing housing stock at 23 per 1,000 inhabitants and also put housing deficit at 15 million houses which will require N12 trillion to finance. Assessing this output shows that 43 persons will occupy a housing unit of two-bedroom flat which is about 21 persons per room.

The problem of qualitative housing has been a concern for both the government and individuals. Appreciating these problems, both public and private sector developers make effort through various activities to bridge the gap between housing supply and demand, but the cost of building materials, deficiency of housing finance arrangement, stringent loan conditions from mortgage banks, government policies amongst other problems have affected housing delivery significantly in Nigeria [3]. Other factors include lack of fund or misappropriation of available fund, bureaucracy on land acquisition, continuous rural-urban drift and geometrical increase in population.

Concrete is one of the most versatile construction
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materials because of its excellent resistance to water, fire, cyclic loading, ease of maintenance and its potential to be formed into various shapes and sizes. Cement, being the only manufactured constituent of concrete, is the most expensive component which makes concrete for housing construction unaffordable by average Nigerians. Seeking alternative cheap materials that have been considered as waste in partial substitute of cement in concrete will reduce cost and minimise environmental hazards associated with production of cement and also ensure sustainable environment which is the goal No. 7 of the MDGs (millennium development goals).

In this paper, effort is made to look into the state of housing as well as cement production and consumption in Nigeria. The effect of high cost of cement on the cost of building is viewed. An attempt has also been made to assess the utilization of agro-by-products as partial substitutes of cement and their advantages. Finally, a case study of a two-bedroom flat is used to substantiate the relative decrease in cost of building if RHA (rice husk ash) is used as pozzolan in concrete.

2. State of Housing Delivery in Nigeria

Adequate housing delivery in Nigeria is still an illusion despite efforts being made by successive governments to face out what could be considered as national embarrassment.

The National Rolling Plan of 1990-1992 estimated housing deficit at 4.8 million. The 1991 housing policy estimated that 700,000 housing units are to be built each year if housing deficit is to be cancelled. The documents indicated that not less than 60% of the new houses are to be built in urban centres. In 2006, the Ministry of Housing and Urban Development declared that the country needs about 10 million housing units before all Nigerians can be sheltered.

Between 1975 and 1980, there were plans to deliver 202,000 housing units to the public but only 28,500 units, representing 14.1% was achieved. Also, out of 200,000 housing units planned to be delivered between 1981 and 1985, only 47,200 (23.6%) was constructed. Under the NHF (National Housing Fund) programme initiated in 1994, to produce 121,000 housing units, it was believed that less than 5% was achieved [4, 5].

Of recent the Federal Government created a new Ministry of Lands, Housing and Urban Development with a view to tackling the housing deficit in Nigeria put at 54,500 housing units across the country [6]. What could have been responsible for these shortfalls?

One factor that is always being attributed to the failure of the past programmes and policies is lack of enough funds to finance them. This can be linked to high cost of construction materials in which cement takes a lion share.

3. Cement Consumption in Nigeria and Its Attendant Effect on Adequate Housing Delivery

In Nigeria, annual cement consumption was put at 19.5 million metric tons out of which 9.5 million tons are produced locally [7]. As a developing country with much construction work to do, our cement demand will even go beyond this projection in view of our ever growing population and desire for shelter and other infrastructure.

Presently, more than 60% of our local cement consumption is imported. This situation is a potential threat to our yearning for rapid infrastructural development and desire to meet the housing need of the nation estimated at 14 millions.

Despite the increase in Nigeria’s cement consumption which has increased from 8 million tons in 2001 to 11 million tons in 2006 and now 19.5 million tons, the per capital cement consumption in Nigeria is still low when compared to some other countries. For instance, South Africa’s cement consumption per capita is 280 kg which is about four times that of Nigeria’s 75 kg. China has 610 kg, Mauritius 600 kg, Saudi Arabia 900 kg and Angola 105 kg [8].

Even at that, cement prices in Nigeria remain among the highest in the world. The price of 50 kg (a bag) of
Cement has moved from N625 in 2002 to between N1530 and N1800 in 2010 depending on the location. The price of cement in the country is said to be four times the price in Egypt and South Africa and ten times the price in the United States. Such situations required interventions.

In order to bring down materials costs and stimulate construction, as well as make housing more affordable to the Nigerian population, the government should continue its reconsideration of restrictions on the importation of cement and other building materials. Another alternative we could explore in the long-run is to conduct more research on how we can use local materials such as clay and other local building materials [9].

4. RHA as Pozzolan in Concrete for Low Cost Housing and Environmental Sustainability

It is known that the incessant generation of solid waste materials represents a serious problem. For that reason, it is very important to study and develop any technology, procedure or method that may help to exploit them efficiently.

At present, pozzolanic materials are, in most cases, industrial by-products and solid wastes that can be used as active additions to portland cement. This is due to their capacity for reacting with CH (calcium hydroxide), produced during the hydration of the portland cement. It is well known that the hydrated compounds formed during the pozzolanic reaction improve the performance of new cements elaborated with them [10, 11].

The incorporating agricultural wastes, once calcined at high temperatures, as pozzolans of high activity, such as rice husk ash, have been studied with positive results in the manufacture of mixed cement. Other materials like sugar cane straw ash, rice husk ash, and silica fume were used as pozzolans [12, 13]. Ketkukah and Ndububa [14] establish that groundnut husk ash is a potential pozzolanic material. These ashes are characterized by their very low density and very high volume.

Similarly, for a variety of reasons, the concrete construction industry is not sustainable. Firstly, it consumes huge quantities of virgin materials which can remain for next generations. Secondly, the principal binder in concrete is portland cement, the production of which is a major contributor to greenhouse gas emissions that are implicated in global warming and climate change. From 1880 to 1996, the world’s annual consumption of portland cement rose from less than 2 million tons to 1.3 billion tons. Thirdly, many concrete structures suffer from lack of durability which may waste the natural resources.

In Nigeria, cement is expensive, whereas, United Nations Millennium Development Goal Number 1 is to “eradicate extreme poverty and hunger.” Since more than a billion people still live on less than US$1 a day, there is a need for low cost and locally available substitutes for portland cement. Therefore, if a community obtains materials locally, their labor can usually be considered as an in-kind cost to the project’s sponsors[15]. Hence, people can afford to build houses at relative low costs.

The use of RHA in concrete was patented in the year 1924. Up to 1978, all the researches were centered on utilizing ash derived from uncontrolled combustion. Later, it was discovered that the type of RHA which is suitable for pozzolanic activity is amorphous rather than crystalline. Results of researches conducted on RHA in concrete, as reported in Ref. [16], showed that RHA is responsible for:

- increased compressive and flexural strengths;
- reduced permeability;
- increased resistance to chemical attack;
- increased durability;
- reduced effects of ASR (alkali-silica reactivity);
- reduced shrinkage due to particle packing, making concrete denser;
- enhanced workability of concrete;
- reduced heat gain through the walls of buildings;
- reduced amount of super plasticizer;
• reduced potential for efflorescence due to reduced calcium hydroxide.

On what amount of RHA will be adequate to be used as partial replacement of cement to cause the potential asset, Habeeb and Fayyadhin [17] investigated the effects of concrete incorporating 20% RHA as partial replacement of cement at three different particle sizes. They found that the compressive strength of the resulting concrete was on the increase. The same percentage of 20% was recommended by Oyekan and Kamiyo for low cost housing development [18]. In the same vein, Oyetola and Abdullahi favored an optimum replacement level of 20%. In the works of Zhang and Mohan [19] and Mahmud et al. [20], 10% RHA and 15% of RHA optimum replacement were recommended, respectively.

5. Cost Assessment of a Two-Bedroom Flat Using RHA Concrete

BEME (Bill of Engineering Measurement and Estimates) of a 2-bedroom flat shown in Fig. 1 was carried out. The amount of concrete and sandcrete blocks required for complete construction of the housing unit was estimated.

![Plan view of a typical two-bedroom low cost housing unit.](image)

The quantity of cement to be used for the production of sandcrete blocks of mix ratio 1:6 and that of concrete and mortar of mixes 1:2:4 and 1:5 respectively were estimated. Then cost comparison analysis was carried out between pure concrete, mortar and sandcrete with their corresponding products where 15% of RHA were used.

Table 1 shows the quantity of materials and cost. 44.22 m$^3$ and 59.43 m$^3$ of concrete and mortar will be needed at costs of N1,017,060.00 and N385,522.41 respectively while 1990 sandcrete blocks will be needed at cost of N358,433.54. Thus, the building will cost a total sum of N2,059,515.00. The cost of which is beyond the reach of an average citizenry in Nigeria. This was acknowledged by the new minister of the newly created Ministry of Lands, Housing and Urban Development, Nduse Essien, who said that “the human development index shows that over 86% of Nigerians live on $2 or less per day. This translates to less than N10,000 a month. The implication of this is that over 86% of Nigerians can not afford a house valued at N1.5 million even if they invested 100% of their earnings over a period of 10 years. “Obviously, this is a very unlikely scenario as no one can save 100%
Table 1  Quantity of materials and cost implication for a 2-bedroom flat.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity</th>
<th>Cost (N)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>44.22 m³</td>
<td>1,017,060.00</td>
<td>49.38</td>
</tr>
<tr>
<td>Mortar</td>
<td>59.43 m³</td>
<td>385,522.41</td>
<td>18.71</td>
</tr>
<tr>
<td>Sandcrete blocks</td>
<td>1990 nos</td>
<td>298,500.00</td>
<td>14.49</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>358,433.54</td>
<td>17.72</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,059,515.95</td>
<td>100</td>
</tr>
</tbody>
</table>

It could be seen that concrete, mortar and sandcrete block are responsible for 82.58% (Fig. 2) of the total cost (N1,761,015.95). To produce these materials (concrete, mortar and sandcrete blocks), 524.3 bags of 50 kg cement will be needed which will cost N865,095 (about 50% of the cost of total cost of producing concrete, mortar and sandcrete blocks) as shown in Table 2. When comparing the cost of cement with the overall cost of the building, cement alone is responsible for 42% of the total cost.

Also in Table 2, when 15% of RHA is used as partial substitute of cement N129,764.27 will be saved. If 20% of the total cost saved is considered to be responsible for the production of RHA, then N90,834.99 (7% of cost of building) will be preserved. Monetarily, it may appear to be insignificant but considering its role in sustaining our environment it will be highly appreciated. Some associated environmental costs of cement production are Ref. [21]:

- After vehicle and utility emissions, cement manufacturing is the largest industrial producer of CO₂ and accounts for over 50% of all industrial CO₂
emissions;

- For every ton of cement produced, 1 t to 1.25 t of CO₂ are produced;
- Approximately 7,040 kg of raw materials is required to manufacture 4,400 kg of cement.

This shows that use of RHA as partial replacement of cement will reduce the consumption of cement and subsequently reduce associated environmental problems linked with the production of cement. In view of this, a two bedroom flat, which required 26.215 t of cement (Table 2) have potential to generate between 26.215 t and 32.769 t of CO₂ while 41.94 t of raw materials will be consumed. If this trend continues unchecked, then our desire to meet the MGD Goals No. 7 to “ensure environmental sustainability” will be a mirage. Other environmental problems such as non-renewable resource depletion, acid rainwater and contamination by sedimentation resulting from cement production could be limited if consumption of cement is reduced. Local cement production may also contribute to noise, vibrations and scenic ecological degradation. All these are reduced for every kilogram of cement substituted for by RHA.

Furthermore, the use of RHA provides other benefits of scientific, technical and economic nature such as the improvement in the mechanical performance and durability of cement, as well as the reduction of energy consumptions associated with the production of clinker [16].

6. Conclusions

The study investigated the effect of using RHA as partial replacement of cement on the cost of construction of a typical low-cost housing delivery. The following conclusions were made:

- Cement is responsible for the high cost of building as 42% of total cost of a two-bedroom flat housing unit is spent on cement;
- Partial replacement of cement by 15% RHA saves N70,000 of the cost of construction and thus, make housing relatively affordable;
- The use of RHA as partial substitute of cement in the production of cement-based products will improve their performance;
- The use of RHA as partial substitute for cement reduces cement consumption, hence, environmental problems associated with cement production are curtailed.

Reference

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