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Sustainable Building Materials Constituents, Preparation and Application -A Survey

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ABSTRACT

The significance of a healthy and thriving housing sector and housing stock of any country is in the availability of sustainable and cheap building materials on all fronts of building construction as well as creating new material systems that have minimal impact on the environment and ecosystem. The prevailing trend globally is to source less polluting materials locally and mostly recyclable at the end of life. However, this will grossly depend on the material constituents, preparations and application with issues of embodied energy through their production processes, transportation and use especially during the construction phase in pursuit of a thriving housing sector. Passive strategies of massing, orientation, operational energy and occupants' wellbeing have always been a key part of sustainable design. Buildings using less materials and those with less embodied carbon and material efficiency should be the panacea; however, converting policy to action starts with government perspective informed by that of the industry many sectors or by general public's needs and desires. This requires that government drive the legislation aligned with regulation, assessment procedures, incentives, funding initiatives and training programs with an industry that is aware. This paper will focus on a survey of sustainable building material constituents, their preparation and application as it pertains to a sustainable housing sector and material usage.

Keywords: Building Materials, Housing, Sustainability

INTRODUCTION

The importance of the availability of sustainable building materials in the housing sector is essential in invigorating material efficiency and economic growth and this fact cannot be understated. Economic development and housing development are intrinsically linked, with each influencing the other in various ways. Housing is essential for maintaining physical and mental health. Thus, the construction of qualitative housing by both government and individuals is a necessary condition for sustainable development and increasing the productivity of an economy. (Uwatt, 2019) Sustainable development requires housing, and achieving affordable housing requires the use of sustainable materials and this is especially important in Nigeria where there is a serious housing shortage. According to estimates from the Federal Ministry of Power, Works, and Housing (2017), there is a housing shortage of more than 17 million units, and it is growing as a result of rising urbanization and population increase. Innn Nigeria, traditional building practices for homes sometimes entail the use of non-economically and ecologically wasteful materials and construction processes. The result of this is the shift to sustainable housing development which becomes imperative in order to provide sufficient, reasonably priced, and ecologically friendly dwelling options and the materials to deploy for a sustainable future. Despite the established benefits of sustainable housing, various barriers prevent its broad implementation in Nigeria. One of the main obstacles is money because building sustainable housing usually requires more upfront investment than building conventionally (Adebayo, 2013). Material efficiency and sourcing of sustainable materials and Implementing sustainable housing practices becomes a vital route to explore. made more difficult by inadequate infrastructure, especially by unstable water and electricity supply systems (Oluwoye & Kheni, 2015). Furthermore, Nigerian regulatory frameworks are frequently inadequate or poorly implemented, which makes it difficult for sustainable housing solutions to be adopted (Agbola & Alabi, 2010). Effective promotion of sustainable housing is hampered by stakeholders' lack of knowledge and technical proficiency, which exacerbates these issues even more. The purpose of this article is to investigate the opportunities of exploring various already existing components of nature towards designing and creating new material systems that can be harnessed to address the prevalent housing deficit challenges in Nigeria whilst upholding the core principles of sustainability.

CORE CONSIDERATION FOR MATERIAL USE IN NIGERIA – SOUTH-SOUTH NIGERIA

a. **Material Durability**: Material must be durable, and withstand the harsh climatic conditions of south-south Nigeria's tropical rainforest zone.

b. **Availability**: Material must be readily available to prospective home owners as well as existing home owners

c. **Ease of Integration**: New materials must be such that they are easily integrated into the already existing built environment and technology of the day with little or no need for creation of new systems of application.

d. **Security**: Material quality must be such that it provides a level of security to the end users both from natural elements to all other elements foreseeable and otherwise.

e. **Affordability**: Materials must be accessible and affordable to the vast majority of Nigerians that are already wallowing way below the poverty line.

f. **Ease of Maintenance**: material must be easy to maintain, change and upgrade as the case may be.

g. **Sustainable**: One of the most important factors to consider whilst developing new material combinations for use in the built industry is the aspect of sustainability and must be adhered to strictly.

h. **Marketability and scalability**: Material production, integration and implementation must be such that its production processes can be scaled to accommodate demands and market forces.

3. Alternative Material Sources to Consider Core Construction Elements

A. Walls And Load Bearing Elements

1. **Adobe Bricks:** Adobe is Spanish for **mudbrick**. Adobe bricks are rectangular prisms small enough that they can quickly air dry individually without cracking. They can be subsequently assembled, with the application of adobe mud to bond the individual bricks into a structure. There is no standard size, with substantial variations over the years and in different regions. In some areas a popular size measured 8 by 4 by 12 inches (20 cm × 10 cm × 30 cm) weighing about 25 pounds (11 kg); in other contexts, the size is 10 by 4 by 14 inches (25 cm × 10 cm × 36 cm) weighing about 35 pounds (16 kg). The maximum sizes can reach up to 100 pounds (45 kg); above this weight it becomes difficult to move the pieces, and it is preferred to ram the mud in situ, resulting in a different typology known as rammed earth.

Table 1: Optimum Adobe Soil Mixture

Soil Textural Name	Percent Sand	Percent Clay	Percent Silt
Loamy sand	70 – 80	0 – 15	0 – 30
Sandy Loam	50 – 70	15 – 20	0 – 30
Sandy Clay Loam	50 – 70	20 – 3-	0 – 30

Source: Hohn., C. ABC.s of making Adobe Bricks, Cooperative tension service (Las Cruces, New Mexico: New Mexico State University, 1978)

Table 2: Average Dry Compressive Strength of the Adobe Bricks

	SAMPLE A	SAMPLE B	SAMPLE C
7-day strength (Sun-dried), MN m^{-2}	0.65	0.84	0.72
14-day strength (Sun-dried), MN m^{-2}	2.02	1.92	1.79
28-day strength (Sun-dried), MN m^{-2}	2.18	2.12	1.94
14-day strength (Oven-dried), MN m^{-2}	2.16	2.14	1.97

Source: Okunade (2007)

Figure 1: Adobe Brick

Figure 2: Rice Husk Ash

Figure 3: Coir

Figure 4: Coir Fibre

Constituent mixes:

a. Clay
b. Sandy soil
c. Coconut husk (coir)
d. Rice Husk Ash
e. Lime
f. water

Mix and Preparation

- Clay: 50-55%
- Sandy Soil: 20-30%
- Rice Husk Ash: 5-10%
- Coir: 5-10%
- Lime: 10-15%

The above mix ratio can thus be simplified as thus:

Clay (50%): Sandy Soil (20%): Rice Husk Ash (10%): Coir (10%): Lime (10%)

- **Clay and Sandy Soil**: The primary components, clay provides plasticity and binding properties, while sandy soil helps reduce shrinkage and cracking.
- **Rice Husk Ash**: Acts as a pozzolanic material, enhancing the strength and durability of the bricks.

- **Coir**: Adds tensile strength and helps in reducing brittleness.
- **Lime**: Improves the overall stability and water resistance of the bricks. For this purpose,
  hydrated lime (calcium hydroxide) is recommended.

  Sources of Lime in Nigeria:
  Cross River and Ebonyi States: Major deposits of limestone, which is processed into lime. Other States: Abia, Akwa Ibom, Anambra, Bauchi, Bayelsa, Benue, Borno, Edo, Enugu, Imo, Ogun, Ondo, and Sokoto.

  Climate Adaptation:
  Humidity and Rainfall: Ensure proper curing and drying of the bricks to prevent moisture absorption and degradation.
  Stabilization: Consider additional stabilizers like lime or cement if higher durability is needed, especially in areas prone to heavy rainfall

SMALL-SCALE PRODUCTION

Adobe bricks can be produced small scale, and implemented into building construction with little or no technical knowledge. The process can also be scaled to any degree, depending on the requirements. Resources and materials needed for production are naturally occurring and require little or no industrial refinement(s).

Figure 6: Mould fabrications and Samples of clay bricks

WALL FINISHES, CEILING

The finishing stages of any construction project takes up between 2-3 times the cost

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of construction. While all areas (plumbing, electrical services) may not be totally tweaked
towards achieving lower costs in terms of overall construction the façade as well as roof and ceiling finishes can be worked on towards achieving sustainable solutions.

Plantain / Banana Fibre Boards:
Mixed with other naturally occurring additives, plantain as well as banana husks present an ample array of opportunities to be used as an alternative wall / ceiling finish material in building construction. Plantain husks are always being discarded after the plantain fruits have been harvested. Utilising this biodegradable, yet abundantly occurring economic solution not only impacts positively on the various material outcomes but also on food production and security as the demand for Plantain fibre from husk will generate higher yields in plantain production for agricultural purposes which presents a win in both food security and housing security.

Figure 7: Plantain/Banana Fibre Extraction Process

Table 3: Mechanical Properties of Treated and Untreated Plantain Fibre

NaOH Solution (w/w) (%)	Young's Modulus (GPa)	Tensile Strength (MPa)	Strain (%)
0	26.98	2084.04	9.85
2	52.86	5398.54	10.02
4	23.68	1071.56	4.64
6	10.02	327.447	4.86

Source: (Adeniyi, Onifade, Ighalo, Abdulkareem, & Amosa, 2020)

EXTRACTION AND PREPARATION OF PLANTAIN FIBRES
Extracting fibers from plantain stems involves several steps to separate the useful fibers from the rest of the plant material. Here is a detailed overview of the process:

a. **Harvesting and Preparation**
Selection: Choose mature plantain stems, as they contain more robust fibers.
Cutting: Cut the stems into manageable lengths, typically around 1-2 meters.

b. **Retting**
Definition: Retting is the process of decomposing the pectin that binds the fibers to the woody core and surrounding tissues.

2. **Methods**:
a. Water Retting: Submerge the stems in water for several weeks. This allows microbial action to break down the pectin.
b. Dew Retting: Spread the stems on the ground and let dew and natural moisture aid in the decomposition process. This method takes longer but is more environmentally
friendly.

c. **Extraction**
Manual Extraction: After retting, manually strip the fibers from the stems. This involves scraping and pulling the fibers away from the woody core.
Mechanical Extraction: Use machines designed to crush and separate the fibers from the core. This method is faster and more efficient.

d. **Washing and Drying**
Washing: Thoroughly wash the extracted fibers to remove any remaining pectin, dirt, and other impurities.
Drying: Spread the fibers out to dry in the sun or use drying equipment to ensure they are completely dry before further processing.

e. **Processing**
Combing and Carding: These processes align the fibers and remove any short or damaged fibers, resulting in a more uniform and usable product.
Spinning: The fibers can then be spun into yarn or thread for use in textiles and other applications.

f. **Applications**
Construction: Used as reinforcement in composite materials for eco-friendly building materials.
Crafts: Utilized in making baskets, mats, and other handicrafts, ceiling mats and tiles.

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g. **Environmental Benefits**

Sustainability: Using plantain fibers reduces waste and provides a renewable resource for various industries.

h. **Biodegradability**: The fibers are biodegradable, making them an environmentally friendly alternative to synthetic materials.

Figure 8: Banana ceiling tiles

ROOF FINISHES AND COVERING

Roofing:

Adobe Roof tiles- Adobe roof tiles are a sustainable and traditional roofing material made from natural ingredients. Here's a breakdown of their constituents, mix, and production process:

Constituents

c. Clay: The primary component, providing plasticity and strength.

d. Sand: Helps to prevent cracking by reducing shrinkage.

e. Water: Used to mix the ingredients and form the tiles.

f. Straw or Natural Fibers: Adds tensile strength and helps bind the mixture together.

Mix

The typical mix ratio for adobe tiles is:

- Clay: 60-70%
- Sand: 30-40%
- Straw or Natural Fibers: 5-10% (by volume)

Production Process

g. Preparation: Gather and sift the clay and sand to remove impurities.

h. Mixing: Combine clay, sand, and straw with water to form a homogeneous mixture. This can be done manually or with mechanical mixers.

i. Molding: Shape the mixture into tiles using molds. Traditional methods involve wooden molds, but modern techniques may use metal molds for uniformity.

j. Drying: Allow the molded tiles to dry in the sun for several days. This step is crucial to ensure the tiles harden properly.
k. Firing (Optional): In some cases, the dried tiles are fired in a kiln to increase their durability and weather resistance.

Benefits

- Sustainability: Made from natural, locally sourced materials.
- **Energy Efficiency**: Provides excellent thermal insulation.
- Aesthetic Appeal: Offers a rustic and traditional look.

Adobe roof tiles are not only environmentally friendly but also contribute to the thermal comfort of buildings, making them a great choice for sustainable architecture.

Figure 9: Circular and normal pitch roof tiles

Recycled Plastic Roof Tiles: Recycled plastic roof tiles are an innovative and sustainable alternative to traditional roofing materials. Here's an overview of their constituents, mix, and production process:

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Figure 10: Recycled Plastic Roofing sheets

Constituents

l. **Waste Plastic**: Typically, high-density polyethylene (HDPE), polypropylene (PP), or a mix of various plastics.

m. **Sand**: Provides bulk and strength to the tiles.

n. **Fly Ash**: Sometimes added to improve the mechanical properties.

o. **Color Pigments**: Optional, for aesthetic purposes.

Mix

A common mix ratio for recycled plastic roof tiles is:

- **Plastic**: 60-70%
- **Sand**: 30-40%
- **Fly Ash**: Up to 10% (if used)

Production Process

p. **Collection and Sorting**: Waste plastics are collected and sorted by type.

q. **Shredding**: The sorted plastics are shredded into small pieces.

r. **Melting**: The shredded plastic is melted at high temperatures.

s. **Mixing**: The molten plastic is mixed with sand (and fly ash, if used) to form a homogeneous mixture.

t. **Molding**: The mixture is poured into molds to shape the tiles. This can be done using a hot press process.

u. **Cooling**: The molded tiles are cooled to harden and set.

v. **Finishing**: Any excess material is trimmed, and the tiles are inspected for quality.

Benefits

- **Durability**: High resistance to weathering and impact.
- **Waterproof**: Excellent water resistance, making them ideal for roofing.
- **Lightweight**: Easier to handle and install compared to traditional materials.
- **Eco-Friendly**: Utilizes waste plastic, reducing landfill waste and environmental impact.

CONCLUSION

The transition to sustainable housing development is essential to address Nigeria's housing deficit while promoting economic growth, social inclusion, and environmental conservation. Locally sourced materials such as adobe bricks, plantain fibre and recycled plastic tiles provide viable solutions. These materials align with Nigeria's climate, resource availability, and economic realities, ensuring the development of affordable, eco friendly and scalable housing solutions.

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