COCONUT SHELL FLOORING FOR AFFORDABLE HOUSING IN KENYA

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ABSTRACT

This study is based on the potential use of coconut shell waste for providing flooring solutions for the Affordable Housing Programme in Kenya. Research has shown that the husk takes eight years to decompose organically, which leads to poor disposal methods. Additionally, previous research shows that most uses of coconut shell waste are limited to product and jewellery design. Advancement in technology has proven that coconut shell waste can be used for creation of flooring, roofing and wall tiles. The problem of this study arises from poor disposal of coconut shells and the state of the housing crisis in Kenya. It was recognized that the government of Kenya had initiated The Affordable Housing Program in order to provide cost-friendly housing solutions for the low-income families in Kenya. One of the objectives of the program was to employ the use of local materials to promote the artisans in Kenya. The study was guided by the following key research question: How can coconut shell waste be used to produce interior flooring solutions that support affordable housing in Kenya? By prevalently applying qualitative research, the author used purposive and snowballing sampling methods to collect relevant research information. The study was predominantly based in Nairobi, however, there was initial reconnaissance involved in other coastal counties in Kenya such as Mombasa, Watamu and Kilifi. The subjects of this study were thirty, which included suppliers of construction materials, coconut-based furniture experts and professional interior designers based in Kenya. The main data collection tools involved were the use of Google Form questionnaires and in-depth interviews. The results of this study proved that despite being an excellent material, it was difficult to establish a key link with the AHP due to inaccessibility and unavailability of the tile. Nonetheless, it was established that the tile could still play a key role if further experimentation and production could be conducted for purposes of prototyping and mass commercialization.

Keywords: coconut shell, flooring, affordable housing

INTRODUCTION

The coconut tree, an ancient presence predating humans, holds significant importance along coastlines. Its traditional uses encompass cooking oil, charcoal, and more. Modern technology reveals additional applications, notably in interior and exterior design (Agriculture Authority (2021). Recent trends highlight the coconut shell's potential for sustainable solutions in construction, including flooring, roofing, and tiling, demonstrated by global research and practical applications ((Ahuja, Siddharth, and Uma, 2014).. Diverse techniques yield eco-friendly products such as flooring, wall panels, furniture, and jewelry. Research pioneers hail from the Philippines, India, Netherlands, and Amsterdam, with implementation in various countries (Mike Foale (2003). While Africa lacks substantial evidence, its climate and coconut waste suggest promise for similar endeavors. This study draws from primary and secondary sources, spanning from 1999 onwards and encompassing international contexts before focusing on Kenya. Its goal is to develop eco-conscious design solutions, while addressing the improper disposal of coconut shells in Kenya, and to contribute to Kenya's Affordable Housing Programme by offering sustainable, affordable materials for low-income families.

Problem Statement

The problem arises from poor disposal of coconut shells and the state of the housing crisis in Kenya. According to research, a coconut shell takes around 8 years to decompose - under natural conditions. The conventional and easy but dangerous solution is therefore to burn the waste or to dispose off it carelessly to a landfill. These disposal systems contribute to air and land pollution. Another major issue to tackle is that of shortage of affordable housing. Kenya is racing in creating affordable housing solutions for low-income families, whilst simultaneously trying to support local artisans by employing their skills for the AHP and creating job opportunities. These Kenya is doing through its new bottom up development approach.

Objectives

Main objective: To explore how coconut shell waste can be used to produce interior solutions that support affordable housing in Kenya

Specific objectives:

i. To establish the amount of coconut waste available in Kenya
ii. To assess the uses of coconut waste
iii. To investigate the products and processes that can be created from coconut waste
iv. To propose a framework for coconut shells application as interior flooring solutions for affordable housing in Kenya

THEORY

Though coconuts were indigenous to the Indian Ocean, they were introduced to Kenya around the 16th Century by the Portuguese. C oconut palm tree agriculture spread promptly and it soon become a trading crop. It held very high economic significance in Kenya up to the 20th century. The Arabs handled its agriculture and trading until the 19th Century, whereby small-scale farmers started getting involved as well. Many households in the coastal region in Kenya are either directly or indirectly connected with coconut farming. They not only use it for cooking, but also for the other functional uses (Finyange P. et al., 2019).

Quantity of Coconuts in Kenya

The following section will outline statistics on coconut farming and production as of 2021. The data is collected from a memorandum on the coconut industry development bill, by the Cabinet Secretary, Ministry of Agriculture, Livestock, Fisheries and Cooperatives.

According to the data collected by the Ministry of Agriculture in 2021, 6 coastal counties are the major producers of coconuts. These are Kilifi, Kwale, Lamu, Mombasa, Taita Taveta and the Tana River. The study also points out that there is possible opportunity for growth in other parts of Kenya such as Meru, Machakos, Busia, Siaya and Homa Bay due to similar climatic conditions suitable for coconut palm growth.

Kenya has over 10 million trees which are in fruit bearing stage. These trees are able to produce around 250 million mature coconuts or more (Agriculture and Food Authority Kenya, 2021).

The production of coconuts in Kenya in 2018 was about 92,560 tons – valued at 4.7 billion Kenya shillings - from

approximately 200,000 acres. In the following year, the amount leaped to approximately 110,000 tons over an area of 86,843 acres. This amount of coconut holds value of approximately 6.8 billion Kenya shillings (FAO, 2020).

Of the approximate 10 million coconut trees, an estimated 1.3 million are under 10 years of age, 6.5 million are at a fruit bearing age and 2.6 million are senile. Senile trees are those that are over 60 years of age and bear very low output (Ministry of Agriculture, 2021).

The area, quantity and value of coconut trees in Kenya as of 2021 are as follows:

Table 2.1: Coconut tree statistics in Kenya (2021)

Source: AFA Nuts and Oil Crops Directorate, 2021

The graph below also shows the production value of the coconut fruit from the year 2007-2019. The expeditious nature of the graph is owing to recent farmer sensitization programs that helped improve the coconut farming sector. Some aspects that were considered during the program are replanting quality seedlings to replace the senile ones, and farmer empowerment to embrace good agricultural practices (Ministry of Agriculture, 2021).

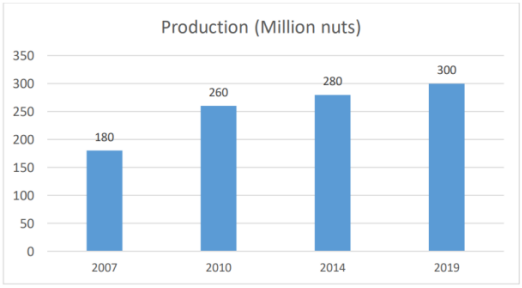

Table 2.2: Coconut tree production in Kenya from 2007-2019

Source: Ministry of Agriculture, 2021

A highly crucial factor to note is that the Ministry of Agriculture reports that only 53% of the potential of coconut has been utilized. This denies the country of agro-revenue which can be achieved by comprehending the high economic value of the coconut tree. The ministry additionally emphasizes on the importance of promoting the production of coconut-based products by employing sustainable research and technologies (Ministry of Agriculture, 2021). Consequently, this is one of the factors that indicate a gap for research which would potentially aid the government of Kenya to implement the AHP.

Quantity of Coconut waste in Kenya

According to Wekesa & Majale (2020), Mombasa produces around 2200 tons of waste daily. Of this, only 65% is collected and 35% is uncollected. However, in lesser affluent areas in the county, only 13% of the households are provided with a waste collection system. The amount of waste in Mombasa County annually therefore adds up to around 280,000 tons or more.

Additionally, a large portion of coconut waste in found in coastal areas. It is approximated that 20% of all the waste in Mombasa is from coconut shell waste. Therefore, Mombasa County on its own produces around 56,000 tons of coconut shell waste.

This proves that there is a substantial amount of pollution in the fourth largest coconut-tree producer in Kenya that occurs as a result of poor disposal of coconut shells. It also indicates that there may be more waste in other counties that produce more coconuts as compared to Mombasa.

COUNTY	AREA (Ha)		Quantity(MT)		Value (Ksh.) Millions	
	2019	2020	2019	2020	2019	2020
Kilifi	41,432	41,470	52,853	52,913	2,219.8	2,384.0
Kwale	31,358	31,384	46,227	46,240	2,126.4	2,139.0
Lamu	10,713	10,722	6,771	6,792	304.7	322.0
Mombasa	156	158	2,344	2,361	103.1	122.0
Taita Taveta	99	102	873	858	37.5	36.1
Tana River	1,066	1,070	822	849	37.0	35.3
Total	**84,824**	**84,906**	**109,889**	**110,013**	**4,828.5**	**5,038**

Physical characteristics of the Coconut Shell

In order to understand the reasons as to why the coconut shell holds more uses than those currently known, it is imperative to grasp the physical properties of the material. Recognizing the properties of the material would therefore give an insight into the further uses and functions of the material, as well as the reason as to why local and international artisans and designers employ it in their vocations. Ting et. al (2015) states that the physical characteristics of coconut shell as a material are low density, good thermal properties, toughness and durability,

biodegradability, precise strength and precise modulus. Additionally, it is a low-cost material that possesses good weather resistance. Somashekhar et. al (2018) affirm that coconut shell does not cause damage to the machines employed for production of coconut-based products. This means that the material possesses reduced tool wear (Ting et. al, 2018). Aside from that, the material burns three times slower than wood (Brenya, 2018). Coconut shell is eco-friendly and a sustainable material that is anti-fungal and possesses high strength to weight ratio (Nazir & Maina, 2022). These characteristics indicate that the material possesses outstanding qualities for purposes of value addition in design.

Flooring and Tiling

Over the course of several decades, there has been an ongoing initiative to develop coconut shell tiles. Malang (1999) highlighted Adriano S. Alfonso's study on using coconut shell tiles for flooring solutions. Alfonso's research demonstrated that the durable and stony nature of the shell makes it an excellent choice for flooring, offering both durability and ethnic accents. Despite winning 3rd prize in a utility model contest, the study didn't progress to execution.

A more recent study by Sujatha and Balakrishnan (2020) compared coconut shell flooring tiles with sawdust flooring tiles. These materials were used as aggregates in concrete. The coconut shell tiles exhibited satisfactory results in terms of flatness, perpendicularity, straightness, water absorption, and transverse strength, outperforming conventional tiles. The study encouraged the use of coconut shell for construction flooring.

Chathurangani et. al (2012) explored creating wall surface materials and tiles from coconut coir extracted from coconut shells. The process involved mixing latex, acetic acid, water, and coir fiber in a mold, followed by drying and hardening. The study concluded that these tiles effectively reduced noise to a certain extent.

Pilar et. al (2015) focused on producing tiles using two waste materials: coconut coir and UPVC waste. This approach aimed to address construction material shortages and solid waste management issues. The resulting wood tiles displayed satisfactory properties, being durable and environmentally friendly,

with improved physical and mechanical properties compared to regular tiles.

Din and Abdullah's (2014) research demonstrated the potential of using coconut shell aggregates in concrete to create roof tiles. These tiles were lightweight yet able to withstand heavy loads, stress, and forces, offering a cost-effective and environmentally friendly roofing option.

Additionally, Haran et. al (n.d.) found that coconut fiber roof tiles exhibited better water absorption rates than standard roof tiles.

From an interior perspective, coconut shell can be fashioned into tiling solutions by crafting small cuts of coconut shells that are joined to create larger tiles. These tiles improve indoor air quality due to improved circulation within the tiles.

Figure 2.1: Coconut tiles, Source: ResearchGate, 2021

Housing

Bah et. al (2018) state that Africa's population growth is projected to grow from 1.18 billion in 2015 to 2.44 billion in 2050. Rural-urban migration is at an all-time high with people moving to urban areas that are not fully developed. Additionally, inadequate planning leads to pressure on infrastructure and resources which subsequently leads to housing deficits. Most rural migrators therefore settle in slums.

Housing solutions will tremendously contribute to economic activity and employment opportunities. The construction sector in any part in the world plays a key role in providing job opportunities and growth of a national economy. Some developing countries majorly affected by the housing crisis are Congo, Egypt, Nigeria, Mozambique, South Africa, Tanzania and Kenya amongst others (Bah et. al, 2018).

Affordable Housing in Kenya

The Affordable Housing Program (AHP) in Kenya was one of the big four agenda that was proposed to provide housing to low-income families in Kenya. The program aimed to create half a million

houses by 2022. Findings by Kieti et. al (2020) showed that the program created opportunities for artisans in the informal sector. The same study also indicated that the government should take initiative for standardized mass production for the purposes of faster affordable housing.

Affordable housing is not only a difficult concept for developing countries such as Kenya – but it is also an idea that has not been adapted by developed countries. One of the major factors to consider is the fact that construction is highly costly – especially with imported materials. It is unaffordable for individuals with low-income to build homes. However, shelter is one of the basic human rights of any global citizen. Housing is an essential tool to nurture families in order to provide a healthy, safe and protective environment (Kieti et. al, 2020).

MATERIAL PROCESS

The process of creating coconut shell floor tiles, summarized from various scholarly articles (Ogunleye et al., 2019; Díaz-Díaz et al., 2017; Lee and Wang, 2018; Amusan et al., 2021), involves several steps for clarity and comprehension. Key machinery required, along with their prices in Kenya, is highlighted. The process includes:

1. Sourcing and Cleaning: Obtain coconut shell waste, sort out strong shells, wash, and sun-dry for about 4 days. Warmer environments are preferable for drying.
2. Breaking Down the Shell: Depending on the desired by-product, either a biomass shredder machine can grind shells with coir into a powdery product, or a Coconut Husk Chipper machine can create rough cuts for aggregates.
3. Mixing Coconut Shell and Binder: Mix the broken-down shell or aggregates with a suitable medium like concrete, latex, acetic acid, water, UPV plastics, or other binders based on the finish needed. A concrete mixer is essential.
4. Pouring into Moulds: Pour the mixture into molds and allow drying for a few days. Different sizes and methods yield varying textures or appearances.
5. Finishing: Sand, polish, or seal the tiles with water-resistant

coatings before installation, considering specific usage areas.

The initial investment for tile creation ranges from KES 700,000 to KES 1,000,000 (USD 5,058 to USD 7,225), with potential for significant profit after prototyping and commercialization.

Illustrated Process

The following is the process represented visually:

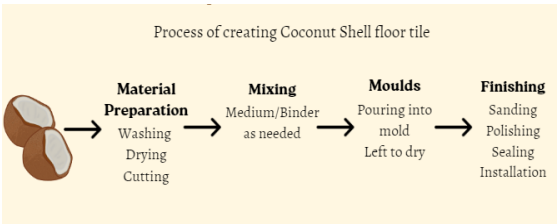

Figure 2.1: Process , Source: Author, 2023

METHODOLOGY

This study employed the use of qualitative research design. The main method that used was descriptive research design. The population consisted of 30 subjects that were found as a result purposive and snowballing methods. The scope of this study was Nairobi and two Coastal counties. The target population was manufacturers with high potential of producing coconut-based interior products and professional interior designers. The data collection tools were interviews, questionnaires/surveys, photography, observation and immersion. The data analysis tools are narrative, interpretive and content analysis. Data will be presented textually, photographically and in form of graphics. The population consisted of 30 participants including manufacturers of coconut-based products and interior design experts in Nairobi and Coast. The study was conducted in Nairobi and Coastal Kenya. The target population was manufacturers with high potential of producing coconut-based interior products and professional interior designers.

RESULTS AND DISCUSSION

Analysis of response

The researcher approached thirty (30) respondents, of which a total of twenty-six 26 individuals or organizations responded. This represents eighty-seven percent (87%) of the intended population. The study is therefore said to have been successful. The set consisted of fifteen (15) professional designers who responded to questionnaires via Google Survey and eleven (11) furniture and/or finishing makers in Kenya who were interviewed personally.

The researcher found that a hundred percent (100%) of the respondents were familiar with sustainable design. This was inquired in relation to materials used for design purposes. It was found that 22 of the respondents representing eighty-three percent of the group (83%) believed that Kenya has plenty of coconut shells, whereas 4 of the respondents representing seventeen percent (17%) of respondents disagreed that there may not be enough. Most of the respondents, amounting to sixty-seven percent (67%), were aware of products made of coconut shell. On the other hand, thirty-three percent (33%) had not heard of, or encountered any. The respondents were asked whether they have ever heard of, or considered using coconut shell for interior solutions. Thirteen of the respondents amounting to half of the group (50%) voted 'No', nine of the respondents representing thirty-three percent (33%) voted 'Maybe' and 4 respondents representing seventeen percent (17%) voted 'Yes.' All the respondents were asked if they would consider using coconut shell to solve design issues by simultaneously creating organic and effective design solutions. Twenty-two of the respondents amounting to eighty-five percent (85%) voted 'Yes' whereas four of the respondents representing fifteen percent (15%) of the

population voted 'Maybe'. All respondents were asked if they would use coconut shell in design for purposes of flooring. Twenty-one of the respondents representing eighty-two percent (82%) voted 'Yes' and the rest of the five respondents representing eighteen percent (18%) voted 'Maybe.' It should be noted that none of the respondents voted 'No.' All respondents were asked if coconut shell flooring would assist to solve the housing crisis by providing a sustainable flooring solution for the AHP. The researcher explained the positive aspects of using the materials such as affordability, availability, aesthetic nature and slow burning amongst others. Majority of the respondents, who were twenty-two in number, strongly believed that it could help to create a sustainable solution for the AHP. This amounted to eighty-five percent of (85%) of the group. Four of the respondents amounting to fifteen percent (15%) voted 'Maybe'.

Discussion

The research objectives and questions guided the discussion, addressing various aspects related to coconut waste availability, current uses of coconut waste, sustainable design with coconut shells, and flooring solutions for affordable housing projects in Kenya.

Amount of Coconut Waste in Kenya

The study confirms the availability of sufficient coconut shell waste in Kenya for potential applications. Data shows a significant amount of waste, including over 110,000 metric tonnes in Kenya as of 2021, with even more in specific areas like Mombasa. Respondents also indicated that there is ample waste for research and implementation.

Uses of Coconut Waste

Coconut shell waste in Kenya is predominantly used for decorative items, jewelry, bags, and other similar products. Respondents were familiar with these uses, but there's limited awareness of using coconut shells for interior applications, particularly flooring.

Coconut Shell for Sustainable Design

While other countries have explored using coconut shells for sustainable design solutions, Kenya lacks innovative research in this area. Despite having abundant coconut waste, Kenya lags behind in utilizing it for sustainable solutions, even compared to countries with less coconut availability.

Flooring Solutions for Affordable Housing Projects (AHP) in Kenya

Affordable housing is a critical issue in Kenya, and coconut shell tiles are proposed as a potential solution. The study highlights that such tiles have proven to be durable, lightweight, eco-friendly, and cost-effective. Industry experts express interest in using these tiles, indicating their potential suitability for the AHP.

Recommendations

- The author suggests various recommendations based on the study's findings:
- Encourage research and innovation in using coconut shells as a material in Kenya.
- Allocate a portion of the AHP budget for new material research.
- Engage organizations like KIRDI, universities, and the Ministry of Agriculture in researching the material.
- Encourage product designers and artisans to contribute to the production of coconut shell tiles.
- Highlight the versatility of coconut shell tiles for various housing solutions.

Conclusion

While the study's focus was on the AHP, the researcher concludes that there's currently limited market presence for coconut shell tiles, making them a risky recommendation for the AHP. However, the study's findings still hold value for other housing solutions, especially in coastal regions where coconut waste is abundant.

Areas for Further Research

The study identifies gaps for further research, especially towards experimental development and production of coconut shell tiles. The researcher suggests that more research and innovation should be undertaken to test the tiles' use in different spaces and conditions.

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