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Assessment of Pathologies and Remedial Strategies to Enhance the Durability of Plant-Based Roofing Materials in Benin

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Abstract **Original Research Article**

Plant-based materials, including thatch, palm leaves, and bamboo, remain a key resource for building roofing in Benin. They are distinguished by their low carbon footprint, local availability, and low cost. However, their adoption is hampered by challenges related to sustainability, fire risk and competition from modern materials, and insufficient regulation.

This article proposes an integrated approach including a classification of materials, therapies for their sustainability, and regulatory recommendations for their use.

Keywords: Vernacular Architecture, Architectural Sovereignty, Local Materials, Sustainable Construction, Plant-Based Materials

INTRODUCTION

In a global context marked by growing concerns for sustainable development and the resilience of infrastructures in the face of climate change, plant-based roofing materials are positioned as an ecological and economical alternative. In this logic, Rabah (2013, p. 29) states that "the greening of roofs or building facades has gradually become a solution for connecting the city to nature".

These materials, mainly derived from local resources such as thatch, palm leaves, and bamboo, are widely used in rural and peri-urban areas of many developing countries, particularly in Benin where many citizens still use palm leaf or thatch roofs. These materials play a central role in vernacular architecture, offering interesting thermal performances adapted to tropical climates while maintaining a low carbon footprint compared to industrialized materials (Ravindranath & Ostwald, 2020). Their low cost, availability, and reduced ecological footprint make them attractive for environmentally friendly constructions (ED Ouest, 2023). However, their adoption remains limited by several challenges, including their perception as “precarious” and “traditional” materials (Batirama, 2023), as well as their low durability in the absence of suitable treatments (Florie, Philippe, & Joffroy (Dir), 2021). This social perception of the value of these materials, often associated with poverty and social marginalization, hinders their adoption (Asare et al., 2021).

The plant materials used in Benin have several pathologies, such as biological degradation due to termites and mold, low mechanical resistance, and a high flammability risk, making their life cycle particularly short without appropriate interventions. At the same time, the emergence of modern materials, largely imported, exerts competitive pressure on local materials. By embracing a dynamic of promoting local materials, this article addresses the challenges of their use from several angles and strengthens their competitiveness while responding to the challenges of climate resilience and improving the living conditions of populations.

1. Material and Method

The general objective of this article is to propose sustainable solutions for the use of plant covering materials in buildings in Benin, by responding to technical, socio-economic, and environmental challenges. More specifically, the objectives are:

- Identify the plant materials commonly used for the covering of buildings in Benin
- Analyze the main pathologies affecting these materials
- Propose technical treatments to improve the durability of the materials.
- Formulate recommendations for the establishment of regulations to promote the use of local materials in construction in Benin

To achieve these objectives, the following hypotheses were put forward:

- Plant materials have specific characteristics that influence their performance as roofing materials for buildings
- The main pathologies affecting these materials are linked to local climatic conditions, biological attacks, and the absence of suitable treatments
- The durability of this type of material depends on the choice of technical treatment and the policy of maintenance and upkeep of roofs

To test these hypotheses, the methodology adopted consisted of conducting a documentary review to understand the various key concepts of the study. It then consisted of carrying out fieldwork through a campaign of direct and/or participant observation of the constructions and a series of semi-directive interviews conducted with 69 residents (craftsmen, builders, owners). The purpose of these contacts is to assess the perception of plant materials, identify usage constraints, and identify regulatory expectations.

The resulting synthesis allowed for continued analyses according to the different centers of interest selected in the methodology.

For the sake of readability, three distinct climatic zones were chosen for the surveys on roofing materials:

- the coastal zone for palm leaves (oil and raffia) and coconut,
- Savannah zone (Natitingou, Djougou) and the lower Ouémé valley for thatch,
- The Wetlands of southern Benin for bamboo.

For the identification of pathologies, visual analysis was adopted.

2. Results and discussions

2.1. Classification of local roofing materials

Several types of materials were identified during these investigations. Thatch as illustrated in photo No. 01 comes from dried plants and is a traditional roofing material used in several regions of Benin.

Photo No. 01: Residential house in the black river valley in Adjarra

The availability of this material and its characteristics vary depending on the geographical areas. Photo No. 02 is a thatched building in Ségbana in the far north-east of the country.

Photo N°02: Traditional habitat in Ségbana in the far north of Benin

To distinguish the thatches, Table N°01 highlights the main characteristics as well as the destination.

Table I: Typology and use of thatch in Benin

Materials	Characteristics	Origin Dominant use	Origin Dominant use
Grass thatch	Grasses offering long, flexible stems ideal for weaving and hedging	savannah areas in the north and center of Benin	Traditional dwellings
Thatch of palm trees	Leaves of different types of palms (palm palm and oil palm) are dried and tied into bundles for better coverage	coastal and humid areas (Cotonou, Ouidah, Abomey-Calavi, and regions close to the Ouémé valley)	Houses, kiosks, temporary constructions
Reed thatch	Reed is a quality roofing material, prized for its flexibility and relative resistance to humidity	wet and marshy areas, particularly around lakes and river valleys (Ganvié, Porto-Novo, and around Lake Nokoué)	Lake constructions
Sorghum stubble and other agricultural residues	Materials are often considered secondary due to their low mechanical strength and limited durability	northern agricultural areas	Temporary structures

Reading Table I reveals a diversity of thatch material, its geographical distribution, and a plurality of uses in roofing.

The analysis of the frames reveals the adoption of several types of wood in particular bamboo which offers flexibility and appreciable mechanical strength. Other types of local wood such as teak, iroko, mahogany, and raffia stems serve as a roofing structure.

In photo No. 03, the use of these materials allowed the roofing of a building used as a restaurant in Zè north of Cotonou.

Photo No. 03: Roofing of a building used as a restaurant in Zè

2.2. Associated risks and pathologies

The use of plant materials for roofing buildings has many advantages but is also subject to various pathologies and risks that limit their durability and large-scale adoption.

2.2.1. Biological and climatic degradation

Due to their organic composition and prolonged exposure to bad weather, plant roofing materials undergo degradation such as termite attacks, mold, and prolonged exposure to humidity.

Biological degradation is mainly due to attacks by microorganisms, insects, and other living organisms that feed on or colonize plant materials. Indeed, in the absence of preventive or periodic treatments, high humidity in coastal and humid areas promotes the growth of mold and fungi, the attacks of which reduce the aesthetics of roofs. (Nkunika, 2002: 46) notes that termites consume plant fibers, thereby causing irreversible structural damage. Of greater intensity in savannah and tropical forest regions (where high temperatures and humidity promote their proliferation), wood-eating insects also participate in the degradation of these materials. In the same vein, the degradation of plant cellular components by bacteria accelerates the loss of fiber cohesion and the formation of cracks in the materials (Schmidt and Liese, 2015). Added to this is the degradation by climatic factors that compromise their integrity and functionality. Thus, heavy rains cause materials to become saturated with water, leading to swelling and a reduction in their mechanical stability, while prolonged exposure to humidity promotes biological attacks (Fellenius and Holmberg, 2019: 115). Photo No. 04 is representative of the degradation by this factor.

Photo No. 04: Destruction of the roof of the exhibition hall of the tourist site of the Dogbo tailed men by bad weather

2.2.2. Fire risk

The vulnerability of plant roofing materials to fires represents a major constraint to their sustainable adoption. These materials, made of organic fibers, are inherently flammable. In the Beninese context where domestic and environmental fires are frequent, especially in the dry season, it is therefore crucial to develop effective strategies such as fire retardant treatments to prevent them and limit or, failing that, minimize the risks.

2.3. Therapies for sustainability

Faced with the many challenges identified, innovation opens the way to the sustainability of plant roofs. Three avenues are available for this reflection: preventive treatments, material innovation, and a design and maintenance policy adapted to endogenous realities.

2.3.1. Preventive treatments

The treatments envisaged may be natural or chemical in light of the failures observed. In the first case, the application of vegetable oils, such as neem oil, can protect against insects and fungi. This age-old practice is widespread across the country. However, its adoption is limited by the use of imported chemical solutions based on borax or other fungicides that are more accessible and help prevent biological infestations.

2.3.2. Design and maintenance

The main criticism of vegetable materials is their vulnerability to rainfall hazards. Therefore, an appropriate design is a guarantee of durability. Thus, to facilitate the flow of water and avoid stagnation, it is essential to adopt a sufficient slope.

Furthermore, a regular inspection will help detect and repair early damage to the roof by maintaining a sufficient layer to ensure waterproofing. Similarly, the development of new materials by combining plant fibers and natural binders is a serious avenue to consider for improving the strength and durability of materials while preserving vernacular architecture.

Concerning fire safety, the integration of fire safety standards in constructions made of plant materials is a challenge to be met. This standardization could involve the application of fire retardant products on roofing materials but also the requirement of a minimum distance between plant buildings and high-fire-risk areas.

2.3.3. Towards regulation of green roof constructions

The construction of plant roofs is an empirical activity based on endogenous techniques. Therefore, the lack of standards does not allow these building elements to be certified. A standardization test therefore requires the integration of technical aspects but also institutional measures.

On the technical level, the mandatory prescription of fire retardant and fungicide products is an avenue to be used in fire risk prevention. The integration of plant materials into design software will lead to an increase in aesthetic potential. The deployment of research and development projects could promote the production of panels based on agricultural residues that are likely to compete with imported materials. The establishment of training programs in the construction and maintenance of plant structures is an open boulevard in the transmission of traditional techniques to both designers and workers. The labeling of practices could also certify the sustainability and safety of local materials.

At the institutional level, the updating of the regulations on the establishment of a minimum quota of local materials in public or private constructions will encourage their use. Similarly, the imposition of annual inspections by qualified craftsmen will make it possible to anticipate degradation.

CONCLUSION

The use of plant roofing materials in Benin offers significant potential for ecological, sustainable, and affordable constructions. However, their large-scale adoption requires clear regulations prescribing the mandatory integration of local materials in construction, investments in research, and increased awareness. Furthermore, the adoption of fire protection measures through the combination of preventive and curative strategies, and the implementation of a materials maintenance policy can guarantee their sustainability. Finally, to address the challenges related to their perception and competition with imported materials, an integrated approach based on innovation, education, and political support is essential.

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