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Potentials of Hempcrete in Building Technology in Nigeria: A Concise Review

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Abstract**:** *In Nigeria, traditional construction materials are discovered in large amounts and combinations with their economic benefits relative to their geographical regions. In the industrialized phase of sustainable construction, energy use is a crucial and important environmental factor in the manufacturing of building materials, requiring the use of readily available building materials with low carbon emissions that are usually recyclable. The increase in house infrastructure costs has remained a major concern for the Nigerian government because of the over-dependency on the application of building materials that are imported. Therefore, the high time to take a cursory look at hempcrete as sustainable natural building resources with the option of creating new opportunities for housing cost reduction for their thermal properties, economic advantages, and benefits of reduced energy costs. Conclusively, the approach with this traditional building material in the contemporary building techniques were highlighted with respect to how it can be practically integrated into the Nigerian construction sector.*

Keywords: Hempcrete, construction materials, renewable, sustainable and Nigeria**.**

1.0 INTRODUCTION

The construction industry is one of the main sectors with intensive energy consumption and significant environmental emissions [1]. At an unparalleled pace in history, the greenhouse gases in the atmosphere are driving the earth's climate change through direct emissions of the gases contributing tremendously to global warming [2].Thirty-two percent of global energy consumption and nineteen percent of greenhouse gas emissions are attributable to the building and construction sectors [3]. Therefore, the development and use of environmentally stable construction resources are becoming more relevant. In other words, the use of sustainable resources with the reduction of greenhouse gas emissions has been a global priority in recent years. Environmental impacts such as climate change and global warming influence the values of architecture and construction of buildings. Energy conservation and the ideals of the green building increase the market for environmentally sustainable building methods [4]. On a global priority scale, climate change impact migration efforts have centered on mitigating climate change under the Paris Agreement with Kyoto Protocol [5]. Environmental issues about natural resource preservation and biodiversity have been an important catalyst for researchers to investigate the composite materials that are environmentally sustainable, low environmental impact, long-term social advantages, and profitabilities [6]. Construction with sustainable material lowers the manufacturing expenses, enables policy planning, and safeguards our environment because of their low environmental consequences and renewable energy, environment-friendly building materials and methods met expectations. The thermal, hygrometric, and acoustic properties, qualify plant-based biomaterials to be commonly used in building [7]. Similarly, plant-based resources can be adopted as an aggregate in non - load-bearing concrete mix due to their stable thermal and insulation properties, building facades control, the building, energy consumption, comfort, hydrothermal behavior, and quality of indoor air [8]. The hygroscopic activity depends on the materials' thermal conductivity, thermal power, absorption curve, and vapor permeability. It was established that hygroscopic resources can be used in low-energy structures [9]. Different attempts have engaged to evaluate novel energy-saving materials integrating optimal structural efficiency and properties of thermal insulation [10]. The bio composite material, a mixture of hemp hurds, lime, sand, or pozzolans, is specifically a form hempcrete or hemp-lime that is used as a material for insulation and building [11]. Hempcrete is simpler than conventional lime combinations to deal with as an insulator and regulator of moisture. It lacks the fragility of concrete and therefore does not require expanding joints [12]. As it blends insulation and thermal mass, the result is a lightweight insulating material suitable for most climates. Around 5,000 tons of hemp fiber is currently used annually for building purposes in France, the nation that began to build insulating construction materials from cannabis in the early 1990s, after other European nations with growth on global attention in the last fifteen years [13]. Hemp-based construction materials vary from flexible wool (100 percent hemp), thermo-welded insulating panels (85 percent hemp fiber or 80 percent hemp hurdles) and non-woven felts for acoustic leveling (100 percent hemp fiber) to drywall and ceiling particle boards (up to 100 percent hemp), slab pellets (pressed dust, decorated by hemp fiber product) and hem fiber decortication varnish foundation [13]. Hemp insulation panels substitute insulation materials such as glass and rock wool that display the same or very similar thermal

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conductivity with non-renewable resources and energy-consuming potential [13].

2.0 METHODOLOGY

2.1 Traditional and sustainable building methods in Nigeria

In rural communities across Nigeria, the majority of buildings are still built with traditional materials and techniques. In the meantime, modern building development techniques have been increasingly used in recent years, propelled by a variety of factors including demands for accelerated construction, building security, and a lack of expertise. Examples of traditional building materials include natural building materials, such as stone, wood, straw, sheep's wool, fibers, hemp, cork, and clay. But there has been an upsurge of interest for natural and unconventional building materials in the last 15 years [14]. One of the most important human necessities is shelter, which is a fundamental component of environmental sustainability. In general, sustainability is divided into the economic, environmental, and social fields as the three elements of sustainable development [15]. Sustainability is defined as an economy that meets the needs of the present generation without compromising the opportunities and potential of future generations. Sustainable development impacts short and long-term economic targets in the building environment. Through a simplified construction process, low shipping costs, lower economic demands, and conventional building materials minimize the cost of the overall construction. The occupants need to control the building design (current and future), which will provide an extremely flexible strategy that enables the building to be immediately re-purposed as the layout alters the requirements [14]. A building that can be used for a very long period illustrates a dynamic design that prevents the detrimental effects of destroying an existing building and re-constructing [20]. The building's environmental protection is approached by an improvement in the effective use of resources, so the construction should be designed in a manner that requires natural resources for both heating and other energy-requiring operations. This as well includes the installation of measures that conserve water, control waste, and use renewable local construction materials. The design and orientation of a structure will render it more environmentally sustainable as the main advantages of the use of traditional construction materials in modern strategies. According to the three pillars of sustainable growth, the following economic sustainability involving the construction of buildings with innovative construction techniques with conventional materials have fewer impacts with rapid construction [14]. There is a higher level of design efficiency as the construction process can be stimulated by mass manufacturing of prefabricated parts on-site or at the factories.

Table 1. Applications and properties of natural materials.

Function	**Example**	Reference
Structural materials	Stone, clay bricks, wood, rammed earth, straw bales, coconut lumber	**[21],[24], [26],[28]**
Insulation materials	Hempcrete, sheep wool, rice hull	**[22]**
Complementary materials	clay	**[27]**
Fire resistance material	Sodium carbonate, sheep wool, bamboo	**[23],[25]**

Table 2.Thermal properties and applications of the selected organic building material [24]

Bio material	**Density (kg/m3)**	**Thermal conductivity [W/(mK)]**	**Application**
Hempcrete	90 - 180	0.440 – 0.063	Fiber, roof and floor composites insulations
Straw	90 - 180	0.044 – 0.063	Roofing and load balancing construction
Sheep's wool	15 - 25	0.056 – 0.030	Infilling, roofing, flooring, wall and wood framing protection
Bamboo	90 - 180	0.044 – 0.065	Load support and roofing protection with wooden framed construction
Clay	1000 - 2200	0.200 – 0.950	Construction plastering

2.2Construction properties of Hempcrete

In the mid-1980s in France, the concept of modern hemp-based concrete was first developed. The composite was originally designed as a maintenance product with an absorbent paving material with old straw reinforced structures. The idea developed into material for hemp-lime insulation, hempcrete. Hempcrete, unlike concrete, is not a load-bearing material, to withstand pressure, it needs an additional framework [16]. There are three main components in hempcrete: hemp hurds, which is a woodchip from the stem of a hemp plant (Cannabis Sativa), a binder, and water hemp composites. Adhesion between the hemp hurds is produced by water mixed with the binder. The components in the hempcrete (cannabis Sativa) hemp plant are grown all over the world. It is a traditional plant, grown because of its seeds and fibers. Hemp plant parts are used for food, textiles, paper, building materials, and many more. [16] According to Magniont, roughly 32% of fibers, 42% of shives, 18% of powder and pitch, and 8% of seeds form a hemp plant and all parts of the plant can be used [16]. Hemp stem, which is a key ingredient in hempcrete, is also a by-product of a fiber or seed-grown hemp plant. The production of hemp is not competitive, either economically or ecologically, for hemp hurds alone [16]. It can be very helpful to grow the hemp plant, as an annual plant produces and yields reasonably quickly and has different soil-improving characteristics. There is very little care needed for the plant, and it does neither chemical fertilizers nor pesticides are needed. Due to its rapid growth, the plant is excellent at crop rotation [16]. In hemp composite materials, different binders can be used as an adhesive. Portland cement and lime, more precisely, hydrated lime [$Ca(OH)_2$], are some common binders. The binder is usually a combination of lime or cement mortar with chemicals including fly ash or metakaolin such as gypsum. Various binding formulations are being used to obtain various material properties, such as mechanical and thermal properties [16]. Portland cement and hydrated lime are produced at high temperatures by burning limestone (calcium carbonate, $CaOH_3$). The clinker is oxidized with limestone around 1200 to 1280 degrees Celsius for Portland cement [16]. At 900 to 1100^{O}C [16], hydrated lime is burned. Carbon dioxide (CO_2) and calcium oxide (CaO), also known as quick lime, result from $CaCO_3$ burning. With water (H_2O), quick lime is absorbed, resulting in the binder for hempcrete as hydrated lime ($Ca(OH)_2$). Compared to the production of Portland cement, the production process of hydrated lime releases more carbon dioxide. The emission rate, however, is beneficial for the lime binder. In a hempcrete wall, the calcium binder begins to carbonate, indicating that the lime reabsorbs carbon dioxide from the environment in a chemical reaction, converting back to calcium carbonate ($CaCO_3$). Throughout a period of one hundred years, up to 60% of carbon dioxide is reabsorbed by lime [16].

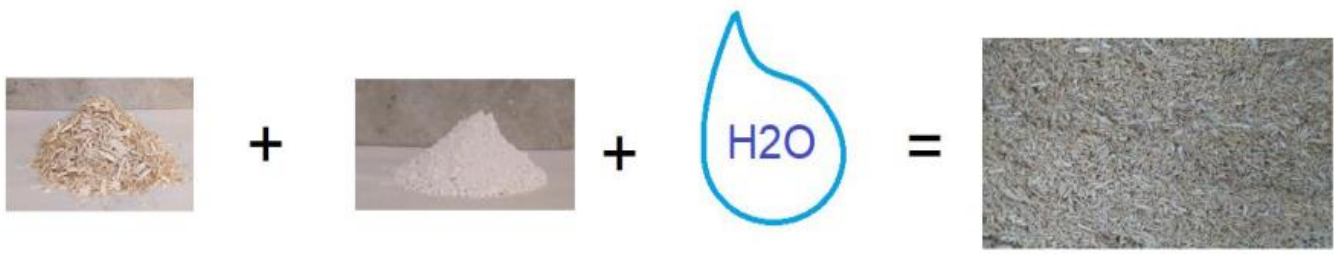

Figure 1. Hempcrete formation

2.3 Environmental impacts

Hempcrete should be used as a building material with low negative effects [17]. The hemp concrete wall life cycle assessment effect of density and insulation research, conducted at the European University of Brittany, investigated the environmental consequences of hemp concrete slabs. The research demonstrates how large the spectrum of hempcrete emission sources is. Transportation is an important factor, but the binder and its related emissions are the main contributors to total emissions [18]. The width of the hempcrete is therefore relative to the carbon dioxide bonded to the hempcrete [18]. The estimated wall's life span was set at one hundred years and the hempcrete was disposed of at the end of its life cycle. For landfilling applications, almost no emissions are generated [18].

2.4 Technical features

Hempcrete, like any building material, has to satisfy national requirements that vary by country. Paragraph 117 of the Finnish Ministry of the Environment Land Use and Building Act specifies the criteria that construction must comply with that a building must comply with the necessary criteria of concrete strength, stability, fire protection, sanitation, health and environment, protection in use, noise reduction, energy economy, and insulation, as defined by the intended use of the structure[19].

Table 3. Technical features of Hempcrete [20].

Property	**Value**
Density	275 kg/m^3
Heat Capacity	1500-1700 J/Kg
Fire Rating	1 hr. BS EN 1365-1:1999
Flexural strength	0.3- 0.4 N/mm^2

Air Permeability	0.75 $g/m^2/mmHg$
Vapour Diffusion Resistance	4.84
Airtightness	<2 m^3/m^2.hr at 50Pa
Carbon capture	130 $kgCO_2/m^3$
Thermal conductivity	0.06 W/mK
Mean Acoustic Absorption Coefficient	0.69 NRC

Table 4. Physicochemical Properties of hemp [21]

Physical property	**Remark**
Colour	Yellowish grey to deep brown
Length	4 to 6.5 feet
Tensile strength	Strong fiber
Elongation at break	Easily stress
Elastic Recovery	Very poor
Moisture Regain	12%
Effect on Heat	Excellent resistance to heat degradation
Effect on Sunlight	Resistant
Luster	Bright
Chemical property	
Acidic Effect	Disintegrated when attacked by hot dilute acids or cold concentrated acid
Effect of Alkali	Resistant
Effect on Organic solvent	No reaction
Effect on Micro organism	Attacked by fungi and bacteria

Hempcrete does not seem to work very well when comparing the technical values (Table 1) with the values of some traditional insulation materials. Hempcrete, however, offers some useful features that improve its efficiency beyond the stated values. The product has the added benefit of a clean and healthy environment. Hemp and lime encourage a safe and healthy environment because of their organic, and hygroscopic nature [22]. The framework of a hempcrete building regulates the relative humidity and temperature of the indoor air as a hygroscopic product. The humidity is moved to a region with lower relative humidity by a higher humidity level. Hempcrete with higher heat inertia, implying that the material slowly heats up and slowly gives out the thermal energy as well. The wall balances the thermal conditions of the ambient air when the thickness of a hempcrete layer is constructed properly. It stores heat energy during the day and dissipates the stored heat to the indoor air at night time [16]. The high thermal inertia of the material decreases the need for heating by 5 to 10% [16]. As many other widely used thermal insulation materials have, the thermal conductivity factor of hempcrete is very low as the absolute thermal transmission is more significant for a building's thermal efficiency. Hempcrete houses may be built without cold bridges, which are a significant contributor to the lack of heat in buildings. Therefore, the overall value of a hempcrete construction with the prescribed thickness can be very competitive with the houses that have the insulation materials that are widely adopted [16].

2.5 Structural Applications of hempcrete

Typically for manually compressed concrete, cast walls, painted protective coatings, external and internal plasters, prefabricated blocks, and panels for non-load-bearing or load-bearing applications, floor slabs, slabs, and roof insulation, including structural applications [13]. The densities of this concrete begin at 200-250 kg /m^3, while the wall mixture typically ranges from 400-500 kg / m^3 for non-load bearing applications [13]. Whereas the use of hemp remains unchanged, higher densities of 600 kg-1000 kg are

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attained with higher binder content, among other technologies [13]. In plasters, exterior renders, and load-bearing installations, these concrete and mortars are used. In load-bearing conditions, non-calcined binders, such as clay-based ones, are suitable for economic and environmental reasons. Hemp aggregate is primarily known as the construction of hemp-lime, an excellent idea in addition to the fact that lime porosity does not inhibit the ability of hemp to absorb, move and alter the process of water in liquid and vapor states [13]. Also, it assists in controlling the surrounding temperature through osmotic pressure. Though aerial lime carbonates as hardening develop slowly and are climate-sensitive, hydraulic lime, as well as blends of aerial lime and pozzolanic mixes, are optimal alternatives that speed up the hardening stages of a hemp aggregate with important composites or wall thicknesses without losing the diffusion rates of water vapor relative to the lime composite. Although higher than in hydraulic limes and with only a very limited quantity of carbon dioxide released during this process, the hydraulic hardening process is reabsorbed [13]. Conversely, with unfavorable drying conditions, the addition of small quantities of natural cement to aerial lime may be useful as natural cement is a product similar to hydraulic lime, but it hardens rapidly due to the composition of its raw material and gains considerable mechanical strength in a short period of time. Compared to hydraulic lime, the use of pure cement does not substantially improve the mechanical strength as it causes major setting problems in a hemp concrete matrix and may not compete with other positive material properties of lime and other natural binders such as clay [13].

Figure 2. Hemp hurds with 5% fibers

Figure 3. Natural and tinted hempcrete specimen

3.0 CONCLUSIONS

A large proportion of greenhouse gas emissions globally are caused by the building industries. The incentive for the construction industry to reduce its emissions is considerable. Following climate agreements, countries have developed guidelines targeted at decreasing the use of energy in buildings. Basically, the trend of energy demand legislation is moving to the phase where, in the future, either exceptionally low-energy structures will be new. Most of the latest vulnerable buildings have had complications with the consistency of ambient air. Difficulties including the inappropriate levels of humidity, contaminants from indoor air, and elevated levels of CO_2 with temperature. A hydrothermal and organic insulator like hempcrete may provide a section of the response to the challenges of indoor air quality. Although Concrete has a distinct advantage against hempcrete with the use in load-bearing buildings, hempcrete with the advantages in its capacity to resist mold, and moisture, which are the problems encountered by many residents while staying in older structures, and can induce severe respiratory health complications. However, both concrete and hempcrete are fire retardants, sustain heat energy, and serve as effective resources for sound-proofing. In addition to having a positive effect on the atmosphere, global warming, and climate change, hempcrete also offers warmth in houses as its outstanding hygrometric performance contributes simultaneously to indoor air quality and a comfortable indoor microclimate. Hempcrete demonstrates low thermal conductivity, density, strength, high absorption, and buffer potential for moisture. By acquiring more practical experience, the increased interest of researchers makes hempcrete more useful. Hempcrete offers a building structure that could be used for wall, roof, and floor use. As the water absorption cannot be standardized in the manufacturing of hempcrete, the proportions of the mixture should be measured correctly according to the region of application in order to prevent unpredictable effects. Guidelines to facilitate hempcrete usage in buildings should be developed as contractors should be facilitated. The cannabis plant, which has many industrial applications, is leading to the manufacture of new drugs and new advances in technology. Hemp is an acceptable plant for cultivation in conditions other than severe desert climates around high mountain areas. However, warm-weather areas with well-drained soil rich in organic matter are the best growing environments for hemp. Hemp agriculture can, therefore, be extended in order to promote hempcrete use in the construction of the building while legislation is produced with encouragements. Hemp-related research is expected to increase in the coming years with the production of novel and innovative products.

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