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Strawbale as a Sustainable Building Construction Material

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Abstract: **Strawbale is generated from dried stalk of wheat, rice, rye or oats straw put together in bales and used for construction or gardening. The construction method is referred to as Strawbale construction or Brown construction. Strawbale can be used as a material for building insulation, structural building element or both. It is a sustainable material as it is being sourced for from agricultural grain waste. This research is aimed at exploring the thermal characteristics, cost efficiency, weight and growth rate of strawbale as a sustainable building construction material. The research was based on literature review and observation of existing buildings made from strawbale as both structural material and building insulation. It was found that strawbale construction can be one of the best alternative building construction technique because it is a renewable resource having high thermal performance, lightweight, cost effectiveness, health value and fire retarding ability. The research found out that strawbale construction can be applied to all kinds of construction if care is taken during placement of the bales. It requires relatively less technical know-how and funding. It also provides a sustainable alternative for which to put grain stalk waste to as against burning which introduces carbon dioxide into the atmosphere. It was found that the cost efficiency of strawbale falls at 48% and its lightweight properties falls at 68% compared to adobe block. The research concludes that strawbale is indeed among the best alternative sustainable building construction material and its construction can be explored and applied in Nigeria as we have the available natural resource in abundance.**

***Key Words*— eco-friendly, renewable resource, strawbale construction, sustainable material, sustainability**

1. INTRODUCTION

Strawbale construction is a type of Natural building Construction technique which incorporates sustainable design practices so as to create a building not too far off from the environment in which it is built in (Dancing Rabbit Ecovillage, 2016). Natural buildings in most cases rely upon naturally-occurring, minimally processed and locally available and renewable materials which are recyclable and salvageable (Dancing Rabbit Ecovillage, 2016). Strawbale construction goes back to dates when homes were built using naturally sourced out materials (Marks, 2005). It is a system of construction that uses bales of straw most commonly rice, hemp, barley, wheat, rye and oats (King, 1996) as building insulation structural elements or both. The best type of straw used for strawbale construction is rice straw because it has high silica content which increases its resistance to decay (Zhang, Ghaly, & Li, 2012). That is why it is difficult for it to decompose because all organic materials require oxygen and water. It is a genuinely inactive material with a comparative substance makeup as wood. It is very hard to make it disintegrate. Straw is made of cellulose, hemicelluloses, lignin and silica (Myhrman & MacDonald, 1997).

These materials are sustainable and also provide high levels of insulation in both hot and cold climatic areas (Peckenham, 2016). Straw bales, usually of rectangular shapes are used to form walls as they are arranged and tied in place using pins made from wood or metal (Green Cross Australia, 2017). There are two types of straw-bales; two-stringer and three-stringer, commonly used for construction which are defined by the number of strings they are tied with (Jones, 2002).

There are three main ways of using straw bales for construction. Non-load bearing walls also known as in-fill method- this method includes posts and beams constructed of timber, bamboo or steel to form the structural frame work and finally the strawbale is used to in-fill the frame work. The weight of the roof is being carried by the bamboo and timber beams. It requires more materials other than bales for its construction and also takes more time and technical know-how to construct.

Load bearing walls also referred to as Nebraska-style- In this type of construction method, the bales are placed together and pinned to the foundation and to each other with coppiced hazel. This method is faster, requires less skill, minimal use of other materials such as timber and bamboo. The bales themselves take the load of the roof, however, it limits the amount of levels at which one can go.

Hybrid- This type of construction is a combination of frameworks and load-bearing elements. This makes use of mainly timber or bamboo framework which are light-weight materials and cannot stand alone so it has to be supported using a crow props for stability.

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Other types of straw construction methods include straw-clay building and pressed straw panels; this involves mixing blended clay water with free straw to form a flapjack paste or compressed at a uniform density of 100 kg/m3 which is a constant pressure force (Ecococon, 2017)

II. NATURAL BUILDING

As described earlier, Natural building is a means of working with nature to provide healthy living, work and play places by means of using materials not far from their original state (School of Natural Building, 2016) in order to achieve sustainability as it puts in to use, human labour much more than technology (Kennedy, Smith, & Wanek, 2002). The materials most common to Natural buildings are clay, wood, straw and earth which can be made into earth bags or rammed earth. Other materials include salvaged chunks of used concrete called urbanite and recycled glass (Kennedy, Smith, & Wanek, 2002).
Natural building materials have properties such as vapour permeability, low embodied energy, non-toxic, easily accessible, naturally occurring and can be beautiful and in the long run, durable (Dancing Rabbit Ecovillage, 2016).

SUSTAINABLE BUILDING CONSTRUCTION MATERIALS

Sustainability is defined as is a means of creating balance, suppleness and an interaction which allows human beings to cater for their present needs within the environment without putting a strain on the ability of the ecosystem towards restoring those needs nor degrading or harming the ecosystem (Morelli, 2011). Over the years, there exist a numerous amount of sustainable building materials (Robinson, 2016). These includes; bamboo, adobe, cob, baled straw, straw-clay, hemp and other fibres, earth bags and wood. They are used in different parts of the building construction from foundation up to finishing. Strawbale goes back to dates when homes were built using naturally sourced out materials. These materials are sustainable and also provide high levels of insulation in both hot and cold climate areas (Peckenham, 2016). It is among the most favoured building materials due to being highly renewable (Robinson, 2016).

STUDY AREA

AUSTRALIA is the smallest continent in the world which has an area of 7,682,300 km2 and a population size if 22,681, 261 citizens. The capital is Canberra and lies on a latitude of 27.00 degrees South and 133.00 degree East (Maps of the World. Current, 2017). Australia has largest areas mainly reserved for agricultural processes. Most of the rainfalls along the coast. The daytime maximum temperature hardly drops below 30 degrees Celsius while night temperature ranges between 15-20 degrees Celsius. Australia lies in the tropics and so mostly warm. The rainfall maximum is less than 600mm a year. Between 1896 and 1945, an estimated 70 strawbale buildings including houses, churches and grocery shops were built in the Sand hills (Marks, 2005). Typically field bales which are those created on farms and baled using machines which were used supported 900kg per linear meter of wall. However, rice straw compressed blocks have been developed to support up to 6000 kg per linear meter of wall (Magwood & Mark, 2000).

TAMIL NADU, INDIA

Tamil Nadu is one of the twenty-nine states of India, located in the southern part of the Indian peninsula. Its capital, Chennai is the largest city bordered by Punducherry, Kerala, Karnataka and Andhra. On the North, it is bordered by Eastern Ghats and Nilgiri, Anamalai Hills, Kerala on the west. To the east is the Bay of Bengal and the south east is the Gulf of Mannar and Palk Strait on the southeast. It has a population density of 550km2 (1,400/sq mi) over a land area of 130,060km2 (50,220 sq mi). The coordinates are 11.1271 degrees North and 78.6569 degrees East (Maps of the World. Current, 2017). Tamil Nadu is an agricultural state historically covering 21% of the state's economy, it is the leading producer of rye and corn and the eight largest producers of rice (Maps of India, 2017) which the straw is processed into bales and used for building construction (Auroville, 2017).
Tamil Nadu is home to Auroville, an experimental township founded in 1968 by Mirra Alfassa and designed by Architect Roger Anger. As at 2014, it had a population of 2400 people from different parts of the world (Auroville, 2017). The main purpose for the creation of this town is to practically research sustainable co-existence and the future cultural, social and spiritual and environmental needs of mankind (Soliman, 1993).

III. MATERIALS AND METHODS

The research method adopted for the study was purposive sampling method using critical case sample approach based on the fact that the study areas make use of strawbale for construction. The study area considered were Western Australia and Auroville in the Tamil Nadu State of India.
A general survey of the properties of rice straw, advantages and disadvantages of the use of strawbale for construction was carried out majorly based on literature review. The variable studied include thermal characteristics of straw, cost of construction, weight, fire retardancy, and relative time for regrowth. The discussion of the results are presented in

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subheadings that best describe the issue that was examined which is in line with the aim of the study.

IV. RESULTS AND DISCUSSION.

THERMAL CHARACTERISTICS OF STRAW.

Thermal characteristics of straw according to Scientist Jim Hanford of Lawrence Berkley Laboratory (LBL) on table 1 is the shown below. It was found that Straw-bale building construction technology gives the best energy performance with 15 percent improvements in overall building energy-efficiency in heating compared to other new building techniques such as adobe (Energy, 2003)

Table 1; showing strawbale properties such as R-Value, U-Value, weight and heat capacity.

Wall type STRAW BALE	R-Value (hr-sqft-F/Btu)	U-Value (Btu/hr-sqr-F)	Weight (llb/sqft)	Heat capacity (Btu/sqft/ sqft-F)
23" bale @ R-1.8/inch (-25%)	42.7	0.023		
23" bale @ R-2.4/inch	56.5	0.018	21.4	6.4
23" bale @ R-3.0/inch (+25%)	70.3	0.014		

Table 2; showing Adobe block properties such as R-Value, U-Value, weight and heat capacity.

Wall type ADOBE BLOCK	R-Value (hr-sqft-F/Btu)	U-Value (Btu/hr-sqr-F)	Weight (llb/sqft)	Heat capacity (Btu/sqft/ sqft-F)
Uninsulated 10''	3.5	0.0284	95.0	17.9
Insulated 10''	11.9	0.084	95.3	18.0
Uninsulated 24''	6.8	0.147	183.4	34.2
Exterior insulated 24''	15.1	0.066	183.6	34.3

It can be seen from the above two tables, that the R-value of strawbale is greater than that on adobe block put under the same conditions and same time frame (one hour).

COST EFFICIENCY

Using a plan with dimensions 5m x 3m x 3m, an approximate 500 units of straw bale blocks of dimension 150 x 200 x 400 mm is used for the construction (excluding foundation cost), the total estimate cost of production of the straw blocks is 40,000 which covers the cost of straw, sand, lime water solution and labor cost for the production.

The cost of production of a unit of straw block = N40,000 /500 = N80.00

For a 150 mm (6 inches) sandcrete block estimate, approximately 490 units will be required.

Unit cost of the sandcrete block = N160

The cost of 490 units of the block = N160 x 490 = N78,400

Cost saving with the use of straw block = N78,400 – N40, 000 = N38,400

The percentage saving in the cost of block production = (38400/ 78400) x 100 = **48.98%**

This is almost half of the price of a normal block

WEIGHT

Approximate weight of a 6 inch block of one meter square is 197kg while that of a straw of the same size if 75kg

1m2 of block = 197kg

1m2 of straw = 75kg

The weight difference between the two blocks is

197-75= 122/197 x 100 = **61.92%**

From the above calculations, it is evident that weight of the strawbale is far less than that of concrete blocks which by more than 50%

TIME OF REGROWTH

Rice crop is harvested when 80% of the crop has turned to straw having a yellow color. The ideal time for harvesting is between 110 days for crops that reach maturity early, 113 and 125 days for medium harvest, 130 and 136 days after sowing late (Rice Knowledge Bank, 2017)

V. CONCLUSIONS AND RECOMMENDATIONS

From the above findings, it can be gathered that strawbale buildings are a sustainable viable option because they are built using non-toxic and natural materials and for that it is highly healthy to man. It has an R-Value of 70.3 (hr/sqft-F/Btu) while conventional walls have an R-Value of between 2.0 and 3.0 (hr/sqft- F/Btu). This makes it highly Insulative and more energy efficient than standard walls. They are highly flexible and sculptural which makes them have great aesthetic values. Strawbale walls are high fire retarding elements. Unrendered strawbale has a fire resistance of 30 mins while rendered has 2 hours (Morrison, 2007), vermin resistant, earthquake stable, these are all proven by official tests. Strawbale are a byproduct of agricultural waste, this

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makes it eco-friendly and available since all materials are natural elements and so readily sourced and replenished without damaging the eco-system.
On the other hand, strawbale walls are susceptibility to rot if not constructed properly and requires high space requirements for the straw itself (thickness of wall is usually around 10-20 inches).

On this bases, strawbale buildings should be considered as better and more sustainable options of building construction material because they are a healthier option for the eco-system, cheaper to construct and safer to man and the environment in the long run.

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