GREEN BUILDING STRATEGIES AND MATERIAL SELECTION FOR HOT-DRY CLIMATIC CONDITIONS OF NORTH-WESTERN NIGERIA; A DELPHI APPROACH

BY

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Abstract

Generally, buildings provide society with countless benefits; however, they also have major negative impacts on the environment. Hence, Green Buildings (GB) have been proposed to solve this issue as they adopt fewer harmful materials and enable the use of local materials to adapt to climate conditions while consuming natural renewable resources with an emphasis on environmental sustainability. However, there is a dearth of research that focuses on the types of GB materials that could be adopted in the Nigerian construction industry. Hence, this research aim at finding out available materials and strategies that can be adopted towards attaining a GB status within the hot-dry areas in the north-western part of Nigeria. A total of 25 experts were drawn from across three professional bodies including the Nigerian Institution of Estate Surveyors and Valuers (NIESV), the Nigerian Institute of Architects (NIA) and the Nigerian Institute of Building (NIOB). Using a 5-point Likert scale ranking, the study explores 33 materials cum strategies for hot-dry climatic conditions. The Delphi method was adopted to find available materials and strategies that can be adopted towards attaining a GB status within the study area. The consensus was reached at the 4th round of the survey where 19 number materials were agreed upon as easily available and suitable for the region. These include straw bales using cane straw, wheat stalks, maize husks, cottonseed husks, tamarin hull particles, adobe bricks, ash waste bricks, autoclaved aerated concrete, onion peels, groundnut shells, sunflower stalk, cork and fired clay for walling and insulation. Jalis and wind-catchers for ventilation; grass Crete and timber Crete for outdoor flooring and living roof and clay roof tiles as roofing materials. Hence, this study recommends the adoption of these materials to reduce heat-related impacts on the environment caused by buildings.

Keywords: *Green building, sustainable materials, Delphi technique, Nigeria*

INTRODUCTION

Building is generally considered a very important facet in every nation's economy as it serves as the basis for most economic activities. However, most modern buildings are serviced, completely, using non-renewable energy materials (Noble, 2013), not only within the developed nations, but the trends have equally encroached into the developing nations such as Nigeria, where vernacular building strategies are being replaced with modern building strategies.

With a population of over 7.8 billion people, 50% of the world population reside in urban centres resulting in severe pollution and energy challenges (Agarwal et al., 2019). Henderson (2012) affirms that the world's population is on a continuous increase, thus a surge in energy consumption, which has risen to 80 times over the past 2 centuries, where a large portion of the increase occurred within the last 5 decades. However, a bunch of energy consumption comes from the construction industry as the building industry is known to generate so much energy and produce much of the waste recorded all over the world. He (2019) confirms that global warming caused by an increase in building activities has led most cities to urban overheating crises.

Odebiyi et al. (2010) reported that the construction industry is a major contributor to overall global warming. Swan and Ugursal (2009) affirm that energy consumption of the residential real estate sector alone accounts for approximately 30% of worldwide energy consumption; this is devoid of energy consumed by other sectors of the built environment including the commercial, industrial and agricultural sectors. In the UK for example, Akinyemi et al. (2017) reported that waste generated from construction materials is as high as 70 million tons annually, which about 50% of the entire CO_2 emissions result from the building industry. In the US, 73% of electricity supply and 41% of energy usage is consumed by buildings (Rahman et al., 2018), while 16% of the total water is consumed by buildings (Akinyemi et al., 2017). In another instance, Zander et al. (2015) confirm that hot weather in Australia rendered over 70% of people less productive in 2014 leading to a loss of over US$1,560.6 Billion. Moreover, Office of Energy Efficiency and Renewable Energy -EERE (2015) predicted that the projected values will surge in the years to come.Hence the need for greening by infusing green skills in the building industry (Hamza et al., 2019).

In Africa, energy consumption cum energy-related CO_2 emissions are lower when compared with developed countries (United Nations Environment Programme -UNEP, 2009). However, Badr (2014) confirm that the African traditional practices have been broken through neglect, thus giving away the natural passive design strategies involving orientation, shading, thermal mass, ventilation and lighting for mere active and mechanical design strategies. This is evidenced in most parts of the African settings, particularly the hot-dry region of north-western Nigeria which is gradually experiencing the fading away of traditional vernacular structures as most modern buildings are made of industrial construction materials involving corrugated iron sheets or aluminum sheets as roof covers and concrete sand-cement blocks for walls. Hence, Abisuga and Okuntade (2020) affirm that while the Green Building Council of Nigeria (GBCN) is in existence, however, the existing GB policy is not fully operational. However, Odebiyi et al. (2010) and Yakub et al. (2017a) suggest the need for Africa to embrace their locally produced materials in construction as African indigenous architecture is seen to be synonymous with GB which will aid a drastic reduction in energy's environmental impact, water conservation and controlling waste generation.

Nigeria being a nation located within the temperate region is characterised by varied seasonality between dry and humid climatic conditions on the one hand, and hot and cold on the other hand, thus the difficulty faced in managing buildings towards suiting their varied level of needs. Such needs include storage, provision cum distribution of heat during varied seasonality's by maximizing heat during winter periods while minimizing heat and optimizing both ventilation and cooling in summer. However, the incessant power failures due to the erratic nature of Nigeria's electricity power supply, escalating energy prices, the excessive reliance on electricity generating sets which produces a lot of carbon emission, poses grave danger to human health, environmental degradation and radical climatic changes. On the other hand, water generation, consumption, conservation and the attendant waste generation is another call for concern. This creates the need for a timely review of the power and water utilization, as well as the consumption of natural renewable resources in buildings across Nigeria and other developing countries towards energy-efficient and climatic adaptive real estate, with particular emphasis on environmental sustainability.

Therefore, the study aims at identifying building strategies that consume less energy, have minimal reliance on non-renewable energy and reduce non-degradable waste generation. Hence, the question '*What materials will be suitable for building units in hot-dry climatic areas of north-western Nigeria?'* This became necessary, as there is no research available on types of materials that are suitable for GB, most especially, in the hot dry regions of Nigeria.

Green Building and indigenous sustainable architecture

The United State Environmental Protection Agency define GB as an ecologically accountable building that taps the earth's limited and renewable resource towards providing a habitable building (Rahim, 2017). Simply, GB is a building planned to reduce energy consumptions and emissions thus improving energy efficiency and conserving water through the adoption of non-toxic and durable materials in construction (Huhu et al., 2015), obtained through renewable sources (Al-Asad & Emtairah, 2011). Hence, they are environment-friendly, resource-efficient buildings, comfortable to live in and providing good indoor and outdoor quality (Hu et al., 2014) and serving as a solution to environmental challenges including global climate change (Irvin et al., 2009; Osofsky & Levit, 2008).

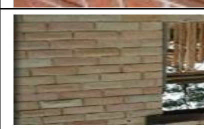
Zeigler (2012) confirm that the essence of a green project is life sustainability. Sustainability may be considered as an economically affordable; technologically efficient and environmentally healthy building that can record high performance (Akinyemi et al., 2017). Hence, the UN's Brundtland Commission Report (1987) term sustainable building as a development that is capable of meeting the present needs of its inhabitants without compromising the needs of generations yet unborn. The report caution that over-exploitation of resources through developments in technology may result in compromising the future, thus marking a major difference between GB and contemporary buildings which are reliant on non-renewable energy sources.

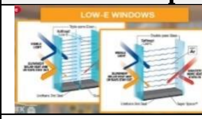
Zeigler (ibid) therefore, observe that there are five key principles of a GB - site design; conservation of energy/environment; water conservation cum quality; materials/resources conservation; and assurance of indoor air and environmental quality. Hence, most importantly GB should serve as an exporter, rather than an importer of energy and water resources. Akinyemi et al. (2017) opine that GB is an incomplete concept without inculcating sustainability, thus while a sustainable building may not be green, a green building must be sustainable through consumption of less energy and water. Also inculcating the use of recycled materials that are low in CO_2 emission (Aghdam et al., 2018; Akinyemi et al., 2017). This is why Retzlaff (2009) view GB as a form of development that is designed to improve sustainability levels in a building including improved efficiency of such structures, thereby decreasing the possibility of health hazards during occupation. Thus, it contributes to the improved health of residents (Guo et al., 2010; Kyu-in & Dong-woo, 2011) and providing an environmentally-friendly building (Dahiru et al., 2014). Hence, GB is a kind of building that assimilates sustainable development principles to reduce environmental impacts on the habitability of the building, thus should be capable of solving energy and water challenges while preserving a healthy environment.

Although GB may be high in initial upfront cost (Retzlaff, 2009), it still a better option over conventional buildings for its enormous advantages of enhanced asset value, reduced operation costs/optimisation of real estate's lifecycle and economic performance. To households, GB offers a saving in electricity and water bills (Badr, 2014) besides the creation of new industries and jobs. (UNEP, 2011) estimated that for every one million US dollars invested in enhancing building efficiency retrofits, 10 to 14 new direct jobs are created. GB reduces CO_2 emissions by 33%, consuming 45% and 54% less energy and water respectively, with 13% lower maintenance costs (White Paper, 2008). Thus, Durmus-pedini and Ashuri (2010) see GB as a necessity rather than a luxury or a matter of choice. Hence, the need for shifting the trend of building construction to energy-efficient buildings that maximizes the opportunities created in terms of renewable energy while minimizing the wastage of resources.Some samples of these GB materials can be visualised in table 1.1 below;

Table 1.1: Pictorial samples of material that are adaptable as GB compliant

	Material	Qualities	Pictorial samples
Walling and building insulation materials	Sunflower stalk and Eggplant stalks	Good insulation materials (Binici et al., 2014; Guntekin & Karakus, 2008)	
	Straw bale	A good insulation against heat and cold climatic conditions (Aksogan et al., 2018) and resistant to fire (Almusaed et al., 2020).	
	Cottonseed husk and stalk in conjunction with ash	A good thermal insulator (Binici & Aksogan, 2014; Gurjar, 1993).	
	Autoclaved aerated concrete (AAC)	It is an eco-friendly product (Saurabh, 2019) with good thermal properties and capable of withstanding fire outbreaks (Baiden et al., 2005).	
	Adobe or Mud bricks	Provides sufficient thermal mass in buildings, and often adopted due to its non-toxic and fireproof properties (Nandhini et al., 2020).	
	Rammed earth	It has a prolonged cooling and heating process (Gallo C, Sala M, 1998) and capable of withstanding earthquake (Almusaed et al., 2020)	
	Wheat stalk	Good insulation material with great thermal conductivity and compressive strength and lower cost (Binici et al., 2020)	
	Fly ash	A material gotten from burnt remains of high-quality coal (Binici & Aksogan, 2017). Fly ash is made up of 80% of the burnt coal residue, thus light and tremendously fine in nature (Nwankwo et al., 2020) Fly ash is superior to concrete in terms of its comfortable indoor temperature (Binici & Aksogan, 2014). Thus, it has been investigated by many scholars than other geo-polymer concretes (Zakka et al., 2021)	
	Cane straw and Straw bale	A renewable and environmentally friendly insulation material (Binici et al., 2020), which has an efficient thermal insulation effect is hence traditionally	

	Material	Qualities	Pictorial samples
		used in hot climates (Almusaed et al., 2020). It is mostly used for aesthetics in buildings (Buys & Hurbissoon, 2011)	
	Brick wall from green materials	Green materials are generally suitable for insulations in building (Binici et al., 2014)	
	Durian peels	These are suitable GB materials in building as they compose of fibers and parenchyma, thus having high moisture absorption ability (Khedari et al., 2004)	
	Sheep's wool	A textile industry waste (Jannat et al., 2020), which is eco-friendly material adopted in buildings (Latha et al., 2015)	
	Groundnut shells	These are renewable and environmentally friendly building materials adopted in thermal insulation (Luamkanchanaphan et al., 2012)	
	Mycelium	Mycelium is sourced from mushrooms and fungi, combined with sawdust with the ability to withstand extreme temperature. It can be used in concrete, likewise can be molded into lightweight bricks. It has good acoustic and thermal insulation properties (Girometta et al., 2019)	
Flooring	Bamboo	Lightweight and good tensile strength (Van Der Lugt et al., 2015).	
		Slower in degeneration (Van Der Lugt et al., 2015).	
	Cork	A material harvested from cork-tree bark (J. Kim et al., 1998). It is readily available (Van Der Lugt et al., 2015).	
	Terra cotta tiles	Effective in absorption, storage, and discharge of heat (Nandhini et al., 2020).	
	Grass-Crete	Improves water penetration in the form of drainage (Nandhini et al., 2020).	
	Mangalore tiles	Eco-friendly material that serves as a good filler and reinforcement material, which can reduce construction cost by 30-40% (Nandhini et al., 2020)	
	Timber Crete	An interesting construction material made of saw-dust (a waste product) and concrete mixture that reduces transportation emissions and replaces energy-intensive constituents of concrete due to its lightweight (A. A Yakub et al., 2017)	
Roofing	Living/Green roof	Sustainable tool in mitigating urban heat (Zahir et al., 2014); Enhances built environments' aesthetic cum environmental quality (Vandermeulen et al., 2011);Reduces risks of floods (Karteris et al., 2016); Long-term maintenance advantage (Sproul et al., 2014);	
Openings & Ventilations	Wind catcher	Alternative to mechanical cooling equipment's, hence providing a natural cooling through vertical shafts oriented towards the directions of the prevailing wind, catching and pushing the breeze into the building (Badr, 2014). It enhances productivity, reduce energy consumption and greenhouse gas emission most especially in hot-dry regions (Alwetaishi & Gadi, 2020)	

	Material	Qualities	Pictorial samples
	Low Emissivity (E) windows	Absorbs UV rays, allows light, and blocks heat (Farooq & Yaqoob, 2019).	
	Plus doors	Reduces landfill waste and also decreases the demand for reclaimed lumber (Nandhini et al., 2020).	
	Jalis	The moderate indoor temperature through compressing the air that passes through the brick holes (Shaw, 2009).	
Painting	Low Volatile Organic Compound (VOC) paints	Free of causing irritation and respiratory challenges to the inhabitants (Farooq & Yaqoob, 2019).	
	Terra cotta and Linseed oil	Good natural coloring agents in painting works (Nandhini et al., 2020).	
Water efficiency	Water-efficient features and used-water recycling techniques	Toilet type and designs are crucial as new toilet components require less than 40% of the water needed in flushing. Likewise,water from wash hand basins and kitchen sinks can be recycled for reuse (Ahmad, 2016).	

Source; Various research articles as cited in the Table

MATERIALS AND METHOD

This study adopts a Delphi research approach which Hasson et al. (2000) term as a versatile and iterative multi-stage methodology designed to turn individual views into a collective consensus that contributes to an enlarged knowledge base that exposes each panelist to the responses of the entire community. It is a forecasting method that selects a panel of experts carefully and systematically to provide correct answers to problems where there is incomplete information through a continuous feedback mechanism that is eventually stopped by the researcher when a consensus is reached (Sekaran & Bougie, 2009), thus a consensus-seeking research approach (Hasson & Keeney, 2011).

The Delphi technique is said to be advantageous as it only deals with the opinion of experts who are interested in the subject matter and the fact that it is easier to receive input from a group of experts than the opinion of an individual expert, thereby gaining validity through inter-subjectivity (Almusaed et al., 2020; Binici et al., 2014). Delphi technique also offers professionals the ability to re-examine their opinions having viewed the opinions of other participants without any interference from other panelists (Kim & Yeo, 2018).

Hence, this study engaged 25 experts from three technical bodies, including the Nigerian Institution of Estate Surveyors and Valuers (NIESV), the Nigerian Institute of Architects (NIA), and the Nigerian Institute of Construction (NIOB) in the survey. These experts were selected following the opinion of researchers, while Weinstein (1993) view an expert as a person who can explain prepositions within a field of research, Keeney et al. (2001) consider an expert as an educated person with advanced expertise in a particular area.

In selecting the ideal number of rounds in a Delphi survey, Ludwig (1994) notes that, depending on the circumstances of the issue, a range of three to five rounds can be assumed to be adequate, whereas Pivo (2008) believes that three to four rounds are adequate to achieve convergence. Though, Nandhini et al. (2020) and Gallo and Sala (1998) adopted three rounds in their survey, while Yakub et al. (2022) adopted 4 rounds. Nevertheless, Brady (2015) claims that the execution of a Delphi phase should be continued until the predetermined thresholds are met by consensus.

Hence, this survey adopted four rounds. The first round of the survey served as a preliminary round that introduced the research topic and obtained reactions from the panelists using open-ended questions addressing the materials suitable for GB in the case study. Therefore, this process gave the panelists a degree of freedom to answer questions, which contributed to a large amount of knowledge generated, as themes were formed from these responses in conjunction with GB materials found in the literature were collated into a single questionnaire. These were used in drafting the second-round questionnaire which consisted of closed-ended questions where the survey examined GB strategies for hot-dry climate conditions where the panelists were asked to rank each of the materials according to their level of availability and usefulness, using a 7-point Likert scale ranking while focusing on two selected northwestern cities of Kano and Katsina. However, the experts were given the room to suggest ideas that are not listed among the variables, which may be regarded as important to the local settings.

Thereafter, the third round served as the beginning of the consensus-seeking rounds while round four was the final round. Each of the rounds consisted of the same set of questions as those in the second round, but integrated with feedbacks, after evaluation of the response in each round, and recirculated to inspire the panelists while giving them a chance of reevaluating their initial responses. However, it was noted that there was a wide range of discrepancies in the opinion of the panelists in the second round, but by the end of the 4th round of the survey there was a reasonable level of convergence, hence consensus was reached and a conclusion drawn.

In analyzing the responses, Kendall's Coefficient of Concordance (Kendall's *W*) was adopted in measuring the level of agreement. Kendall's W is seen as the most recognized rating methodology adopted in a nonparametric statistical test to calculate the level of agreement within the responses of the panelists (Okoli & Pawlowski, 2004). Kendall's *W* is a criterion for consensus that reflects the degree of consensus among the different participants in a sample (Binici & Aksogan, 2017; Nwankwo et al., 2020). It is a scale adopted in determining the level of cooperation and the degree of agreement cum relationship between different ranks involving 'k' phenomena (Habibi et al., 2014).

Kendall's *W* is given as $W = \frac{12S}{m^2(n^3-n)-mT}$

$$\text{Where } S = \sum_{i=1}^{n}(R_i - \bar{R})^2$$

And R_i = Total rank of a factor; m = number of the raters (judges)

n = number of ranked factors or phenomena (questions/papers/objects/individuals being ranked) and T = the correction factor (only used when there is a tide rank, otherwise = 0

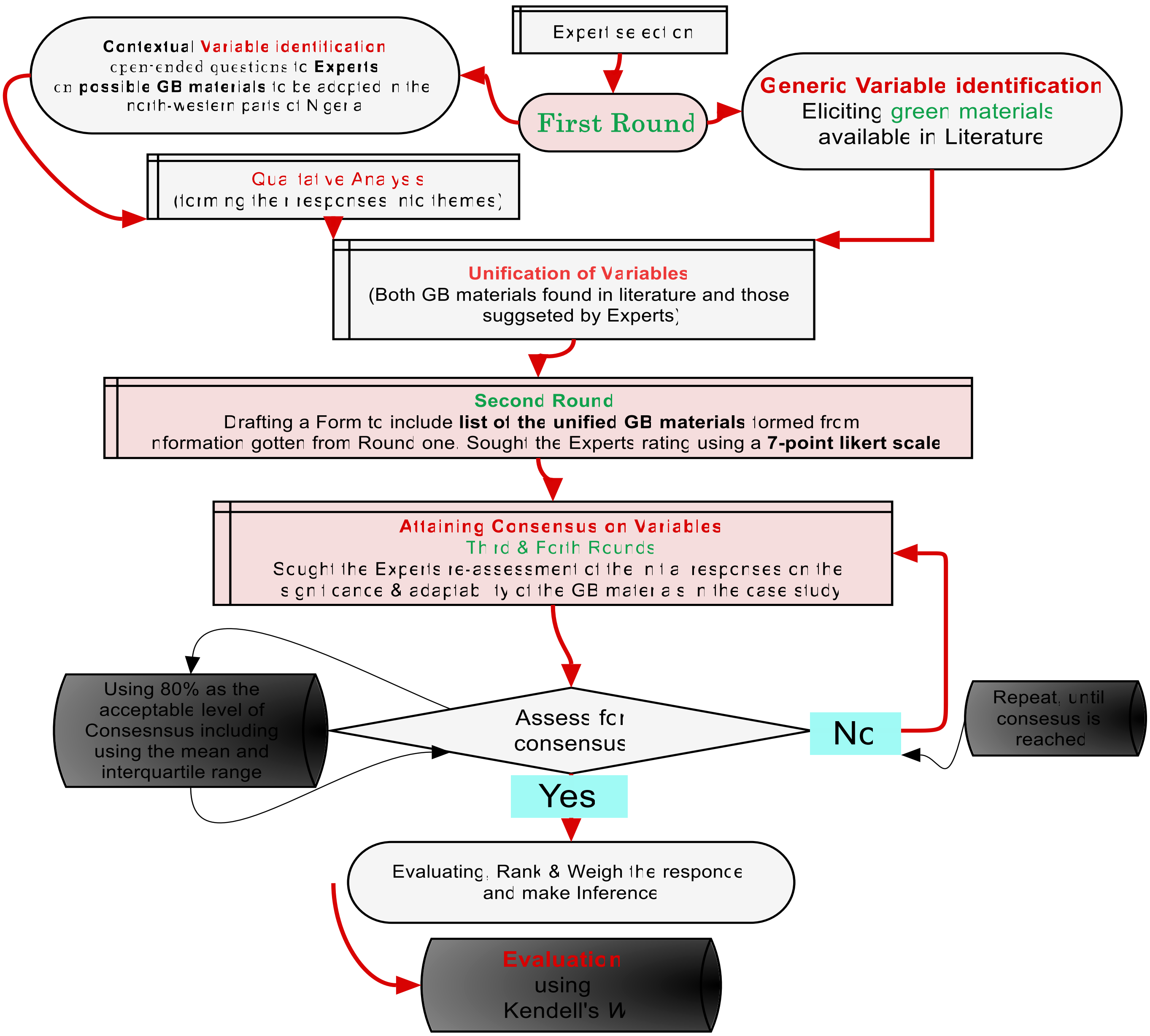


Figure 1: Delphi procedural Diagram for the study

Source; Author's Survey, 2021

RESULTS AND DISCUSSION

The first round of this survey consisted of open-ended questions, while the second round serves as the first round that sought the ranking of the experts on the GB materials, hence the study did not seek consensus of the experts in the first round, and rather consensus was sought from the second until the fourth round. Thus, from the 4-rounds of the Delphi survey carried out in this study, it was realized that the level of consensus became better in the succeeding rounds. Pivo (2008) also affirms that there were changes in the outcomes in each of the subsequent rounds in their analysis, thus the possibility of a stronger consensus with more rounds. Hence, the strong consensus signified the stoppage of the iterative rounds.

Table 1.2: Descriptive Statistics of GB material availability and suitability in north-western parts of Nigeria

Suitability					Availability				
	(3rd round)		(4^{th} round)			(3rd round)		(4th round)	
GB Material	Mean	Std. Dev.	Mean	Std. Dev	GB Material	Mean	Std. Dev	Mean	Std. Dev
Cane straw	4.76	0.52	**5.00**	0.00	Groundnut shells	4.40	1.23	**5.00**	0.00
Wheat stalks	5.00	0.00	**5.00**	0.00	Cane straw	4.6	0.96	**5.00**	0.00
Fired clay	4.36	0.70	**4.80**	0.41	Wheat stalks	4.52	1.33	**5.00**	0.00
Cottonseed husk and stalk	4.80	0.41	**4.80**	0.41	Onion peels	4.48	1.23	**5.00**	0.00
Grass-Crete	4.76	0.44	**4.76**	0.44	Tamarind hull particle	4.40	1.16	**4.96**	0.20
Living/Green roof	4.72	0.46	**4.72**	0.46	Grass-Crete	4.52	1.01	**4.92**	0.28
Tamarind hull particle	4.88	0.33	**4.72**	0.46	Living/Green roof	4.24	1.01	**4.92**	0.28
Ash wastes	4.60	0.50	**4.60**	0.50	Eggplant stalks	4.72	0.61	**4.92**	0.28
Adobe or Mud bricks	4.28	0.74	**4.52**	0.59	Wind-Catchers	4.28	1.10	**4.84**	0.37
Reclaimed wood	4.32	0.48	**4.44**	0.51	Adobe or Mud bricks	4.48	0.77	**4.80**	0.41
Timber	4.60	0.50	**4.44**	0.51	Sunflower stalk	4.44	0.87	**4.72**	0.54
Autoclaved aerated concrete	4.44	0.51	**4.44**	0.51	Maize/Corn cob and husk	4.44	0.71	**4.68**	0.48
Clay roof tiles	4.44	0.65	**4.44**	0.65	Cottonseed husk and stalk	4.36	0.76	**4.68**	0.48
Maize/Corn cob and husk	4.40	0.50	**4.40**	0.50	Rammed earth	4.40	0.87	**4.60**	0.50
Timber Crete	4.00	0.91	**4.36**	0.57	Cork	4.08	1.08	**4.56**	0.58
low Emissivity (E) windows	4.04	1.02	**4.36**	0.49	Fired clay	4.28	0.74	**4.48**	0.51
Jalis	4.16	0.37	**4.16**	0.37	Jalis	4.20	1.00	**4.48**	0.51
Plus doors	4.12	0.33	**4.12**	0.33	Ash wastes	3.92	1.00	**4.28**	0.74
Mycelium	3.28	1.21	**4.00**	1.00	Autoclaved aerated concrete	4.28	0.54	**4.00**	0.58
Sheep's wool	3.72	0.46	3.72	0.46	Timber Crete	3.48	0.51	3.48	0.51
Onion peels	3.72	0.46	3.72	0.46	Clay roof tiles	3.84	0.62	3.48	0.51
Groundnut shells	3.92	0.81	3.68	0.56	low Emissivity (E) windows	3.00	1.00	2.64	0.49
Wind-Catchers	3.24	0.83	3.64	0.49	Sheep's wool	2.32	0.95	2.48	0.77
Cork	3.60	0.50	3.60	0.50	Hemp Crete	2.92	0.95	2.36	0.49
Sunflower stalk	3.36	0.49	3.36	0.49	Plus doors	4.04	6.28	2.36	0.49
Hemp Crete	3.16	0.47	3.16	0.47	Reclaimed wood	2.08	0.64	1.88	0.44
Rammed earth	3.56	0.51	2.80	0.50	Timber	2.16	1.03	1.80	0.50
Eggplant stalks	3.20	1.00	2.80	0.41	Wooden roof	2.20	1.12	1.76	0.52
Durian peels	2.04	0.74	2.52	0.51	Mycelium	1.96	0.98	1.60	0.65
Coconut fibre	2.32	0.75	2.48	0.51	Terra cotta tiles	1.56	0.71	1.44	0.51
Terra cotta tiles	2.48	0.65	2.48	0.65	Coconut fibre	1.68	0.95	1.28	0.46
Bamboo	1.76	0.72	1.76	0.72	Bamboo	1.80	1.29	1.16	0.37
Wooden roof	1.52	0.51	1.52	0.51	Durian peels	1.32	0.63	1.04	0.20
Kendall's W(a)		0.659	**0.755641**			0.586		**0.886518**	
Chi-Square		526.896	604.5128			468.561		709.2144	
Df			32					32	
Asymp. Sig.			7E-107					1.4E-128	

Source; Author's Survey, 2021

Table 3: Key to table 1.2

Key (colour)	Decision Boundary	Suitability	Availability
Dark Green	4.1-5	Extremely Suitable	Extremely Available
Light Green	3.1-4	Very Suitable	Available
Yellow	2.1-3	Suitable	Somewhat Available
Black	1.1-2	Not so Suitable	Not so Available
Red	0-1	Not Suitable	Not Available

Source; Author's Survey, 2021

Test of concordance and significance of Kendall's W

The third round recorded a Kendall's *W* of 0.66 for suitability of GB materials while 0.59 was recorded for the availability of the materials in the region, hence denoting the low level of agreement between the experts. These figures increased significantly at the fourth stage when the experts were provided with the chance to re-assess, thus re-rank the attributes as shown in table 1.2 above were suitability improved by 12.78% to arrive at 0.75 while the availability of materials within the region improved by 50.26% giving a new Kendall's *W* of 0.88. This indicates a good improvement in the level of agreement between the various built environment professionals involved. Likewise, there were improvements in the mean values of the fourth round over the third, which affected 11 and 19 items rated under suitability and availability respectively. Although 13 and 4 items were also affected under availability and suitability respectively, on a general note, these changes increased the overall ratings, thus the Kendall's *W*.

However, it should be noted that Kendall's *W* only determines the association in terms of the degree of agreement among ranks assigned by the panelists rather than giving the significance of the *W* figure. Hence, (Bevan & Kendall, 1971) gave the commonly adopted significance test model for *W* to be;

$$\text{Critical } x^2 \text{ values} = m\,(n-1)\,W$$

where m is the number of panelists, n is the number of objects ranked and *W* is Kendall's coefficient.

Hence, x^2 for suitability gave 585.62, while x^2 for availability equals 687.05, which are all greater than the chi-square statistical table value of 46.19 at 0.05 significance level, thus confirming a strong agreement in the ranking of the panelist regarding both the availability and significance of GB materials in the north-western part of Nigeria, thus a significant *W* value.

The mean and standard deviation of the final round for both GB materials that are suitable and available for the case study are presented in table 1.4. Out of the 18 number materials that were said to be extremely suitable for GB construction, only 11 representing 61% had an equal rating in terms of their availability within the region. While autoclaved aerated concrete, timber-Crete and clay roof tiles were rated 4.0, 3.48, and 3.48 respectively, thus available, low emissivity (e) windows, plus doors, reclaimed wood, and timber were rated as somewhat available.

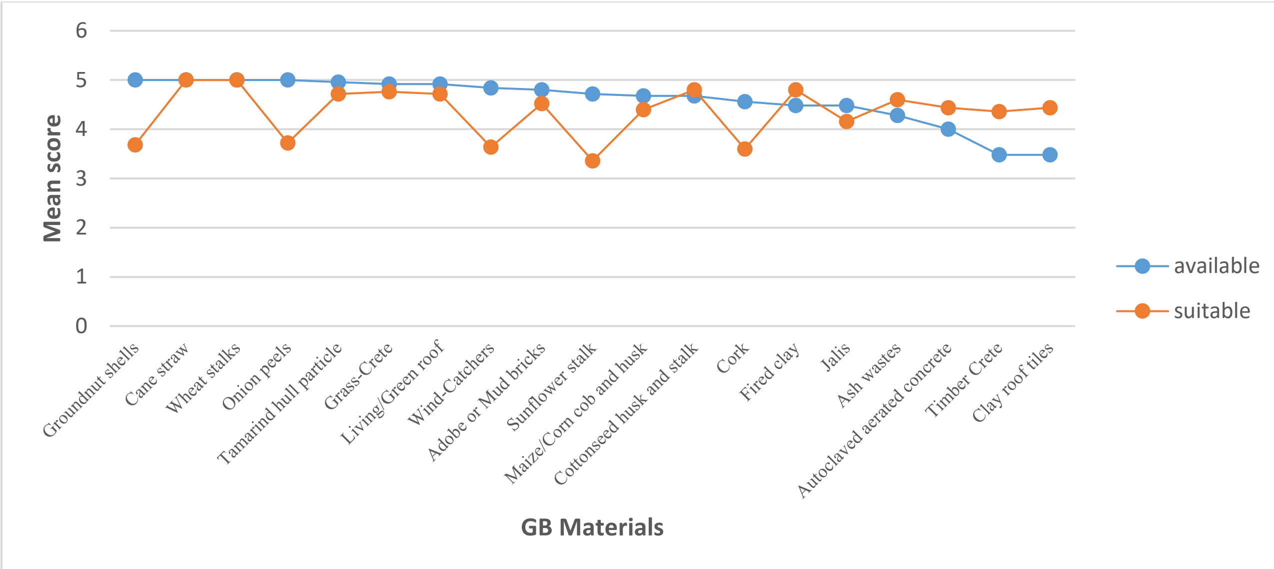


Figure 2: Identified GB materials that are both suitable and available

Source; Author's Survey, 2021

Suitability and availability of GB materials in the region

From the results of the study, 18 GB materials are found to be 'extremely suitable' for adoption in the region. These include cane straw, wheat stalks, fired clay, cottonseed husk and stalk, grass-Crete, living/green roof, tamarind hull particle, ash wastes, adobe or mud bricks, reclaimed wood, timber, autoclaved aerated concrete (AAC), clay roof tiles, maize/corn cob and husk, timber Crete, low emissivity (e) windows, Jalis and plus-doors. However, out of these 18 materials, only 11 are found to be extremely available, while are three (3) available (timber Crete, AAC and clay roof tiles). Low emissivity (e) windows and plus-doors are somewhat available, while reclaimed wood and timber are not so available.

In terms of thermal insulation, Aksogan et al. (2018) affirm that both canes stalks and waste newsprint papers can be used for both ultrasound and thermal insulation in buildings. Both corn stalks and wheat stalks are wastes from one of the most widely grown agricultural products in most kinds of climatic and soil conditions. Binici et al. (2020) and Binici & Aksogan (2017) affirm that they can be adopted as building insulation materials commercially, thus reducing energy consumption. Other GB materials that may perform the dual purpose of building blocks and insulation include the Cottonseed husk and stalk in conjunction with ash wastes. Binici and Aksogan (2014) and Gurjar (1993) affirm that they can be adopted in the production of lightweight and low-cost building materials such as in concrete block mixtures serving as good thermal insulators. In addition, they are superior to the conventional concrete block thus giving a comfortable indoor temperature. Another GB material rated as extremely suitable is Grass-Crete, a method of concrete floor-laying pattern where openings are left within the concrete floor for grasses to grow to provide a green environment and improve water penetration in the form of drainage. Rachtanapun (2010) affirm that tamarind hull particles are quite suitable for particleboards production.

Almusaed et al. (2020) also affirm that wood generally serves as a good thermal insulator, which is good for hot climates, hence the use of Reclaimed wood materials made from trees. While

Timber can be used in load-bearing walls, ceilings, and flooring (Agyekum et al., 2020), they are capable of withstanding fire outbreaks, aesthetically sound and have good thermal properties (Baiden et al., 2005).

Likewise, AAC can be adopted in GB. AAC is a hunk of precast foam concrete with an addition of aluminium powder, which serves as an enlargement agent that expands and rises the mixture. This lightweight mixture can be adopted in making blocks. Saurabh (2019) affirm that AAC, an eco-friendly product, has better sound and heat insulation as compared with conventional blocks.

Timber Crete is a waste product made from the sawdust from sawmill waste can be mixed with a binder including cement and cellulose, thus providing an insulated lighter concrete, which can be used in molding blocks with the ability to store thermal energy.

Another suitable sustainable material that can serve a GB purpose is the Adobe or Mud bricks, which are nontoxic fireproof GB material, made from a combination of mud, sand, clay, and lime alongside water with straw or rice husks as binding materials. They can provide sufficient thermal mass in buildings (Nandhini et al., 2020). They are heat resistant, thus effective for cooling in summer and heating of building's internal space during the winter, most especially when they are adopted in constructing thick external walls resulting in an eco-friendly and receptive architecture. This, by implication, allows a slower process of flushing out the stored temperature at night, hence ensuring a more comfortable night temperature within the building, thus having better evaporative cooling phenomena than the modern cement brick resulting in better indoor thermal comfortability (Shanthi Priya et al., 2012). Although they resemble rammed earth construction, adobe requires dry weather for proper curing.

In terms of ventilation and opening device, low emissivity (E) window is rated as extremely suitable. E-windows come with thin layers that help in absorbing ultraviolet rays and allowing light, but at the same time blocking heat. It is an energy-efficient glass that disallows heat from fleeing through openings such as windows with the glass reflecting warmth into the building (Farooq & Yaqoob, 2019). Others include Plus doors, which are recycled wood that has the double advantage of reducing landfill waste and reduce the demand for reclaimed lumber (Nandhini et al., 2020). Likewise, Jalis, which is a perforated brick wall (Shaw, 2009) that can bring down the temperature by compressing the air that passes through the holes**.** Chowdhury and Gupta (2019) affirm that Jalis are found in Indian architecture.

Concerning roofing using GB material, green roof otherwise termed living roof stands out. Although, generally Sproul et al. (2014) affirm that living roofs are more expensive than conventional roofs, but it has a long-term maintenance advantage as it reduces the need for cooling by over 50%. Green roof otherwise termed living roof, eco-roof or roof garden is a vegetated roof cover that contains a waterproof membrane on a traditional roof and a layer of soil that serves as the growing medium for the plants/vegetation (Pisello et al., 2015). The vegetated roof serves as a sustainable tool in mitigating urban heat, thus enhances built environments' aesthetic cum environmental quality (Zahir et al., 2014), hence giving a better indoor environment (Farooq & Yaqoob, 2019; He, 2019), while providing aesthetics (Vandermeulen et al., 2011). Among other benefits of a green roof is the fact that it improves the health conditions of dwellers (Besir & Cuce, 2018), reduction in greenhouse gas emission, reduction in urban heat, improving water quality and retaining excess water thereby reducing risks of floods (Karteris et al., 2016). Such a reduction in heat flows from roofs of buildings can be about 80% during summer periods (Besir & Cuce, 2018; Karteris et al., 2016), while energy consumption can be reduced by as much as 16.7% (Besir &

Cuce, 2018; Coma et al., 2016). Thus, a perfect solution to energy consumption challenges and green-house gas emissions (Besir & Cuce, 2018). Thus, a green roof serves a dual purpose of being insulation meant to reduce heat gain in a buildings inner part on one hand and a very beneficial element to the atmosphere as it discharges oxygen to the environment

In addition to the 18 extremely suitable GB materials, eight (8) others are rated ‘very suitable’ for the region including mycelium, sheep's wool, onion peels, groundnut shells, wind-catchers, cork, sunflower stalk, and hemp Crete. From the 8 ‘very suitable’ materials, 5 are rated ‘extremely available’, while sheep's wool and hemp Crete are ‘available’ and mycelium is not available

Onion peels are suitable for insulation, most especially in areas exposed to a lot of radiation (Binici & Aksogan, 2017). Sampathrajan et al. (1992) confirms that groundnut shells have better thermal conductivity and higher mechanical strength than coconut fibre. Binici and Aksogan (2014) affirm that Sunflower stalk can also be adopted in insulation. Hence, rather than the continuous burning of the sunflower stalks during winter which unnecessarily heats up the atmosphere, it can be productively employed in building construction. Likewise, hemp Crete, a renewable material made up of bio-fibre alongside lime, as a mineral binder can be adopted in providing a good insulator in roofs, walls or slabs to reduce their energy requirements.

On the other hand, in providing natural ventilation to a building towards GB compliant, wind catcher stands out. It is a traditional cum natural ventilation and cooling element in buildings serving as a means of directing wind-driven ventilation (Ahmad, 2016) and atmospheric air into the inner parts of a building so as to provide adequate comfort to the inhabitants without spending exorbitantly on energy-consuming mechanical cooling equipment’s. The technique is said to enhance productivity, reduce energy consumption and greenhouse gas emission most especially in hot-dry regions (Alwetaishi & Gadi, 2020).

Likewise, cork can also be adopted which is a type of flooring derived from a sustainable material with its source from the bark of trees through stripping of the tree bark, which can be repeated up to 20 times or over during the lifetime of the tree.

Those rated ‘suitable’ include rammed earth, eggplant stalks, durian peels, coconut fibre and terra cotta tiles. From the ‘suitable’ materials, Rammed earth and Eggplant stalks are rated as ‘extremely available’, while the others are either ‘not so available’ or ‘not available’. Rammed earth is an old wall and flooring construction material, which is constructed by compacting soil in the form of clay, sand and lime in a castle with forms, where the forms are removed after air would have been quizzed out of the mixture and the mixture solidifies. It has the ability of thermal storage in the daytime, thus releasing the warmth in the cold night. Agyekum et al. (2020) affirm that they can be used in the form of clay or laterite, which Almusaed et al. (2020) affirm that can withstand earthquake, thus commonly used in earthquake-prone countries of Iraq, Iran, India, China among others. Rammed earth acts as an insulation layer during sunny periods thus a thermal mass providing cushioning effect against temperature instabilities (Zuaiter, 2015). It has a prolonged cooling and heating process, thereby taking a long time to heat-up or cool-off than lighter weight walls (Gallo & Sala, 1998).

Eggplant stalks is another good insulation material as confirmed by Guntekin and Karakus (2008) in a study on the possibility of adopting eggplant stalks in manufacturing particleboards, the result indicates that it is technically viable.

Sampathrajan et al. (1992) affirm that coconut fibre, groundnut shells and maize cob and husk are the best materials for low-density particleboards suitable for insulation in construction in hot regions. Nandhini et al. (2020) affirm that coconut fibre is also good for plastering. Durian peels can also be adopted as thermal insulation materials in buildings (Khedari et al., 2004)

Terra cotta tiles can also be adopted in flooring is as it is effective in absorption, storage and discharge of heat, thus making the building warmer in cold seasons and cooler during heat (Nandhini et al., 2020). It is a non-slippery earthy material made from clay.

Bamboo and Wooden roof are rated as 'not so suitable'. Although bamboo is the fastest-growing renewable green material with lightweight and good tensile strength, hence outperforming most other renewable building materials (Van Der Lugt et al., 2015). Thus, it is an alternative sustainable traditional flooring and framing technique gotten from bamboo grass, serving as a better alternative to wood, which is slower in regeneration. However, it is not common in the hot-dry region of the north-western parts of Nigeria.

However, from the 33 materials presented to the experts, none was found to be unsuitable to the region, while only 1 (Durian peels) was rated unavailable in the region.

CONCLUSION

The basic objective of this study was the identification of suitable GB materials alongside their availability in the north-western region of Nigeria using an exploratory research technique. Hence, using Delphi technique, a qualitative cum quantitative technique (Critcher & Gladstone, 1998; Hsu & Sandford, 2007) that aims at using collective human intelligence course to arrive at consensus (Linstone & Turoff, 1975). This study found out that 21 GB material serves as the most available cum suitable for the region. However, only 19 of these are suitable including Cane straw, Wheat stalks, Fired clay, Cottonseed husk and stalk, Grass-Crete, Living/Green roof, Tamarind hull particle, Ash wastes, Adobe or Mud bricks, Maize/Corn cob and husk, Jalis, Timber Crete, Autoclaved aerated concrete, Clay roof tiles, Onion peels, Groundnut shells, Wind-Catchers, Cork and Sunflower stalk.

Hence, the identified materials will aid the governments of the 7 states in the north-western region including Kano, Katsina, Jigawa, Sokoto, Zamfara, Kebbi and Kaduna states, and particularly prospective developers in selecting suitable and available GB materials towards contributing their quota to reducing CO_2 emission and protecting the global environment. Aside from solving the global warming challenges, adoption of green building in Nigeria, and by implication, sub-Saharan Africa, will imply the use of local and indigenous materials in construction, which will boost the economy of the sub-region and reduce importation. Hence, the shift in the reliance on foreign materials will enhance indigenous technological development, thus giving room to job opportunities and development.

RECOMMENDATIONS

There is the need for rigorous public enlightenment towards the advantages of green building, most especially with the present governments' interest in the provision of social housing units for low-income earners across the nation. An example of these proposed housing units is 300,000 units which (Obin, 2020) reported that the production of the housing inputs is expected to be done locally on the site. Moreover, to be able to properly monitor the progress in green building implementation, there is the need to embark on establishing a building construction bank where present and future building constructions can be properly monitored.

Further Research

Further researches would look at the cost of these identified GB materials in Nigeria as compared to conventional building materials both at the short and long run.

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Reference

Abiodun Olatunji Abisuga, & Okuntade, T. F. (2020). The Current State of Green Building Development in Nigerian. *Green Building in Developing Countries: Policy, Strategy and Technology (Green Energy and Technology)*, 129–148.

Agarwal, S., He, J., Sing, T. F., & Song, C. (2019). Do real estate agents have information advantages in housing markets? *Journal of Financial Economics*, *134*(3), 715–735. https://doi.org/10.1016/j.jfineco.2019.05.008

Aghdam, K. A., Rad, A. F., Shakeri, H., & Sardroud, J. M. (2018). Approaching green buildings using eco-efficient construction materials : a review of the state-of-the-art. *Journal of Construction Engineering and Project Management*, *8*(3), 1–23. https://doi.org/10.6106/JCEPM.2018.8.3.001

Agyekum, K., Kissi, E., & Danku, J. C. (2020). Professionals' views of vernacular building materials and techniques for green building delivery in Ghana. *Scientific African*, *8*, e00424. https://doi.org/10.1016/j.sciaf.2020.e00424

Ahmad, S. F. (2016). Techniques for improving lives by green low income housing. *Sustainable Construction Materials and Technologies*, *2016-Augus*. https://doi.org/10.18552/2016/scmt4s112

Akinyemi, A. P., Adekunle, A. O., Joseph, O. O., Anthony, A. I., & Dabara, D. I. (2017). the Need for Green Building Rating Systems Development for Nigeria : the Process , Progress and Prospect. *Academic Journal of Scienc*, *07*(02), 35–44.

Aksogan, O., Resatoglu, R., & Binici, H. (2018). An environment friendly new insulation material involving waste newsprint papers reinforced by cane stalks. *Journal of Building Engineering*, *15*(October 2017), 33–40. https://doi.org/10.1016/j.jobe.2017.10.011

Al-Asad, M., & Emtairah, T. (2011). Cities and Building. In H. Abaza, N. Sa'ab, & B. Zeitoon (Eds.), *Report of the Arab Forum for Environment and Development: Green economy - sustainable transition in a changing Arab World* (pp. 161–204).

Almusaed, A., Almssad, A., Homod, R. Z., & Yitmen, I. (2020). Environmental profile on building material passports for hot climates. *Sustainability (Switzerland)*, *12*(9). https://doi.org/10.3390/su12093720

Alwetaishi, M., & Gadi, M. (2020). New and Innovative Wind Catcher Designs to Improve Indoor Air Quality in Buildings. *Energy and Built Environment*. https://doi.org/10.1016/j.enbenv.2020.06.009

Badr, S. (2014). Towards Low Energy Buildings through Vernacular Architecture of Arab Cities. *Academia*, 1–23.

Baiden, B. K., Badu, E., & Menz, F. S. (2005). Exploring the barriers to the use and potential of timber for housing construction in Ghana. *Construction and Building Materials*, *19*(5), 347–352. https://doi.org/10.1016/j.conbuildmat.2004.08.003

Besir, A. B., & Cuce, E. (2018). Green roofs and facades: A comprehensive review. *Renewable and Sustainable Energy Reviews*, *82*(October 2017), 915–939. https://doi.org/10.1016/j.rser.2017.09.106

Bevan, J. M., & Kendall, M. G. (1971). Rank Correlation Methods. *The Statistician*, *20*(3), 74. https://doi.org/10.2307/2986801

Binici, H., & Aksogan, O. (2014). Engineering properties of insulation material made with cotton waste and fly ash. *Journal of Material Cycles and Waste Management*, *17*(1), 157–162. https://doi.org/10.1007/s10163-013-0218-6

Binici, H., & Aksogan, O. (2017). Insulation material production from onion skin and peanut shell fibres, fly ash, pumice, perlite, barite, cement and gypsum. *Materials Today Communications*, *10*(112), 14–24. https://doi.org/10.1016/j.mtcomm.2016.09.004

Binici, H., Aksogan, O., Dıncer, A., Luga, E., Eken, M., & Isikaltun, O. (2020). The possibility of vermiculite, sunflower stalk and wheat stalk using for thermal insulation material production. *Thermal Science and Engineering Progress*, *18*(September 2019). https://doi.org/10.1016/j.tsep.2020.100567

Binici, H., Eken, M., Dolaz, M., Aksogan, O., & Kara, M. (2014). An environmentally friendly thermal insulation material from sunflower stalk, textile waste and stubble fibres. *Construction and Building Materials*, *51*, 24–33. https://doi.org/10.1016/j.conbuildmat.2013.10.038

Brady, S. R. (2015). Utilizing and Adapting the Delphi Method for Use in Qualitative Research. *International Journal of Qualitative Methods*, *14*(5), 160940691562138. https://doi.org/10.1177/1609406915621381

Buys, F., & Hurbissoon, R. (2011). Green buildings : A Mauritian built environment stakeholders ' perspective. *Acta Structilia*, *18*(1), 81–101.

Chowdhury, S., & Gupta, S. (2019). Character, identity and symbolism contemporary interpretations of british colonial architecture. *Proceedings of the International Conference of Architectural Science Association*, *2019-Novem*, 61–68.

Coma, J., Pérez, G., Solé, C., Castell, A., & Cabeza, L. F. (2016). Thermal assessment of extensive green roofs as passive tool for energy savings in buildings. *Renewable Energy*, *85*, 1106–1115. https://doi.org/10.1016/j.renene.2015.07.074

Critcher, C., & Gladstone, B. (1998). Utilizing the Delphi technique in policy discussion: a case study of a privatized utility in Britain. *Public Administration*, *76*(3), 431–449. https://doi.org/10.1111/1467-9299.00110

Dahiru, D., Dania, A. A., & Adejoh, A. (2014). An investigation into the prospects of green building practice in Nigeria. *Journal of Sustainable Development*, *7*(6), 158–167. https://doi.org/10.5539/jsd.v7n6p158

Durmus-pedini, A., & Ashuri, B. (2010). *An Overview of the Benefits and Risk Factors of Going Green in Existing Buildings*. *1*(1), 1–15.

Farooq, S., & Yaqoob, I. (2019). Awareness towards efficiency of green and conventional building materials used in Pakistan. *Proceedings of the Pakistan Academy of Sciences: Part B*, *56*(3), 59–68.

Gallo C, Sala M, S. A. M. . (1998). *Architecture Comfort and Energy*. *February*, 234.

Girometta, C., Picco, A. M., Baiguera, R. M., Dondi, D., Babbini, S., Cartabia, M., Pellegrini, M., & Savino, E. (2019). Physico-mechanical and thermodynamic properties of mycelium-based biocomposites: A review. *Sustainability (Switzerland)*, *11*(2). https://doi.org/10.3390/su11010281

Guntekin, E., & Karakus, B. (2008). Feasibility of using eggplant (Solanum melongena) stalks in the production of experimental particleboard. *Industrial Crops and Products*, *27*(3), 354–358. https://doi.org/10.1016/j.indcrop.2007.12.003

Guo, H. F., Ge, J., Yue, M., Zhou, X., & Jin, W. (2010). Landscape design method for a green community based on green building design theory. *Journal of Zhejiang University: Science A*, *11*(9), 691–700. https://doi.org/10.1631/jzus.A1000241

Gurjar, R. M. (1993). Effect of different binders on properties of particle board from cotton seed hulls with emphasis on water repellency. *Bioresource Technology*, *43*(2), 177–178. https://doi.org/10.1016/0960-8524(93)90179-F

Habibi, A., Sarafrazi, A., & Izadyar, S. (2014). Delphi Technique Theoretical Framework in Qualitative Research. *The International Journal Of Engineering And Science (IJES)* ||, 8–13.

Hamza, S., Jamal, A. H. B. M., Kamin, Y. Bin, Al-Rahmi, W. M., Kosnin, A., Saud, M. S., Suhairom, N., Yahya, N., & Nordin, M. S. (2019). Assimilating Green Skills in Building Construction Programme: Crucial to Realizing Environmental Sustainability. *IEEE Access*, *7*, 125214–125224. https://doi.org/10.1109/ACCESS.2019.2933658

Hasson, F., & Keeney, S. (2011). Enhancing rigour in the Delphi technique research. *Technological Forecasting and Social Change*, *78*(9), 1695–1704. https://doi.org/10.1016/j.techfore.2011.04.005

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*, *32*(4), 1008–1015. https://doi.org/10.1046/j.1365-2648.2000.t01-1-01567.x

He, B. J. (2019). Towards the next generation of green building for urban heat island mitigation: Zero UHI impact building. *Sustainable Cities and Society*, *50*(di), 101647. https://doi.org/10.1016/j.scs.2019.101647

Henderson, H. (2012). *Becoming a green building professional a guide to careers in sustainable architecture, design, engineering, development, and operations*. John Wiley & Sons.

Hsu, C. C., & Sandford, B. A. (2007). Minimizing non-response in the Delphi process: How to respond to non-response. *Practical Assessment, Research and Evaluation*, *12*(17).

Hu, H., Geertman, S., & Hooimeijer, P. (2014). Green Apartments in Nanjing China: Do Developers and Planners Understand the Valuation by Residents? In *Housing Studies* (Vol. 29, Issue 1, pp. 26–43). Taylor & Francis. https://doi.org/10.1080/02673037.2014.848268

Huhu, H., Geertman, S., & Hooimeijer, P. (2015). Planning support in estimating green housing opportunities for different socioeconomic groups in Nanjing, China. *Environment and Planning B: Planning and Design*, *42*(2), 316–337. https://doi.org/10.1068/b130192p

Irvin, T. R., Appel, P. A., Mcentire, J. M., & Rabon, J. C. (2009). Kyoto comes to Georgia: How international environmental initiatives foster sustainable commerce in small-town America. *Georgia Journal of International and Comparative Law*, *36*(3), 559-613.

Jannat, N., Hussien, A., Abdullah, B., & Cotgrave, A. (2020). Application of agro and non-agro waste materials for unfired earth blocks construction: A review. *Construction and Building Materials*, *254*, 119346. https://doi.org/10.1016/j.conbuildmat.2020.119346

Karteris, M., Theodoridou, I., Mallinis, G., Tsiros, E., & Karteris, A. (2016). Towards a green sustainable strategy for Mediterranean cities: Assessing the benefits of large-scale green roofs implementation in Thessaloniki, Northern Greece, using environmental modelling, GIS and very high spatial resolution remote sensing data. *Renewable and Sustainable Energy Reviews*, *58*, 510–525. https://doi.org/10.1016/j.rser.2015.11.098

Keeney, S., Hasson, F., & McKenna, H. P. (2001). A critical review of the Delphi technique as a research methodology for nursing. *International Journal of Nursing Studies*, *38*(2), 195–200. https://doi.org/10.1016/S0020-7489(00)00044-4

Khedari, J., Nankongnab, N., Hirunlabh, J., & Teekasap, S. (2004). New low-cost insulation particleboards from mixture of durian peel and coconut coir. *Building and Environment*, *39*(1), 59–65. https://doi.org/10.1016/j.buildenv.2003.08.001

Kim, C. H., & Yeo, K. (2018). Beyond consensus: A review of Delphi research published in Malaysian social science journals. *International Journal of Business and Society*, *19*(S2), 312–323.

Kim, J., Rigdon, B., Intern, P., Graves, J., Intern, P., Planning, U., & Arbor, A. (1998). *Sustainable Architecture Module: Qualities,Qualities , Use , and Examples of Sustainable Building Materials* (J. Graves & P. Intern (eds.)). National Pollution Prevention Center for Higher Education.

Kyu-in, L., & Dong-woo, Y. (2011). Comparative study for satisfaction level of green apartment residents. *Building and Environment*, *46*(9), 1765–1773. https://doi.org/10.1016/j.buildenv.2011.02.004

Latha, P. K., Darshana, Y., & Venugopal, V. (2015). Role of building material in thermal comfort in tropical climates – A review. *Journal of Building Engineering*, *3*, 104–113.

Linstone, H. A., & Turoff, M. (1975). The Delphi Method: Techniques and Applications. *Journal of Marketing Research*, *13*(3), 317. https://doi.org/10.2307/3150755

Luamkanchanaphan, T., Chotikaprakhan, S., & Jarusombati, S. (2012). A Study of Physical, Mechanical and Thermal Properties for Thermal Insulation from Narrow-leaved Cattail Fibers. *APCBEE Procedia*, *1*(January), 46–52. https://doi.org/10.1016/j.apcbee.2012.03.009

Ludwig, B. G. (1994). *Internationalizing Extension: An exploration of the characteristics evident in a state university Extension system that achieves internationalization*. The Ohio State University.

Nandhini, V., Ambika, D., Kumar, V. S., Priya, S. D., Poovizhi, G., & Rubini, V. S. (2020). An analysis on low cost and energy efficient materials for sustainable housing. *SSRG International Journal of Engineering Trends and Technology*, *68*(2), 88–96. https://doi.org/10.14445/22315381/IJETT-V68I2P215S

Noble, A. (2013). *Vernacular Buildings a Global Survey* (Vol. 1). Bloomsbury Publishing. Cop.

Nwankwo, C. O., Bamigboye, G. O., Davies, I. E. E., & Michaels, T. A. (2020). High volume Portland cement replacement: A review. *Construction and Building Materials*, *260*, 120445. https://doi.org/10.1016/j.conbuildmat.2020.120445

Obin, P. (2020). *FG to guarantee 1.5m Nigerian families to own low income houses under Economic Sustainability Plan (ESP)*. 5.

Odebiyi, S. O., Suneetha, S., & K., B. A. (2010). Green Architecture: Merits for Africa (Nigerian Case Study). *Journal of Alternative Perspectives in the Social Sciences*, *2*(2), 746–767.

Office of Energy Efficiency & Renewable Energy -EERE. (2015). Open Data Catalog Buildings Energy Data Book. *US Department of Energy*, *2011*, 2011.

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information and Management*, *42*(1), 15–29. https://doi.org/10.1016/j.im.2003.11.002

Osofsky, H. M., & Levit, J. K. (2008). The Scale of Networks?: Local Climate Change Coalitions. *Chicago Journal of International Law*, *8*(2).

Pisello, A. L., Piselli, C., & Cotana, F. (2015). Thermal-physics and energy performance of an innovative green roof system: The Cool-Green Roof. *Solar Energy*, *116*, 337–356. https://doi.org/10.1016/j.solener.2015.03.049

Pivo, G. (2008). Responsible property investment criteria developed using the Delphi Method. *Building Research and Information*, *36*(1), 20–36. https://doi.org/10.1080/09613210701574795

Rachtanapun, A. (2010). Effects of blended starch adhesive contents and particle sizes of tamarind hulls on

properties of particleboard . *Proceedings of 48th Kasetsart University Annual Conference: Agro-Industry, February 3-5, Bangkok, Thailand.*, 117-123.
Rahim, M. H. B. A. (2017). *The Green preferences of office tenants in Malaysia*. Universiti Teknologi Malaysia.
Rahman, A., Srikumar, V., & Smith, A. D. (2018). Predicting electricity consumption for commercial and residential buildings using deep recurrent neural networks. *Applied Energy*, *212*(October 2017), 372–385. https://doi.org/10.1016/j.apenergy.2017.12.051
Retzlaff, R. C. (2009). Green buildings and building assessment systems: A new area of interest for planners. *Journal of Planning Literature*, *24*(1), 3–21. https://doi.org/10.1177/0885412209349589
Sampathrajan, A., Vijayaraghavan, N. C., & Swaminathan, K. R. (1992). Mechanical and thermal properties of particle boards made from farm residues. *Bioresource Technology*, *40*(3), 249–251. https://doi.org/10.1016/0960-8524(92)90151-M
Saurabh, K. S. and J. K. (2019). *An Overview of Advantages and Disadvantages of Autoclaved Aerated Concrete Review of Autoclaved Aerated Concrete : - Advantages and Disadvantages*. *March*.
Sekaran, U., & Bougie, R. (2009). *Research methods for business: a skill building approach* (5th ed.). John Wiley & Sons Ltd.
Shanthi Priya, R., Sundarraja, M. C., & Radhakrishnan, S. (2012). Comparing the thermal performance of traditional and modern building in the coastal region of Nagappattinam, Tamil Nadu. *Indian Journal of Traditional Knowledge*, *11*(3), 542–547.
Shaw, A. (2009). Town planning in postcolonial India, 1947-1965: Chandigarh re-examined. *Urban Geography*, *30*(8), 857–878. https://doi.org/10.2747/0272-3638.30.8.857
Sproul, J., Wan, M. P., Mandel, B. H., & Rosenfeld, A. H. (2014). Economic comparison of white, green, and black flat roofs in the United States. *Energy and Buildings*, *71*, 20–27. https://doi.org/10.1016/j.enbuild.2013.11.058
Swan, L. G., & Ugursal, V. I. (2009). Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. *Renewable and Sustainable Energy Reviews*, *13*(8), 1819–1835. https://doi.org/10.1016/j.rser.2008.09.033
UN's Brundtland Commission Report. (1987). *Our common future*. https://doi.org/10.2307/3147240
UNEP. (2011). Cities: investing in energy and resource efficiency Book section. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*, 453–492.
United Nations Environment Programme -UNEP, A. R. (2009). *Environment for Development: Annual Report*.
Van Der Lugt, P., Vogtländer, J. G., Van Der Vegte, J. H., & Brezet, J. C. (2015). Environmental Assessment of Industrial Bamboo Products - Life Cycle Assessment and Carbon Sequestration. *10th World Bamboo Congress*, 1–16.
Vandermeulen, V., Verspecht, A., Vermeire, B., Van Huylenbroeck, G., & Gellynck, X. (2011). The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landscape and Urban Planning*, *103*(2), 198–206. https://doi.org/10.1016/j.landurbplan.2011.07.010
Weinstein, B. D. (1993). What is an Expert? *Theoretical Medicine*, *14*, 57–73.
Yakub, A. A, Salawu, A. O., Gimba, S. D., Ahmad, A., & Jolaoye, A. (2017). Analysis of green building strategies for hot-dry climatic conditions in north-western cities in nigeria; lessons from Botswana, Burkina Faso & South Africa. In S. Laryae & E. Ibem (Eds.), *Proceedings of the West Africa Built Environment Research (WABER) Conference, 16-18 August* (pp. 274–289).
Yakub, Abdurraheem A, Hishamuddin, Mohd. Ali Kamalahasan, A., & Jalil, R. binti A. (2022). An analysis of the determinants of office real estate price modelling in Nigeria: using a Delphi approach. *Property Management*. https://doi.org/10.1108/PM-08-2021-0060
Zahir, M. H. M., Raman, S. N., Mohamed, M. F., Jamiland, M., & Nopiah, Z. M. (2014). The Perception of Malaysian Architects towards the Implementation of Green Roofs: A Review of Practices, Methodologies and Future Research. *E3S Web of Conferences*, *3*. https://doi.org/10.1051/e3sconf/20140301022
Zakka, W. P., Abdul Shukor Lim, N. H., & Chau Khun, M. (2021). A scientometric review of geopolymer concrete. *Journal of Cleaner Production*, *280*, 124353. https://doi.org/10.1016/j.jclepro.2020.124353
Zander, K. K., Botzen, W. J. W., Oppermann, E., Kjellstrom, T., & Garnett, S. T. (2015). Heat stress causes substantial labour productivity loss in Australia. *Nature Climate Change*, *5*(7), 647–651. https://doi.org/10.1038/nclimate2623
Zeigler, P. (2012). What is a Green Building?: Fundamental Principles of Green Building and Sustainable Site Design. In *Building Green in Pennsylvania*. Harrisburg, PA: Governor's Green Government Council (GGGC).
Zuaiter, L. (2015). *Vernacular Passive Cooling Strategies in Hot-Dry Regions of Middle East and North Africa. Sustainable Residential Buildings in U.A.E*. 57.