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APPLICATION OF GREEN BUILDING MATERIALS FOR RESIDENTIAL BUILDING CONSTRUCTION IN MINNA, NIGER STATE

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Abstract: *The study assessed the application of green building materials for residential building construction in Minna Niger State. Specifically, the study determined the level of application of organic, inorganic and composite green building materials for residential building construction in Minna, Niger State. Three research questions and three null hypotheses guided the study. A descriptive survey design was adopted for the study. The study was carried out in Minna Niger State, Nigeria. The target population for the study was 257 respondents comprising of 52 architects, 96 builders, 56 engineers and 53 quantity surveyors by construction industries in Minna Nigeria. Using simple random sampling technique was used to select 276 respondents from the population and were used for the study. A well-structured questionnaire titled "Questionnaire on Level of Adoption of Green Building Materials in Residential Building Construction (QLAGBMRBC)" was used for data collection of the study. The instrument was face validated for content by three experts; two experts from Department of Industrial and Technology Education, Building Technology option, Federal University of Technology, Minna and one expert from Department of Building Technology, Niger State College of Education Minna Niger Sate. The reliability was analysed using Cronbach Alpha formula and an overall index of 0.78 was obtained. Data collected by the instrument was analysed using mean, standard deviation and Analysis of Variance (ANOVA). The findings of the study revealed that the level of application of organic and inorganic green building materials for residential building construction were moderate with the grand mean of $\overline{\chi}_R = 2.78$ and $\overline{\chi}_R = 2.74$ respectively. The findings of the study also revealed that the level of application of composite green building materials for residential building construction was low with a grand mean ($\overline{\chi}_R = 2.48$). Based on the findings, it was recommended among others that government should organize workshops and webinars to raise awareness among builders, architects, and homeowners about the benefits, availability, and potential applications of organic green building materials in residential construction. It was also recommended that building professional bodies should train and educate their members more on the importance of using inorganic green building materials in residential construction so as to incorporate the lofty practice in their daily practices. It was further recommended that building construction stakeholders should organize workshops and seminars on environmental and health benefits of using composite green building materials in residential building construction for developers and homeowners to understand the importance of incorporating the materials in building.*

Keywords: *Application, Green Building, Green Building Materials, Residential Buildings*

Introduction

Green building is the practice of creating healthy facilities that are designed and built in a resource efficient manner, using ecological based principles. According to United States Environmental Protection Agency (USEPA, 2021) green building refers to a structure that is resource-efficient in terms of economy, utility, durability, and comfort. Green building construction reduces the use of raw materials and labour, reduces energy and water consumption, and, as a result, reduces the release of dangerous pollutants into the environment (McMahon *et al.,* 2018). However, the conventional architectural practice in Nigeria overlooks the interrelationships between a building, its materials and components usage and the environment. This makes building consume more resources, causing an undesirable effect on the environment and creating a tremendous amount of waste. It subsequently results in buildings that are expensive to operate in terms of energy and water consumption and contribute to buildings having poor indoor air quality. Thus, in order to put these to bear, there is need for the adoption of green building materials.

Green building materials (GBMs) are sustainable and environmentally friendly products used in construction and building projects. Green building materials are any materials that consist of a fraction of positive eco-friendly distinctive quality (USEPA, 2021). According to Mehta and Sharma (2014), green building materials stimulate the preservation of deteriorating non-renewable materials. These materials are designed to reduce the environmental impact throughout their life cycle, from extraction or production to disposal or recycling. Green construction practices provide safe and affordable homes (Abimbola, 2022), and it helps to achieve high-performance buildings. The main barriers for extensive adoption of green buildings materials and technology in residential building in Nigeria includes higher initial costs of green building materials, limited knowledge and skills on the part of subcontractors, interest and market demand, (Darko, *et al.,* 2017), lack of knowledge and awareness of green building materials and their benefits as well as resistance to change (Chan, *et al.,* 2019). These green building materials are classified into three groups named; composite green building materials, inorganic green building materials and organic green building materials.

Organic green building materials are materials that are sourced from natural and renewable resources, with minimal processing, and have a lower impact on human health and the environment. These materials help reduce reliance on non-renewable resources, minimize environmental impact, improve indoor air quality, and promote a healthier and more sustainable built environment (Julius, 2023). Organic green building materials align with the trend for biophilic design, helping architects create buildings that bring humans closer to nature, just like inorganic green building materials. Inorganic green building materials are materials that are derived from non-living sources, such as minerals and metals. According to USAPA (2021) inorganic green building materials are materials that are derived from non-living sources and have minimal impact on the environment. These materials focus on sustainability, energy efficiency, and reduced environmental impact. Goodman *et al.* (2020) revealed that inorganic materials have high thermal stabilities, unique physicochemical properties and diverse nanostructures, making them highly desirable in various heterogeneous adsorption and catalytic applications just as in composite green building materials.

Composite green building materials are materials made by combining two or more different components to create a new material that possesses unique properties and features. These materials are often designed to be environmentally friendly and sustainable. Composite green building materials focus on utilizing sustainable and recycled components while maintaining desired performance characteristics (USEPA, 2021). The application of these materials in building construction help reduce environmental impact, conserve natural resources, and promote energy efficiency in construction and residential building operations. Darko, *et al.* (2017) reported that higher costs of green building materials are one of the main barriers for extensive adoption of green buildings materials and technology in the construction industries. Fithian and Sheets (2019) added that about 30% of recently residential buildings suffer from sick building syndrome because of poor adoption of green building materials which exposes occupants to unhealthy environmental conditions. Hence, it is in the light of these problems in buildings that this study sought to determine the application of green building materials in residential buildings in Minna, Niger State.

Statement of the Problem

Residential buildings provide occupants with conducive, safe, comfortable, healthy and secured indoor environment to carry out different kinds of activities ranging from work, study, leisure and family life to social interactions. They are designed primarily for housing people, providing living spaces and amenities for private occupancy (Nord, 2017). Residential buildings are expected to provide shelter for people the in urban, suburban, and rural areas to live, sleep, and carry out their daily activities (Verghese, 2023).

However, in Niger state residential buildings face excessive heat, flooding, erosion, acid rain and harsh climate weather which causes residential the walls of residential buildings to easy wear-away of (Francis, *et al.* 2023). Due to the adverse effect of these climate changes, residential buildings experience corrosive roofs, exposed foundation, damaged, stained walls, and dampness, which leads to sick building syndrome which in turn exposes occupants to unhealthy environmental conditions. In Nigeria, according to BEEC, the demand for buildings, ventilation and the cooling of residential buildings accounts for up to 29% of energy use. As more residential buildings are being added to the housing stock and, bearing in mind the country's hot climate, the energy efficiency of buildings needs to be thoroughly considered going forward in order to prevent unsustainable energy demands for cooling. The residential buildings in Niger State consume more resources, causing an undesirable effect on the environment and creating a tremendous amount of waste. This subsequently results in buildings that are expensive to operate in terms of energy and water consumption and contribute to buildings having poor indoor air quality. With practice of green building been recognized to reduce or eliminate the negative impact of climate changes on residential buildings, there was need for this study to determine the application of green building materials in residential buildings in Minna, Niger State.

Purpose of the Study

The purpose of this study was to assess the application of green building materials in residential building construction in Minna, Niger State. Specifically, the objectives were to determine the:

1. Level of application of organic green building materials in residential building construction in Minna, Niger State.
2. Level of application of inorganic green building materials in residential building construction in Minna, Niger State.
3. Level of application of composite green building materials in residential building construction in Minna, Niger State.

Research Questions

The following research questions were formulated to guide the study:

1. What is the level of application of organic green building materials in residential building construction in Minna, Niger State?
2. What is the level of application of inorganic green building materials in residential building construction in Minna, Niger State?
3. What is the level of application of composite green building materials in residential building construction in Minna, Niger State?

Hypotheses

The following null hypotheses were formulated to guide the study and was be tested at 0.05 level of significance.

H0₁: There is no significant difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of organic green building materials in residential building construction in Minna, Niger State.

H0₂: There is no significant difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of inorganic green building materials in residential building construction in Minna, Niger State.

H0₃: There is no significant difference in the mean response of architects, quantity surveyors, builders and engineers on the level of application of composite green building materials in residential building construction in Minna, Niger State.

Methodology

Descriptive survey design was adopted for this study. This is because it involves the use of structured questionnaire developed from the review of related literature to determine the opinion and perception of the respondents. The population for this study was 229 respondents comprising of 93 Architects, 77 Contractors and 59 Development control officers. A well-structured questionnaire consisting of 57 items was used to solicit information from architects, contractors and development control officers for the purpose of generalization. The instrument was designed on a four-point scale of Strongly Agreed (SA)/High Extent (HE), Agreed (A)/Moderate Extent (ME), Disagreed (D)/Low Extent (LE) and Strongly Disagreed (SD)/Very Low Extent (VLE) with numerical values of 4, 3, 2, and 1 respectively. The instrument was subjected to content and face validation by three experts; two from construction industries in FCT, Abuja, and one from Industrial and Technology Education Department, Federal University of Technology, Minna. The instrument was pilot tested using 15 subjects (building professionals) from building industries in FCT Abuja. Cronbach's Alpha statistical technique was used to calculate the reliability coefficient of the three sections of the instrument, which was found to be 0.87, 0.75 and 0.81. The overall coefficient value of the instrument was 0.81, which indicated that the instrument was reliable and considered appropriate for use. The data were analysed using mean and standard deviation. The data collected was analyzed using mean, standard deviation and Analysis of Variance (ANOVA). Mean and standard deviation were used to answer the research questions while Analysis of Variance (ANOVA) was used to test the null hypotheses at 0.05 level of significance.

Results

Table 1: Mean and Standard Deviation of Respondents on the level of application of organic green building materials for residential building construction in Minna, Niger State

S/N	ITEMS	$\overline{X}_R$	SD	Remarks
1	Wood Timber	3.54	0.59	HL
2	Bamboo	3.17	0.57	ML
3	Cork	3.07	0.62	ML
4	Straw bales	3.01	0.64	ML
5	Hempcrete	3.04	0.67	ML
6	Linoleum	3.05	0.66	ML
7	Wool insulation	2.72	0.76	ML
8	Coconut coir	2.58	0.84	ML
9	Seagrass	2.56	0.80	ML
10	Jute	2.83	0.62	ML
11	Rice husks	2.46	0.70	LL
12	Cotton insulation	2.81	0.84	ML
13	Terrazzo	2.93	0.65	ML
14	Recycled paper insulation	2.77	0.60	ML
15	Sunflower seed board	2.77	0.76	ML
16	Mycelium	2.94	0.64	ML
17	Pine bark	2.51	0.72	ML
18	Cattail reeds	2.49	0.76	LL
19	Water reed	2.46	0.81	LL
20	Sisal	2.62	1.64	ML
21	Kenaf	2.44	0.76	LL
22	Sheep's wool	2.84	0.71	ML
23	Algal bioplastic	2.40	0.74	LL
24	Rammed earth	2.80	0.75	ML
25	Limestone	2.65	0.79	ML
	Grand Mean/SD	**2.78**	**0.75**	**Moderate Level**

Note: N = Number of respondents; $\overline{X}_R$ = Mean; SD = Standard Deviation; HL = High Level; ML = Moderate Level

The results in Table 1 showed the mean responses and standard deviation of the respondents on the 25 items posed to determine the level of application of organic green building materials for residential building construction in Minna, Niger State with a grand mean of 2.78. This implies that the level of application of organic green building materials for residential building construction was moderate. The standard deviation of the items ranges from 0.57 – 1.64, which means that 25 items had their standard deviation less than 1.96, indicating that the respondents, were close to one another in their responses.

Table 2: Mean and standard deviation of respondents on the level of application of inorganic green building materials for residential building construction in Minna, Niger State.

S/N	ITEMS	$\bar{X}_R$	SD	Remarks
1	Recycled concrete	3.02	0.71	ML
2	Steel	3.12	0.55	ML
3	Glass	2.67	0.69	ML
4	Aluminum	3.35	0.61	ML
5	Brick	2.98	0.67	ML
6	Roofing Shingles	3.06	0.65	ML
7	Stone	2.83	0.72	ML
8	Ceramic tiles	2.44	0.76	LL
9	Luminescent Cement	2.65	0.76	ML
10	Precast Concrete Slabs	2.62	0.64	ML
11	Terracotta	2.55	0.70	ML
12	Porcelain	2.74	0.78	ML
13	Geopolymer Concrete	2.59	0.70	ML
14	Wrought iron	2.72	0.63	ML
15	Metal studs	2.79	0.70	ML
16	Fiber cement board	2.61	0.68	ML
17	Zinc	2.51	0.72	ML
18	3D Printed Concrete	3.22	0.73	ML
19	Smart Glass Windows	2.37	0.81	LL
20	Silica	2.60	0.70	ML
21	Gypsum	2.71	0.69	ML
22	Recycled concrete	2.51	0.75	ML
23	Solar Panels	2.37	0.67	LL
24	Roman self-healing concrete	2.76	0.72	ML
	Grand Mean/SD	**2.74**	**0.70**	**Moderate Level**

Note: N = Number of respondents; $\bar{X}_R$ = Mean; SD = Standard Deviation; ML = Moderate Level; LL = Low Level

Table 2 showed the mean responses and standard deviation of the respondents on 24 items posed to determine the level of application of inorganic green building materials for residential building construction in Minna, Niger State. The mean of individual items ranged from 2.37 to 3.35 resulting to a grand mean of 2.74. Based on the stated criteria for real limit of numbers, this implies that the level of application of inorganic green building materials for residential building construction is moderate. The average standard deviation obtained was 0.70 indicating that the responses of the respondents were close to each other. No standard deviation was above the normal standard deviate of 1.96.

Table 3: Mean and Standard Deviation of Respondents on the level of application of composite green building materials for residential building construction in Minna, Niger State.

N = 257

S/N	ITEMS	$\bar{X}_R$	SD	Remarks
1	Recycled plastic lumber	3.28	0.63	ML
2	Wood-plastic composite (WPC)	2.45	0.69	LL
3	Engineered wood	3.09	0.58	ML
4	Fiber-reinforced polymers (FRP)	2.45	0.79	LL
5	Recycled glass countertops	2.42	0.82	ML
6	Paper stone (recycled paper composite)	2.36	0.71	LL
7	Engineered bamboo	2.31	.691	LL
8	Recycled rubber tiles	2.41	0.81	LL
9	Bio-based composites	2.39	0.80	LL
10	Green concrete (incorporating recycled materials)	2.34	0.72	LL
11	Composite decking (made from recycled materials)	2.25	0.75	LL
12	Recycled metal composites	2.83	0.84	ML
13	Thermal insulation composites	2.73	0.65	ML
14	Recycled ceramic tiles	2.71	0.76	ML
15	Composite roofing materials	2.48	0.70	LL
16	Hemp plastic composites	2.31	0.64	LL

17	Plyboo (bamboo plywood)	2.35	0.79	LL
18	Fiberglass-reinforced panels (FRP)	2.48	0.76	LL
18	Composite wall panels (recycled content)	2.46	0.80	LL
20	Recycled aluminum composite panels	2.62	0.97	ML
21	Composite doors (incorporating sustainable materials)	2.43	0.75	LL
22	Coir composite boards	2.47	0.75	LL
23	Sustainable fiberglass	2.40	0.74	LL
24	Straw-plastic composites	2.43	0.74	LL
25	Composite windows and frames	2.67	0.80	ML
	Grand Mean/SD	**2.48**	**0.75**	**Low Level**

Note: N = Number of respondents; $\bar{X}_R$ = Mean; SD = Standard Deviation; ML = Moderate Level; LL = Low Level

Table 4.3 showed the mean responses and standard deviation of the respondents on 25 items posed to determine the level of application of composite green building materials for residential building construction in Minna, Niger State. The mean of individual items ranged from 2.25 to 3.28 resulting to a grand mean of 2.48. Based on the stated criteria for real limit of numbers, this implies that the level of application of composite green building materials for residential building construction is low. The average standard deviation obtained was 0.75 indicating that the responses of the respondents were close to each other. No standard deviation was above the normal standard deviate of 1.96.

Table 4: One-way analysis of variance summary table showing the difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of organic green building materials for residential building construction in Minna, Niger State.

	Sum of Squares	df	Mean Square	F	Sig.	Remark
Between Groups	28.291	3	9.430	223.30	.008	SD
Within Groups	10.685	254	.042			
Total	38.976	257				

(P<0.05) SD = Significant Difference

Table 4 revealed that there was significant difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of organic green building materials for residential building construction. This is supported by the hypothesis $F(3, 254) = 223.30$, $p = .008$. The mean and standard deviation for architects was 2.55 and 0.17 respectively. Similarly, the mean and standard deviation for quantity surveyors was 3.42 and 0.26. More so, the mean and standard deviation for engineers was 2.73 and 0.13. In addition, the mean and standard deviation for builders was 2.57 and 0.22 respectively. Hence, the null hypothesis (Ho_1) was rejected. This means that there was significant difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of organic green building materials for residential building construction in Minna, Niger State. The post-hoc test is showed in Table 5.

Table 5 - Post Hoc Turkey HSD Test showing the significant difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of organic green building materials for residential building construction in Minna, Niger State

(I) Designation	(J) Designation	Mean Difference (I-J)	Std. Error	Sig.
Architects	Quantity Surveyors	0.028	0.039	0.887
	Engineers	0.499*	0.039	0.000
	Builders	0.023	0.035	0.912
Quantity Surveyors	Architects	-0.029	0.039	0.887
	Engineers	0.471*	0.039	0.000
	Builders	-0.006	0.035	0.998
Engineers	Architects	-0.499*	0.039	0.000
	Quantity Surveyors	-0.470*	0.039	0.000
	Builders	-0.476*	0.035	0.000
Builders	Architects	-0.023	0.035	0.912
	Quantity Surveyors	0.006	0.035	0.998
	Engineers	0.476*	0.034	0.000

*. The mean difference is significant at the 0.05 level.

From Table 5, the Post Hoc Turkey HSD test shows that there was no statistical difference between the mean responses of Quantity Surveyors and Architects (P = 0.88); Builders and Architects (P= 0.91); as well as Builders and Quantity Surveyors (P = 0.99). However, there was significant difference in the mean responses of Architects, Quantity Surveyors and Builders (P = .001) as well as Engineers (P = .001) as regards the level of application of organic green building materials for residential building construction in Niger State. This could be because of poor connection and communication between these construction stakeholders.

Table 6: One-way analysis of variance summary table showing the difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of inorganic green building materials for residential building construction in Minna, Niger State.

	Sum of Squares	df	Mean Square	F	Sig.	Remark
Between Groups	25.744	3	8.581	326.33	.001	SD
Within Groups	6.653	254	.026			
Total	32.397	257				

(P<0.05) SD = Significant Difference

Table 6 revealed that there was significant difference in the mean responses of architects, quantity surveyors, builders and engineers as regards level of application of inorganic green building materials for residential building construction. This is supported by the hypothesis F (3,254) = 326.33, p = .001. The mean and standard deviation for Architects was 2.53 and 0.13 respectively. The mean and standard deviation for Quantity Surveyors was 3.35 and 0.24 respectively. Similarly, the mean and standard deviation for Engineers was 2.69 and 0.13. In addition, the mean and standard deviation for Builders was 2.55 and 0.14 respectively. Hence, null hypothesis two was rejected. This means that there was significant difference in the mean responses of Architects, Quantity Surveyors, Builders and Engineers on the level of application of inorganic green building materials for residential building construction. The post-hoc test is showed in Table 7.

Table 7 - Post Hoc Turkey HSD Test showing the significant difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of inorganic green building materials for residential building construction in Minna, Niger State

(I) Designation	(J) Designation	Mean Difference (I-J)	Std. Error	Sig.
Architects	Quantity Surveyors	-0.821*	0.032	0.001
	Engineers	-0.169*	0.031	0.001
	Builders	-0.017	0.028	0.928
Quantity Surveyors	Architects	0.821*	0.032	0.001
	Engineers	0.652*	0.031	0.001
	Builders	0.804*	0.028	0.001
Engineers	Architects	0.169*	0.031	0.001
	Quantity Surveyors	-0.652*	0.031	0.001
	Builders	0.152*	0.027	0.001
Builders	Architects	0.017	0.028	0.928
	Quantity Surveyors	-0.804*	0.028	0.001
	Engineers	-0.152*	0.027	0.001

*. The mean difference is significant at the 0.05 level.

From Table 7, the Post Hoc Turkey HSD test showed that there was no significant difference between the mean responses of Architects and Builders (P = 0.93). However, there was significant difference in the mean responses of Quantity Surveyors and Engineers (P = 0.001) on the level of application of inorganic green building materials for residential building construction in Minna, Niger State. This could be because of poor connection and communication between these construction stakeholders.

Table 8: One-way analysis of variance summary table showing the difference in the mean responses the mean response of architects, quantity surveyors, builders and engineers on the level of application of composite green building materials for residential building construction in Minna, Niger State.

	Sum of Squares	df	Mean Square	F	Sig.	Remark
Between Groups	38.368	3	12.789	263.85	.001	S
Within Groups	12.263	254	.048			
Total	50.632	257				

(P<0.05) S = Significant

Table 8 revealed that there was no significant difference in the mean responses of architects, quantity surveyors, builders and engineers on the level of application of composite green building materials for residential building construction. This is supported by the hypothesis F (3,254) = 263.85, p = .001. The mean and standard deviation for architects was 2.29 and 0.12 respectively. The mean and standard deviation for quantity surveyors was 3.35 and 0.32 respectively. Similarly, the mean and standard deviation for Engineers was 2.50 and 0.16. In addition, the mean and standard deviation for Builders was 2.41 and 0.22 respectively. Hence, null hypothesis two was rejected. This mean that there was significant difference in the mean responses of Architects, Quantity Surveyors, Builders and Engineers on the level of application of inorganic green building materials for residential building construction. The post-hoc test is showed in Table 9.

Table 9 - Post Hoc Turkey HSD Test

(I) Designation	(J) Designation	Mean Difference (I-J)	Std. Error	Sig.
Architects	Quantity Surveyors	-1.05258*	.04297	.001
	Engineers	-.21049*	.04240	.001
	Builders	-.11651*	.03791	.012
Quantity Surveyors	Architects	1.05258*	.04297	.001
	Engineers	.84209*	.04219	.001
	Builders	.93608*	.03768	.001
Engineers	Architects	.21049*	.04240	.001
	Quantity Surveyors	-.84209*	.04219	.001
	Builders	.09399	.03702	.056
Builders	Architects	.11651*	.03791	.012
	Quantity Surveyors	-.93608*	.03768	.001
	Engineers	-.09399	.03702	.056

*. The mean difference is significant at the 0.05 level

From Table 9, the Post-hoc Turkey HSD test showed that there was no statistical difference between the mean responses of engineers and builders since the P-value (P = 0.56) was above 0.05. However, there was significant difference in the mean responses of Quantity Surveyors and Architects regarding the level of application of organic green building materials for residential building construction since their P-value (P= .001) was less than 0.05 level of significance. This could be because of the disconnect that exist between these construction stakeholders. Further details of the Post Hoc test is shown in Appendix L page 133.

Discussion of Findings

The major findings of the study were discussed in the order of the research questions and hypotheses formulated for study.

Findings on research question one revealed that the level of application of organic green building materials; such as wood timber, bamboo, cork, straw bales, hempcrete, linoleum, wool insulation, coconut coir, seagrass, jute, rice husks, cotton insulation, terrazzo, sunflower seed board, mycelium, sunflower seed board, pine bark, sheep's wool, rammed earth, limestone among others for residential building construction were moderate. Findings on hypothesis one revealed that there was significant difference there was significant difference in the mean responses of architects, quantity surveyors, builders and engineers (P = 0.001) as regards the level of application of organic green building materials for residential building construction in Minna Niger State. The finding is in agreement with the findings of Eze *et al.* (2021) who found that the level of adoption of organic green building materials (such as natural clay and mud, stone, bricks and tile, cellulose, stray bales, grasses, limestone, and wood timber) is moderate in South-East geopolitical zone of Nigeria. Similarly, the finding supports that of Otali and Ujene (2020) who revealed that the level of adoption of sustainable practices among construction firms in Niger Delta region of Nigeria is moderate. The findings suggested that there is still more work needed in educating and training building professionals, and enforcing government regulations to drive the adoption of organic building material in residential building in Minna Niger State. It also implies that there is potential for growth in the use of organic building materials in construction projects in the state.

Findings on research question two revealed that the level of application of inorganic green building materials (recycled concrete, steel, aluminum, brick, roofing shingles, ceramic tiles, luminescent cement, precast concrete slabs, terracotta, smart glass windows, geopolymer concrete, solar panels, 3D printed concrete, porcelain, wrought iron, gypsum among others) for residential building construction were moderate. Findings on hypothesis two revealed that was significant difference in the mean responses of architects, quantity surveyors, builders and engineers (P = 0.001) as regards the level of application of inorganic green building materials for residential building construction in Minna Niger State. The finding is in agreement with the findings of Imakwu (2022) who revealed that the level of adoption of inorganic green building materials (geopolymer concrete, solar panels, 3D printed concrete, smart glass windows, and precast concrete slabs) for building construction in Abakaliki Metropolis of Ebonyi State was moderate. The findings of this study on research question one suggested that there is need to develop and implement public awareness campaigns to educate builders, architects, developers and homeowners about the benefits of using inorganic green building materials.

Findings on research question three revealed that the level of application of composite green building materials (that is; wood-plastic composite, fiber-reinforced polymers, paper stone, engineered bamboo, recycled rubber tiles, bio-based composites, green concrete, recycled metal composites, thermal insulation composites, hemp plastic composites, plyboo, straw-plastic composites, recycled metal composites, coir composite boards among others) for residential building construction is low. Findings on hypothesis three revealed that was significant difference in the mean responses of architects, quantity surveyors, builders and engineers (P = 0.001) as regards the level of application of composite green building materials for residential building construction in Minna Niger State. This finding is in line with the findings of Eze *et al.* (2021) who revealed that the level of adoption of composite green building materials (wood-plastic composite, bio-based composites, hemp plastic composites, coir composite boards, straw-plastic composites, paper stone, composite wall panels, recycled aluminum composite panels, composite decking and green concrete) is moderate in South-East geopolitical zone of Nigeria. The finding is also in conformity with the report of Julius (2023) that stated that the level of adoption of green building standards for construction works in Nigeria is still slow. The finding is also in support of the findings of Baron and Donath (2016) who revealed that level of incorporation of sustainable building materials for attaining a sustainable built environment is still very low in developing countries. The finding suggests that there is need to promote and prioritize the adoption of composite green building materials in residential building construction in Minna, Niger State.

Recommendations

The following recommendations were made for government and construction stakeholders' implementation based on the findings of this study;

1. Government should organize workshops and webinars to raise awareness among builders, architects, and homeowners about the benefits, availability, and potential applications of organic green building materials in residential construction.

2. Professional bodies should train and educate their members more on the importance of using inorganic green building materials in residential construction so as to incorporate the lofty practice in their daily practices.
3. Building construction stakeholders should organize workshops and seminars on environmental and health benefits of using composite green building materials in residential building construction for developers and homeowners to understand the importance of incorporating the materials in building.

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