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Estimating the Contribution of Various Construction Materials on Construction Waste Generation Onsite in South Eastern Nigeria

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ABSTRACT: There are many challenges arising from the generation of construction waste onsite, chief of them are environmental pollution and material loss. A number of factors can lead to the generation of construction waste. Hence, the objective of this paper was to ascertain the construction material that leads greatest onsite generation of construction waste in Nigeria using structured questionnaire to gather data from primary source by surveying fourteen most common construction materials. Results obtained revealed that timber, ceramic tiles and mortar ranked 1st , 2nd and 3rd with standard deviation of 1.14, 1.156 and 1.265; while roofing sheets, PVC water pipes and paint contributed the least 12th, 13th and 14th with a standard deviation of 1.115, 1.222 and 1.095 respectively.

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Waste has been defined as a substance with little or no value. The presence of waste in the environment often affects the ambience and beauty of that environment. Waste generation is a major problem felt throughout the globe. Kushendar *et al* (2023) opined that the amount of waste generated in any society is a measure of its population. The increase in solid waste generation throughout the globe can be attributed to urbanization and industrialization (Khan *et al*, 2022). The rate of solid waste generation is a direct function of the kind of production and consumption in the region; this implies that the more the consumption in a region, the more the waste generated. Wowrzeczka 2021 opined that municipal waste is a measure of the environmental demand and that certain characteristics of the waste generated that affect its generation rate and will depend on factors like the economy of the region in question, industrialization, and urbanization amongst others. It has been observed that there is an increase in the incidence of health as well as environmental risk owing to the fact that many semi-urban metropolis are struggling with respect to proper management of the rapidly increasing solid waste due to the teeming population Zikli *et al* (2022).There are many types of waste being generated today. Jabeen *et al* (2022) observed that the composition of the municipal solid waste generated was a pointer to the degree of development in that country; it was further observed that the composition of municipal solid waste generated in developing countries had a large chunk of organics and biodegradable materials while that of more advanced countries were made up of

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processed materials. Hasmori *et al* (2020) opined that the increase in the rate of construction waste generation can be attributed to the poor waste management practices observed in construction projects. Construction waste can be generated as a result of new construction and is a function of the amount and type of materials procured for construction and usually accounts for about 1-10% of waste generated (Low *et al*, 2020). Yu *et al* (2021) stated that in China, the construction waste generated is usually comprised of a variety of inert and non-inert materials from construction activities such as excavation, demolition, renovation etc. Many materials are used for the purposes of construction. These materials are sometimes derived from the natural environment and modified through certain industrial processes to meet their intended need. Liu *et al* (2022) opined that the production of some of these materials used for construction purposes often leads to pollution and contamination of the natural environment. Hernandes *et al* (2023) opined that construction materials can include materials used for insulation, damping, wiring piping etc A lot of materials used in construction process usually end up as construction waste; some of these materials include concrete, timber, bricks, metal etc (Hassan *et al*, 2022). Huang *et al* (2022) carried out an assessment of construction and demolition waste from railway engineering projects, from the assessments, it was opined that the material that yielded the highest amount of waste were rubble, cement and Sand. Ahmed *et al* (2021) listed sand, concrete, bricks, paints, wood, mortar etc as typical construction materials used for construction. The production of construction materials sometimes leads to the use of thermal or electrical energy. Some of these materials include cement, steel, roofing sheets etc (Maraveas, 2020). Jones *et al* (2020) opined that the continuous rate of urbanization has put significant pressure on the raw materials used in the production of construction materials such as cement, steel, wood etc.The generation of construction waste has become a global challenge that needs to be reduced to the barest minimum. This is because it leads to the environmental pollution and loss in terms of cost. Hasmori *et al* (2020) opined that the generation of construction waste can be attributed to poor management of construction activities. An evaluation of typical construction materials that lead to construction waste in Jordanian construction industry showed that sand aggregate and tiles constituted 14%, 12% and 11% of the entire waste generated while cement, steel reinforcement, blocks stones etc also contributed the generation of construction waste (Sweiss*et al*, 2021). According to the European Union, construction waste can be divided into eight, which are brick/concrete/ceramic/tile; glass/wood/plastic; coal/asphalt; metals; soils; gypsum containing construction materials and waste from other sources. (Luangcharoenrat *et al*, 2019). In a study campaigning for the adoption of prefabricated construction materials as a way of reducing construction waste in china, it was observed that although the off-cuts from steel reinforcement bars can be considered as waste, they could still be recycled.; however, construction waste generated from construction materials such as timber, mortar and concrete may not be easily recycled (Hao*et al*, 2021). Therefore, the objective of this paper was to ascertain the construction material that leads greatest onsite generation of construction waste in Nigeria.

MATERIALS AND METHODS

In this study, the primary method used for the data collection was through questionnaires. These questionnaires were prepared and distributed to high ranking professionals with reasonable experience in construction. These include site engineers, contractors and project management. The data obtained was analysed using Statistical package for social sciences (SPSS) and the construction material mentioned were ranked. The demographic area of this research was limited to south eastern part of Nigeria. The questionnaire was sent to 150 people however only about 120 responded.

RESULTS AND DISCUSSIONS

This section presents the results of the study conducted and the view of various construction professionals on the construction materials that generates the most construction waste in South east Nigeria.Mean item score for the extent to which various construction materials contribute to the generation of construction waste onsite. Table 1 reveals the respondent's ranking of the extent to which various construction materials contribute to the generation of construction waste onsite. Respondents were requested to indicate the extent to which each of the identified skills were important to industry success, using a five-point scale: 1-5 where 1 is the least and 5 the highest. From table 4.15 below, 'timber' ranked first with 79.04% (M=3.952, SD= 1.14). 'Ceramic tiles' ranked second with 70.72% (M=3.536, SD=1.156). 'Mortar ranked third with 69.04% (M= 3.452, SD=1.265). 'Concrete blocks ranked fourth with 67.62% (M=3.381, SD=1.017). 'Concrete ranked fifth with 64.28% (M=3.214, SD=1.098). 'Cement' ranked sixth with 55.48% (M=2.774, SD=1.101). 'Nails' ranked seventh with 53.58% (M=2.679, SD=1.328). 'Asphalt' ranked eight with 51.9% (M=2.595, SD=1.088). 'Fine aggregates' ranked ninth with 49.28% (M= 2.464, SD=1.123). 'Steel reinforcement' ranked tenth with 46.42% (M=2.321, SD=0.996). 'Coarse aggregate ranked eleventh with 43.52% (M=2.176, SD=1.173). 'Roofing sheets' ranked twelfth with 43.34% (M=2.167, SD=1.118). 'PVC water pipes ranked thirteenth with 40.48% (M=2.024, SD=1.222) while 'paint' ranked fourteenth with 38.58% (M=1.929, SD=1.095).

Table 1: contribution of various construction materials to the generation of construction waste onsite

construction materials	$\bar{x}$	σX	R
Timber	3.952	1.14	1
Ceramic tiles	3.536	1.156	2
Mortar	3.452	1.265	3
Concrete blocks	3.381	1.017	4
Concrete	3.214	1.098	5
Cement	2.774	1.101	6
Nails	2.679	1.328	7
Asphalt	2.595	1.088	8
Fine aggregate	2.464	1.123	9
Steel reinforcement	2.321	0.996	10
Coarse aggregate	2.176	1.123	11
Roofing sheet	2.167	1.118	12
PVC water pipes	2.024	1.222	13
Paint	1.929	1.095	14

$\bar{x}$ = Mean item score; σX = Standard deviation; R = Rank

Factor Analysis for the Contribution of Various Construction Materials to the Generation of Construction Waste Onsite. The 14 identified construction materials were subjected to principal component analysis (PCA) using the SPSS version 22 software. Prior to performing the PCA, the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of co-efficient of 0.6 and above which was suitable for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is a degree of whether the distribution of values is adequate for proceeding with factor analysis. A measure of < 0.5 is not acceptable, > 0.5 is miserable, > 0.6 is mediocre, >0.7 is fair, >0.8 is commendable and 0.9 is marvelous.

Table 2 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.757
Bartlett's Test of Sphericity	Approx. Chi-Square	535.708
	Df	91
	Sig.	.000

Table 2 presents the results of the KMO with the data returning a value sampling adequacy of 0.757. This is considered sufficient to conduct a factor analysis as any value above 0.6 (the cut-off point) is considered acceptable (Eiselen *et al.* 2007). The *p*-value of Bartlett's test of sphericity (represented by "Sig"), indicates a measure of the multivariate normality of the set of distributions. According to George and Mallery (2003), a significant value < 0.05 indicates that the data does not produce an identity matrix and are thus acceptable for factor analysis. This set of data returned a significance value of 0.000, indicating that the data was acceptable for factor analysis.

Anti-image Correlation: On the anti-image correlation table, the various measures running diagonally marked with 'a' indicate the extent to which each item is correlated to another. They are called the measures of sampling adequacy (MSA). The MSA values should exceed or be equal to 0.6 to show their efficient correlation to remain in the factor unless the researcher chooses to retain the item due to its theoretical relevance (Eiselen *et al.* 2005:112). From the anti-image correlation table, the items exceed 0.6 so it is safe to proceed with the factor analysis process.

Communalities Table: Table 3 shows the various items after extraction and should contain values above 0.3. The values as seen from the table all consists of items greater than 0.3.

Table 3: Communalities

	Initial	Extraction
MAT 1:	1.000	0.830
MAT 2:	1.000	0.830
MAT 3:	1.000	0.598
MAT 4:	1.000	0.547
MAT 5:	1.000	0.502
MAT 6:	1.000	0.638
MAT 7:	1.000	0.504
MAT 8:.	1.000	0.678
MAT 9:	1.000	0.732
MAT 10:	1.000	0.780
MAT 11:	1.000	0.406
MAT 12:	1.000	0.696
MAT 13	1.000	0.655
MAT 14	1.000	0.411

Extraction Method: Principal Axis Factoring.

Total Variance Explained: Table 4 shows the perception of the Nigerian construction industry regarding the factors influencing the generation of construction waste onsite and their respective Eigen values. The latent root or Kaiser's criterion of retaining the factors with Eigen values greater than 1.0 was employed. Hence, three factors with Eigen values exceeding 1 were retained, resulting in 4.603, 2.703, and 1.502 selected which explains 32.882 percent, 19.304 percent, and 10.730 percent of the variance respectively. This infers that the first cluster of factors accounted for 32.882 of the perception of the Nigerian construction industry regarding the factors influencing the generation of construction waste onsite. In the same vein, the second cluster of factors accounted for 19.304 percent, and the third cluster of factors accounts for 10.730 percent..

Table 4 Total variance explained

Factor	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.603	32.882	32.882	4.603	32.882	32.882
2	2.703	19.304	52.186	2.703	19.304	52.186
3	1.502	10.730	62.916	1.502	10.730	62.916
4	.983	7.021	69.938			
5	.771	5.508	75.446			
6	.695	4.963	80.409			
7	.560	4.003	84.412			
8	.501	3.575	87.987			
9	.402	2.875	90.862			
10	.377	2.690	93.553			
11	.271	1.933	95.486			
12	.247	1.765	97.251			
13	.231	1.648	98.900			
14	.154	1.100	100.000			

These three clusters of factors together have a total cumulative percentage of 62.916 percent of the total importance which highlights their significance from the twelve factors shown

Scree plot: An inspection of the scree plot on Figure 4.3 reveals a break after the fourth material. The steep slope shows the important construction materials while the gradual trailing off shows the rest of the construction materials that have an Eigen value lower than 1. The three large cluster factors which are positioned on the steep slope were retained.

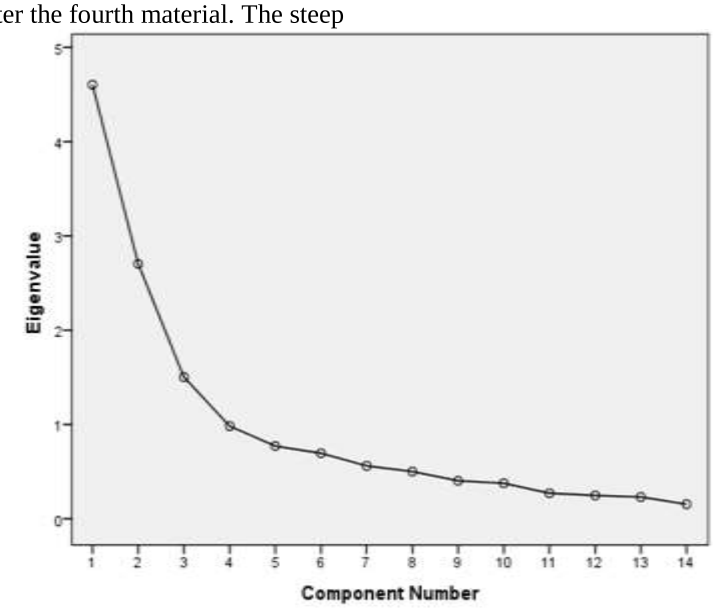

Fig 1: Scree plot for extent to which various factors affect the generation of construction waste onsite

Factor analysis reporting the contribution of various construction materials on the generation of construction waste onsite: Six items loaded onto group 1. From the summary below, it can be observed that that these six items all relate to the type of component used in producing the construction material and their influence in the generation of construction wastes onsite. This factor loads 'roofing sheet', 'paint', PVC water pipes', 'Asphalt', 'nails' and 'steel reinforcement'. These factors are fundamental in determining the constituent of these construction materials and their influence on the generation of construction waste online. Thus, they were labeled 'Metallic materials'. With a variance of 32.882% of the total variance, this set of factors was identified as the most significant construction materials that contribute to the generation of construction materials onsite. A total of six items loaded onto Factor 2. From the summary below,, these six items relate to binding properties of construction materials. This factor loads

'Ceramic tiles', 'mortar', 'concrete blocks', 'timber', 'concrete' and 'cement'. This factor was labeled 'Cementing materials or binder materials'. With a total This factor loads 'fine aggregate and coarse aggregate'. This factor was labeled 'aggregate with a total variance of 10.730%.

Summary of clusters of various construction materials and the role in generation of construction waste onsite
GROUP 1 – Metallic materials

i. MAT 10 – Roofing Sheets
ii. MAT 12- Paints
iii. MAT 3– PVC water pipe
iv. MAT 14 - Asphalt
v. MAT 11- Nails

variance of 19.304% of the total variance. From the summary below, the two items were loaded onto group 3 relate to the type of aggregate used in construction.

vi. MAT 7- Steel reinforcement

GROUP 2 – Cementing materials or binding materials

i. MAT 9 - Ceramic tiles
ii. MAT 13- mortar
iii. MAT 6- concrete blocks
iv. MAT 4– timber
v. MAT 8- concrete
vi. MAT 5- Cement

GROUP 3 – Aggregate

i. MAT 1 – Fine aggregate
ii. MAT 2- Coarse aggregate

Table 5: Contributions correlated with selected construction materials

Cluster Factor Groupings	Factor Loadings	Eigen Values	Percentage of Variance	Mean
GROUP 1 – Metallic materials		4.603	32.882	2.64
Roofing Sheets	.897			2.70
Paints	.834			2.50
PVC water pipe	.681			2.67
Asphalt	.601			2.52
Nails	.590			2.80
Steel reinforcement	.551			
GROUP 2–Cementing materials or binding materials		2.703	19.304	3.39
Ceramic tiles	.851			3.69
Mortar	.787			3.59
concrete blocks	.768			3.21
timber	.683			3.06
Concrete		0.672		3.214
Cement		0.569		2.774
***Factor 3* – Aggregate**		1.502	10.730	3.22
Fine aggregate	.907			3.71
Coarse aggregate	.799			2.73
Total variance explained			62.916	

Conclusion: Many materials used for purposes of construction still generate waste. This could be due to factors such as poor management and supervision systems as well as inefficient procurement methods. From the study results of the study presented above, it can be observed that timber, ceramic tiles and mortar are the construction materials that contribute most significantly to the generation of construction waste onsite. More studies should be carried out on other factors that lead to the generation of construction waste onsite such as procurement methods as well as management methods.

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