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**Research Paper**

# An on-site Quantification of Building Material Wastage on Construction Projects in Anambra State, Nigeria: a comparison with the Literature

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***ABSTRACT:*** *Materials are invaluable constituents of building construction works and failure to provide or ascertain reasonable allowances for their wastage during the estimating process invariably results in financial loss to the client and undue profits to the contractor. The study was aimed at ascertaining the actual percentage quantities of building materials presently wasted on construction sites in Anambra State and the major contributory factors, with a view to comparing them with the percentage waste allowance in estimating books and advancing a more realistic allowance for waste in construction estimating. To achieve this, the researchers selected five building materials which form the bulk of building material costs, namely: concrete, tiles, reinforcement bars, timber and sandcrete block on five sites systematically selected and located in Awka, the State capital for a period of four months. The materials purchased were recorded with the aid of well trained store officers, while actual quantities incorporated into the works were tracked via measurement. Based on this, it was possible to ascertain the percentages wasted on the various sites and compute the average wastes of the materials on all sites. Results revealed that timber has the highest average percentage waste, with 5.5%, followed by tiles with 3.47%; sandcrete block with 1.6%; reinforcement bars with 1.58% and finally, concrete with 1.55%. Wastage on these sites occurred mostly from handling, and the percentage waste allowances derived from site measurement were much lower than that provided in estimating literature. The study concludes that this could be as a result of improved workmanship and site management due to recent measures taken by the government to address the spates of building collapse. It was recommended that materials on site should be carefully handled, competent site managers/supervisors, artisans should be engaged on projects and strong materials management policies should be established by construction firms. The final output of this research, which is the percentage building materials waste allowance is also recommended for adoption by quantity surveyors and construction estimators to reduce pre-tender cost estimates for public and private projects and ultimately save cost for government and informal clients respectively.*

***Keywords:*** *Building material wastes, Construction project, Construction site, Quantification, Estimating, Nigeria*

## I. INTRODUCTION

Like every manufacturing concern, where conventional consumer goods are produced, the construction industry aims at using the available resources optimally in producing the best output in terms of cost and materials management since these are of great interest to the client. Building construction represents one of the most dynamic and complex industrial development the world over, involving varying forms of materials. These materials are synthesized to erect or construct structures; in fact, no field of engineering is conceivable without their use [1]; [2]. They constitute a major component of construction and contribute immensely to the quality and cost of construction, from the foundation to the finishing. The building materials industry is regarded as an important contributor to the national economy of any nation as its output governs both the rate and the quality of construction. Various researches carried out by [3], [4], [5], [6], [7] have established that materials account for as much as 50 -60% of building construction, hence it demands a serious attention, especially in view of practices which contribute to their wastage. The wastage issue can be considered a dire one, because [8], [9] maintain that wastes generated on most capital projects are generated account for more than 60% of their production costs. [10] also submit that for every 100 houses built in the UK there is enough waste material to build another 10 houses.

[4] emphasises that material wastage has a direct impact on the cost of a project, which means that any increase in materials cost of a project will lead to cost overruns by as much as 50%, which is uneconomical for the project stakeholders, especially the client. In extreme cases, excessive cost overruns could lead to project abandonment. Again, whenever large wastages on materials are recorded on sites, there will probably always be time overrun. This is so because time will be needed to procure fresh materials for finishing the works.

Furthermore, wastage of materials can lead to strained relationship between clients and contractors. This is not good for the construction industry and for the built environment at large. When the professionals and tradesmen in the building construction industry fail to carry out their various responsibilities as they should, wastages are recorded. Previous works have shown that construction personnel like the quantity surveyors, architects, builders, engineers, site operatives, site Supervisors and even manufacturers can enormously contribute to wastage of building construction materials both on and offsite (for prefabricated members). Also, poor monitoring of works on sites and nonchalant attitudes on the part of the site workers are factors that have also been identified as fuel that increase the intensity of the wastage fire [4]; [8].

The foregoing stresses the need for materials to be judiciously utilized and handled, not just on site, but during the estimation of material quantities and cost prior to commencement of the project. High margins of wastage allowed during the estimating process invariably results in high pre-tender cost estimates which is uneconomical to the client and unduly increases the contractor's profit margin. These issues raise some pertinent questions which motivated this study, such as: to what extent presently, are materials when supplied to site judiciously/effectively used or wasted? What factor(s) bring about these wastes?

## II. AIM AND OBJECTIVES

The aim of this study is to determine the percentage quantities of selected building materials wasted on construction projects/sites in Anambra State, with a view to comparing with the percentage waste allowance in estimating books and advancing a more realistic waste allowance for estimating. The following objectives formed the basis for achieving this aim:

(i) To compute the quantities of some selected building materials supplied, used and wasted on site.
(ii) To determine the relationship (in percentage) between the quantities of selected materials procured and incorporated into the works, with those actually wasted.
(iii) To ascertain the factors causing these material wastages on the surveyed projects.
(iv) To compare the percentage quantities obtained with the percentage waste allowance in estimating texts.

## III. LITERATURE REVIEW

### 3.1 Definition of Material Waste

Material waste has been defined by many writers and scholars in different ways. In each of these definitions, waste as it relates to materials used in a typical building construction site is considered a loss both to the building client and the contractors. According to [11], wastes are as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client."Construction material wastes is also defined as the by-product generated and removed from construction, demolition and renovation work places or sites of building and engineering structure" [9]. [12] defines construction material wastes as "Waste materials generated by construction activities, such as scrap damaged or spoiled materials, temporary and expendable construction materials and aids that are not included in the finished project, packaging material and waste generated by the work force". Other definitions of construction wastes include "Any material, apart from earth materials, which needs to be transported elsewhere from the construction site or used within the construction site itself for the purpose of land filling, incineration, recycling, reusing or composting, other than the intended specific purpose of the project due to material damage, excess, non-use, or non-compliance with the specifications or being a by-product of the construction process."[13]. Furthermore, "material wastage is any extra cost over and above the materials used, plus their handling as contained in the estimated price for the job" [5].

From the above definitions, the researchers re-define material wastes as materials meant for incorporation into a building or engineering work but owing to mishandling, damage or excess misapplication become unfit for the intended purpose.

**3.2 Overview of Building Material Wastage and the Implications on the Construction Industry**

An eastern Nigerian adage has it that "no one gets rich by accumulating and throwing away". How true these words are! Wastage of materials procured for building projects has led to loss of savings for many building clients and loss of profits on the part of contractors too. Thus, managing wastes on a construction site is a vital component of a sustainable building project.

The issue of material mishandling and waste has become the concern of many construction professionals and researchers all over the world. Some of them have focused on the environmental damage that results from the generation of material waste. For instance, [14] stressed the consequences of high levels of waste in both reducing the future availability of materials and energy. The Hong Kong Polytechnic and the Hong Kong Construction Association Ltd in 1993 conducted a research on construction waste aimed to reduce the generation of waste at source, and to propose alternative methods for treatment of construction waste in order to reduce the demand for final disposal areas [11]. [15] conducted a research project in the Netherlands, concerned with the measurement and prevention of construction waste, regarding sustainability requirements stated by Dutch environmental policies.

There have also been a number of studies concerned with the economic aspect of waste in the construction industry [11]. In the UK, [16] developed one of the most extensive studies on this theme. He monitored material waste in 114 building sites, concluding that there is a considerable amount of waste that can be avoided by adopting relatively simple prevention procedures. In addition, storage and handling were pointed out as major causes of waste. Most of the problems concerning waste on building sites are related to flaws in the management system, and have very little to do with the lack of qualification of workers. Furthermore, he pointed out that waste is usually caused by a combination of events, and not due to an isolated factor.

In Brazil, a number of surveys on material waste have also been developed. [17] developed a study based on one site only, pointing out the fact that indirect waste (materials unnecessarily incorporated in the building) can be higher than direct waste (rubbish that should be disposed in other areas). The first research project on construction waste developed at the Federal University of Rio Grande do Sul (UFRGS) started in April 1992. The main objective of that study was to analyze the main causes of material waste in the building industry in order to propose guidelines for controlling it in small sized firms. Seven building materials were monitored in five different sites during a period ranging from five to six months. [18] presents a detailed description of this study.

More recently, a much more ambitious research project carried out by [19] on material waste measurement was developed for the Brazilian construction industry. It was a two year study, co-ordinated by the Brazilian Institute for Technology and Quality in Construction (ITQC), involving 15 universities including UFRGS) and more than one hundred building sites. Eighteen materials had their waste monitored by using a data collection method similar to that applied in the study carried out by [18].The main conclusions drawn from those two studies are as follows:

(i) The waste of building materials is far higher than the nominal figures assumed by the companies in their cost estimates;

(ii) There is a very high variability of waste indices from site to site. Furthermore, similar sites might present different levels of wastes for the same material. This indicates that a considerable portion of this wastage can be avoided;

(iii) Some companies do not seem to be concerned about material waste, since they do not apply relatively simple procedures to avoid waste on site. None of them had a well-defined material management policy or systematic control of material usage and

(iv) The lack of knowledge was an important cause of waste. Most building firms did not know the amount of waste they had before the development of the study. As in the work of [16], most causes of waste are related to flaws in the management system, and have very little to do with the lack of qualification and motivation of workers. Also, waste is usually the result of a combination of factors, rather than originated by an isolated incident.

Despite the importance of those previous studies in terms of both highlighting the importance of waste management and identifying the causes of waste, their contribution for establishing waste control systems has been relatively small for the reasons presented below:

(i) Most studies tend to focus on the waste of materials, which is only one of the resources involved in the construction process. This seems to be related to the fact that most studies are based on the conversion model, in which material losses are considered to be synonymous of waste;
(ii) Data collection is usually very expensive, involving a large team of researchers, including people who are heavily involved in monitoring the work on site. Consequently, the procedures used for controlling waste in research studies are not easily adapted in real time production control systems;
(iii) The results of such surveys take a long time to be produced, usually after the work being monitored has finished. This limits the impact of those studies in terms of corrective action;
(iv) There is relatively little involvement of people from the company in both data collection and analysis, since most waste control procedures are external to the organization. As a result, the learning process in the company resulting from those studies tends to be very limited. These reasons reflect a major limitation of such a kind of study, which refers to the fact that it offers little opportunity to build continuous improvement into processes.

[20] points out some key factors such as focus on measurable and actionable improvement, people involvement and learning that must be balanced in order to implement the new production philosophy. More reliable and faster information flows are also required when shortening production cycle time. Unfortunately, little attention has been paid on these aspects in those studies. In 1998, the U.S. Environmental Agency (EPA) estimated that 136 million tons of building-related waste is generated in the U.S. annually, which is 25% - 40% of the national solid waste stream. A 2003 update of the report shows an increase to 164,000 million tons annually of which 9% is construction waste, 38% is renovation waste, and 53% is demolition debris [12]. According to [12], Construction wastes and Demolition debris (C&D) triggers a sequence of adverse effects that are not always apparent to building professionals. These effects include loss of useful property, green house gas generation and environmental stressors associated with the production of new materials instead of using existing materials.

In their work, which formed part of the proceedings of a winter simulation conference held in 2002, [21] showed that about 1- 10% by weight of the purchased construction materials, depending on the type of material, leaves the site as wastes even though 50 – 80% of these waste materials are reusable. They also pointed out that construction companies benefit by reducing the waste generation in a number of ways, including reducing transportation, disposal cost and cost of purchasing virgin materials. They added that in terms of sustainability, the topic of management and reduction of construction wastes can be considered an issue that focuses on the danger of depletion of materials used in the construction industry such as timber, sand and gravel.

From the foregoing, it is obvious that wastes are not to be encouraged in projects in any way. To eliminate this trend from the industry, it is pertinent to identify the root causes of waste on sites. The causes of material wastages are linked to the type or category of waste. Hence it is also important to identify the classifications of waste.

**3.3 Types of Material Wastes**
[11] classifies wastes according to the nature of the wastes, as follows:
**(a) Overproduction Waste:** related to the production of a quantity greater than required or earlier than necessary. This may cause waste of materials, man-hours or equipment usage. It usually produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate. An example of this kind of waste is the overproduction of mortar or concrete that cannot be used on time.
**(b) Substitution Wastes:** monetary waste caused by the substitution of a material by a more expensive one (with an unnecessary better performance); the execution of simple tasks by an over-qualified worker; or the use of highly sophisticated equipment where a much simpler one would be enough.
**(c) Waiting time Wastes:** related to the idle time caused by lack of synchronization and leveling of material flows, and pace of work by different groups or equipments. One example is the idle time caused by the lack of material or by lack of work place available for a gang.
**(d) Transportation Waste:** concerned with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways can cause this kind of waste. It is usually related to poor layout, and the lack of planning of material flows. Its main consequences are: waste of man hours, waste of energy, waste of space on site, and the possibility of material waste during transportation.
**(e) Processing Wastes:** This is related to the nature of the processing (conversion) activity, which could only be avoided by changing the construction technology. For instance, a percentage of mortar is usually wasted when a ceiling is being plastered.

**(f) Inventories Wastes:** related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, vandalism), and monetary losses due to the capital that is tied up. It might be a result of lack of resource planning or uncertainty on the estimation of quantities.
**(g) Movement Wastes:** concerned with unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.
**(h) Production of defective products Wastes:** occurs when the final or intermediate product does not fit the quality specifications. This may lead to rework or to the incorporation of unnecessary materials to the building (indirect waste), such as the excessive thickness of plastering. It can be caused by a wide range of reasons: poor design and specification, lack of planning and control, poor qualification, lack of the team work, lack of integration between design and production, etc.
**(i) Other Types of Wastes:** waste of any nature different from the previous ones, such as burglary, vandalism, inclement weather, accidents, etc.

[22] classifies construction wastes as (i) Structural Wastes; concrete fragments, reinforcement bars, abandoned timber plates and pieces and (ii) Finishing Wastes; surplus cement mortar, broken tiles and ceramics. [23] classifies waste according to their sources. They include: design wastes, procurement wastes, handling wastes, operational wastes and residual Wastes. Construction material wastes can also be categorized as (i) avoidable wastes; those that occur due to improper handling of materials or carelessness and (ii) unavoidable wastes; those that happen due to application of materials like paint, concrete, mortar, and block. [23] further classifies wastes as (i) Direct; irreparable damage to a material and (ii) Indirect; Improper use of materials resulting to financial loss. Waste produced on the site can be classified as inert, non-hazardous, or hazardous [24].

The above classifications are based on the causes of the various classes of material wastes on building sites. Fig. 1 explains the categorization.

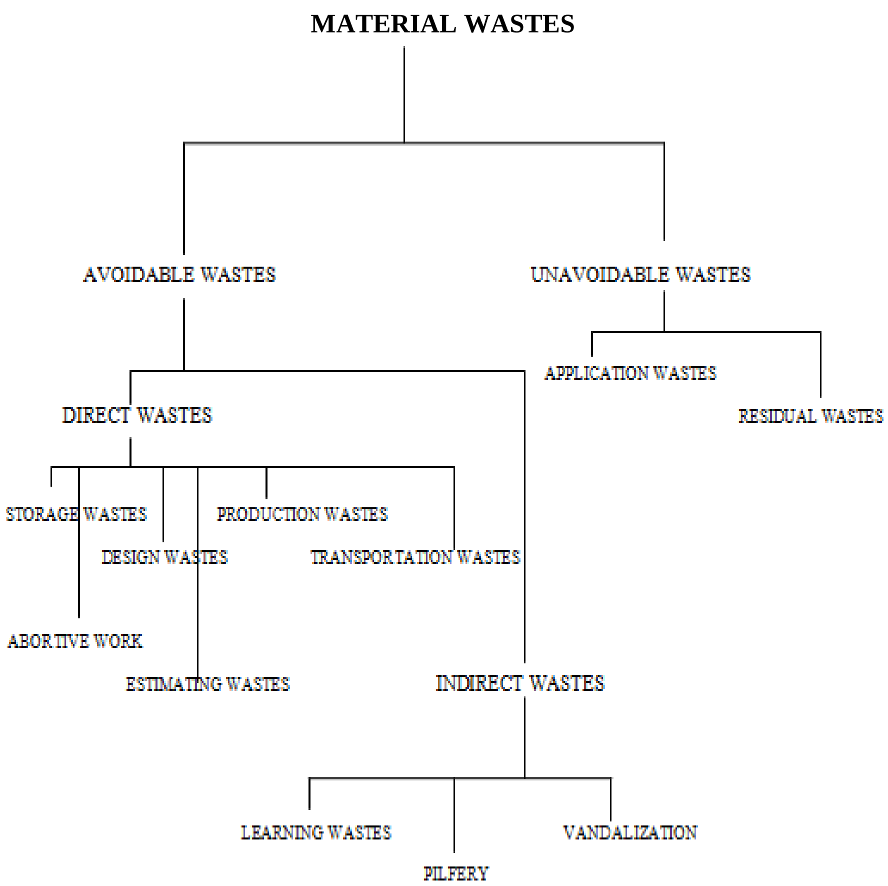

**Figure 1**. Classifications of Material Waste. Source: (Researchers' survey, 2017).

**3.4 Causes of Material Waste**

[11]; [13] explain the various causes of material wastage as follows:

**((a) Application Wastes**: This type of waste occurs own to the usage of materials in working. It also includes wastes which occur as a result of the attitude of the workers making use of the materials in working. Some major causes of application wastes include:

**(i) Incompetence of skilled men:** When incompetent or poorly skilled men are employed for work, they waste materials since they are not proficient in the application of the materials they work with. Such materials occur in the use of such materials as paints, concrete, mortar, blocks, timber, ceiling boards, roofing sheets, reinforcement bars, tiles, sanitary and electrical appliances.

**(ii) Poor Monitoring/Incompetence of Site Officer:** This factor results in wastes by condoning;

- **Poor Quality mixes:** When materials are poorly mixed, the resultant item of work delivered with such unstandardized mix will become a poor quality item of work and can easily get destroyed or damaged during use. For instance, a block molded with a poor mix of cement and sand will shatter at touch or a little awkward lift for work. In many sites, breakage of blocks is caused by this factor.
- **Carelessness of Workmen:** Site workers often handle materials carelessly. This attitude has always resulted in wastes arising from breakages, spills, wrong dimensioning and cutting of materials, damaging of freshly finished works and accidents.
- **Treachery and Nonchalance of Workmen:** Owing to poor supervision of site works, workmen intentionally waste working materials either for the purpose of avoiding work or being outright lazy. For instance, on a site where a skilled mason laying blocks is paid based on how many blocks he is able to lay per day, he may resort to carrying and laying more than he can ordinary handle, to make more money, thereby resulting in the breakages of blocks. Some unskilled workers even resort to hiding or breaking the blocks in order to increase the number of blocks they are able to lift from the store in a day.

  Furthermore, during casting of concrete elements, poorly monitored work men may mix more than the required quantity of concrete and as a result, leaving unused concrete on site which becomes useless by the next working day. In addition to this, workmen when unmonitored, haphazardly perform tasks which result in wastes. For example, at the sub-structure, unmonitored workers haphazardly compact laterite filling, which may lead to collapse when the concrete bed is finally cast.

**(b) Residual Wastes:** This refers to the remains of materials which cannot be incorporated into works due to the contamination of the material by the surfaces which it comes into contact with. When materials are deposited on or come in contact with dirty surfaces or the bare ground, it becomes difficult to separate some part of the materials in contact with the dirty surface or bare ground from the particles of dirt or sand. For instance, mixing concrete or mortar on bare soil or dirty floor, pouring paints into a dirty container leaves some of the concrete, mortar or paint unfit for use.

**(c) Storage Wastes:** This is the wastage arising from long storage period or poor storage conditions. This can bring about degeneration in quality of the materials making them unfit for use. e.g. storing cement in a humid or cold environment.

**(d) Abortive work:** These are wastes that result because of variations. When a contractor has completed a section of work before a variation order is given, he has to demolish the executed works in order to effect the variation. The demolished works constitutes a waste of materials. This kind of waste is avoidable.

**(e) Design Wastes:** This is the type of waste that arises due to poor conversion of design dimensions or misinterpretation of the design. Design waste can also occur as a result of wrong dimensioning of drawings or incomplete designs.

**(f) Transportation Wastes:** Wastes occur when materials are on transit. This can be as a result of materials (sand, gravel etc) pouring out of or leaking from the vehicle during transit, breakages owning to potholes and road bumps, accidents and poor offloading.

**(g) Estimating Wastes:** occurs when a quantity surveyor gives poor specifications or over estimates quantities.

**(h) Production Wastes:** These are wastes that occur as a result of unstandardized products that do not fit into the design.

**(i) Learning Wastes:** occurs when a 'learner' or apprentice practices with working materials and tools. This could be in the form of on – the – job training.

**(j) Pilfery:** This is an indirect material waste factor, where materials procured for works are pilfered by workmen or security men on site.

**(k) Vandalization**: Outright vandalism by known or unknown persons during periods of unrest such as riots, tribal clashes, terrorism, wars, etc also results in wastage of materials.

Other causes of material wastes include:
**(a) Unmotivated workmen:** when workmen are not motivated with good wages other welfare schemes; they will be less keen on the judicious use of working materials.
**(b) Poorly coordinated work programme:** when resources in a project programme of works are not properly scheduled and controlled, it can result to financial, material and labour wastes. More materials than necessary could be allocated to an activity and if not allocated to another activity, the excess could become wastes. This factor can also lead to untimely order/procurement of working materials which is a sure way of recording material wastes.
**(c) Poor site organization/improper positioning of materials on site:** poor site organization and improper material positioning can lead to accidents and or collisions frequently on site as well as damaging of works. It also brings about triple handling of materials. Such accidents, collisions or damages bring contribute to wastes.
**(d) Abandonment of projects:** when projects are abandoned for a long time, materials incorporated into such projects such as timber and block work deteriorates to such an extent that they may replacement when the work recommences.

According to [4], some causes of material wastes are:
**(a) Substitution:** This is an indirect cause of material wastage. It is the act of using a material meant for an item of work in executing another. Substitution occurs for three reasons viz;
(i) Because the quantity of a particular material brought to site is more than required. This results in using the material as a substitute of a similar material.
(ii) It is increasingly the practice in building to substitute materials like blocks with bricks or concrete. This is so because it is a more effective method to form a bearing surface for such elements as floors or roofs.
(iii) Facing bricks with minor defects can still be used in position as functional building units but if the damages occurred on the internal skin of walls, it will have to be covered with plaster to.
**(b) Negligence:** This is the act of using more materials than specified. This could be due to a contractor doing more than he is supposed to do or due to poor workmanship [23]; [24]. [9] provides the causes of material wastes at different phases of a project as shown in table 1.

**Table 1.** Causes of waste at different project phases

| S/N | Project Phase | Causes of waste |
|---|---|---|
| 1 | Design | Plan errors, detail errors, design changes |
| 2 | Procurement | Shipping error, ordering error |
| 3 | Materials handling | Improper storage, deterioration, improper handling (on-site or off-site) |
| 4 | Construction/renovation | Human and other labour error, equipment error, others(catastrophes, accident, weather) |
| 5 | Demolition | Tipping |

**Source: [9].**

**The following explains the items in table 1.**
**(i) Design:** carelessness at the design stage leads to excessive cutting wastes and shortages of materials on site. Architectural design and rare standard formwork can affect the constructability and assemblies of a building. Plan and detail errors as a result of time constraint can cause variations that require input of additional materials.
**(ii) Procurement:** faulty take-off or quantification, unfinished detailing and small quantity of materials required in renovation work are the main causes of over-ordering. Lack of care during transportation can result in materials damage.
**(iii) Material Handling:** lack of confined space always causes storage problem for materials. Consequently, waste results from bad stacking, rusting of steel, damaging and aging of formwork.
**(iv) Construction/Renovation:** the construction process accounts for the physical generation of waste materials. Poor supervision of site labour and sub-contractors by the main contractors can result in human error that also results in waste generation. Over-mixing and materials surplus frequently occurs for wet trades like concreting and block work. Malfunction of equipment and its use by labourers could cause damage to materials.
**(v) Demolition:** This is contrasted with deconstruction which is the pulling down of building. It is done when the structure is no longer safe to be used by the public. The tipping of materials from demolition generates a large proportion of wastes.

## IV. METHODOLOGY

This study relied on field observation and direct measurement to generate data required. Five ongoing projects were surveyed for a period of four months in Anambra State, Nigeria, as follows - Project A: Hostel development in Awka, Anambra State; Project B: Hotel development in Awka in Awka, Anambra State, Projects C, D and E: construction of a Departmental Building, a Church development and a donor funded

Building at the Federal University in Awka, Anambra State. These projects were selected via purposive sampling, primarily due to the willingness of the clients and project consultants to grant the researchers access to their materials purchase records. Awka, being the capital of Anambra is also regarded as the construction hub of the State; presently witnessing rapid development in building infrastructure. Five materials were selected for the survey, namely: concrete, timber, reinforcement bars, tiles and sandcrete block. This choice was primarily informed by their frequency of usage in construction projects in the study area.

Furthermore, the contractors, quantity surveyors, purchasing officers and store keepers, tradesmen and artisans on these project sites were interviewed to ascertain the major causes of the material wastes on site .These personnel were chosen since they are directly involved in quantification, purchase, storage and handling of the building materials. The study also employed sample mean, percentage frequency, mode and tables to analyze and present data respectively

Sample mean is expressed as follows:

$$\bar{X} = \frac{\sum X}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where: $\sum$ **X**is sum of all data values
N is total number of data items in sample

Simple percentage is expressed as:

$$\text{Simple percentage (\%)} = \frac{X}{n} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where: x is number of individual items
n is total number of items or data

## V. DATA PRESENTATION AND ANALYSIS

The following are the data gathered from the surveyed project sites.

**Project A**

**Table 2.** Quantity supplied, used and wasted, and causal factor on project A

| Item | Concrete($m^3$) | Timber($m^2$) | Reinforcement bars(kg) | Tiles($m^2$) | Sandcrete block($m^2$) |
|---|---|---|---|---|---|
| Qty supplied (A) | 563 | 2,573 | 61,273 | 1,753 | 3,197 |
| Qty used (B) | 557 | 2,509 | 59,435 | 1,669 | 3,101 |
| Qty wasted (C) | 6 | 64 | 1,838 | 84 | 96 |
| % of C to A | 1.1% | 2.5% | 3% | 5% | 3% |
| % of C to B | 1.1% | 2.6% | 3.1% | 5% | 3.1% |
| Causal Factor | Over measurement | Over estimation | Over measurement | Handling | Handling and poor quality material |

Source: (Researchers' site measurement and interview, 2017).

**Project B**

**Table 3.** Quantity supplied, used and wasted, and causal factor on project B

| Item | Sandcrete block($m^2$) | Timber($m^2$) |
|---|---|---|
| Qty supplied (A) | 100 | 756 |
| Qty used (B) | 99 | 744 |
| Qty wasted (C) | 1 | 12 |
| % of C to A | 1% | 1.6% |
| % of C to B | 1% | 1.6% |
| Causal Factor | Handling | Handling |

Source: (Researchers' site measurement and interview, 2017).

**Project C**

**Table 4.** Quantity supplied, used and wasted, and causal factor on project C

| Item | Reinforcement bars(kg) | Sandcrete block($m^2$) |
|---|---|---|
| Qty supplied (A) | 13,402.62 | 100 |
| Qty used (B) | 13,381.32 | 98.6 |
| Qty wasted (C) | 21.30 | 1.40 |
| % of C to A | 0.16% | 1.4% |

| | | |
|---|---|---|
| % of C to B | 0.16% | 1.4% |
| Causal Factor | Design | Poor quality material |

Source: (Researchers' site measurement and interview, 2017).

**Project D**

**Table 5.** Quantity supplied, used and wasted, and causal factor on project D

| **Item** | **Timber($m^2$)** | **Sandcrete block($m^2$)** | **Concrete($m^3$)** |
|---|---|---|---|
| Qty supplied (A) | 216 | 133 | 6.16 |
| Qty used (B) | 189 | 131.7 | 6.03 |
| Qty wasted (C) | 27 | 1.3 | 0.13 |
| % of C to A | 12.5% | 1% | 2% |
| % of C to B | 14.3% | 1% | 2% |
| Causal Factor | Poor quality material | Handling | Application |

Source: (Researchers' site measurement and interview, 2017).

**Project E**

**Table 6.** Quantity supplied, used and wasted, and causal factor on project E

| **Item** | **Tiles($m^2$)** |
|---|---|
| Qty supplied (A) | 27.90 |
| Qty used (B) | 27.36 |
| Qty wasted (C) | 0.54 |
| % of C to A | 1.94 |
| % of C to B | 1.97 |
| Causal Factor | Design |

Source: (Researchers' site measurement and interview, 2017).

**Table 7.** Frequency of causal factors of material wastage on the surveyed projects

| **Material** | **Poor quality** | **Handling** | **Application** | **Design** | **Over estimation** | **Over measurement** |
|---|---|---|---|---|---|---|
| Concrete | | | √ | | | |
| Tiles | | □ | | □ | | |
| Sandcrete block | □ | □<br>□<br>□<br>□ | | | | |
| Reinforcement bars | | | | □ | | □ |
| Timber | □ | □ | | | □ | |
| Total | 2 | 6 | 1 | 2 | 1 | 2 |

Source: (Researchers' field survey, 2017)

**Table 8.** Average percentage material wastage on surveyed projects

| **Mean** | **Concrete(%)** | **Sandrete block(%)** | **Reinforcement bars(%)** | **Tiles(%)** | **Timber(%)** |
|---|---|---|---|---|---|
| $\overline{x}$ (of C to A) | 1.55 | 1.60 | 1.58 | 3.47 | 5.50 |
| $\overline{x}$ (of C to B) | 1.55 | 1.60 | 1.63 | 3.49 | 6.17 |

Source: (Researchers' computation, 2017)

**Table 9.** Frequency of causal factors of material wastage on the surveyed projects

| **Causal factor** | **Frequency** |
|---|---|
| Poor quality | 2 |
| Handling | 6 |
| Application | 1 |
| Design | 2 |
| Over estimation | 1 |
| Over measurement | 2 |
| Modal Value = 6 (Handling) | |

Source: (Researchers' computation, 2017)

## VI. DISCUSSION OF RESULTS

Tables 2 to 6 show the quantities of the selected building materials supplied, used for the works and wasted on the five sites surveyed, as well as the causes of each wasted, obtained from interviews with the respondents. The computed percentage of quantities wasted, to the quantities supplied and the quantities used are also captured. A careful observation of these tables reveals that on project A, the quantities obtained were for materials quantities comprise concrete, timber, reinforcement bars, tiles and sandcrete block, for project B, the materials include sandcrete block and timber; for project C: reinforcement bars and sandcrete block; for project D: timber, sandcrete block and concrete and project E: tiles. This was because, the quantities of all five materials could not be readily quantified on all sites due to lack of accurate data on purchase and usage.

From the analysis of the data collected, the frequency table shows that handling of materials is the factor that contributes mostly to materials wastages, with a frequency of 6(*see table 7*). The study also shows that design, poor quality materials and over measurements are strong factors of materials wastage on sites with frequencies of 2 each. Other factors identified as causing waste of materials are over estimation and methods of application of these materials with the frequencies of 1, even though the frequencies show they only contribute minimally.

Table 8; which shows the average percentage material wastage on the surveyed projects, indicates that for every $1m^3$ of concrete mixed on site for use, 1.55% of it is wasted. It shows that for every 10 blocks ($1m^2$) supplied to site, 1.6% of these blocks leave the site as wastes. From the study 1.58% of every 1kg of reinforcement brought site leaves the site as waste. 3.47% of every $1m^2$ of tiles supplied to the site leaves as wastes. While 5.5% of $1m^2$ of timber supplied to the become wastes after the first use.

Furthermore, for every $1m^3$ of concrete work cast on site, 1.55% of it is wasted. The study also shows that 1.6% of every 1m2 of block work built, leaves the site as waste. It was also discovered that 1.63% of 1kg of reinforcements used on works become waste at the end of the day. The analysis further shows that 3.49% of every 1m2 of tiles used for work is disposed off the site as wastes. Finally the study confirms that 6.17% of timber used for form work becomes waste after a first usage.

### 6.1. Comparison of percentage material wastage from the study with percentage waste allowance in literature (construction estimating books)

**Table 10.** Percentage of material wasted obtained from the study and percentage of waste in literature

| Item | % from the study | % allowed in estimating books | Sources |
|---|---|---|---|
| Concrete | 1.55 | 5 | [25], [26], [27], [28], [29] |
| Tiles | 3.47 | 2.5 - 5 | [25], [26], [27], [28] |
| Sandcrete block | 1.60 | 5 - 10 | [25], [26], [27], [28] |
| Reinforcement bars | 1.58 | 5 - 10 | [25], [26], [27], [28], [30] |
| Timber | 5.50 | 2.5 - 10 | [25], [26], [27], [28] |

Source: (Researchers' field survey, 2017).

The average percentage of material waste obtained in the study was compared with the percentage allowed in literature/ estimating text books, as shown in table 10. The comparison reveals that there is a large difference between both sources. For instance, the 1.55% and 5.5% waste for concrete and timber obtained from the study is lesser that the 5% and 2.5% - 10% waste allowance respectively, as proposed by authors like [25], [26], [27], [28], [29] and [30]. A similar scenario applies to other materials surveyed. The foregoing shows that the percentage waste allowance contained in texts, for estimating or pricing of building materials especially is lesser than the actual percentage witnessed on site. This does not however rule out site peculiarities, where some materials are prone to greater wastage than others due to poor workmanship and site management. On a general note, the position of this study is that estimators or Quantity Surveyors should play down on waste allowances provided during the estimating process in order to reduce pre-tender project cost estimates and reduce financial losses for clients.

## VII. SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

**The following surmises the findings obtained in this study:**

a) The percentage relationship between the quantity of materials supplied to site and that wasted varies from one material to the other as well as from site to site.
b) The percentage relationship between the quantity of materials incorporated into work and that wasted varies from one material to the other.

c) Wastage of construction materials in some sites result mostly from the way such materials are handled on site.
d) Other major factors that contribute to material wastage on the surveyed sites are poor quality materials, over estimation and application methods.
e) Timber has the highest level of wastage on construction sites in Anambra State, with 5.5%, followed by tiles with 3.47%; sandcrete block with 1.6%; reinforcement bars with 1.58% and finally, concrete with 1.55%.
f) The percentage waste allowance for the surveyed building materials in estimating literature is higher than the actual percentage waste from site measurement.

From the foregoing, the study concludes that caution should be exercised by construction estimators in Anambra State in applying percentages for wastage in materials like concrete, tiles, timber, sandcrete block and reinforcement bars, especially in view of the fact that they are not as high as initially perceived; albeit with the exception of cutting wastes for timber. This will help reduce pre-tender cost estimates for both public and private projects and result in savings to the government and informal clients alike and increase profits for contractors and builders. Perhaps, the reduced percentage of waste established in the study when compared with literature can be attributed to improved workmanship and site management in Anambra State due to recent measures taken by the government to address the spates of building collapse.

In view of the findings of this study, the following measures are advanced;

- Care should be taken to ensure proper and careful handling of materials on sites in view of the fact that handling is the major contributory factor for material wastage.
- Competent and experienced site managers/supervisors as well as trained artisans should be engaged in construction works. The principles of the 4Rs: review, reduce, reuse and recycle should also be upheld.
- Construction firms should establish strong material management policies and sanction any contributors to any kind of waste.
- When estimating for building works during the tender process, quantity surveyors or construction estimators should play down on high percentage waste allowances for building materials and consider those derived from the study for economic reasons. Also, to ensure economy in estimating, the full percentage waste an items like timber (formwork) should be split, considering its reuse. That is; about 50% – 70% of the waste used in a previous stage should be provided for in the next stage.

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