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An Architectural Approach to Solid Waste Management on Selected Building Construction Sites in Bauchi Metropolis

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ABSTRACT

Construction waste is becoming a serious environmental problem in many cities around the world, Bauchi not being an exception. This is due to the growing in volume and complexities of modern economies. International research has also shown that building construction industry generates high volume or quantities of material waste often attributed to the lack of on-site material control. Construction and Demolition (C & D) debris frequently makes up 10 -30% of the waste received at many landfill sites, owing to the fact that contractors or captains of industries fail to adopt proper controlling procedure in what is considered an elaborate and expensive process. This paper examines the problem of waste management on construction sites in Bauchi metropolis unearthing inherent dangers material waste poses to the construction industry. Using quantitative methods, the study revealed that material wastage not only increases cost to the construction project, but also reduces the profit of the contractor, considering the cost of storing and transporting construction waste along with the loss of revenue from un-reclaimed waste. In addition, poor managerial practices and its attending awareness inadequacies are the major causes of ineffective waste management. The study finally recommended recycling and reusing of construction waste as a viable option in construction waste management, and that incentive giving to workers for good handling of materials.

Keywords: Construction and Demolition (C&D), Construction Waste Management, Green Waste Disposal, Recycling

INTRODUCTION

Waste, in solid or other forms is generated during industrial activities in which economically valuable products are supplied to end users. Waste management is the collection, transportation, processing, recycling or disposal of waste material usually one produced by human activities. Solid waste in the built environment will include construction and demolition activities of the built environment. Construction waste is defined as the byproduct removed from construction work places or sites of building and engineering structures [1]. For every 100 houses built there is enough waste material to build another 10 houses [2]. This is why Akinpelu (2007) opines that waste generated on most capital projects accounts for more than 60% of their production costs. There is a growing concern over the amount of waste generated in the construction industry, with recycling being identified as one of the most feasible way to overcome construction waste. In most cases, up to 90% of the waste generated is recyclable [3]. Recycling of construction materials can be defined as the separation and saving of recoverable waste materials generated during construction and remodeling. Packaging, new materials

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scraps, masonry materials, doors and windows are all regarded as recyclable material [4].

Most construction waste goes into landfills, thereby increasing the burden on landfill loading and operation; this practice is predominant in third world nations where a significant portion of the remaining are dumped indiscriminately. Construction activities are major sources soil and water pollution through waste sources such as solvents or chemically treated wood. Landfills are the main storage for construction waste in Nigeria [5], however, landfills are expensive and a persistent source of environmental hazards.

The proliferation of construction solid waste is an indication of development and growth of construction activities within the built environment, owing to urbanization and centralization of the society which places high value on comfort and economic growth. There have been many uncertainties surrounding actual accurate accounts of the Construction and Demolition (C&D) waste produced by the construction industry because of the highly variable nature of its generation. In the United States, the amount of waste generated from construction projects can be as high as 15% of all materials used in the project. It is estimated that residential construction generates waste upwards of $3kg/m^2$ of new construction.

The aim of this study therefore is to identify the means of construction waste management in Bauchi metropolis, examining the practice patterns of stakeholders and studying mechanism to ameliorate the associated problems including depletion of natural resources and environmental degradation. The motivation of this study stems from the general lack of environmental awareness among building industry professionals and contractors which has caused irreversible damage to the environment by indiscriminate disposal of waste materials, increasing construction costs. It is obvious that effective construction waste management must be properly implemented in a bid to stem these negative consequences. Reducing, reusing and recycling waste are profitable alternatives that will increase the lifetime of landfills, eliminate the environmental hazards of dumping, and reduce exploitation of natural resources. PoonYu and Jaillon (2004) assert that construction waste management conserves natural resources, reducing the cost of waste treatment prior to disposal. They further state that involvement of design professionals through green waste disposal would steer the construction industry in the right direction.

BACKGROUND

Construction waste consists of structural and finishing waste. Structural waste include concrete fragment, reinforcement bars, abandoned timber plate and pieces, while finishing waste include those generated during the finishing stage of a building e.g. surplus cement mortar, broken raw materials like tiles and ceramics.

Throughout the life cycle of a construction project, there are a number of factors leading to the production of wastes. The causes of waste generation can be viewed from these following five phases. They are design, procurement, materials handling, construction/renovation and demolition. [7], The waste associated with a construction site has been categorized into two principal types: direct waste or total loss of materials, and indirect waste. Indirect is distinguished from direct waste in that the materials are not usually lost physically, only the payment of part or the whole of the value. Some of the example of direct waste are as follow ;delivery waste, site storage waste , conversion waste, cutting waste , management waste, waste caused by other trades [6]. Indirect waste includes substitution waste, production waste, operational waste and negligent waste. The aforementioned are the broad ways in which waste can be categorized [8]. Construction waste management includes design, procurement, material handling, operational, residual and others. According to Building

Establishment, material wastage on construction site has four discreet groups; design waste, taking off waste, ordering waste, supply waste and to mention finally contract waste. In the light of this it is said that construction waste generation has two broad perspectives; direct and indirect waste.

The Role of Architects and Allied Professionals in Construction Waste Generation

Negligence, imprecision and as well inaccuracy at the design stage has a huge turn on waste generation on construction site. This carelessness at the crucial stage of construction 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. This is due to the poor coordination of all parties involved during the design stage of the project and lack of attention to standard sizes of specified products. Plan and detail errors as a result of time constraint can cause variations that require input of additional materials. Errors in contract documentation has also played its role, this where material are used in excess of those indicated or not clearly defined in contract documents, that is additional concrete in trenches which was dug wider than was designed. Furthermore, all design changes i.e. demolition of work due to change in design at an advanced stage of the project can be a great source of waste generation on construction site.

Waste could result from construction site from faults in taking-off; unfinished detailing and small quantity of materials required in renovation work and the main courses of over ordering. Causes of over-ordering include lack of care during transportation can have a devastating effect on materials resulting to their damage. Procurement as tool of waste generation has the following pathways; material delivery procedure, order error, material wastage and internal transport and a well as suppliers' error.

Certain deficiencies like lack of confined space have poised a great problem for materials storage. Consequently, waste results from bad stacking, rusting of steel, damaging and aging of formwork. An example of bad material handling could result to chipping of ceramic tiles which could hypothetically render them useless. The construction process accounts for the physical generation of waste materials. This evident where measures are given lackadaisical approach to, which is glaring in Poor supervision by the main contractors over the labour and sub-contractors which can result in human error then the resultant effect is great amount of waste generation i.e. over-mixing and materials surplus frequently occurs for wet trades like concreting and block wall. Malfunction of equipment and its use by the labourer could cause damage to materials. Demolition Works in contrast with deconstruction which is the pulling down of building is done when the structure is no longer safe to be used by the public. The tipping of materials from demolition creates a large proportion of wastes**.**

In summary some of the causes of waste during the construction phase of waste generation; errors by trades men, equipment problem, inclement weather, damage by subsequent trade, use of wrong material, accident poor site management and supervision, lack of coordination of responsibilities between contractor and sub-contractors, lack of contractors influence, last but not the least lack of knowledge of construction during design activities. In addition errors by trades men such as wrong measurement, alignment and material, and the damage caused by another trade person whose work comes after a major work have been completed have shown to cause to cause a lot of waste on site.

Construction Waste Management

It has become a thing of utmost necessity to minimise the rate of waste generation on construction site due to the low turnover experienced by contractors and developers of land. In the light of this, waste management is becoming a pressing problem worldwide. The management of construction waste is no

longer just the responsibility of the municipal or the government authorities but that of the developer of the particular land area. In other words, the waste management process comprises material reduction in the design and planning stages, reducing scrap and waste at the building site, reusing materials on site, and recycling material that the initial project owner can no longer partake of its usage. Potential alternatives to conventional construction techniques, include planning practice and waste disposal options that incorporate strict waste management techniques as well as their cost and benefits. In managing waste, therefore, source reduction; Reuse; Recycling; Incineration; Landfill; Onsite recycling and Job-site recycling can be adopted

The Role of Architects and Allied Professionals in Construction Waste Management

The importance of the Architect should not be overlooked in the waste reduction effort. One of the first steps in reducing the amount spent on waste disposal is to reduce the amount of waste produced or created. The initial step in a construction waste reduction strategy is good planning. Design should be based on standard sizes and materials should be ordered accurately. In addition, using high quality materials such as engineered products would reduce rejects. This approach can reduce the amount of material needing to be recycled and bolster profitability and economy for the builder and customer. Architects should therefore design and specify materials for reuse and recycling. Architectural design choices will ultimately create demand with manufacturers to increase research and development in recycled content materials and increased use of recycling in the production of materials.

Since client satisfaction is paramount, the client would be in the best position to demand advanced (green) waste management. Most often this is in the form of recycling, simply because recycling is a known technique. However, it is also important that the architect ensures the client is aware of all levels of the waste management hierarchy to optimise the resources utilized on construction projects. Construction managers are in a unique position that lends itself to optimising all waste reduction possibilities. The construction manager's work with the architects, consultants and subcontractors intimately and therefore can influence waste creation and disposal throughout the project duration. At this stage specific waste management specifications can be worked into projects prior to the tender process. The project manager (PM) or general contractor will ultimately be in charge of implementing all site specific procedures. The project managers will control site set up, layout, and is responsible for the subcontractors and site. The PM's responsibility is not only implementation, but also enforcement. In the case of Design and Build (D&B), the developer also has an obligation to practice sustainable principles. Often, the developer is in control of large commercial areas of development or tract housing projects that are made-up of many multiple-units of similar design. There is tremendous opportunity in standardising materials in these large developments.

In order to encourage waste reduction and recycling practices, architects and engineers can develop pertinent language to include in their specifications. Recycling and waste reduction specifications communicate to prospective bidders that the project will not involve the traditional waste management practices. Contract language can address:

- Waste reduction techniques to use during specific phases of construction
- Material re-use techniques to employ for specific operations
- Salvage of specific components
- Return of unused portions of materials to vendors
- Recycling programs for specific materials.
- Contractors for tender may also be asked to develop a waste management plan and cost estimate.

Several advantages are associated with waste reduction and recycling specifications. For bidders, these specifications can eliminate concerns that they may be at a competitive disadvantage if they choose to recycle or practice other waste reduction techniques at the job. The specifications can be developed so that the contractor makes a waste management plan and cost estimate for recycling after being selected as the builder on the project. In this manner, it is up to the owner to choose whether to go ahead with the plan if it is more costly, and the cost burden does not fall on the contractor.

Another advantage of waste reduction and recycling specifications is that they clearly identify what types of measures are to be instituted at the job-site. This helps eliminate any confusion about which materials are target recyclables and which waste reduction techniques are to be employed. If pertinent language is tailored to all contract documents for specifications, subcontractors would realize that they are required to be involved in the designated waste reduction and recycling programs along with the general contractor.

When developing language within the specifications that addresses waste reduction and recycling, architects should be conscious of the following:

- Additional reporting requirements usually constitute additional cost
- Adequate markets must exist for materials targeted for recycling
- Conditions vary on each project so language must be customised to fit the project
- Adequate time must be set aside for discussions with bidders if specifications require them to submit recycling alternative.
- All specifications must be in compliance with local and state waste management regulations

SCOPE OF RESEARCH

Two sources of data i.e. (primary and secondary) were employed in the course of this work. Primary Sources of data were sourced from the sites through visits and observations, interviews, administration of questionnaires to respondents (professionals involved in the construction processes on each of the sites in the study area). Their opinions, observations and general comments regarding the cause of waste on site were sourced. In addition, the efforts their various firms have done so far, how effective are those strategies. Secondary data were sourced from documented materials in Bauchi State Environmental Protection Agency (BASEPA). This research relied optimally on primary data, which was obtained using questionnaires having both closed and open-ended (uncoded) questions; comprising various questions on material wastage and management. It was directed at the respondents who were professionals in the construction industry who had worked on construction site within Bauchi Metropolis and its environs. The professional were architects, engineers quantity surveyors, builders and contractors who were to identify the various sources of waste encountered on construction sites and how these wastes can be minimised and managed. The data obtained were analyzed using tables and statistical indices.

The scope of this research is limited to construction sites and firms in Bauchi Metropolis and its environs. The targeted population for this study included construction sites within Bauchi Metropolis and environs. Sites includes: residential, commercial, and institutional construction sites within Bauchi. According to the 2006 population census, the state has a population of 4,653,066 and the population of Bauchi Metropolis, is placed at 493,810. The idea behind the introduction of its environs is to get a holistic view or perspective. Furthermore, a sizeable number of all firms chosen to constitute the sample for this research were undertaking one form of construction or the other at

different stages in the states, therefore information gathered can be broadly applicable to the entire state. To further substantiate the details of the responses in the questionnaires. Purposive sampling technique was used and the questionnaire was analyzed using frequencies, percentages and relative index. Average index was used for the analysis of the data. The formula used was

$$\text{Average index} = \frac{\Sigma aiXi}{\Sigma Xi} \quad (1)$$

Where ai = constant which represents the weight i and xi = variable which represents the frequency of respondent

For i = 1,2,3,4,5

RESULTS AND DISCUSSION

The result of the analysis indicated that in Bauchi Metropolis and its environs that primary sources of waste generated in construction sites are demolition and renovation, followed by material handling. The method most frequently used for disposal of construction waste is dumping while the least method is open air burning and reuse as indicated in Tables 1 and 2. Some of the problems associated with the recycling of construction waste include contamination, collection and transport, sorting, transforming and disposing, quantity of waste, size of market, lack of information, time penalty clauses and bureaucratic bottle necks. The most frequent reasons identified are collection and transport, sorting, transforming/disposing and quantity of waste. Table 3 indicates that 65.5% of the respondents generate greater than 1 ton of construction waste per day, per project, 12.5% generate more than 5 ton per day per project on the average, while only 25% indicated that they generate less than or equal to 1 ton. The indicated volumes were higher than anticipated so respondents were interviewed to establish possible reason for these high figures. The respondents explained that most of this waste is generated in renovation and demolition which is not recycled so they all end up as waste, underscoring the need for construction waste management policies. Table 5 shows the percentage cost of materials to the total cost of the project. Sixty-six percent of the respondents indicated that the percentage cost of materials to the cost of the project is above 50%, closely followed by 22% who were of the opinion that the percentage cost of materials to the cost of the project is between 41 and 50%. Furthermore, it can be observed from Table 6 that a substantial number of firms did not indicate the method used for keeping store records, while 21% indicated that use of stock card system is the best, 10% believed that the bin card system is the best. Also 10% believed in the use of daily stocktaking, 13% expressed confidence in the use of the log book.

Tables 7 and 8 show the methods used by firms to minimise waste on sites, sources of wastes and incentives for good handling and minimising waste. Forty percent of the firms agreed that the major source of waste was due to adoption of a storage system; this was closely followed by 38% of the firms who were in agreement with the aforementioned that the major source of waste was due to transport and delivery to site. Other sources of waste pointed out by the respondents but not shown in Table 8 include residual wastes, over estimation of quantities required and the use of unskilled labours. Figure 1 indicated firms' provisions for incentives for good handling and minimum waste, 41% of the firms agreed that there were incentives for good handling and minimising waste while 59% suggested that there were no incentives. Ranking of the incentives are detailed in Figure 1. In addition, Table 9 analyzed the data collected on material stock control and storage before its movement to the site for utilization. Fifty-one percent of the firms used a centralized system of storage, while 25% used a mixed procedure, that is, the combination of the centralized and decentralized systems. On methods used in material stocktaking, most firms used a periodic stock

checking procedure, about 85%, while the remaining 15% used perpetual inventory that is, continuous stock checking. Table 10 outlined source of materials supplied to site, 70% of the respondents obtained their materials direct from the suppliers, while 39% usually contracted the supply out. Others (24%) purchased before use and stored in a central store. The results are presented in concerning time of placing order of materials prior to use, responses showed that 32% of the firms placed their orders less than two weeks before they were required, 27% placed orders between three and four weeks while the remaining 41% usually placed immediately stock becomes less. As regards, responsibility for damaged materials in transit, majority of the firms claimed that the suppliers bared the ramifications; they held the opinion that the materials were still in possession of the suppliers as long as they had not arrived on site. However, a minority of firms, about 11% had a different opinion as illustrated in Table 11.

On the usage of plants on construction sites, Table 12 showed that 42% of the firms utilized wheelbarrows, 17% employed concrete mixers among other options. Other equipment indicated by the respondents included head pans, shovels, diggers, vibrators and tipper lorries. In the interim, question on whether fragile materials should be given special attention and handling or not, 59% of the respondents opined that special attention and handling was paid to these materials, while 18% of the firms surveyed indicated that no such care was essential. The remaining 23% of the firm surveyed did not give any response.

Table1. *Average Index for Factor indicated in Waste Generation*

Factors	Number of Respondents					AI	Importance Level
	1	2	3	4	5		
Design	7	-	8	-	1	2.3	Less important
Procurement	5	3	5	3	-	2.4	Less important
Materials handling	1	3	3	8	1	3.3	Moderately
Construction/renovation	1	-	1	9	5	4.1	Important
Demolition	1	-	2	4	9	4.3	Very important

Source: *Authors Field Studies*

Table2. *Average Index (AI) for the Types and Frequency of Construction Waste Methods*

Methods	Number of Respondents					AI	Frequency Level
	1	2	3	4	5		
Open air burning	15	3	2	-	-	1.4	Least frequency
Landfill	10	2	4	2	2	2.2	Less frequency
Dumping	1	1	4	6	8	4.0	Very frequency
Recycling	11	6	2	1	-	1.7	Less frequency
Incineration plant	17	2	1	-	-	1.2	Least frequency
Reuse	10	3	5	-	2	2.1	Less frequency

Source: *Authors Field Studies*

Table3. *Average Volume of Waste Generated/ Day /Project*

Volume Of Waste	Frequency	Percentage %
≤ 1 ton	10	25
>1 ton	25	65.5
> 5 ton	5	12..5
	40	100.0

Source: *Authors Field Studies*

Table4. *Problems Faced in Recycling of Construction Waste*

Problems of Recycling	Number of Respondents					AI	Frequency Level
	1	2	3	4	5		
Contamination	5	2	7	4	2	2.8	Moderately important

Collection and Transport	3	1	3	9	4	3.5	Very important
Sorting, Transforming & Disposing	2	1	5	8	4	3.6	Very important
Quantity of waste	1	1	7	7	4	3.6	Very important
Size of market	4	1	5	4	6	3.4	Moderately important
Lack of information	3	2	4	6	5	3.4	Moderately important
Time penalty clauses	4	5	7	2	2	2.7	Moderately important
Bureaucratic bottle necks	3	2	6	5	4	3.3	Moderately important

Table5. *Percentage Cost of Materials to the Cost of the Project*

Options	Frequency	Percentage %
Below 20%	2	3
20-30%	2	3
31-40%	4	6
41-50%	16	22
Above 50%	47	66

Source: *Authors Field Studies*

Table6. *Methods for Keeping Store Records*

Methods	Frequency	Percentage%
Using trusted people	2	3
Stock balance sheet	3	4
Storage in computer	3	4
Bin card system	7	10
Daily stock taking	7	10
Log book	9	13
Stock card system	15	21
No response	25	35

Source: *Authors Field Studies*

Table7. *Methods of Minimising Wastes on Sites*

Options	Frequency	Percentage %
Locating store very close to the working area	29	41
Sending workers on formal training.	4	6
Supervision by engineers or trained personnel.	40	56
Good site accounting.	39	55

Source: *Authors Field Studies*

Table8. *Sources of Waste on Building Sites*

Sources of waste	Frequency	Percentage %
Wrong use	6	8
Mismanagement of materials	8	11
Demolition waste	10	14
Conversion waste	14	20
Pilfering and theft	15	21
Negligence	16	23
Fixing	17	24
Wrong specification	21	30
Intra – site transit	22	31
Transport and delivery to site	27	38
Site storage	29	40

Source: *Authors Field Studies*

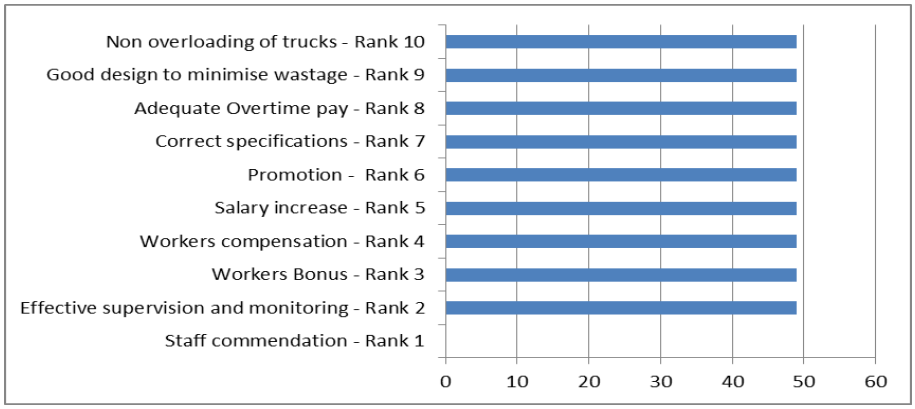

Fig1. *Incentives Identified by the Firms and their ranking*

Source: *Authors Field Studies*

Table9. *Materials Storage System*

Option	Frequency	Percentage %
Centralized system	36	51
Decentralized system	17	24
Mixed system	18	25

Source: *Authors Field Studies*

Table10. *Origin of Materials Supplied to Site*

Options	Frequency	Percentage %
Direct purchase from Suppliers	50	70
From the company's central store	17	24
The company usually contract it out	28	39
Others	-	-

Source: *Authors Field Studies*

Table11. *Responsibility for Damaged Materials in Transit*

Option	Frequency	Percentage %
The Supplier	53	75
The Client	8	11
(a) and (b)	10	14

Source: *Authors Field Studies*

Table12. *Usage of Plants on Construction Sites*

Option	Response	% Response
Wheel barrow	68	96
Concrete mixer	30	42
Hoist	15	21
Conveyors	8	11

Source: *Authors Field Studies*

CONCLUSION

Large volumes of waste are generated on the typical construction sites in Bauchi Metropolis but very little effort is taken to minimise the volume of waste generated either through recycling or reuse. Respondents indicate that over 1 ton of waste is generated per day on the average from most of the sites though it was implied that most of these wastes come from demolition and renovation work. Demolition and renovation work followed by material handling are the highest factors for construction waste generation in Bauchi as indicated the results.

Most waste is disposed of indiscriminately in dump sites and landfills. This implies that only a fraction of construction waste is actually recycled. A major challenge this poses is the inability of the site to enjoy the identified advantages of recycling and reuse. Valuable land is lost to dumping and landfills which are costly and constitute environmental hazards. The most frequently indicated problems associated with the recycling of construction waste identified in the study include, contamination, collection and transportation of waste, sorting, transforming and disposing and quantity of waste.

If materials handling and control are to mean anything, high control needs to be exercised between the parties involved. It has been noticed with total dismay that the cost of materials when compared to the total cost of project may well be over 50%, hence materials should be judiciously utilized and handled. The major sources of waste that was revealed was due to improper site storage, although a high proportion of firm surveyed also believed that the transportation and delivery of materials to site were important considerations as well.

Mechanisation of the movement of materials about the construction sites offer advantages in both cost and time saving, but from the present study, manual labour is by far more extensively used in comparison to mechanised labour. This is as a result of 'mushroom' construction companies which cannot meet the challenges of modern construction industries. Usage of manual labour for materials handling increases the level of waste that occur on sites and this can be readily observed on construction sites from the way materials litter such areas.

The study also observed that handling of fragile materials in the study area by contractors in poor is comparison, as opposed to what is practiced in developed countries where such items are treated with care. The supervision of fragile materials should be done by experts and only single handling should be allowed. Furthermore, some of the firms studied did not provide incentives for good handling and minimising wastage of materials. Advocacy and awareness programmes for stakeholders have now become imperative so material handling could be minimised. In addition manufacturers should be encouraged to develop basic standard for materials to minimize waste from off-cuts. Government should introduce sanctions on waste disposal methods that are not in line with modern day industrial best practices, particularly methods like dumping and open air burning. Legislative incentives like tax rebates would encourage green waste disposal techniques like recycling and reuses, as it is evident from the results that nearly all construction firms sampled in Bauchi are yet to start recycling or reusing waste materials on site. Giving contractors the option of reusing or recycling waste will determine the economic feasibility of such operations.

RECOMMENDATIONS

From the conclusion, the following are recommended:

- Construction waste recycling and reusing is a viable option in construction waste management and from further studies or research, laboratory experiments can be performed on some construction wastes like broken aggregates or demolished concrete to establish the feasibility of this option It would be worthwhile extending the investigation to other building materials like timber, iron-mongery, broken glass, sanitary wares and similar items.
- The use of computers should be adopted for storing records on construction site and for construction planning, though it has its ramifications like crashing of hard disc there should be a backup hard disc to save it all.

- There should be awareness programmes for all construction companies and architectural firms on construction waste management through reuse and recycling. Also formal education should be given to storekeepers and the foremen on effective materials handling and systems.
- The Federal Government should come up with a policy on construction waste management which may include introduction of heavy tipping charges on construction wastes (particularly those that can be reuse or recycled) and taxes for dumping or disposing wastes carelessly.
- This research is focused on the construction industry in terms of waste utilization and management. However, the methodology adopted here could similarly be extended to other fields in the context of engineering.

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