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Evaluation of Qualities of Demolished Debris used as Substitutes of Aggregate in Construction Projects Management in Nigeria

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ABSTRACT

Experts and stakeholders in the construction industry in Nigeria are skeptical regarding reuse of debris as substitutes at construction sites. This is largely due to scanty literature to demystify the inherent properties of debris. This study aims to evaluate the quality of demolished debris used as substitutes of aggregates in construction sites. The study adopted an experimental survey approach, in an attempt to accurately determine the values of the metrics upon which quality of debris and its justification for reuse and substitution as aggregate is based. Samples of demolished debris were collected, Furthermore, Statistical Package for Social Sciences (SPSS, version. 21) was used to compute the results obtained to aid in making inferences on the data. The simple mean and percentages were obtained where appropriate and Analysis of Variance (ANOVA) was used to evaluate the significance difference in the means of water absorption capacity, density and compressive strength between the fine aggregate and the coarse aggregates (denoted as J, A, K and S) as obtained from the four different construction companies in River's state. A total of 60 cubes measuring 150mm x 150mm x 150mm were cast and cured for 7, 14, 21, and 28 days before being crushed. Due to the presence of porous cement paste on the rocks, recycled concrete waste aggregate absorb more water than typical fresh granite. A significant difference exists in level of water absorption and density between the natural concrete cubes and the recycled aggregates at $\alpha = 0.05$, except for compressive strength of the concretes. The study therefore recommends that, a well-prepared sample could be used in the absence of natural concrete, but it is expected to compulsorily meet the specified requirements.

Key words: Construction, Demolished, Quality, Substitute, Aggregate, Debris.

1. INTRODUCTION

Construction debris is made up of both construction and demolition detritus like building material supplies such as insulation materials, nails, electrical wire, shingle, roof materials, as well as garbage coming from site preparation such as dredging materials, and tree stumps are all examples of construction waste. Construction trash may contain lead, asbestos, and other hazardous materials, from road construction and maintenance that require numerous numbers of aggregate materials from rock quarrying, that allows the use of secondary (recycled) materials rather than primary (virgin) material to prove its beneficial status in reducing demand from extraction [1].

Destruction of buildings, roads, bridges, and other infrastructure may result production waste known as demolished debris. Concrete, woods, asphalt, bricks, clay tiles, steel, and drywall are parts of principal components by weight of debris. Many aspects of demolition trash have the can actually be recycled. Many building materials, like bricks, concrete, and wood, may be damaged during construction and classified as waste for different reasons. Different field studies have shown the range as high as 10 to 15% of materials used during structural development, which is more than 2.5-5 percent specifically anticipated by quantity surveyors for the construction industry. Quality planning and design variations management best practices at different building sites, would create room for waste reduction at construction sites; [2] Population explosion, lifestyle choices, consumption, and technological innovation have impacted on rate of material waste creation and will continued to increase at such, emphasizing the need to address environmental challenges that the construction industry generates like, enormous amount of wastes with its associated several impacts on the health and safety of construction workers as well as the environment. These impacts are the resultant effects of vague approach in material waste management technique and practice [3].

According to [4] Concrete waste generates much environmental burden in the Nigeria construction industry, since it is generated and accumulated from the time new concrete is mixed on-site or off-site until it hardens. This has been attributed to the fact that, concrete makes up the greatest share of the construction industry's solid waste burden by weight. Recycling and utilization of such waste products would be part of adaptation measure to environmental protection that save natural resources, reduce the space required for land filling, and lower transportation costs in the course of construction works.

There are serious natural resource limitations for concrete production but use has expanded so much, resulting in increase in use of natural aggregate materials, that are the most important concrete components [5]. Today's appraisal of structures and technology shows that, people tend to go towards development through updating buildings resulting in refreshed buildings either through dismantling or renovating the buildings within 10 years. Advanced concrete technology can minimize the use of natural resources and hence reduce pollution in the environment while the use of recycled aggregate concrete was developed with the goal of reducing costs and preventing material waste. The number of high-rise structures is increasing in the developing world, and the traditional technique of renovating a multi-story building is to demolish it [2].

[6] observed that demolition of concrete structures generates massive amounts of garbage and leftovers across the world, which have the potential to be used as coarse aggregate in fresh concrete mixture. Many structures throughout the world are now being demolished for numerous reasons which include; approaching the end of their expected life cycle, replacement by new investments, or built below local or international standards. Large amounts of concrete ruins result from the maintenance or destruction of such structures. Reuse of these concrete leftovers will save landfill space increase natural resource conservation in a sustainable way.

Recycling construction concrete debris into aggregates in fresh concrete mixes is a recent trend for preventing environmental pollution by lowering the requirement for natural materials and minimizing concrete waste [6]. The feasibility of using destroyed concrete as coarse aggregates has been examined in several research. Given the creation of large quantities of construction remains and the major changes in the imposed environmental standards, the reuse of building trash is attracting increasing interest across the world. Concrete recycling is required from the standpoints of environmental preservation and resource efficiency. At the moment, recycled aggregate is mostly used in road sub-bases and backfill projects. A significant amount of concrete trash is disposed of. There is expected to be a rise in the volume of concrete waste, a lack of disposal places, and natural resource depletion, particularly in the United States [7].

These factors lead to the use of recycled aggregate in new concrete production, which is thought to be a more efficient use of concrete waste in order to meet the huge demand for aggregates, which is estimated to be around 40 billion tonnes, and to reduce material costs, which account for more than 60% of total project costs. However, 10% of construction materials end up as demolition trash each year, and aggregate is considered a useful building component. As a result, methods to ensure that destroyed material is effectively utilized must be developed [8].

Cement, fine aggregates, coarse aggregates, and water make up concrete. However, the quick depletion of such resources, and hence the rising cost, is becoming a hot topic, with building sectors facing shortages due to the simple availability of those materials. As a result, several solutions, such as the reuse and recycling of building debris, are being used to combat the problem. Reusing hardened concrete as aggregate is a tried and true method. It may be crushed and utilized in fresh concrete construction as a partial replacement for natural aggregate. Hardened concrete aggregate can be obtained either through the destruction of concrete structures at the end of their useful lives – recycled concrete aggregate – or from leftover fresh concrete that has been left to harden on purpose – leftover concrete aggregate. Concrete materials can be recycled or recovered for two reasons. It reduces the usage of natural aggregate and the accompanying environmental expenses of mining and shipping, as well as the use of landfill for non-recyclable components [9].

Currently, there is a general expectation in the construction industry, particularly in developed countries, that concrete, the universal building material whose main ingredient is coarse aggregate made up of natural resources such as stone products and sand, will exhaust and leave this sector deficient in aggregates, to which [10]. They stated that there will be wisdom in reuse of recycled concrete and demolition waste generated during the construction process. The use of recycled coarse aggregate will improve waste management efficiency, reduce environmental damage, and increase sustainability. unless considerable mechanical characteristics and workability deterioration occur, reuse of such trash as a substitute for fresh aggregates is considered an efficient technique [11].

In Nigeria, construction firms are impacted upon through continuously generating debris and its associated management system that is below specified standards, bringing into play, effective management system has as major concern in the industry since debris cannot be completely avoided due to off-cuts of materials from the irregular shape, change in design during construction that brings about diverse wastes [12]

However, we still lack information concerning recycled aggregate concrete which brings up the recommendation that more specific information on the features of recycled aggregate concrete should be obtained [3]. The quest to ascertain the potency of reuse of debris as substitutes of aggregates during construction, has triggered this study that aims at evaluating the qualities of demolished debris used as substitutes of aggregate in construction projects, specifically to determine and compare the porosity, density and compressive strength of a fine and coarse aggregate.

1.1 Demolished Debris Management Methods in Construction

Construction waste materials reuse will serve as the best option for construction materials waste management at building construction sites. This will enhances resource conversation for sustainable economic. Thus recycling these waste at building construction sites may result to almost waste free construction.

Reuse method that are used at construction sites include; **Salvage Method:** which is the act of good management to rescue things from difficult situations keeping and proper storage. [13] stated that, salvaged materials are recoveries from demolition as well as construction waste subsequently reused or purchased for use for another facility. [14] state that, salvage method is an avenue to utilize building construction materials waste at sites, preserve unused new materials, reduces materials waste that may be dumped in the landfill so as to creates neat work space for construction site team members. Thus salvaging in construction industry involves cleaning construction material, creation of standard parking store for materials, storage of material in standard ware house until installation and use, protection of such material from damage at the time of storage or transportation, while reusable material must meet the requirement or specification [15].

Repair Method: Repairing building construction waste materials also promotes reuse on construction sites. This entails maintenance of defective material to be used for the proposed function [14]. Thus, repairing construction facilities would create room for enhancement of performance of contractors that will eliminate waiting time to place order, supply, and fixing of equipment. Repairs help in maximization of use of resources while minimizing waste accruing from high demand for housing and infrastructure in cities [16]. [13] clarified issues on high monetary value of construction material and equipment at such, should be repaired than discarding them. Thus reducing the occurrence of delays that may be caused by reordering and repurchasing construction materials.

Remanufacture Method: This method of reuse finds secondary use of waste construction materials [17]. This technique redirects reusable or recyclable materials to manufacturing process. [14] stated that remanufacture is a method of using parts from discarded materials (waste materials) to reproduce new product that would perform the same function. This will result in reduction in the volume of natural resources that will be used thus, strategizing for promoting economic development with low rate of emission but expanding possibilities for living in a more pleasant and healthy environment.

Refurbish Method: Composite items such as furniture, doors, and windows are commonly known for this process. [14] stated that refurbishing is a method of restoration of old product to an updated status. Refurbished materials should be Painted with non-toxic finish materials and treatment chemicals that would prevent the damage [13].

Repurpose Method: According to [14] repurpose is a method of using discarded construction materials or parts to develop or construct new material with different function. This method is seen as the best construction materials waste reuse technique at construction sites due to the fact that additional cost and energy are not required.

2. MATERIALS AND METHODS

The study adopted an experimental survey approach, in an attempt to accurately determine the values of the metrics upon which quality of a debris and its justification for reuse and substitution as aggregate is based.

Cement: Dangote cement was used in all mixtures in this study and was found to have specific gravity of 3.13. 90 minutes and 220 minutes were discovered to be the first and ultimate setup times, respectively.

Fine aggregate: Fine aggregate is made from locally accessible river sand with sizes ranging from 0.125mm to 8mm. Sand has a 2.64 specific gravity and a fineness modulus of 3.64. The loose and compacted bulk density values obtained were 1556 Kg/m3 and 1644 Kg/m3, respectively, with 1.10 percent water absorption.

Coarse aggregate: The coarse material is sourced from a nearby quarry. The coarse aggregate is of size ranging from 4.75mm to 25mm.

2.1 Sample Collection and Preparation

Concrete trash was gathered from four separate building sites in Rivers State, Nigeria, where concrete mixed in the proper proportions is used for diverse concrete projects: Ferotex, Lee Engineering, Rodnab, Darycet, Construction businesses. This comprises trash from the casting of columns and bases, as well as slab and flooring procedures. The collected hardened concrete wastes were crushed to a particular size to provide recycled aggregates that were free of pollutants such as dirt, clay, wood, and other debris. Each site's samples were tagged for appropriate identification. Fresh crushed stone aggregate samples were taken from a quarry.

2.2 Experimental Tests

2.2.1 Sieving

Sieve analysis was performed using BS sieves ranging in size from 0.125mm to 8mm (for fine aggregate) and 4.75mm to 25mm (for coarse material). The samples that were kept after sieving were collected, weighed, and documented. Concrete was made using both natural and recycled concrete waste particles with a maximum size of 25mm.

2.2.2 Water Absorption Test

The purpose of this test was to evaluate the quantity of water (in percent) absorbed by aggregates, as well as the aggregates' porosity and soundness. The quantity of water necessary to transport an aggregate in a concrete from its air-dry condition (AD) to its saturated–surface dry (SSD) weight was estimated as the effective water absorption (EA). A certain amount of aggregate was wrapped in a net and submerged in water for 24 hours, then dried and reweighed. Equation 1 is used to calculate the aggregate's water absorption capability.

$$Water\ Absorption\ Capacity = \frac{Final\ mass - Initial\ Mass}{Initial\ mass} \times 100 \quad (1)$$

2.2.3 Concrete Cube Casting

Ordinary Portland cement was mixed with fine aggregates and recycled concrete waste, as well as natural aggregate as coarse aggregates, in a 1:2:4 ratio. A 150x150x150 mm mold was used to cast concrete cubes test prototypes.

2.2.4 Test of Compressive Strength

According to [18] concrete cubes were cast in triplicate and cured for 7, 14, 21, and 28 days, before they were crushed under incremental compressive load until it failed to obtain maximum compressive load for 7, 14, 21, and 28 days, and average compressive strength for the different maturing age was determined. For each of the cured cubes, the progress in failure was tracked on the compression machine, and the compressive strength was calculated using Equation 2.

$$Compressive\ Strength(N/mm^2) = \frac{P}{A} \quad (2)$$

The density of the cubes was also calculated using relation in equation 3.

$$Density\ of\ concrete = \frac{weight\ of\ cube\ (kg)}{volume\ of\ the\ cube\ (m^3)} \quad (3)$$

2.3 Data Analysis

Primary data that consists of computations obtained for water absorption capacity, density and compressive strength of the fine aggregate were used as control and the coarse aggregate, were subject to analysis through experiment. The results were reported for 7, 14, 21, and 28-day period. The simple mean and percentages were obtained and the Analysis of Variance (ANOVA) was used for evaluating the significant difference in means of water absorption capacity, density and compressive strength between the fine aggregate and the coarse aggregates (denoted as J, A,K and S) as obtained from the four different construction companies. The SPSS (version.21) analytical tool was used for the computations in study.

3. RESULTS

3.1 Concrete Cubes' Water Absorption

Average percentage of water absorption values for concrete cube, formed from each aggregate types used are shown in Table 1. From the seventh to the 28th day, there was a rise in rate of absorption of water. Water absorption of natural aggregate concrete was within the typical range of 0.5 - 1 percent. Concrete produced from recycled concrete construction waste, sample J had maximum absorption at conclusion point of 28-day test (5%), which is far from reaching the 10 percent threshold set by [19]. The results showed that recycled concrete waste aggregate absorbs more water than new granite because of the presence of porous cement paste on the aggregates (see Table 1) below:

Table 1: Water absorption test results for concrete cubes on average (%)

Aggregate type	Testing Days			
	7	**14**	**21**	**28**
Fine (Control)	0.79	0.94	1.0	0.96
Sample J	2.61	3.19	3.53	5.0
Sample A	2.88	3.51	3.60	3.91
Sample K	3.06	3.14	3.62	3.67
Sample S	2.81	3.44	3.58	3.90

Table 2: Descriptive statistic

	Mean	**Std. Deviation**	**Std. Error**
Fine (Control)	.9225	.09179	.04589
Sample J	3.5825	1.01848	.50924
Sample A	3.4750	.43209	.21604
sample K	3.3725	.31700	.15850
Sample S	3.4325	.45748	.22874
Total	2.9570	1.15660	.25862

Table 2 above is the average value of water absorption of the Fine and the recycled aggregates. Table 1 and 2 indicate that, the Fine aggregate absorbed less water as the cubes matured from 7th to the 28th day. This property makes Fine aggregate better than the recycled aggregates. However, sample K (M=3.37, SD=0.31) was the next sample whose absorption value was close that of Fine aggregate, making it the next best aggregate substitution for Fine aggregate.

Table 3: ANOVA Table

	Sum of Squares	**df**	**Mean Square**	**F**
Between Groups	20.790	4	5.198	6.851
Within Groups	4.627	15	.308	
Total	25.417	19		

Significance= $p < 0.05$

It is already apparent that close to Fine aggregate in water absorption level was sample K. In an attempt to ascertain if a significant difference exists between the Fine and the recycled aggregates, at 0.05 level of significance, Table 3 was prepared, from which it could be inferred that, a significant difference exists, since p-value =0.00.

Table 4: Post Hoc Test

Multiple Comparisons

Dependent Variable: Results

(I) Aggregate Type	(J) Aggregate Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Fine (Control)	Sample J	-2.66000*	.39271	.000	-3.8727	
	Sample A	-2.55250*	.39271	.000	-3.7652	
	sample K	-2.45000*	.39271	.000	-3.6627	
	Sample S	-2.51000*	.39271	.000	-3.7227	-1.2973

Table 4 reveals that, none of the recycled aggregate share a close similarity in water absorption level relative to Fine aggregate.

Table 5: Concrete Cubes' Average Density (kg/m^3)

Aggregate Kind	Testing Days 7	14	21	28
Normal (Control)	2465	2409	2405	2406
Sple J	2264	2313	2243	2272
Sple A	2273	2254	2277	2315
Sple K	2493	2488	2395	2487
Sple S	2399	2318	2378	2234

Table 6: Descriptive statistic

	Mean	Std. Deviation	Std. Error
Natural (Control)	2421.25	29.216	14.608
Sample J	2273.00	29.337	14.669
Sample A	2279.75	25.552	12.776
sample K	2465.75	47.240	23.620
Sample S	2332.25	73.948	36.974
Total	2354.40	88.386	19.764

Table 5 and 6 show that, sample K (M=2465.75, SD=47.2), natural aggregate (M=2421.25, SD=29.21) and sample A had the highest value in density, implying that, samples K and A can could switch lot with the Fine aggregate in terms of density, and are deemed most suitable.

Table 7: ANOVA Table

Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	118227.800	4	29556.950	14.680	.000
Within Groups	30201.000	15	2013.400		
Total	148428.800	19			

Significance= $p < 0.05$

Table 7 indicates that, there is a significance difference in the density of natural aggregate and the recycled aggregates. This implies that, while samples A and K are close to the natural concrete in density, yet they cannot take its place, except at the absence of the natural concrete.

Table 8: Post Hoc Test

Multiple Comparisons

Dependent Variable: Results

(I) Aggregate Type	(J) Aggregate Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Natural (Control)	Sample J	148.250*	31.729	.000	80.62	215.88
	Sample A	141.500*	31.729	.000	73.87	209.13
	sample K	-44.500	31.729	.181	-112.13	23.13
	Sample S	89.000*	31.729	.013	21.37	156.63

Table 8 shows that, sample K is almost not different from the natural aggregate in density. Implying that, sample K is the next best sample to be used for substitute for the natural concrete cubes.

3.3 Compressive Strength of the Concrete Cubes

Table 9 below shows average compressive strengths of concrete cubes. Concrete constructed with naturally crushed stone aggregates showed rise in compressive strength with age, reaching maximum strength at 28th day. Incorporating increasing age, the compressive strength of concrete of recycled concrete waste aggregates showed rise. Concrete built with natural crushed stone aggregates had greatest average compressive strength of 24.4N/mm2. At the 28th day, the concrete formed using recycled concrete waste aggregate samples J, A, K, and S, had maximum compressive strengths of 18.0, 22.8, 24.3, and 17.5N/mm2, respectively. K and A, samples had compressive strengths that were almost identical to natural crushed stone aggregates.

Table 9: Compressive strength of concrete cubes (N/mm^2)

Aggregate type	Testing Days 7	14	21	28
Fine (Control)	11.6	14.9	19.6	24.4
Sample J	10.9	12.7	17.3	18.0
Sample A	10.03	13.3	17.8	22.8
Sample K	11.4	13.8	19.2	24.3
Sample S	10.2	10.9	16.4	17.5

Table 10: Descriptive statistic

	Mean	Std. Deviation	Std. Error
Natural (Control)	17.6250	5.58353	2.79177
Sample J	14.7250	3.46831	1.73415
Sample A	15.9825	5.55007	2.77503
sample K	17.1750	5.76216	2.88108
Sample S	13.7500	3.73318	1.86659
Total	15.8515	4.62169	1.03344

As pertaining to compressive strength, the natural concrete (M=17.6, Sd=5.5), sample J (M=14.72, Sd=3.4), sample A (M=15.98, SD=5.5), and the recycled concrete cubes; sample K (M=17.17, SD=5.7), and sample S (M=13.7, SD=3.7) share high similarity.

Table 11: ANOVA Table

Results

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	42.398	4	10.599	.437	.780
Within Groups	363.442	15	24.229		
Total	405.840	19			

Significance= $p < 0.05$

Our observation at Table 10 is just validated by Table 11, implying that difference between the natural concrete and the recycled concrete cubes is so negligible.

4. DISCUSSION

Water absorption strength, density and compressive capacity of the natural and recycled concrete cubes were check experimentally and there was variations in obtained results at end of 7, 14, 21, and 28 days. The capacity of water absorption for natural concrete varied from 0.79 to 0.96, sample J varied from 2.61 to 5.0, sample A from 2.88 to 3.91, sample K from 3.06 to 3.67 and sample S from 2.81 to 3.90. These values show that recycled concrete debris aggregate absorb more water than the fresh granite. Sample K was the worst aggregate in terms water absorption capacity. This is line with the work of [4] who was of the opinion that concrete produced with recycled concrete waste aggregate could be used for walkways and kerbs production in construction of roads, due to their high level of water absorption.

The density of the natural concrete cubes varied from 2465 to 2406, sample J varied from 2264 to 2272, sample A varied from 2273 to 2315, sample P varied from 2493 to 2487, and sample S varied from 2399 to 2234. It has become evident that natural, samples K and A, had the highest density at the close of the 28th day, making them suitable for substitutes with new material concrete in construction. This is also in line with the findings of [11] suggesting that aggregates could be substitutes for the natural concretes, but mixture from different companies or workmanship might be a determinant.

And lastly, the compressive strength of the natural and the recycled concretes had no significant difference, which implies that the natural and the recycled concrete could do same function but only at the absence of fine granite. This is supported by [4], who state that despite possible lower compressive strength, recycled concrete waste aggregate, can be used for road construction, building walkways and kerbs, backfilling, and concrete manufacturing for light load, bearing structural components to produce a sustainable environment and save natural resources.

5. LIMITATIONS

The major hurdle the researcher encountered during the course of undertaking this study, was transportation. The study also faced some form of impedance while data collection phase lasted, probably because it was experimental. The study took about two months of revisiting the sites to where the samples were prepared.

6. CONCLUSION

Feasibility to recover, recycling and reuse of hard concrete debris from building construction materials for value addition application was investigated in other to maximize economic and environmental benefits.

Results gotten, indicated that when we compare fresh aggregate concrete, new concrete generated from recycled concrete waste aggregates absorbs more water owing to earlier cement paste bonding on the aggregate surface.

The compressive strength of concrete formed from recycled concrete waste aggregates increases with each curing day, regardless of aggregate type.

The compressive strength of concretes made with recycled concrete waste aggregates had a variation depending on the location of collection, showing that the quality of the mix and workmanship have significant effect on the quality of the produced concrete, and the quality of the concrete to be produced, if the concrete waste generated from those productions were reused aggregates.

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Declaration for Conflict
This article has not been published before now through our permission.
We therefore state that this article is free from conflict of any form.

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