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Research Paper

Recycling Of Concrete Waste Material From Construction Demolition

Aiyewalehinmi E.O[1] and Adeoye T.E[2]
Department of Civil Engineering, the Federal University of Technology, Akure.

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ABSTRACT:-This study investigates the engineering properties of demolished concrete aggregates wastes along Arakale Road, Akure. The purpose is to recycle and reduce the amount of construction wastes materials going into landfills and dumping pits. The study identifies about 15% to 20% of construction waste materials go into landfill and dumping pits in Akure. Four different mixes at 0.5, 0.55, 0.60 and 0.65 water/cement ratios were performed and a total of 96 (48 each) concrete cube samples were cast, cured and crushed. The results showed that at lower percentage water/cement ratios, the compressive strength of used aggregates at day 28 were much lower than virgin aggregates (16.89N/mm^2, 19.93N/mm^2) while at higher percentage water/cement ratios, the compressive strength of used aggregates at day 28 was almost the same as Virgin aggregates (18.07, 18.37). It shows that the used aggregates can attain the same compressive strength as virgin aggregates at higher water/cement ratios.

Keywords:-Demolished Aggregate, Natural Aggregate, Construction waste, Compressive Strength, Coarse Aggregates

I. INTRODUCTION

Construction and Demolition(C&D) debris includes bricks, concrete, masonry, soil, rocks, lumber, paving materials, shingles, glass, plastics rocks, lumber, aluminum (including siding), steel, drywall, insulation, asphalt roofing materials, electrical materials, plumbing fixtures, vinyl siding, corrugated cardboard, and tree stumps (Construction Waste Recycling, (2012)). The construction waste materials produced in Akure metropolitan are in large quantities, and they are found everywhere along Akure roads. Reuse of Construction waste materials attracts new Technology, Social values, costs and employment. It also helps to reduce the dependency on virgin materials and importation of foreign materials. Reuse of discarded construction waste materials in Nigeria is not new, it is only they have not been properly documented for future use. The concept of reuse of discarded material is associated with Recycling Technology. This type of technology is driven on the basis of needs. At the construction site demolished aggregate materials can be processed or recycled to replace virgin materials for immediate needs. In term of transformation, the process may in involve new technology, new product and new skill. Recycling of construction waste materials in Nigeria would save the country a considerable amount of money, worth billions of Naira annually. In Nigeria and most of other developing countries where technological development is still growing, some regions especially large urban areas already facing problems of obtaining adequate aggregate supplies at reasonable cost due to distance. For example in some local government areas in Ondo State, there is a critical shortage of natural aggregate for concrete production. The issue of recycling of construction waste materials cannot be ignored. Moreover, the increase in demand to cut costs demonstrates environmental construction sensitivity.

Furthermore, a continued environmental awareness instigates the pressure for re-use construction materials instead of classifying them as waste materials. Using construction waste material as an aggregate for developing new concrete product is technically viable and may, in some circumstances, be environmentally beneficial. Recycling is an important process which is used to produce a useful source of aggregate for the construction industry. Concrete recycling is increasingly becoming popular way of utilizing aggregate left behind demolished structures, road construction materials and site waste materials. In the past, demolished structural materials were disposed into landfills and dumping pit little or no attention being paid to environmental consideration, concrete recycling allows reuse of the rubble while also keeping construction costs down.

*Corresponding Author: Aiyewalehinmi E.O
Department of Civil Engineering, the Federal University of Technology

Considering the cost of storage, transporting and loss of revenue it makes financial sense for construction companies to take action, to minimize construction waste materials (Akinkurolere & Franklin, (2005)). Buck (1977) and Frondistion-Yannas (1977) have shown that it is possible to produce new concrete from crushed concrete, but that recycled concrete may be expected to have lower strength than concrete made with similar aggregate not previously used**.** Okafor (2010) indicated that recycled aggregate can be used to produce quality concrete which meets the required strength of a concrete. According to Okafor, virgin concrete is much higher in strength than the recycled concrete.

II. MATERIALS AND METHODS

Demolished structural material samples collected from the construction site at Arakale Road, Akure, Ondo State for the study are demolished concrete aggregates and sandcrete blocks (see Plates 2.1a, b and c). Plates 2.1a shows the demolished sites and the area while 2.1b shows the demolished concrete structure piled up at the site where the demolished concrete rubbles were carefully collected and broken into small parts using ordinary hammer. The purpose of using ordinary hammer was to crush the coarse aggregates carefully to retain their natural appearance otherwise destroyed under impact of hammer. Demolished Sandcrete block waste samples were equally crushed into fine aggregate sizes. These crushed aggregates were soaked in water for 3 days in order to wipe down the attached cement paste. After soaking, the particles were dried using sun energy. Sieve analysis was performed on the demolished aggregates to determine engineering property of the material. Standard concrete cubes were cast and cured for 7, 14, 21 and 28 days and crushed to determine the compressive strength.

Plate 2.1a: Arakale Street Undergoing Building Demolishing Due to Road Dualization.

2.4 TESTED PARAMETERS

All the tests on the collected samples were carried out at the Laboratories (Concrete, Geotechnical and Structural Laboratories) of the Civil and Environmental Engineering Department, Federal University of Technology Akure,

Plate 2.1b: Demolished Concrete Materials pilled-up at the Site from which the sample used was taken.

Plate 2.1c: Showing the process of breaking the demolished concrete

FUTA. The tests on the aggregates include: Grain size distribution, specific gravity, aggregate crushing value, aggregate impact value and aggregate water absorption value, compacting factor and the compressive strength.

2.2 Specific Gravity

The bulk specific gravity test which is used in the phase relationship of air, water and solids in a given volume of the material was carried out in accordance with ASTM Standard Test Method D854:2006: Standard Test Methods for Specific Gravity of Soil Solids by water Pycnometer. Table 3.1, shows that the discarded coarse aggregate is specific gravity is (2.54) while the natural coarse aggregate is (2.78). The specific gravity of the natural coarse aggregate satisfies the BS 882 (1992) requirements of greater than 2.6 while the discarded coarse aggregate failed to meet the requirement of greater than 2.6. However, the bulk specific gravity of an aggregate is not directly related to concrete performance and moreover, specification of bulk specific gravity is often done to meet minimum density requirements.

2.3 Aggregate Crushing Value

Aggregate Crushing Value test helps to determine the aggregate crushing value of coarse aggregates according to BS 812, Part 110:1990. These values are shown in table 3.1; aggregate crushing value of the discarded aggregate is (28.91%) while the natural aggregate is (23.63%) which implies that the discarded aggregate has lower strength than the natural aggregate.

2.4 Aggregate Impact Value

Aggregate Impact Value test also helps to determine the aggregate impact value of coarse aggregates according to BS 812, Part 112:1990. The results obtained for impact value of the coarse aggregates for this study (natural and used coarse aggregates) are given in table 3.1. From the table, it can be seen that the aggregate impact value for discarded or used aggregate (24.17%) is higher than that of the natural aggregate (20.73%) which implies that the discarded aggregate is lower in strength than the natural aggregate. Construction Standard (CSC, 2013) recommended that aggregate impact value of coarse natural aggregate when determined in accordance with section 15 of the standard shall not exceed 30%. The results of both coarse aggregates satisfy the recommendation.

2.5 Aggregate Water Absorption

The Aggregate Water Absorption Test conducted on both Natural and discarded coarse aggregates were done in accordance with the provision of BS 1881, Part 122, 2011. The water absorption values of the aggregates are shown in table 3.1; discarded aggregate scored 2.44% while natural aggregate scored 0.69%. In accordance with British Standards, BS 8007: 1987 recommends that aggregate absorption should not be greater than 3% with a maximum value of 2.5%. Both values satisfy the BS 8007:1987. Construction Standard (CSC, 2013) also recommends that water absorption of natural coarse aggregates and discarded coarse aggregates in accordance with section 17 should not exceed 0.8% and 10% respectively. The results satisfy both recommendations.

2.6 NATURAL AGGREGATES

The natural aggregates used were the same type as those used in the demolished structure for uniformity. Thus, the coarse aggregate used was crushed granite while the fine aggregate used was sharp sand. Sieve analysis was equally performed on the natural aggregate material. Standard concrete cubes samples were equally cast, cured and crushed to determine their compressive strength as control.

2.7 CONCRETE MIX

A nominal mix of 1:2:4 was used to prepare the discarded aggregate and natural aggregate concretes. The batching approach also was based on BS 5328 – 2 Standard. For both operations (Mix), Ordinary Portland Cement was used as the binding agent. Four different mixes were performed on discarded aggregates and natural aggregates. For these mixes water / cement ratios were varied 0.5, 0.55, 0.6 and 0.65. In each of the mix, twelve (12) standard cube samples were cast from both natural and used, three (3) cubes for each, cured for seven (7), fourteen (14), Twenty-one (21) and Twenty-eight (28) days. Ninety-six (96) standard concrete cube specimens were cast, cured and crushed. Forty-eight (48) sample cubes each from both discarded aggregates and natural aggregates.

III. RESULTS AND DISCUSSION

3.1 Results

The results of the engineering properties of Coarse Aggregate such as Specific Gravity, Aggregate Crushing Value, Aggregate Impact Value, Aggregate Water Absorption and Sieve Analysis Test are shown in table 3.1 and also presented graphically in figure 3.1 below. The specific gravity of the natural coarse aggregate showed 2.78 while recycled showed 2.54 This indicates that natural coarse aggregates satisfies the BS 882 (1992) requirements greater than 2.6 for concrete while the discarded coarse aggregate is failed to meet requirement. From the values shown in table 3.1, aggregate crushing value of the discarded aggregate (28.91%) is higher than that of the natural aggregate (23.63%). This indicates that the discarded aggregate has lower compressive strength than the natural aggregate. The result obtained for impact value of the coarse aggregates for this project work (natural and discarded coarse aggregates) is given in table 3.1. From the table, it can be seen that the aggregate impact value for discarded aggregate is (24.17%) while natural aggregate is (20.73%). Construction Standard Code (CSC, 2013) recommends that aggregate impact value of coarse natural aggregate when determined in accordance with section 15 of the standard shall not exceed 30%. The table also shows that discarded aggregate has higher water absorption rate (2.44%) than natural aggregate (0.69%). The water absorption in this study is limited to British Standards, BS 8007: 1987 which recommends that water aggregate absorption rate should not be greater than 3% as it can be seen from the table both are less than 3% (2.44 and 0.69), this indicates that both values satisfy the BS 1881 recommendation. Construction Standard Code (CSC, 2013) also recommends that the water absorption of coarse natural and discarded aggregates were determined in accordance with section 17 of the standard shall not exceed 0.8% and 10% respectively. In line with CSC recommendation these results satisfy CSC recommendations

Table 3.1. Physical Properties of the Aggregates

Physical Properties	Aggregate	
	Natural	**Discarded**
Specific Gravity	2.78	2.54
Aggregate Crushing Value (%)	23.63	28.91
Aggregate Impact Value (%)	20.73	24.17
Water Absorption Value (%)	0.69	2.44

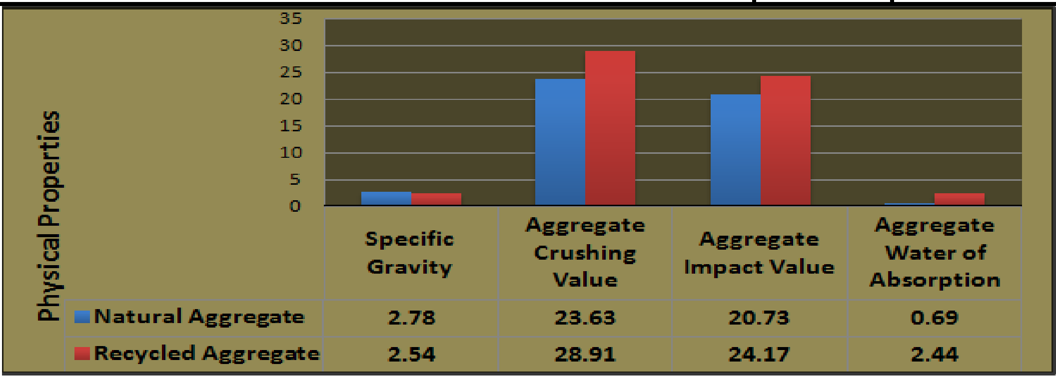


Fig.3.1: Graph Showing Variation in Physical Properties of the Aggregates

IV. SIEVE ANALYSIS

Dry sieve analysis was carried out on both discarded demolished aggregates and natural aggregate samples in accordance with BS 812, Part 103.1:1985. Figure 4.1a-4.1d show the graph of the results of the sieve analysis carried out on both the fine, coarse natural and discarded aggregates. They show the percentage of samples of the aggregates retained on each sieve and the percentage passing (finer than) each of the sieves. Graph of the variation in grading of the natural and discarded fine aggregates is shown in figure 4.2

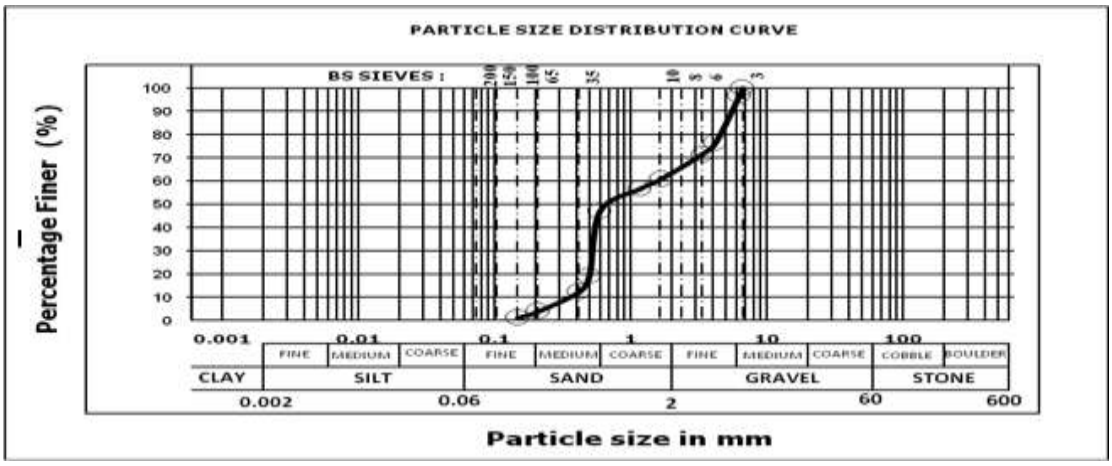


Fig.4.1 a: Graph showing grading of the Natural Fine Aggregate

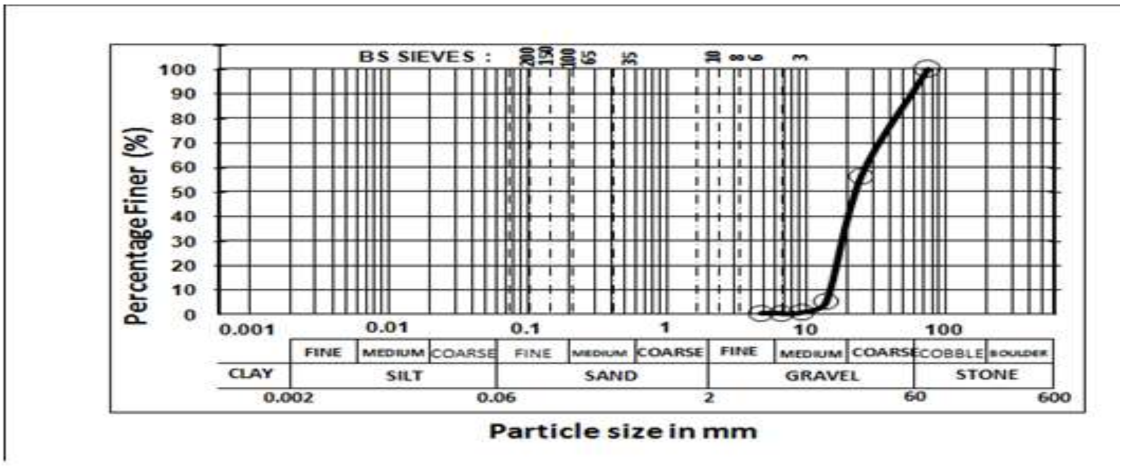


Fig.4.1 b: Graph showing grading of the Natural Coarse Aggregate

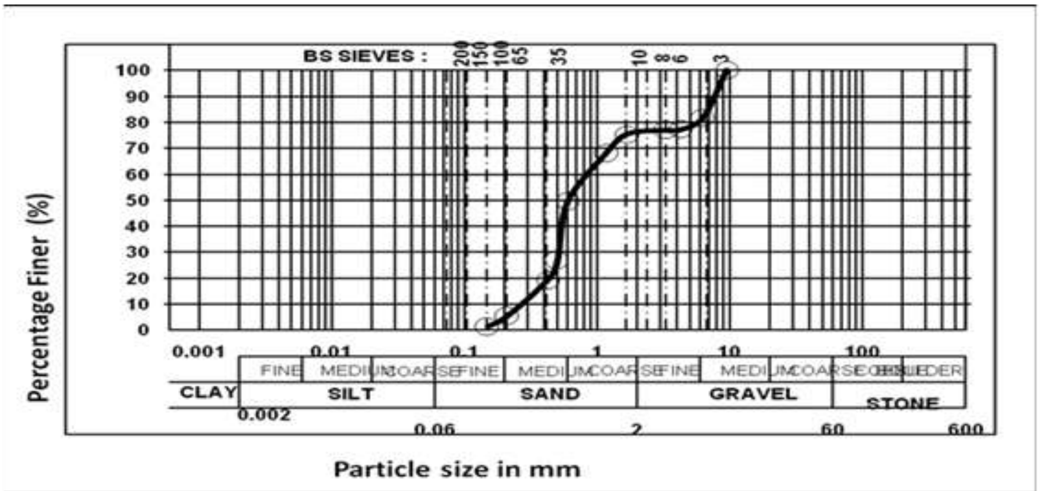


Fig.4.1c: Graph showing grading of discarded Fine Aggregate

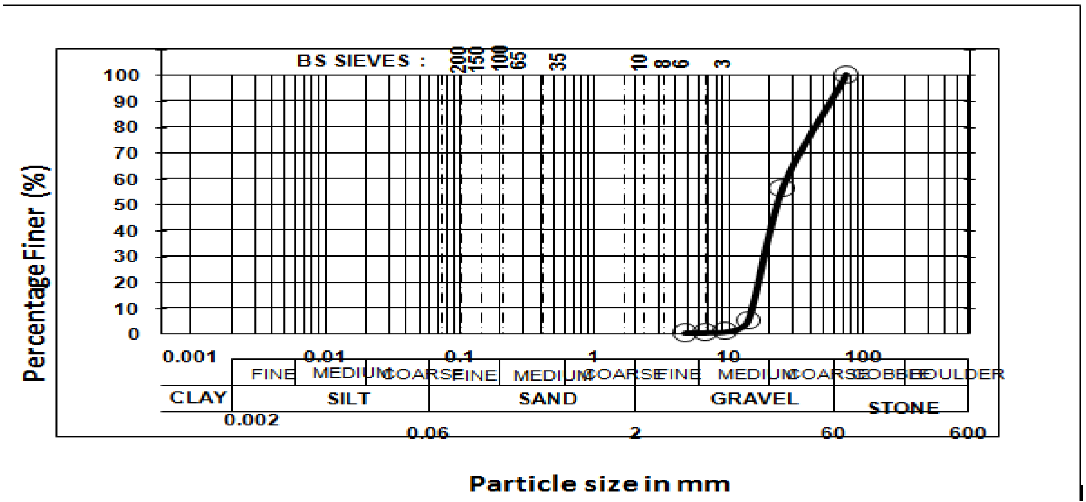


Fig.4.1d Graph showing grading of discarded Coarse Aggregate

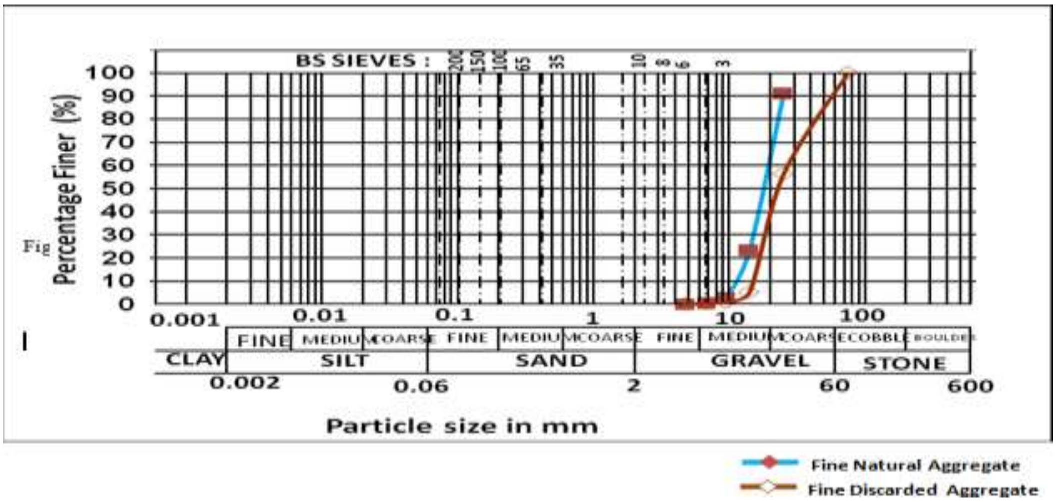


Fig.4.2: Showing Variation in Grading of Fine Natural and Discarded Aggregates

V. LIMIT OF GRADING OF COARSE AGGREGATES (CSC, 2013)

The grading of the coarse aggregates, determined in accordance with section 10 of Construction Standard (CSC, 2013) is within the limits given in table 5.1.

Table 5.1: Limit of Grading of Coarse Aggregates (CSC, 2013)

Sieve Size (mm)	Percentage by Mass Passing Test Sieves (%)							
	Nominal Size of Graded Aggregate (mm)			Nominal Size of Single-Sized Aggregate (mm)				
	40 to 5	20 to 5	14 to 5	40	20	14	10	5
50	100	-	-	100	-	-	-	-
37.5	90-100	100	-	85-100	100	-	-	-
20	35-70	90-100	100	0-25	85-100	100	-	-
14	25-55	40-80	90-100	-	0-70	85-100	100	-
10	10-40	30-60	50-85	0-5	0-25	0-50	85-100	100
5	0-5	0-10	0-10	-	0-5	0-10	0-25	45-100
2.36	-	-	-	-	-	-	0-5	0-30
NOTE: For coarse discarded 20mm and 10mm single sized aggregates, the percentage mass passing 4mm test sieve shall not exceed 5%								

Table 5.2 shows the comparison between the results of the grading of the coarse aggregates and the grading limits given in Construction Standard for coarse aggregate suitable for casting concrete shown in table 5.1.

Table 5.2: Comparison between the results of the grading of the coarse aggregates and the grading limits given in construction standard.

Recommended Limit		Result obtained		
			Natural Coarse Aggregate	Recycled Coarse Aggregate
Sieve Size	Overall Limits (% Passing)	Sieve Size	% Passing	% Passing
50	**100**	-	-	-
37.5	**90-100**	37.5	100	100
20	**35-70**	25.0	90.84	56.22
14	**25-55**	14.00	23.1	5.08
10	**10-40**	9.5	2.98	0.86
5	**0-5**	6.7	0.24	0.36
2.36	**-**	4.76	0	0.3

Comparing the results of the grading of the coarse aggregates with the limits given in table 5.1, coarse natural aggregate falls perfectly within the limits while the discarded/Recycled coarse aggregate falls nearly within the limit. The grading of the fine aggregate determined in accordance with section 10 of Construction Standard (CSC, 2013) is within the limits as shown in table 5.3.

Table 5.3: Limit of Grading of Fine Aggregates (CSC, 2013)

Sieve Size	Percentage by mass passing test sieves (%)			
	Overall Limits	Limits for declared grading		
		C	M	F
10mm	100	-	-	-
5mm	89-100	-	-	-
2.36mm	60-100	60-100	65-100	80-100
1.18mm	30-100	30-90	45-100	70-100
600µm	15-100	15-54	25-80	55-100
300µm	5-70	5-40	5-48	5-70
150µm	0-20	-	-	-

Table 5.4 shows the comparison between the result of the grading of the recycled fine aggregate and the grading limits given in Construction Standard for fine aggregate suitable for concrete casting shown in table 5.5

Table 5.5: Comparison of the result of grading of the fine aggregates with the limits of grading of fine aggregates.

Recommended Limit		Obtained Result		
			Natural Fine Aggregate	Recycled Fine
Sieve Size	Overall Limits (% Passing)	Sieve Size	% Passing	% Passing
10mm	100	9.5mm	100	100
5mm	89-100	6.3mm	96.86	81.9
2.36mm	60-100	2.36mm	71.36	76.92
1.18mm	30-100	1.18mm	56.7	71.02
600µm	15-100	600µm	47.06	49.42
300µm	5-70	425µm	12.36	19.2
150µm	0-20	150µm	1.18	1.28

Comparing grading results obtained for the fine aggregates with the limits given in table 5.3, Both Fine natural and discarded aggregate falls perfectly within the limits.

VI. SLUMP AND THE COMPACTING FACTOR

6.1 Slump and the Compacting Factor

The Slump Test was carried out in accordance with BS EN 12350, Part 2, 2009. Testing Fresh Concrete; Slump Test which replaced BS 1881: Part 102 while the Compacting Factor Test was carried out in accordance with BS EN 12350, Part 4, 2009. Testing Fresh Concrete; Degree of Compatibility which replaced BS 1881: Part 103. The results of slump and the compacting factor tests are shown in Figure 6.1 below. As can be seen in the figure the slump and compacting factor values for natural aggregate are higher than that of the discarded aggregate at the water-cement ratios examined, the difference is very minimal.

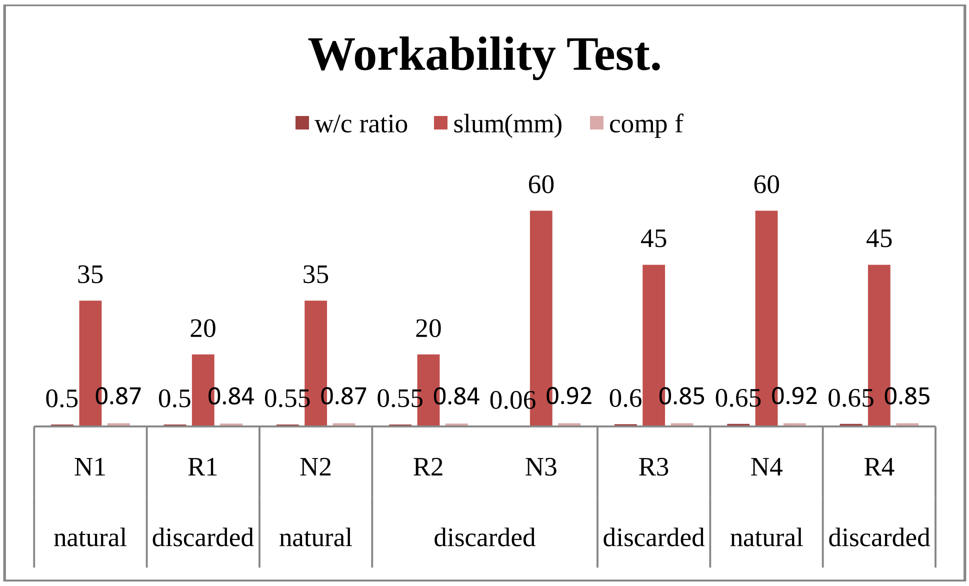


Figure 6.1 Workability Test Slum/Compacting Factor.

6.2. Compressive Strength

The cubes used were cured and tested for compressive strength in accordance with the recommendations of BS EN 12390, Part 3, 2009. Tests for Hardened Concrete Compressive Strength Samples are indicated in a summary of the compressive strength values got after crushing the ninety-six cubes cast and cured, representing the two concrete types at the ages of day 7, day 14, day 21 and day 28, in line with water/cement ratios (w/c) of 0.5, 0.55, 0.6 and 0.65, are presented graphically in figures 6.2(a-d). As can be seen there are differences in the compressive strength of the two types of aggregates relating to the water-cement ratio.

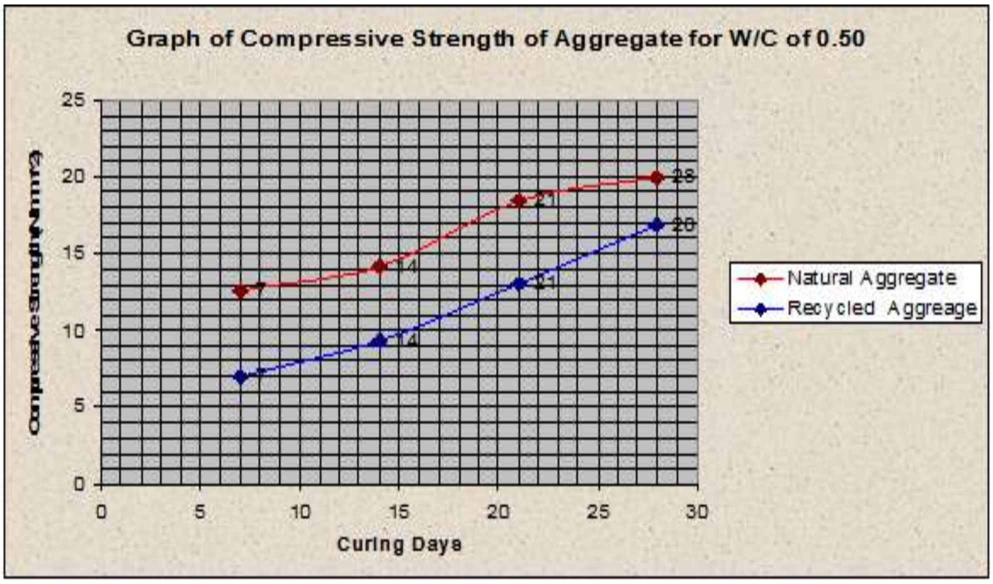


Figure 6.2.a: Compressive Strength of Concrete for W/C of 0.5

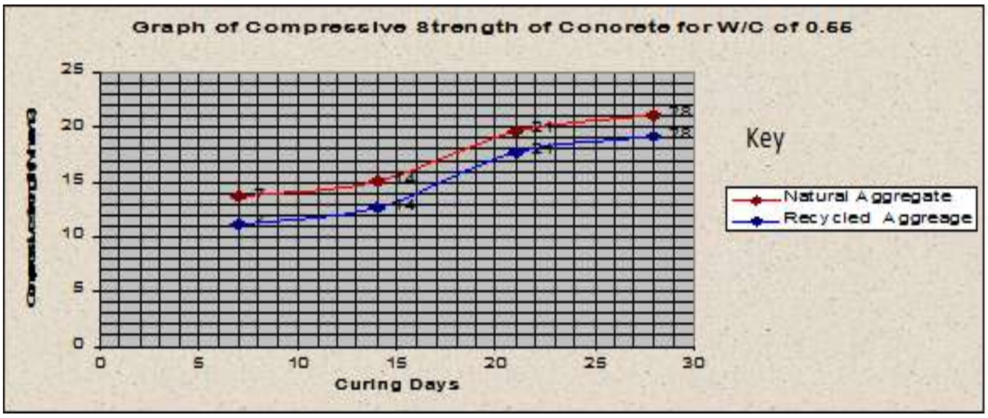


Figure 6.2b Compressive Strength of Concrete for W/C of 0.55

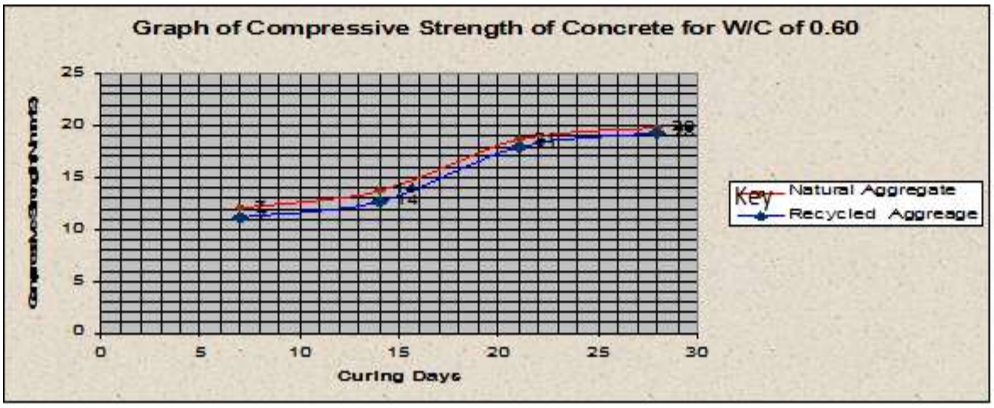
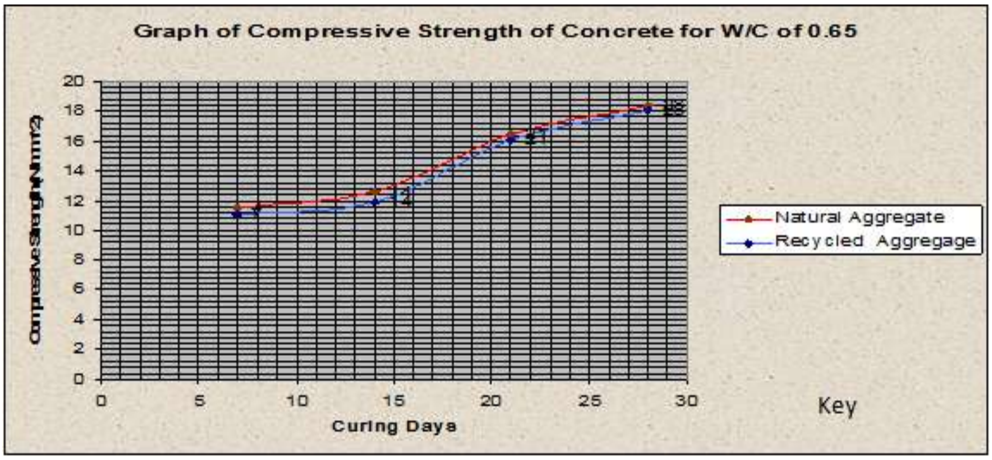


Figure 6.2c: Compressive Strength of Concrete for W/C of 0.60



6.2d: Graph of Compressive Strength of Concrete for W/C of 0.65

VII. CONCLUSION AND RECOMMENDATION

7.0 CONCLUSION

Figure 3.1 shows that discarded aggregate has lower specific gravity ((2.54), higher water absorption (2.44%), higher aggregate crushing value (28.91%) and higher aggregate Impact value (24.17%) than natural aggregate of (2.78) specific gravity, water absorption (0.69%), aggregate crushing value of (23.63%) and aggregate impact value of (20.73%). Thus, all conventional quality indices for aggregate indicate that discarded aggregates are lower in quality compared to natural aggregate. This is in agreement with the observations of Okafor (2010) and Chinwuba (2011). The reason for the lower quality may be associated with old mortar paste stack with the discarded aggregate particles even after been soaked the particles are properly removed. However, the results of workability tests are shown in the figure 6 .1 above shows that discarded/recycled aggregate concrete is less workable than natural aggregate concrete if considered the same free water-cement ratio. The low workability results shown in the figure 5.1 above are based on the two test methods used (Slum and Compacting

Factor) Tests. At water/cement ratio of 0.55, the compacting factor test result obtained for natural concrete was 0.87 while that of recycled concrete was 0.84 and the slum test result obtained for natural concrete was 35mm while that of recycled concrete was 20mm. In the same way, at water/cement ratio of 0.6, the compacting factor test result obtained for natural concrete was 0.92 while that of recycled concrete was 0.85 and the slum test result obtained for natural concrete was 60mm while that of recycled concrete was 45mm. This indicates that the discarded aggregate concrete require more water for nominal slump as compared to natural slump. In line with the analysis of these results, discarded aggregate concrete could attain the same workability level as virgin aggregate concrete with increase water/cement ratio. The main reason for more water requirement may be associated with higher proportion of fine stack particles present in the discarded aggregates than in the natural aggregate. From the analysis of results workability of concretes made from the discarded aggregates seems relatively stable faster than the natural aggregate concretes. However, the results obtained from compressive strength tests show that both discarded and natural aggregates concretes continue to increase with age at a given water/cement ratio. In line with water/cement ratio, the following observations are documented:

i. With increase in water/cement ratio from 0.5 to 0.55, there is an increase in compressive strength of both concretes.
ii. With the increase in water/cement ratio from 0.55 to 0.60, natural aggregate concrete shows reduction in compressive strength whereas discarded/recycled aggregate concrete shows increase in compressive strength.
iii. With the increase in water/cement ratio from 0.60 to 0.65, there was a reduction in compressive strength of both concretes.
iv. At higher water/cement ratios (0.65) the compressive strength of discarded concrete is close to that of natural concrete at all curing level (7, 14, 21, and 28 days). Specifically at day 28 day the compressive strength of discarded concrete attained 84.7% while virgin concrete recorded 84.37. This trend indicates with increase in water/cement ratio the compressive strength of discarded/recycled aggregate concrete may likely attain the same compressive strength standard.

7.1 RECOMMENDATION

Based on the results of this investigation, it was identified with 0.60 and 0.65 water/cement ratio the concrete produced from discarded/recycled aggregate attained almost the same water absorption capacity rate and compressive strength quality. More studies are suggested to continue until the same results are achieved.
There is a need for both three tiers of government to encourage recycling of construction waste materials by supporting individual agency interested in recycling technology specifically construction waste materials.

REFERENCES

[1]. Akinkurolere, O.O. & Franklin, S.O. (2005). Investigation into Waste Management on Construction Sites in South Western Nigeria. American Journal of Applied Sciences 2 (5), 980-984
[2]. American Society for Testing and Materials (ASTM) Standard Test Method D854, 2006. Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer.
[3]. British Standards Institution EN 206-1, 2013. Concrete: Specification, Performance, Production and Conformity, London.
[4]. British Standards Institution BS 812 – 103.1, 1985. Methods for Determination of Particle Size Distribution: Sieve tests, London.
[5]. British Standards Institution BS 812 – 110, 1990. Methods for Determination of Aggregate Crushing Value (ACV), London.
[6]. British Standards Institution BS 812 – 112, 1990. Methods for Determination of Aggregate Impact Value (AIV), London.
[7]. British Standards Institution BS 882: 1992: Specification for aggregates for aggregates from natural sources for concrete , London.
[8]. British Standards Institution BS 1881–122, 1990. Methods for Determination of Water Absorption, London.
[9]. British Standards Institution BS 8007, 1987. Code of Practice for Design of Concrete Structures for Retaining Aqueous Liquid, London.
[10]. British Standards Institution EN 12350 - 2, 2009. Testing Fresh Concrete; Slump Test, London.
[11]. British Standards Institution EN 12350 - 4, 2009. Testing Fresh Concrete; Degree of Compatibility, London.
[12]. British Standards Institution EN 12390 – 3, 2002. Testing Hardened Concrete Compressive Strength of Test Specimens, London.
[13]. Buck, A.D. (1977). Recycled Concrete as a Source of Aggregate. ACI Journal, Proc., 74(5), 212-219.
[14]. Construction Standard CSC, 2013. Aggregates for Concrete, Hong Kong.
[15]. Construction Waste Recycling. (2012). Retrieved July 25, 2012, from http://www.
[16]. Habitat.org/env/restores.aspx. EN 12390-2
[17]. Frondistion-Yannas, S. (1977). Waste Concrete as Aggregate for New Concrete, ACI Journal Proc., 74(8), 373-376.
[18]. Okafor F.O. (2010). Waste Concrete as a Source of Aggregate for New Concrete. Nigerian Journal of Technology, 29 (2), 5-11.