



Investigation on Concrete with Partial Replacement of Aggregate from Demolition Waste

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Abstract. The world is experiencing rapid infrastructural development. This requires a higher quantity of aggregate resulting in a higher amount of natural resources depletion. Also, waste generated from demolition or collapse of the building ends in landfills unlawfully. The strains and high values on existing lands caused by rapid urbanization are making securing dump sites increasingly difficult. These situations have resulted in an environmental threat that needs urgent attention. This research investigated the potential usage of demolished concrete aggregate (DCA) as a partial replacement of granite to produce structural concrete. Laboratory testing of granite, DCA, and the produced concrete was carried out according to British and ASTM standards. The physical properties of DCA present the material to be a potential construction material for sustainable construction and a greener environment. The strength result of DCA concrete keeps reducing as the percentage replacement increases but yet produced satisfactory structural concrete.

Keywords: Construction waste · Waste management · Concrete strength · Sustainable construction

1 Introduction

Waste creation rises year after year as industries and infrastructure develop rapidly in metropolitan areas. Demolition materials thrown on land are currently classed as garbage, meaning they can't be used for anything (Monish et al. 2013). The first plant for recycling construction trash was built by the Ministry of Urban Development in India but such facilities are not available in Nigeria. This approach is sufficient to address the issue of destroyed garbage generation.

Concrete is responsible for about 4 billion tons of carbon dioxide annually (Ramsden 2021). There is a need to reduce CO₂ emissions in our environment. Currently, the concrete industry requires between 8 and 12 billion tons of natural aggregate per year around the world (Krishna 2015). Another big issue is the continued use of natural resources such as stone and sand, which is causing climate change and depletion

of natural resources (Ezeudu et al. 2021). Concrete is a composite material made up of a variety of ingredients such as limiting materials (cement), water, aggregates, and admixtures (Sanusi et al. 2020). Aggregate, which makes up 60–75% of the total volume of concrete is the most important material for any construction work (Linch 2010).

Concrete's adaptability as a development material for large-scale development projects stems from its great strength, low maintenance costs, resistance to long-term impact, cost-effectiveness compared to other development materials, and wonderful underlying exhibition (Akadiri et al. 2012). Furthermore, due to the rapid growth of the economy and population, concrete has become the most non-sustainable material, since its production involves the use of the most natural resources which account for 20 billion tons of raw materials (coarse aggregate) annually (Mandloi and Pathak 2015). (Nassar and Soroushian 2016) estimated that aggregate demand for construction could exceed 26 billion tons by 2012.

Aggregate consumption keeps increasing due to global infrastructural development (Sanusi et al. 2021). However, it has been reported that India is among the top ten countries in the world that use the most important natural resource (Somani et al. 2016). Therefore, it can be deduced that the concrete sector burns up a lot of typical assets, resulting in significant environmental, energy, and monetary losses, as half of the raw material is exploited, (Sharma and Singla 2014).

Some of the challenges associated with cement-concrete waste include the risk of contamination with organic substances when disposed of improperly or with the bulk of chemicals (Yang et al. 2008). Also, unlawful disposal could result in contamination of cement-concrete waste with the industrial and hazardous waste which eventually will hamper the desired concrete strength (Evangelista and de Brito 2007). Hence, when using cement-concrete waste to produce new concrete, attention should be paid to the aforementioned and other contaminants.

This research aimed at investigating the replacement of destroyed concrete (demobilization waste) for a coarse aggregate in concrete production to improve environmental sustainability by reducing solid waste generation, energy consumption, and depletion of natural resources.

2 Materials and Methods

In the study, the materials used were tested under laboratory conditions in line with the specification of the British and ASTM Standard.

Materials used for the concrete production include 53 grade of Ordinary Portland Cement (OPC) complying with BS EN 197–1 and BS EN 196–3 (BSI 2003.b, 2003.a), coarse aggregate which was granite and destroyed concrete aggregate, DCA (40%, 50%, and 60% respectively), Fine Aggregate (FA) and water satisfying the requirement of ASTM C-1602 and BS EN 1008 (ASTM 2006; BSI 2002).

The concrete mix proportion adopted for this research was 1:1.1:2.8 and the water-cement ratio of 0.45. However, the batching was carried out in accordance with British Standard. Slump, compressive, and split tensile tests were carried out using concrete moulds of 150mm³ cubes, and cylinders (150mm diameter and 300mm height) in accordance with (BSI 2019.b, 2019d, 2019.a, 2019.c) respectively. The produced concrete

samples were allowed to be set in moulds for 24 h under room temperature and humidity before being demoulded. The curing method used was full immersion of concrete samples in water for 7, 14, and 28 days respectively in accordance with (BSI 2004).

3 Results and Discussion

This section presents the obtained laboratory test result and its discussion.

3.1 Material Test Result

The materials used for this research are cement, coarse aggregate (granite and DCA), fine aggregate, and water.

Cement Test Result. The result of 53 grade Dangote cement used for this study as shown in Table 1 implies that the Portland cement conforms with the specification spelled out by (BSI 2019.c, India Standard 2013) for cement suitable for concrete production. Therefore, the used cement used is adequate for construction purposes and is expected to produce satisfactory concrete.

Table 1. Physical properties of 53 grade Dangote cement used

Test	Result
Specific gravity	3.15
Standard consistency	33.67
Fineness test	1.70
Initial setting time	27 min 8 s
Final setting time	8 h 10 min

Coarse Aggregate Test Result. The coarse aggregate physical properties presented in Table 2 showed that the specific gravity, abrasion, and crushing test results are marginal as compared with the materials. The results are in line with the recommendation of (Neville 2011; Shetty 2010, BSI 2003). The standard states that the impact, abrasion, and crushing strength of aggregate shall not exceed 30% for the wearing surface and 45% for the non-wearing surface. However, the impact, abrasion, and crushing test results fall within the limit of BS aggregate to be used for wearing coarse surfaces. Also, the bulk densities of the two materials are within the acceptable range of (ACI Committee and 318 2011) for normal-weight aggregate. Although, the water absorption capacity of DCA is higher than that of granite. This implies that the pore space between the DCA is much, therefore, more cement will require to produce the same concrete strength of normal granite. In general, DCA appears to possess lesser strength as compared with normal aggregate. However, the test results of DCA are still within the acceptable limit of coarse aggregate for durable concrete (ACI Committee and 318 2011, Sanusi et al. 2020; Neville 2011). Hence, DCA is a suitable and sustainable material for construction.

Table 2. Physical properties of coarse aggregate used

Serial number	Test	DCA	Granite
1	Specific gravity	2.68	2.70
2	Impact value (%)	24.26	13.23
3	Water absorption (%)	3.52	1.00
4	Bulk density (kg/m ³)	1983	1692
5	Crushing test (%)	20.83	17.42
6	Abrasion test (%)	14.6	13.4
7	Size (mm)	20.00	20.00

Fine Test Result. The bulk density and specific gravity test results of the river sand presented in Table 3 revealed that the material falls within the range of 1120 to 1928 kg/m³ and 2.4 to 2.94 respectively recommended by (ASTM C125, 2000, Sanusi et al. 2020) for concrete aggregate. Also, (BSI 2003) confirms the suitability of the river sand for concrete work.

Table 3. Properties of fine aggregate used

Serial number	Serial number	Description
1	Specific gravity	2.30
2	Bulk density (Kg/m ³)	1678
3	Silt content (%)	4.93

3.2 Laboratory Test on the Produced Concrete

The test conducted on the produced concrete from DCA and normal granite were slump tests on fresh concrete and compressive, and split tensile strength tests on hardened concrete.

Slump Test Result. Figure 1 presents the slump tests. It can be seen from the fig. That as the substitute of DCA for granite increases, the concrete slump reduces. This can be connected to the higher capacity of water absorption for DCA (3.0) as against 1.0 obtained for granite in Table 2. Although, the entire produced concrete slump is within the acceptable range of 10 to 100 mm for satisfactory concrete (Ezeudu et al. 2021).

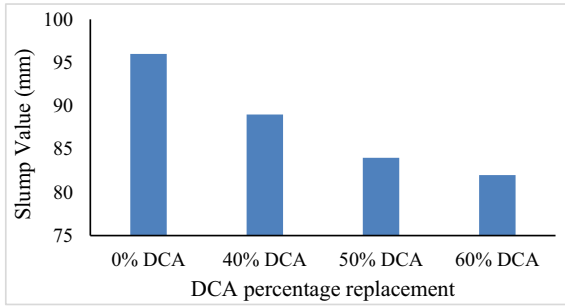


Fig. 1. Slump test

Compressive Test Result from Demolished Concrete Aggregate. The compressive strength test result of each of the produced concrete is presented in Table 4. The results generally show that as the curing age increases, the strength gained of the concrete samples increases irrespective of the materials. However, the result also indicated that an increase in DCA substitutes for granite in the produced concrete leads to a reduction in strength. The strength reduces by 11.86%, 16.27% and 17.73% for 40%, 50% and 60% DCA concrete respectively.

Table 4. Compressive strength of demolished concrete aggregate

Serial number	Mix	7 days	14 days	28 days
1	0% DCA	29.40	35.59	39.70
2	40% DCA	22.06	32.10	34.99
3	50% DCA	21.18	31.42	33.24
4	60% DCA	20.25	30.92	32.66

The strength results also confirm the better strength of conventional granite strength as compared with DCA available in Table 3. Also, the result of 40% DCA concrete agreed with the outcome of (Yehia et al. 2015) which states that the reduction of 7 to 15% compressive strength was recorded for recycled aggregate concrete when the same mix proportion and water-cement ratio were used. Although, 50% and 60% exceeded the range. This is connected to the higher percentage replacement of conventional coarse aggregate with DCA. Figure 2 Presents the graphical representation of the produced concrete compressive strengths.

Split Tensile Test Result from Demolished Concrete Aggregate. Only two levels of headings should be numbered. Lower level headings remain unnumbered; they are formatted as run-in headings.

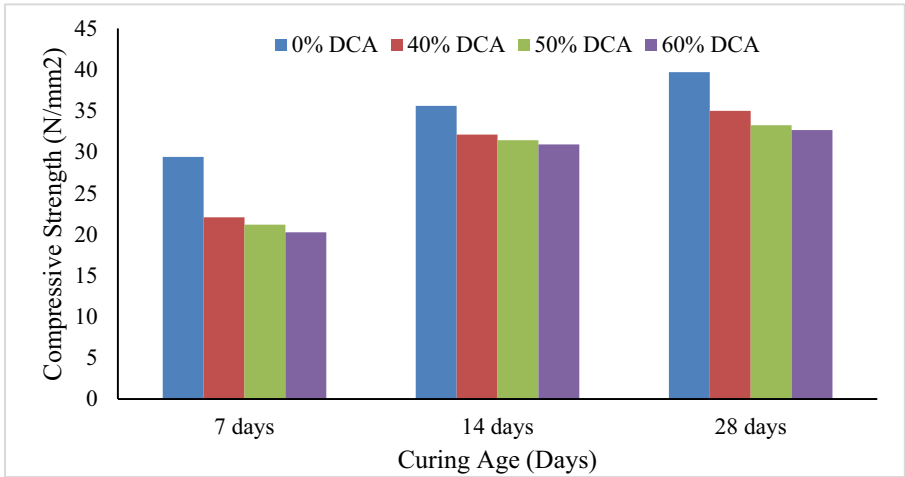


Fig. 2. Produced concrete compressive strength (N/mm²)

Table 5 shows the split tensile strength of the produced concrete. The result follows the same trend of compressive strength. That is, as the strength of the produced concrete reduces as the percentage of DCA increases in concrete. The percentage reduction to the control (0% DCA) at 28 days curing age are 4.48%, 10.36% and 20.7% for 40%, 50% and 60% DCA replacement with granite in concrete respectively. From the estimation, 50% agreed with the augment of about 10 to 15% reduction in modulus of elasticity discovered in the research of (Yehia et al. 2015). However, 40% and 60% were lesser and higher than the modulus of elasticity reduction limit (10 to 15%).

Table 5. Split tensile strength of demolished concrete aggregate

Serial Number	Mix	7 days	14 days	28 days
1	0%	2.26	2.82	3.57
2	40% DCA	2.15	2.59	3.41
3	50% DCA	2.07	2.53	3.20
4	60% DCA	2.02	2.49	2.83

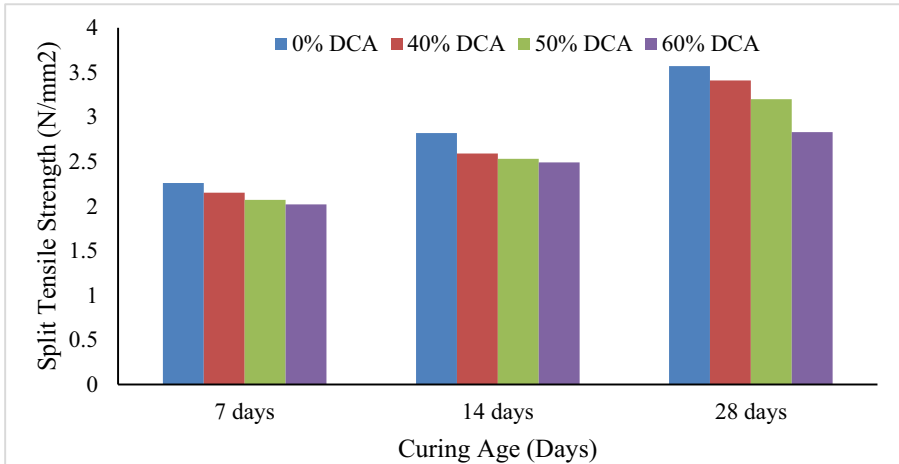


Fig. 3. Produced concrete Split tensile strength (N/mm²)

4 Conclusion

This paper investigated the mechanical behavior of concrete produced from the partial replacement of conventional coarse aggregate (granite) with demolished concrete aggregate (DCA). 40%, 50%, and 60% DCA replacements were considered in this research. Physical properties of the coarse aggregate were experimental study. Also, laboratory tests conducted on the produced concrete were slump, compressive, and split tensile tests. The entire test conducted was in line with the specification of the British and ASTM standard. The following conclusions are drawn based on the outcome of the laboratory experimental study.

- The bulk density and specific gravity of DCA and conversational granite are within the acceptable limit of 1120 to 1928 kg/m³ and 2.4 to 2.94 recommended by ASTM standards. Also, abrasion, crushing, and impact value strength test results of the DCA and granite did not exceed 30% and 45% aggregate to be used for wearing surfaces and non-wearing sur-faces recommended by British standards. Although, the granite possesses higher strength than DCA based on the laboratory experiment.
- The slump test of the produced concrete keeps reducing as the partial replacement of DCA increases. Although, the slump of the entire concrete mix was a true slump. The compressive and split tensile strength of the produced concrete also reduces as the percentage of DCA increases. However, the entire produced concrete under laboratory conditions has proven to be structural concrete that can be used for the casting of structural elements. Finally, this research has solved the problem of construction and environment sustainability by keeping the environment clean from construction demolition waste, thereby reducing the depletion of natural resources (granite) and energy efficiency in the construction world.

5 Recommendation

Considering the outcome of the research, the following recommendations are listed.

- The flexural strength of the DCA concrete should be investigated to provide more structural information regarding the material in concrete.
- Reduction of percentage replacement of DCA (such as 5%, 10%, 15%, and so on) with to the conventional aggregate needs further study as the 40% DCA concrete strength shows the close range to the conventional concrete.
- Longer curing ages of DCA concrete require further research to examine its growth in concrete strength after 28 days.

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