International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 09 Sep. 2024, pp: 141-149 www.ijaem.net ISSN: 2395-5252

Potential Use of Construction and Demolition Wastes as Aggregates for Paver Blocks

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Date of Submission: 05-09-2024 Date of Acceptance: 15-09-2024

ABSTRACT
Construction aggregates, essential building materials, are in high demand globally as population growth and urban development drive construction projects. With a staggering demand exceeding 26.8 billion tons annually, natural aggregates are increasingly utilised, especially in infrastructure projects. This study delves into the mechanical properties and performance of construction and demolition aggregates. Waste concrete from six demolition sites was crushed and rigorously tested for specific gravity, bulk density, particle size distribution, water absorption, Aggregate Impact Value, and Aggregate Crushing Value. While most aggregates met recommended standards, results for other indices varied, showing promise, particularly for lightweight structures.
Keywords: aggregates, construction, performance

I. INTRODUCTION

The construction and demolition (C&D) industry, driven by rapid urbanisation and growing demand for housing and infrastructure, generates a staggering volume of waste. This waste, composed of materials such as Portland cement concrete, asphalt concrete, wood, drywall, and more, accounts for a significant portion of the global industrial waste stream. The environmental impact of C&D waste is exacerbated by the presence of hazardous substances, including heavy metals and persistent organic compounds, making their disposal a considerable challenge.

Statistics reveal the scale of this issue, with construction activities contributing significantly to landfill waste in various countries. For instance, in the United States, construction activities are responsible for depositing 33% of all waste in landfills. In Hong Kong, the figure rises to 65%, and in Canada, it's 35%. The United Kingdom and Australia also grapple with substantial proportions, standing at 50% and 20-30%, respectively. Nigeria is not exempt from this trend, generating over 15 million tons of solid waste annually, including sand, gravel, bitumen, bricks, and masonry concrete from construction industries. The construction sector, in its quest for progress, has unintentionally become a wasteful sector. It depletes natural resources and contributes to the increasing environmental problems arising from the disposal of CDEW waste. Consequently, it becomes imperative to seek sustainable solutions for the reuse of these waste materials to maximize their potential and mitigate the associated environmental challenges.

In recent years, the construction industry has grappled with the challenge of managing the vast quantities of waste generated during construction and demolition activities. This issue not only poses environmental concerns but also presents economic implications and sustainability challenges. In response to this pressing issue, researchers and industry professionals have been exploring innovative solutions to mitigate the adverse impacts of construction and demolition wastes (CDW) while concurrently addressing the demand for construction materials.

One promising area of investigation is the potential utilisation of construction and demolition wastes as aggregates for paver blocks. Paver blocks, commonly used in landscaping, pavement construction, and urban development projects, typically require aggregates such as gravel, sand, and crushed stone. Integrating recycled and excavated waste CDEW aggregates into paver block manufacturing processes could offer a sustainable alternative to conventional aggregate

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sources, thereby reducing the reliance on natural resources and minimizing waste disposal.

Recycled aggregates (RA), derived from construction, demolition, and excavated waste (CDEW), have gained prominence as primary materials for producing paving blocks. The historical use of recycled aggregates dates back to the aftermath of World War II when demolished concrete pavements were repurposed as recycled aggregates for road construction. Concrete remains a vital resource in the construction and highway construction sectors, making the search for sustainable materials a pressing concern. The potential use of construction and demolition recycled concrete wastes as aggregates for construction presents a viable means for addressing the challenges posed by C&D waste. Utilising recycled concrete aggregates not only conserves natural resources but also reduces the carbon footprint associated with traditional aggregate production. Furthermore, incorporating RA into construction projects can enhance the overall performance and durability of concrete structures while promoting circular economy principles.

Numerous studies have demonstrated the technical feasibility and environmental benefits of incorporating RA into concrete mixtures. For example, research by Kou et al. (2020) investigated concrete's mechanical properties and durability incorporating recycled aggregates from construction and demolition waste. Their findings highlighted the potential of RA to meet the requirements of structural concrete applications while reducing environmental impacts. Similarly, a study by Tam et al. (2019) evaluated the performance of recycled concrete aggregates in pavement applications. Their results indicated that RA can effectively substitute traditional aggregates in asphalt concrete mixtures without compromising performance or durability, thus offering a sustainable solution for road construction projects.

Moreover, the economic viability of using recycled concrete aggregates has been demonstrated in various cost-benefit analyses. For instance, a study by Gutiérrez et al. (2018) assessed the life-cycle costs of incorporating RA into construction projects compared to traditional aggregates. Their analysis revealed potential cost savings and environmental benefits associated with the use of recycled aggregates, making it an attractive option for sustainable construction practices. In light of these findings, this journal aims to explore the potential use of construction and demolition recycled concrete wastes as aggregates for construction, highlighting recent advancements, challenges, and opportunities in this field. By fostering interdisciplinary collaboration and knowledge exchange, this journal seeks to promote sustainable solutions for managing CDEW waste and advancing the circular economy in the construction industry.

This investigation therefore evaluates the various aspects surrounding the potential use of CDEW aggregates in paver block production. By examining the technical feasibility, environmental implications, economic viability, and regulatory considerations, this study aims to shed light on the opportunities and challenges associated with this innovative approach. Furthermore, insights from existing research studies, case examples, and industry best practices will be synthesised to provide a comprehensive understanding of the topic.

II. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Concrete wastes were sourced from Four (4) building demolition sites within the F.C.T (Wuye, Dawaki, Jabi, and Kubwa) and the NBRRI testing laboratory, Abuja, Nigeria .

2.1.1 Preparation of Recycled Aggregates (RA)

Concrete wastes were sorted and crushed with a stone crusher as shown in Figure 2.The recovered materials were sieved to classify the size of the RA.

Figure 1: Preparation of Recycled Aggregates

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2.2 Determination of Geotechnical Properties and Performance of Recycled Aggregates

RA samples obtained were tested to determine their basic geotechnical properties for the purpose of classification. The samples were tested in accordance with BS 1377:1990. The tests conducted was also to determine the performance characteristics of recycled aggregates as pavement materials with respect to its crushing value, impact value, abrasion rate, specific gravity, flakiness, water absorption (i.e durability) and bulk density. The results are discussed below

III. RESULTS AND DISCUSSION

3.1 Particle size Distribution

Figure 2 shows the particle size distribution for the aggregate samples. The thicker lines indicate the boundaries for suitable aggregates. From the figure, it can be observed that most of the aggregate samples fell within the envelope. It is, however, generally accepted that aggregates which do not fall within the recommended boundaries can still give satisfactory results in practice as the boundaries are suggested guidelines.

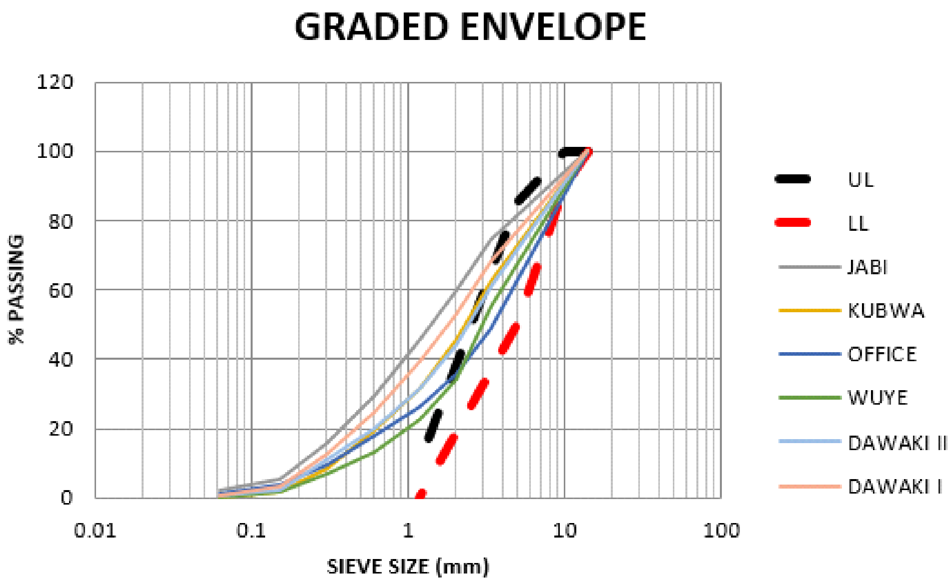

Figure 2: Particle Size Distribution curves for aggregate samples

3.2 Aggregate Crushing Value (ACV)

One of the modes in which pavement materials fail is by crushing under compressive stress. The AIV test was used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied crushing load.

Fig 3: Aggregate crushing machine

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The test was carried out by subjecting the aggregate sample to compression loading in standard mould under standard load conditions (See Fig.7). Dry samples passing through 12.5 mm sieves and retained 10 mm sieves was weighed and poured into the testing cylindrical in three layers. Each layer is tamped 25 times with a standard tamping rod. The specimen was subjected to a compressive load of 40 tonnes, which was gradually applied at the rate of 4 tonnes per minute. Then, the crushed sample was sieved through a 2.36 mm sieve and the weight of passing material (W2) is expressed as a percentage of the weight of the total sample (W1) which is the aggregate crushing value.

Aggregate crushing value = (W1/W2) *100

The aggregate crushing values for all the samples were well within the acceptable range less than 35% with aggregates sourced from the Wuye location giving the best ACV average value of below 30% as seen in figure 13. All others were significantly below 35% and qualify the aggregates for road construction use.

A value less than 10 signifies an exceptionally strong aggregate while above 35 would normally be regarded as weak.

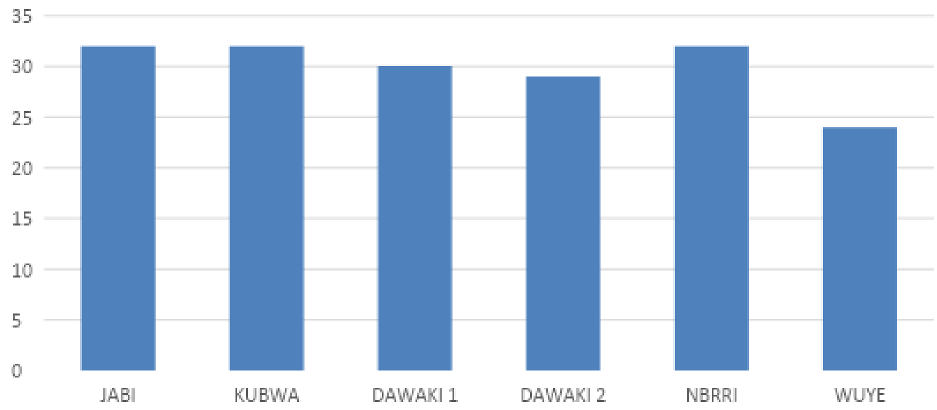

Figure 4: Variation of ACV with RA

3.3 Aggregate Impact Value

The aggregate impact test was used to evaluate the resistance to impact of aggregates passing 12.5 mm sieve and retained on 10 mm sieve. The aggregate was filled in a cylindrical steel cup of internal diameter 10.2 mm and depth 5 cm which was attached to a metal base of impact testing machine as shown in Fig. 8. The material was placed in 3 layers where each layer is tamped for 25 blows. A metal hammer of weight 13.5kg to 14 Kg was arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen was subjected to 15 blows. The crushed aggregate was allowed to pass through 2.36 mm IS sieve and the impact value was measured as a percentage of passing sieve (W2) to the total weight of the sample (W1).

Fig 5 : Aggregate Impact apparatus

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The aggregate impact values obtained showed that most of the aggregates fell within the accepted range of not more than 45% according to BS 812 Part 112 1990, the aggregates from NBRRI office showed better resistance to impact with an AIV value of less than 20% whilst the one from Dawaki 1 gave the weakest value just above 40% as illustrated in figure 12.The standard impact value shouldn't exceed 35 percent.

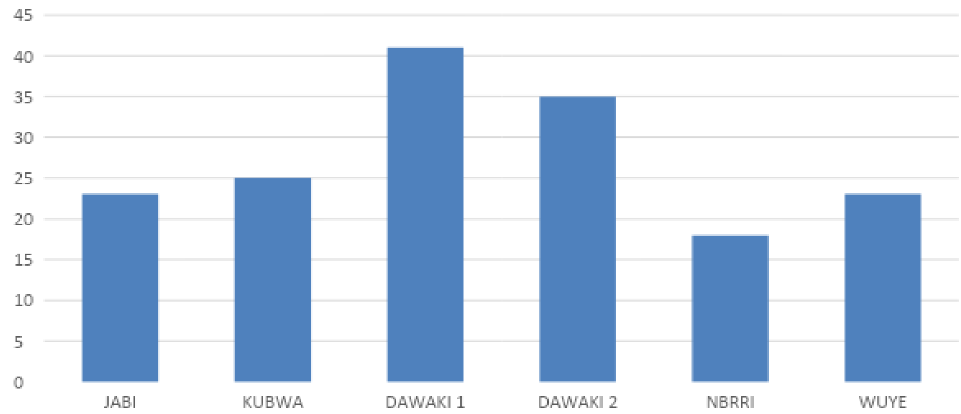

Figure 6: Variation of AIV with RA

3.4 Specific Gravity

The specific gravity of aggregates is an important property required in the design of concrete. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregate samples used in this study contain water-permeable voids, two measures of specific gravity for aggregates were used:

- Apparent specific gravity (Gapp): this was computed on the basis of the net volume of aggregate i.e the volume excluding water-permeable voids. Thus Gapp = [(MD/VN)]/W

Where,
MD is the dry mass of the aggregate,
VN is the net volume of the aggregate excluding the volume of the absorbed matter,
W is the density of water.

- Bulk specific gravity (Gbulk): this was computed on the basis of the total volume of aggregate including water permeable voids. Thus Gbulk = [(MD/VB)]/W

Where,
VB is the total volume of the including the volume of absorbed water.

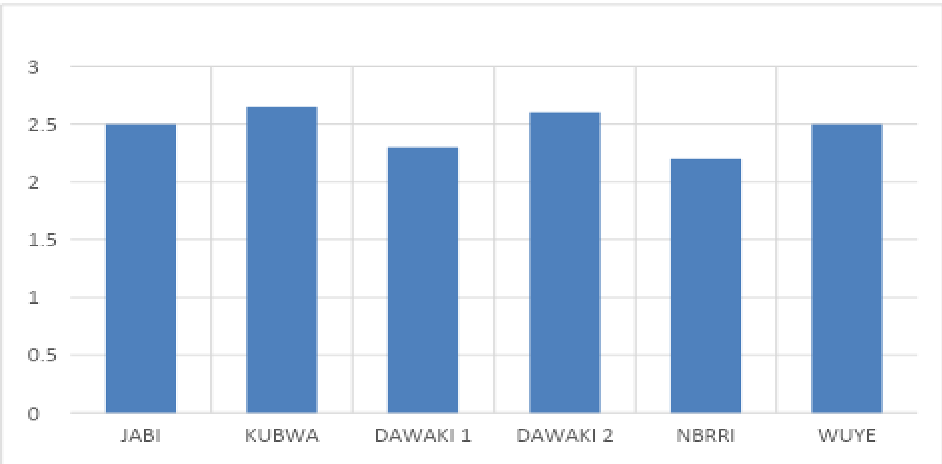

Figure 7: Variation of AIV with RA

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The specific gravity of aggregates normally used in construction ranges from about 2.5 to 3.0 with an average value of about 2.68. 2. Specific gravity of aggregates is considered as an indication of strength

3.5 Water Absorption

The main difference between the apparent and bulk-specific gravities is the water-permeable voids present in the aggregates. The volume of such voids can be measured by weighing the dry material and also in a saturated surface dry condition, with all permeable voids filled with water.
MW is the weight of dry material minus the weight of saturated surface dry condition. Thus,
Water Absorption = (MW/MD)*100
Water absorption characteristics affect the overall performance of the paver blocks in terms of durability. Materials with high water absorption tendencies lead to a loss of strength over time.
According to the standard, maximum water absorption for masonry units should be 12%.

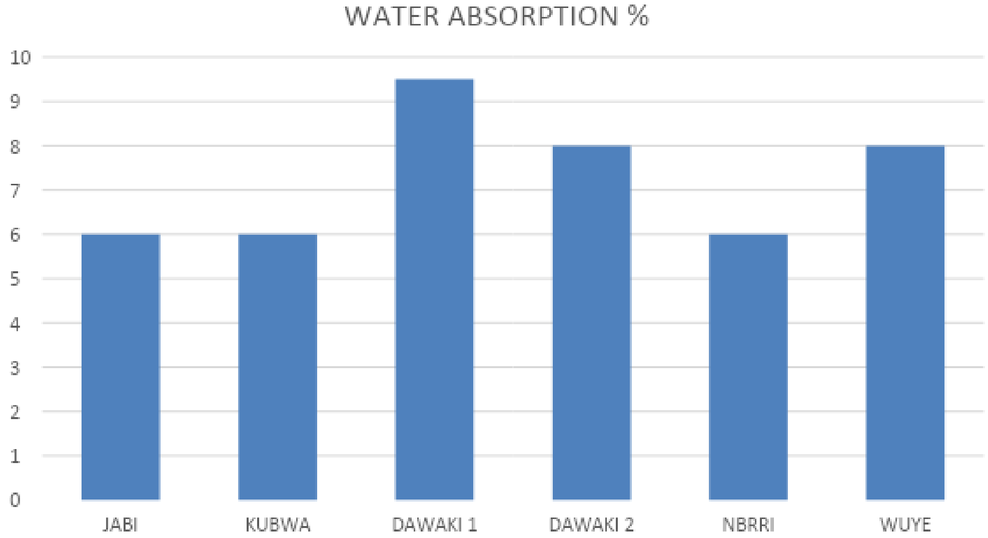

Figure 8: Variation of Water Absorption with RA

3.6 Bulk Density

Bulk density of aggregates is the mass of aggregates required to fill the container of a unit volume after aggregates are batched based on volume.

It depends on the packing of aggregate i.e. either loosely packed aggregates or well dense compacted aggregates. In case the specific gravity of material is known, then it depends on the shape and size of particles. When all the particles are of the same size then packing can be done up to a very limited extent. If the addition of smaller particles is possible within the voids of larger particles then these smaller particles enhance the bulk density of the packed material. The shape of the particles also influences very widely, because the closeness of particles depends on the shape of aggregates.

With a coarse aggregate with higher bulk density, then few of the voids can be filled by using fine aggregates and cement. For testing, British Standard (BS 812) has specified the degree of compaction. These are;

- Loose (Un-compacted)
- Compacted

The test is carried out by using metal cylinder having prescribed depth and diameter and the bulk density was determined depending on the maximum size of aggregates and the degree of compaction.

The bulk density mostly fell within the British standard acceptable range of 1600kg/m^3 - 1700kg/m^3,meaning the aggregates were compacted and thus closely packed together. These satisfactory values make the material suitable for the production of paver blocks.

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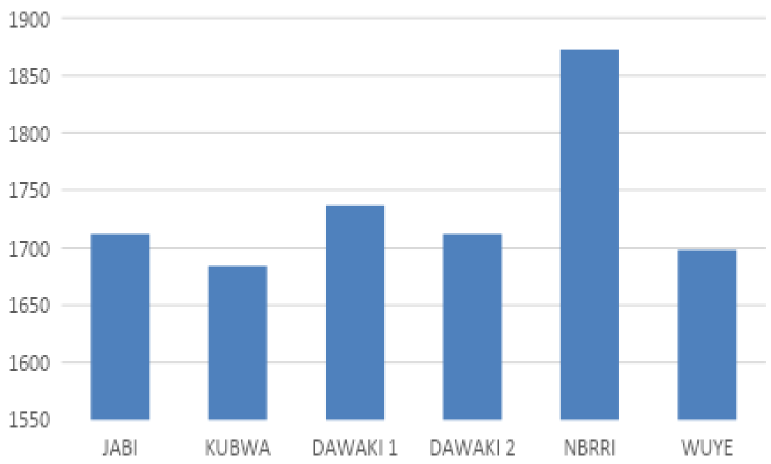

Figure 9: Variation of density with RA

The dry density of paver blocks is largely dependent on the aggregate properties, moisture content during compression and degree of compactive effort (Riza et al., 2011). It has been recorded that the ccompressive strength of individual blocks consistently increases as dry density increases (Houben & Guillaud, 1994).

3.7 Abrasion test

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property.

The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Fig-x). An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g was placed in the cylinder along with the . The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

After specified revolutions, the material was sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

3.8 Flakiness Test

The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Flaky or elongated particles are detrimental to higher workability and stability of mixes.

The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size. A flakiness gauge was used for this test.

The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension. This test applies to larger than 6.3 mm. However, there are no recognised limits for the elongation index. All the samples tested recorded zero flakiness index.

IV. CONCLUSION

The objective of the study was to investigate the potential of wastes derived from construction and demolition (C&D) concrete as aggregates in paver block production. From the investigation conducted, the following conclusion can be drawn:

- There are recommended guidelines for selecting suitable aggregates for use in paver block production with regard to particle size distribution. However, some aggregates in the study deviated from these recommendations, yet gave very satisfying results.
- Most aggregates satisfied the recommended minimum value for impact, crushing, bulk

density. flakiness index and water absorption tests

- Most aggregates did not satisfy the recommended minimum value for specific gravity
- The study shows overall promise towards preserving natural sources of aggregates, lowering the cost of production of blocks.

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