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INFLUENCE OF CRUSHED GRANITE AND WASHED GRAVEL ON THE MECHANICAL PROPERTIES OF CONCRETE

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ABSTRACT

The mechanical performance of concrete is strongly influenced by the type of coarse aggregate used, especially in regions where natural materials vary widely. In Nigeria, crushed granite and washed gravel are among the most commonly used aggregates, yet their comparative effects on concrete strength and durability are not clearly established. This study investigates the effect of aggregate type; crushed granite and washed gravel on the compressive strength and abrasion resistance of concrete to guide optimal material selection for construction. Concrete specimens were produced using a nominal mix ratio of 1:2:3 (cement: fine aggregate: coarse aggregate) and cured for 7, 14, and 28 days. Mechanical properties were evaluated through compressive strength tests and Los Angeles abrasion resistance tests. Concrete made with crushed granite achieved higher compressive strength across all curing ages, reaching 28.89 MPa at 28 days, compared to 27.11 MPa for washed gravel. Conversely, washed gravel exhibited greater abrasion resistance with a lower percentage mass loss (27.07%) than granite (35.70%), indicating stronger resistance to surface wear. Crushed granite is more suitable for structural and load-bearing applications requiring higher compressive capacity, while washed gravel performs better in pavement or finishing works where surface durability against friction and abrasion is essential.

KEYWORDS: *Abrasion Resistance, Coarse Aggregates, Compressive Strength, Concrete, Crushed Granite, Washed Gravel.*

INTRODUCTION

Concrete remains the backbone of modern infrastructure, valued for its adaptability, affordability, and structural reliability. In rapidly developing nations such as Nigeria, concrete is extensively used in residential, commercial, and infrastructural projects from roadways and high-rise buildings to bridges and dams (Langer, 2016; Singh et al., 2023). While the strength and durability of concrete are often associated with cement quality, a significant proportion of its mechanical performance particularly compressive strength and wear resistance depends on the characteristics of its coarse aggregates, which typically account for 60% to 75% of its volume (Kılıç et al., 2008; Kosmatka et al., 2002). Among the most accessible and widely used coarse aggregates in Nigeria are crushed granite and washed gravel. Crushed granite is derived from hard rock sources and is characterised by its angular, rough texture, which promotes mechanical interlock and strong bonding with the cement paste, in contrast, washed gravel commonly sourced from riverbeds is rounded and smoother, leading to improved workability but sometimes at the expense of compressive performance (Chat et al., 2015; Singh et al., 2023). Mechanical indicators such as compressive strength and abrasion resistance are critical for evaluating suitability of concrete in structural and surface applications. Compressive strength determines the load-bearing capacity, while abrasion resistance reflects how well the surface withstands friction, wear, and impact which are vital in pavements, factory floors, and similar contexts (Kılıç et al., 2008; Li et al., 2011; Bamigboye et al., 2016).

Studies have explored how aggregate properties influence concrete behaviour. For example, Chat et al. (2015) reported that properly washed gravel improved strength compared to unwashed variants, likely due to the removal of silt and clay impurities. Similarly, Kılıç et al. (2008) and Bamigboye et al. (2019) observed that crushed granite consistently delivers higher compressive strength due to its mineral content and angular geometry. Despite these insights, few empirical comparisons exist where both aggregate types are tested under standardised mix ratios and curing conditions. The mechanical performance of concrete is significantly influenced by the type, texture, and mineralogy of the coarse aggregate used. Numerous comparative studies have explored how crushed granite and natural gravel affect key properties such as compressive strength and abrasion resistance under various environmental and mix conditions. Chat et al. (2015) conducted a comparative study in Nigeria using natural gravel and crushed granite as coarse aggregates in concrete. Their results indicated that crushed granite yielded higher compressive strength values at all curing stages, attributing this to the angular shape and rough surface texture of granite, which improve bond strength within the cement matrix. A similar regional study by Onwasigwe and Onodagu (2024) supported this claim, reporting that concrete with river gravel consistently underperformed compared to granite-based concrete under identical curing conditions. International findings echo these results. Kılıç et al. (2008) observed that concrete made with crushed granite had both superior compressive strength and surface bonding compared to concrete containing rounded gravel. However, they noted that gravel improved abrasion resistance, likely due to its denser packing and reduced interfacial voids. This trade-off was further explored by Li et al. (2011), who concluded that concrete's resistance to wear often correlates with, but is not always proportional to, compressive strength. Bamigboye et al. (2019) advanced this by examining blended aggregates and found that strategic ratios of gravel and granite could balance compressive performance with durability an approach that could optimise material use in Nigerian construction. Sharma & Vyas (2023) investigated the use of granite waste as partial replacement for natural aggregates and found notable improvement in compressive strength with minimal trade-offs in abrasion resistance, pointing to the significance of aggregate surface properties. Meanwhile, Zhang et al. (2020) emphasised that crushed sand or granite enhanced concrete's resistance to surface degradation due to better particle angularity and cement paste adhesion. Li et al. (2011) noted that while granite aggregates improve strength and stiffness in both normal and high-performance concrete, their influence on wear resistance varies based on microstructural interaction with the cement matrix. Finally, Singh et al. (2016) and Amani et al. (2021) highlighted sustainability by evaluating the use of granite cutting waste and marble-granite powder combinations, respectively. Both studies confirmed that modified or recycled granite aggregates could maintain structural performance while enhancing abrasion resistance and reducing environmental impact.

Across these studies, a clear conceptual pattern emerges: the mechanical behaviour of concrete is strongly governed by the physical and mineralogical attributes of its coarse aggregates. Angular and rough-textured aggregates such as crushed granite tend to form stronger interfacial bonding with cement paste, resulting in higher compressive strength and improved stiffness. In contrast, rounded aggregates like washed gravel reduce internal friction and packing voids, enhancing workability and often improving abrasion and impact resistance due to more uniform stress distribution under surface wear. Mineral composition also plays a crucial role, as harder, more crystalline aggregates generally enhance strength, while smoother grains limit microcracking under repeated frictional forces. These relationships provide an important theoretical basis for comparing granite and gravel under controlled conditions, helping explain why their performance diverges across different mechanical tests.

Although crushed granite and washed gravel are widely used in Nigerian construction, their mechanical behaviour presents a practical performance trade-off, granite typically enhances compressive strength, while washed gravel often improves abrasion and impact resistance. However, direct comparative data generated under a uniform mix design and identical curing conditions remain limited. This lack of controlled evidence makes aggregate selection largely experience-based rather than performance-driven. Therefore, this study provides a systematic comparison of both aggregates to generate clearer, context-specific guidance for engineers and practitioners in Nigeria.

This study aims to evaluate and compare the mechanical performance of concrete incorporating two commonly used coarse aggregates in Nigeria crushed granite and washed gravel. Specifically, it seeks to achieve the following objectives:

1. To assess the abrasion resistance of crushed granite and washed gravel.
2. To compare the compressive strength development of concrete made with crushed granite and washed gravel.

MATERIALS AND METHOD

This study adopted an experimental approach using crushed granite and washed gravel as coarse aggregates. The investigation focused on two mechanical properties: compressive strength and abrasion resistance. A standard concrete mix ratio of 1:2:3 (cement: sand: coarse aggregate) was employed across all test batches to maintain consistency and isolate the effects of the aggregate type. The mechanical tests adopted in this study were selected based on their established relevance in assessing aggregate performance in structural concrete. The Los Angeles abrasion test was included to determine the degradation resistance of aggregates under mechanical wear, which is essential for pavements and surface applications. The impact test was conducted to evaluate the toughness of aggregates and their ability to withstand sudden or shock loading, a property that influences concrete resilience under dynamic loads. Compressive strength testing was carried out because it represents the most widely used indicator of structural performance and determines suitability for load-bearing applications. Together, these tests provide a comprehensive understanding of how each aggregate type influences concrete performance in real construction scenarios. To ensure reliability of results, all tests were conducted in at least two replicates for each aggregate type. During sample preparation, moulds were cleaned, uniformly oiled, and compacted using identical procedures to minimise inconsistencies. Aggregate samples were oven-dried to constant weight and sieved to standardised particle size ranges. All instruments were calibrated prior to testing to ensure accuracy and consistency of measurements.

Source of materials

The materials used in this study include Ordinary Portland Limestone Cement, fine aggregate (sharp sand), coarse aggregates (crushed granite and washed gravel), and clean water. The cement used conformed to BS EN 197-1:2000 standards.

1a: Ordinary Portland Cement

1b: Coarse Aggregate (crushed stone)

1c: Coarse Aggregate (Gravel)

1d: Fine Aggregate

Plate 1: Experimental Materials

Methods

The mix design for this experimental study was based on the BS 1881 standard for making and curing concrete test specimens in the laboratory. The study involved preparing concrete mixes without any admixture. Sieve analysis was performed on the fine aggregate (sand) to determine its particle size distribution, the purpose of this is to obtain well graded and finely distributed input of raw materials so as to have quality mixes. Once the mix was ready, it was cast into 150mm x 150mm x 150mm cube moulds. The concrete in the molds was compacted using a compacting rod to ensure proper density and to remove any entrapped air, which could compromise the integrity of the samples. After 24 hours, the concrete specimens were carefully demolded. Following demoulding, the specimens were immediately placed in a curing tank filled with clean water, the prepared specimens were then left to cure under controlled conditions until the scheduled testing periods. The cubes remained fully submerged in the water throughout the curing period, ensuring continuous hydration of the cement. Curing durations of 7, 14, and 28 days were observed. On the day of testing, the specimens were removed from the curing tank, surface-dried to remove excess water, and then tested according to the respective standards.

2a: Specimen in moulds

2b: Curing

Plate 2: Sample Preparation

The total number of cubical specimens prepared includes twelve cubes of 150mm x 150mm x 150mm dimensions. The twelve larger cubes were divided into two groups: six cubes made using crushed granite and six cubes made using washed gravel as coarse aggregates, specifically for compressive strength testing. The mix proportions for these cubical specimens are presented in in Table 1 below.

Table 1: Mix proportion for cubical specimens

Mix Ref	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)	w/c Ratio
Crushed Granite	9.2 kg	18.4 kg	27.6 kg	5.0 kg	0.54
Washed Gravel	9.2 kg	18.4 kg	27.6 kg	5.0 kg	0.54

Los Angeles Abrasion Test

The Los Angeles (L.A.) Abrasion Test is one of the most widely used methods to assess the relative quality of aggregates, helping predict how they will endure wear and tear over time. This test measures the degradation of aggregates under standardised conditions, where aggregates are subjected to abrasion and impact in a rotating steel drum containing a charge of steel balls. The drum is equipped with an internal shelf that lifts and drops the charge and sample during each revolution at 30-33 rpm, generating significant impact forces. After the test completes the specified number of revolutions, the sample is removed, and the percentage loss in weight is measured.

The procedure for the Los Angeles Abrasion test was reported as follows:

A clean and dried aggregate sample was dried at a temperature between 105°C and 110°C. 5 kg of the aggregate samples for Los

Angeles machine to process. Abrasive charge balls were selected based on the grading of the aggregates. The aggregates and abrasive balls were placed into the Los Angeles abrasion machine's cylinder, ensuring the cover is securely fixed. The machine is rotated at a constant speed of 30 to 33 revolutions per minute. After completing the specified revolutions, the machine was stopped. the aggregate sample was transferred along with any generated stone dust, from the machine's drum to a tray. The entire material was sieved using a 1.70 mm sieve to separate finer particles from coarser ones. The fraction of material larger than 1.7 mm to the nearest gram was weighed to determine the Los Angeles Abrasion Value.

Impact Test

An impact test is a method used to assess a material's ability to resist deformation when subjected to a sudden shock or impulse load. This test involves striking a specially prepared test specimen with a weight to simulate impact conditions. The selected aggregates, sized between 10.0 mm and 12.5 mm, were dried by heating them at a temperature range of 100-110°C for 4 hours and then allowed to cool to room temperature. The cooled aggregates were sieved using 12.5 mm and 10.0 mm IS sieves. The material that passed through the 12.5 mm sieve and was retained on the 10.0 mm sieve was selected as the test sample. The test sample was poured into a measuring cylinder until it filled approximately one-third of the cylinder's depth. The material was compacted by giving 25 gentle blows with the rounded end of a tamping rod. Two additional layers of aggregates were added to the cylinder; each layer being compacted with 25 gentle blows until the cylinder was completely filled. The excess aggregate was leveled off, and the net weight of the filled aggregates was recorded to the nearest gram as W1. The impact machine was set up on a stable, level surface, ensuring that the hammer guide columns were vertical. The filled measuring cylinder was secured firmly in position on the machine's base. The hammer of the impact machine was raised to a height of 380 mm above the surface of the aggregate sample and then allowed to fall freely onto the sample. This process was repeated 15 times, with each blow delivered at an interval of no less than one second. After the hammering process, the crushed aggregate was carefully removed from the cylinder and sieved through a 2.36 mm IS sieve until no significant amount passed through the sieve within one minute. The weight of the material passing through the sieve was recorded to the nearest gram as W2. The portion of the aggregate retained on the sieve was also weighed and noted. The Aggregate Impact Value (AIV) was calculated using the formula AIV= {W2}/{W1}x100. The AIV was determined as the average of two observations and rounded to the nearest whole number.

Compressive Strength Test

Compressive testing is a method used to evaluate how a material reacts under compression, specifically by determining its behaviour when subjected to crushing loads. This type of testing measures the material's ability to resist deformation and its plastic flow behaviour, as well as its ductile fracture limits. In the context of concrete, compressive strength testing is used to assess the strength of hardened concrete by applying a crushing load to specimens in a compression testing machine.

3b: Sample in bowl **3b: Compression testing machine**

Plate 3: Testing Procedures

RESULTS AND DISCUSSION

Impact Test

Table 2: Impact test data

S/N	Details	Aggregate Type	
		Crushed Granite	Washed Gravel
1	Weight of empty measuring cylinder = W_1(g)	970.2g	970.2g
2	Weight of aggregate with measuring cylinder = W_2(g)	4700.3g	4850.7g
3	Weight of empty 2.6mm sieve = W_4 (g)	325.3g	325.3g
4	Weight of aggregate retaining in the 2.36mm sieve with sieve pan = W_5(g)	3746.8g	3782.4g
5	Weight of aggregate passed through 2.36mm sieve = W_3(g)	308.6	423.4

From Table 2, the following values are taken to calculate the following:

i. Weight of the Crushed Granite Sample = W_2(g) – W_1(g) = 4700.3g - 970.2g = 3,730.1g

ii. Weight of the Washed Gravel Sample = W_2(g) – W_1(g) = 4850.7g - 970.2g = 3880.5g

iii. Weight of Granite sample retained on 2.36mm sieve = W_5 (g) - W_4 (g) = 3746.8g – 325.3g = 3421.5g

iv. Weight of Gravel sample retained on 2.36mm sieve = W_5 (g) - W_4 (g) = 3782.4g – 325.3g = 3457.1g

v. Weight of Granite sample passing through 2.36mm sieve = W_3 (g) = [W_2(g) – W_1(g)] – [W_5 (g) - W_4 (g)] = 3,730.1g - 3421.5g = 308.6g

vi. Weight of Gravel sample passing through 2.36mm sieve = W_3 (g) = [W_2(g) – W_1(g)] – [W_5 (g) - W_4 (g)] = 3880.5g - 3457.1g = 423.4g

vii. Impact value of Crushed Granite sample = $\frac{W3\ (g)}{W2(g) - W1(g)}\ x\ 100\%$ = $\frac{308.6g}{3,730.1g}\ x\ 100\%$ = 8.27%

viii. Impact value of Washed Gravel sample = $\frac{W3\ (g)}{W2(g) - W1(g)}\ x\ 100\% = \frac{423.4g}{3880.5g}\ x\ 100\%$ = 10.9%

Table 3: Impact Test Results

Aggregate Type	Sample Weight	Retained Weight	Sieved Weight	Impact Value
Washed Gravel	3730.1g	3421.5g	308.6g	0.0827
Crush Granite	3880.5g	3457.1g	423.4g	0.1090

Note: *Exceptionally strong<10%, Strong 10-20%, Satisfy for surface course 20-30%, Weak for surface course>35%*

Table 3 reveals that weight of the sample of gravel used in the impact test was 3730.1g which is slightly lower than the weight of the granite. The weight of the of granite sample was higher than that of gravel with 3457.1g and 3421.5g respectively, also the weight of sieved granite is higher than that of gravel with 423.4g and 308.6g. This implies that the impact of hammer was greater on the granite than gravel despite the weight of the granite. The impact value of granite which is 10.90% is more than that of gravel which is 8.27%, this implies that gravel has more resistance to a sudden impact or shock than granite. Resistance to sudden impact is different from gradual impact applied in compressive load.

Table 4: Abrasion test result

Aggregate Sample	Weight of Sample (Wi)	Weight of Sample After Loss (W_f)	Weight of the Dust (W_d)	Percentage loss
Crushed Granite	5000g	3213.3g	1786.70g	35.70
Washed Gravel	5000g	3646.5g	1353g	27.07

ix. Sample W_d = (Wi) - (W_f)

x. Washed Gravel W_d = 5000g - 3646.5g = 1353.50g

xi. Crushed Granite W_d = 5000g - 3213.3g= 1786.70g

xii. Percentage loss (Abrasion Value) = $\frac{Wd}{Wi}$ x 100

xiii. Percentage loss (Abrasion Value) ratio for Washed Gravel = $\frac{1353.50g}{5000g}$ x 100 = 27.07%.

xiv. Percentage loss (Abrasion Value) for Crushed Granite = $\frac{1786.70g}{5000g}$ x 100 = 35.70%.

From the calculations, the results show that the percentage loss (abrasion value) of the washed gravel and crushed granite samples was 27.07% and 35.70%, respectively. This indicates that crushed granite experienced a higher loss in mass under abrasive action than washed gravel, implying that the granite aggregate has lower resistance to mechanical degradation compared to the gravel sample. According to the classification of rock types by their Los Angeles abrasion values, both aggregates fall within the granitic range (27–49%), confirming their comparable geological composition and suitability for concrete production, as presented in Table 5.

Table 5: Classification of rock according to Loss Angeles abrasion value

Aggregate type	Los Angeles Abrasion value (%)
Basalt	10-17
Dolomite	18-30
Gneiss	33-57
Granite	27-49
Limestone	19-30
Quartzite	20-35

Source: Adomako et al. (2021)

Compressive Strength Test

Table 6: Compressive strength of samples of 150mm cubes

Specimen	Maximum Load (KN)	Maximum Load (N)	Compressive Strength (N/mm²)	Numbers of Days
Granite Sample A	420KN	420,000N	18.67N/mm2	7
Granite Sample B	480KN	480,000N	21.330N/mm2	7
Average of Granite Sample A&B	450KN	450,000N	20N/mm2	7
Gravel Sample A	375KN	375,000N	16.67N/mm2	7
Gravel Sample B	445KN	445,000N	18.78N/mm2	7
Average of Gravel Sample A&B	410KN	410,000N	18.22N/mm2	7
Granite Sample A	535KN	535,000N	22.78N/mm2	14
Granite Sample B	625KN	625,000N	27.78Nmm2	14
Average of Granite Sample A&B	580KN	580,000N	25.78N/mm2	14
Gravel Sample A	520KN	520,000N	23.11N/mm2	14
Gravel Sample B	580KN	580,000N	25.11N/mm2	14
Average of Gravel Sample A&B	550KN	550,000N	24.44N/mm2	14
Granite Sample A	615KN	615,000N	27.33N/mm2	28
Granite Sample B	685KN	685,000N	30.44N/MM2	28
Average of Granite Sample A&B	650KN	650,000N	28.89N/mm2	28
Gravel Sample A	595KN	595,000N	26.44N/mm2	28
Gravel Sample B	625KN	625,000N	27.77N/mm2	28
Average of Gravel Sample A&B	610KN	610,000N	27.11N/mm2	28

The results in Table 6 indicate that concrete made with crushed granite consistently achieved higher compressive strength than that made with washed gravel across all curing ages. At seven days, granite-based concrete reached 20.00 N/mm², while gravel-based concrete achieved 18.22 N/mm², indicating faster early strength development in granite mixes. By fourteen days, the strength increased to 25.78 N/mm² for granite and 24.44 N/mm² for gravel. At the standard curing age of 28 days, granite reached 28.89 N/mm², compared to 27.11 N/mm² for gravel. Although both aggregates produced concrete within the acceptable compressive strength range, but granite-based concrete consistently outperformed gravel-based concrete, especially in early curing, making it more suitable for applications where early strength is critical.

To enhance the interpretability of the compressive strength data, the results are also presented graphically in Figures 1 and 2. Figure 1 shows the development of compressive strength with curing age for both aggregate types, while Figure 2 compares the average strength of granite and gravel concretes at each curing age.

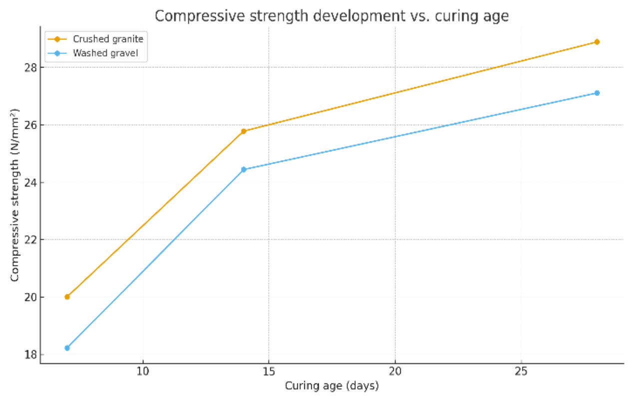

Figure 1. Compressive strength development of concrete produced with crushed granite and washed gravel over 7, 14, and 28 days.

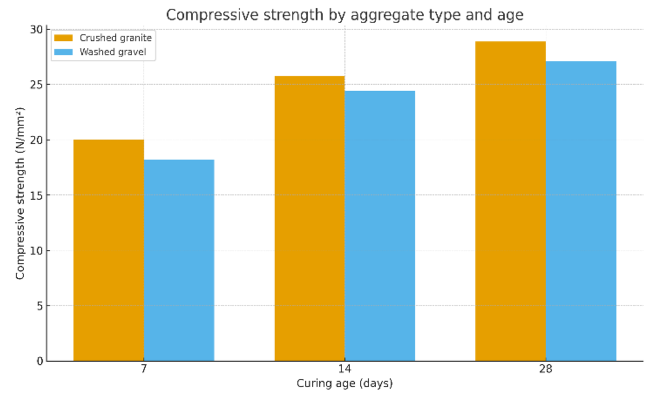

Figure 2. Comparison of average strength of concrete made with crushed granite and washed gravel

The graphical representations clearly illustrate that compressive strength increases with curing age for both aggregate types, with crushed granite consistently achieving higher values at each age. The steeper growth curve observed for granite concrete in Figure 1 indicates faster early strength gain, while Figure 2 confirms its overall superior performance compared to gravel. These trends reinforce the numerical results presented in Table 6.

DISCUSSION

The experimental outcomes of this research clearly demonstrate that aggregate type has a pronounced effect on the mechanical properties of concrete. Based on compressive strength, impact resistance, and abrasion resistance testing, crushed granite and washed gravel have revealed distinct and valuable characteristics for various construction applications.

Concrete mixes using crushed granite exhibited higher compressive strengths at all curing intervals. At seven days, fourteen days and 28 days, granite-based concrete recorded compressive strengths of 20.00 N/mm², 25.78 N/mm², and 28.89 N/mm² respectively. In contrast, washed gravel-based samples yielded 18.22 N/mm², 24.44 N/mm² and 27.11 N/mm². These results align with findings by Sulymon et al. (2017), which demonstrated that angular aggregates such as crushed granite enhance mechanical bonding and strength development. Similarly, Cordeiro et al. (2016) showed that the rough surface texture of crushed granite contributes significantly to early and sustained compressive strength through improved interfacial bonding.

Additional confirmation is found in Bamigboye et al. (2019), who assessed granite-gravel combinations and concluded that crushed granite consistently produces higher compressive values than washed or unwashed gravel in self-compacting concrete. Despite the narrower compressive strength margin observed in granite-based and gravel-based concrete in this study, the advantage of granite makes it more suitable for structural members subjected to high compressive loading.

The impact test results revealed that washed gravel concrete exhibited better toughness and resilience under sudden loading. The calculated impact value for gravel was 8.27%, while granite measured 10.9%. According to standard interpretation, both values fall within the “strong” category, but gravel's lower impact value suggests greater energy absorption capacity and crack resistance. This agrees with findings from Echeta et al. (2013), who noted that rounded gravel particles allow better compaction and distribute impact forces more uniformly throughout the matrix. Arel & Shaikh (2019) also emphasised on the contribution of gravel to improved dynamic durability, particularly under cyclic or vibratory stresses.

In terms of abrasion resistance, concrete with washed gravel again outperformed that made with crushed granite. The abrasion percentage loss was 27.07% for gravel versus 35.70% for granite, indicating that gravel concrete better resists wear and surface degradation under repeated mechanical abrasion. These results reinforce conclusions by Ephraim & Rowland-Lato (2015), who reported that gravel aggregates, owing to their roundness and compactness, produce concrete with higher surface durability. Moreover, Gupta & Vyas (2018) emphasized the importance of aggregate surface properties on long-term abrasion performance, showing that smoother particles often resist surface loss better in service.

Overall, the performance differences between crushed granite and washed gravel reveal a practical trade-off: granite excels in compressive strength, while gravel provides superior abrasion and impact resistance, the selection of aggregate should therefore be driven by the structural requirements of the specific application (Diwate et al., 2024). For high-load-bearing elements, crushed granite is preferable. In contrast, for surfaces exposed to friction, wear, or dynamic loads, washed gravel is more appropriate.

CONCLUSION RECOMMENDATIONS

Conclusion

This study examined the mechanical behaviour of concrete produced with two commonly used coarse aggregates which are crushed granite and washed gravel. The results showed that concrete made with crushed granite consistently achieved higher compressive strength at 7, 14, and 28 days. This improved performance is largely due to the angular and rough texture of granite, which promotes stronger bonding with the cement paste. In contrast, washed gravel exhibited better abrasion resistance and a lower impact value, indicating greater toughness and a higher capacity to absorb sudden loading. These findings reveal a clear performance trade-off between the two aggregates and demonstrate that the choice of aggregate should be guided by the specific mechanical demands of the intended application.

Recommendations

Based on the outcomes of the investigation, crushed granite is more suitable for structural elements that require high compressive strength, such as beams, columns, and foundations. Washed gravel, however, is better suited for applications where durability against wear and impact is critical, including pavements, walkways, driveways, and industrial floors. For structures requiring a balance of both strength and surface durability, a blended aggregate mix may be explored to combine the advantages of each material. Future studies should also assess the long-term durability of these aggregates under real environmental conditions, including chemical exposure, freeze–thaw cycles, sustained dynamic loading, and moisture variations, to provide a more comprehensive understanding of their performance in service.

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