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Comparative Engineering Properties of Basalt and Porphyritic Granite in Tokbet-Katul, Pankshin Sheet 190 SE, North-Central Nigeria

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Abstract

This study investigates the geological characteristics and comparatively evaluates the engineering properties of basalt and porphyritic granite exposed in Tokbet-Katul, Pankshin Sheet 190SE, North-Central Nigeria, to determine their suitability for diverse construction and infrastructure applications. An integrated approach involving field geological mapping, petrographic characterization, structural analysis, and geotechnical testing was adopted. Detailed field mapping was undertaken to delineate lithological units and characterize structural features, while representative rock samples were collected for petrographic examination using polarized light microscopy and subjected to engineering tests, including specific gravity, density, porosity, water absorption, uniaxial compressive strength (UCS), aggregate crushing value (ACV), aggregate impact value (AIV), soundness, flexural strength, and hardness.

Petrographic analysis revealed that the porphyritic granite is composed predominantly of quartz, feldspars, biotite, and minor accessory minerals, whereas the basalt consists mainly of plagioclase, pyroxene, olivine, and opaque minerals, reflecting compositional and textural differences that influence their mechanical performance. Structural analysis identified dominant NNE-SSW joint orientations in the granite and NNW-trending fractures in the basalt, indicating contrasting deformation patterns with implications for quarrying and rock mass behavior. Geotechnical results show that porphyritic granite exhibits superior mechanical strength, with higher specific gravity (2.95 compared to 2.85), uniaxial compressive strength (34 MPa compared to 31 MPa), flexural strength (10.24 MPa compared to 9.45 MPa), and hardness (6.4 compared to 6.1). In contrast, basalt demonstrates better aggregate performance, as reflected by lower aggregate crushing value (19.15% compared to 22.26%) and improved soundness (7.20% compared to 7.45%), indicating greater resistance to crushing and weathering cycles. Both lithologies exhibit very low porosity (<0.08%) and low water absorption (<0.7%), indicative of dense, durable materials. The results indicate that both rock types satisfy international standards for construction materials and are suitable for engineering applications. However, porphyritic granite is more suitable for high-strength structural applications requiring enhanced compressive and flexural resistance, whereas basalt is more appropriate for road aggregates and environments where resistance to impact, crushing, and cyclic weathering is critical. This comparative evaluation provides essential baseline geological and engineering data for the optimal utilization of these locally available rock resources in sustainable engineering and construction projects.

Keywords

Basalt,
Comparative,
Engineering Properties,
Petrography,
Porphyritic Granite

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1. INTRODUCTION

The study area in north-central Nigeria is underlain by a combination of Precambrian crystalline basement rocks and Tertiary to Quaternary volcanic successions, resulting in a terrain that prominently features both granitic intrusions and basaltic lava flows (Wright, 1976; Obaje, 2009). The granitic rocks belong to the widespread Older Granites suite, representing syn- to post-tectonic Pan-African intrusions, while basaltic flows are products of Tertiary to Recent volcanic episodes associated with intracontinental magmatism along the Cameroon Volcanic Line (Rahaman, 1988; Fitton, 1980). The plutonic rocks are typically coarse-grained, compositionally felsic, and structurally jointed, with varying degrees of weathering depending on topography and climatic exposure (Ajibade & Fitches, 1988; Annor & Olobaniyi, 2002). The volcanic rocks occur as lava fields, plugs, cones, and pyroclastic deposits, and are characterized by the presence of pyroxene, plagioclase, and olivine minerals (Abaa, 2002; Kogbe, 1989).

Naturally, rocks are complex geomaterials with their mechanical properties significantly influenced by stress state, lithology and other geological characteristics (He et al., 2025). Infrastructural development across central Nigeria has led to increased reliance on local rock materials for road foundations, concrete aggregates, and structural fill. It is imperative to determine the strength of these rocks being utilized. Consequently, the geotechnical performance of these rocks under construction loading and environmental stress has become a critical area of focus (Ajayi &

Balogun, 1988; Akinbinu, 2015). Rocks can be utilized in engineering structures as fill and reclamation material in construction such as cut slopes, foundations, and underground excavation (Zainil et al., 2023). Basaltic outcrops have been exploited for decades for road stone, aggregates, and construction materials due to their high density and perceived mechanical competence (Choi et al., 2021).

Engineering properties of rocks—including specific gravity, porosity, unconfined compressive strength, and water absorption—are directly influenced by mineralogy, texture, weathering state, and fabric alignment (Bell, 2007; Goodman, 1989). Despite several studies on geotechnical assessment of individual rock types in Nigeria, comparative engineering behavior of basalts and granites within the same geological setting remains insufficiently documented. This study aims to conduct a comprehensive geological investigation and comparative analysis of the engineering properties of basalts and porphyritic granites with the objectives to carry out general geologic and petrographic studies, produce a detailed geologic map, assess engineering properties through standardized laboratory tests, and comparatively evaluate the engineering properties of both rock types.

1.1 Location of the Study Area

The study area is situated within Pankshin Sheet 190SE, located in North-Central Nigeria, between latitudes 9°12'00" and 9°20'00" N, and longitudes 9°15'00" and 9°18'00" E (Figure 1).

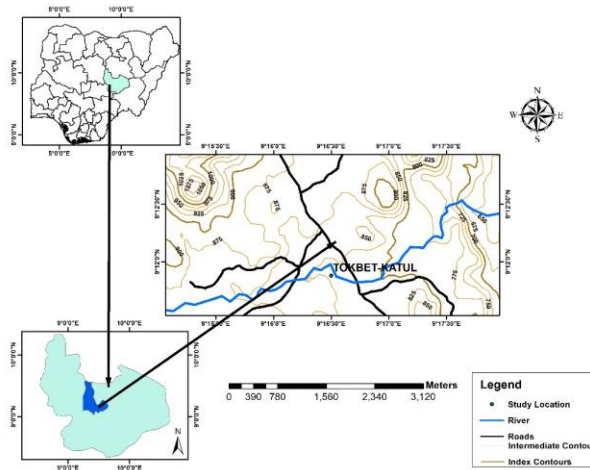


Figure 1: Location Map of the Study Area (Modified from STRM DEM, USGS, 2000)

1.2 GEOLOGICAL SETTING

The study area lies within the Nigerian Basement Complex, which forms part of the Pan-African mobile belt and comprises three main lithological components; the Migmatite-Gneiss Complex, the Schist Belts, and the Older Granites (Rahaman, 1988; Dada, 2006). The Basement Complex in Nigeria has undergone multiple thermo-tectonic events including the Liberian (~2800 Ma), Eburnean (~2000 Ma), Kibaran (~1100 Ma), and Pan-African (~600 Ma) orogenies. The Sara-Fier Complex, within which the study area is situated, represents one of the most significant intrusive suites within the Pan-African Basement Complex of North-Central Nigeria. It is characterized by a diverse assemblage including biotite granites, porphyritic granites, granodiorites, and associated basaltic flows (Ajibade et al., 1987; Annor, 1998).

2. MATERIALS AND METHOD

2.1 Field Mapping

Detailed geological field mapping was conducted on a scale of 1:12,500 using pace traversing method. Global Positioning System (GPS) was used to record coordinates of

outcrops, while compass clinometer measured structural orientations. Structural data including joints, veins, and fractures were recorded for statistical analysis and rose diagram construction.

2.2 Petrographic Analysis

Thin sections of representative samples were prepared at the Department of Geology, University of Jos. Samples were trimmed to 2.5 cm × 4.5 cm blocks, ground flat, mounted on glass slides using epoxy resin, and ground to 30 μm thickness (Grundmann, & Scholz, 2015). Mineral identification and modal analysis were conducted using a polarizing microscope under plane-polarized light (PPL) and cross-polarized light (XPL).

2.3 Geotechnical Sampling and Testing

Representative block samples of porphyritic granite and basalt were collected from fresh exposures within the study area following recommended geological sampling practices outlined by Bell (2007). Both representative samples were subjected to laboratory testing following international standards (Table 1) at the In-Depth Geotechnics Kaduna.

Table 1 List of Laboratory Tests and the Standards Used

| Test | Standard | Purpose |
|-------------------------------|-------------------|---|
| Specific Gravity | BS 812, ASTM C127 | Measure relative density |
| Density | BS 812, ASTM C127 | Determine mass per unit volume |
| Porosity | ISRM (1981) | Quantify void spaces |
| Water Absorption | ASTM C97, BS 812 | Assess moisture uptake |
| Uniaxial Compressive Strength | ISRM (1979) | Determine load-bearing capacity |
| Aggregate Crushing Value | BS 812 | Measure resistance to crushing |
| Aggregate Impact Value | BS 812 | Assess resistance to impact |
| Soundness | ASTM C88 | Evaluate durability under chemical attack |
| Flexural Strength | ASTM C880 | Measure bending resistance |
| Hardness | Mohs Scale | Determine resistance to abrasion |

2.3.1 Specific Gravity

The specific gravity of the rock samples was determined to establish their relative density and assess their suitability for construction works. Representative chips of granite and basalt were oven-dried at 105 ± 5 °C for 24 hours to remove moisture, cooled in a desiccator, and weighed in air (W_1). The samples were then immersed in water for 24 hours to ensure saturation, weighed while suspended in water (W_2), and finally weighed again when surface dried (W_3). The specific gravity (SG) was computed using the relation:

$$SG = W_1 / (W_1 - W_2) \quad (1)$$

where W_1 is the dry weight of the sample in air, and W_2 is the saturated weight in water. This procedure has been widely applied in engineering geology studies to characterize basement rocks in Nigeria (Adeyemi, 1995; Oyediran & Adeyemi, 2011), and it provides a reliable measure of the compactness and density of aggregates, which are critical for evaluating their performance in concrete and road construction.

2.3.2 Density

Bulk density and dry density were measured to evaluate the mass of rock per unit volume, including and excluding pore spaces, respectively. These properties help engineers understand how much material is required to achieve a specific load or volume during construction. Density also affects other engineering characteristics such as compressibility and permeability. The density test results provide insight into how well the rock can resist compaction and deformation under applied loads. The test followed BS 812 (1990) and ASTM C127 (2015). Rock samples were oven-dried, cooled, and weighed to obtain the mass (M). Their volume (V) was measured using water displacement in a graduated cylinder. The bulk density (ρ) was calculated using:

$$\rho = M / V \quad (2)$$

2.3.3 Porosity

Porosity refers to the percentage of void space in a rock relative to its total volume. It plays a critical role in determining the rock's durability and resistance to weathering, especially under fluctuating moisture conditions. Rocks with high porosity tend to absorb more water, making them susceptible to frost action, degradation, and chemical alteration over time. Measuring porosity allows for the prediction of long-term performance, particularly in subgrades and foundations exposed to seasonal moisture variations. The oven-dry weight of the sample (W_d) was first recorded, after which the sample was immersed in water for 24 hours to achieve saturation and then reweighed (W_s). The porosity (n) was then determined as:

$$n (\%) = (W_s - W_d) / W_s \times 100 \quad (3)$$

2.3.4 Water Absorption

This test measures the capacity of the rock to absorb water over a defined period. The result is used as a proxy for permeability and serves as an indicator of potential durability issues. Materials with high water absorption may deteriorate faster in wet conditions or may not meet the required specifications for use in critical structures such as highways and bridges. The procedure was based on ASTM C97 (2015) and BS 812 (1990). Dry weight (W_d) was determined after oven-drying, while saturated weight (W_s) was taken after immersing the sample in water for 24 hours. The percentage water absorption (WA) was obtained from:

$$WA (\%) = (W_s - W_d) / W_d \times 100 \quad (4)$$

Water absorption provides a measure of susceptibility to weathering, with higher values typically implying lower durability for construction purposes (Neville, 2011; Smith & Collis, 2001; Akpokodje, 1987).

2.3.5 Strength Properties

Uniaxial Compressive Strength Test
Uniaxial compressive withstand before failure. Cylindrical or cubic specimens are prepared according to standard dimensions, ensuring smooth and parallel ends. The specimen is placed in a compression testing machine, and load is applied axially at a constant rate until failure occurs. Cylindrical cores were prepared, dried, and placed in a compression testing machine, where load was applied axially at a constant rate until failure occurred. The UCS was then computed as:

$$UCS = P / A \quad (5)$$

where P = peak load at failure and A = cross-sectional area of the sample. UCS is critical in rock classification and engineering design, as higher values indicate greater suitability for

load-bearing structures (Hoek & Brown, 1980).
Aggregate Crushing Value (ACV) Test

The ACV test assesses the resistance of aggregates to crushing under gradually applied compressive load, reflecting their mechanical strength. The procedure was carried out in accordance with BS 812 (1990). Aggregates passing through a 12.5 mm sieve and retained on a 10 mm sieve were placed in a cylindrical steel mould, subjected to compressive loading, and sieved. The ACV was then calculated as:

$$ACV (\%) = (W_2 / W_1) \times 100 \quad (6)$$

where W_1 = original weight of the sample and W_2 = weight of fines produced. Rocks with lower ACV values are generally preferred for road construction and concrete works (Smith & Collis, 2001).

Aggregate Impact Value (AIV) Test

The AIV test evaluates the toughness of aggregates, or their resistance to sudden shock or impact. The test was performed following BS 812 (1990). Aggregates were placed in a mould and subjected to 15 blows of a standard hammer, after which the material passing through a 2.36 mm sieve was weighed. The AIV was computed as:

$$AIV (\%) = (W_2 / W_1) \times 100 \quad (7)$$

This property is especially important for materials used in road construction, as aggregates with lower AIV values are less prone to degradation under dynamic loads (Neville, 2011).

2.3.6 Soundness Test

Soundness evaluates the resistance of a rock to disintegration under alternate wetting and

drying, or under chemical action. The test is carried out by immersing samples in a solution of sodium sulfate or magnesium sulfate for a fixed time, followed by oven drying. This cycle is repeated several times, after which the samples are weighed.

2.3.7 Flexural Strength Test

Flexural strength, also called modulus of rupture, measures the ability of a rock specimen to resist failure in bending. Rectangular specimens are supported at both ends and loaded at the center in a three-point loading arrangement until failure. The maximum load at failure is used to calculate flexural strength.

2.3.8 Hardness Test

Hardness is a measure of resistance to abrasion and wear. For engineering evaluation, the Los Angeles (LA) abrasion test is commonly used. Standard-sized rock aggregates are placed in a rotating steel drum along with steel balls and subjected to a specified number of revolutions. The repeated impact and grinding cause fragmentation of the aggregates.

3.0 RESULT AND DISCUSSION

3.1 GEOLOGICAL MAPPING

The geological map of the study area (Figure 2) reveals three main lithological units: porphyritic granite, basalt, and minor migmatite occurrences. The porphyritic granite forms massive to jointed outcrops with conspicuous feldspar phenocrysts, while basalt occurs as low-lying hills and ridges, locally weathered to lateritic caps.

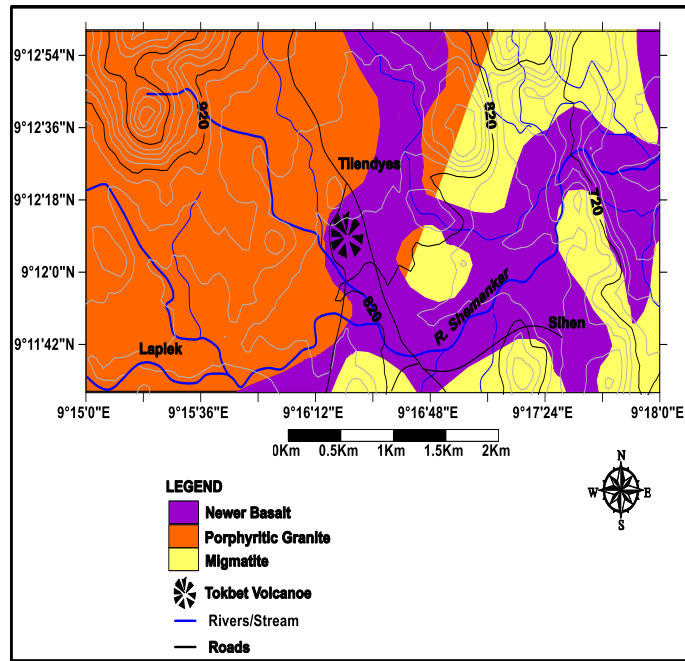


Figure 2: Geological Map of the Study Area

3.2 Petrography

3.2.1 Basalt

Figure 3 shows basalt as fine-grained, dark grey to black volcanic rock with aphanitic texture and under the plane polarized light (PPL) and cross polarized light (XPL).

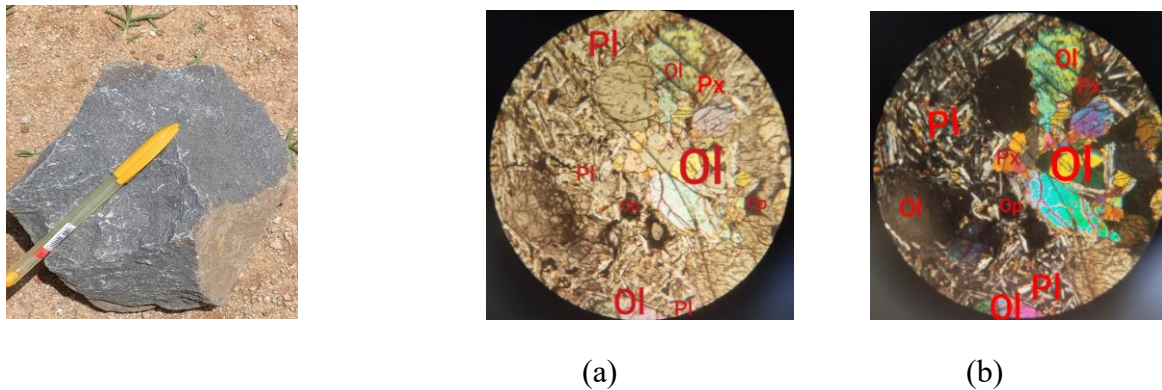


Figure 3 Hand specimen of Basalt Basalt under PPL (a) and XPL (b)

Under (PPL), basalt has lath-shaped plagioclase microlites dominating the groundmass with interstitial pyroxene and olivine. Under (XPL), plagioclase exhibits polysynthetic twinning with first-order gray interference colours, while pyroxene shows higher-order colours.

3.2.2 Porphyritic granite

Figure 4 shows porphyritic granite as coarse- to medium-grained in hand specimen, a light gray to pinkish rock with conspicuous large feldspar phenocrysts set in finer-grained groundmass of quartz, plagioclase, and biotite. While under PPL large feldspar phenocrysts within a finer crystalline groundmass., quartz shows undulose extinction under XPL; biotite exhibits brown pleochroism under PPL.

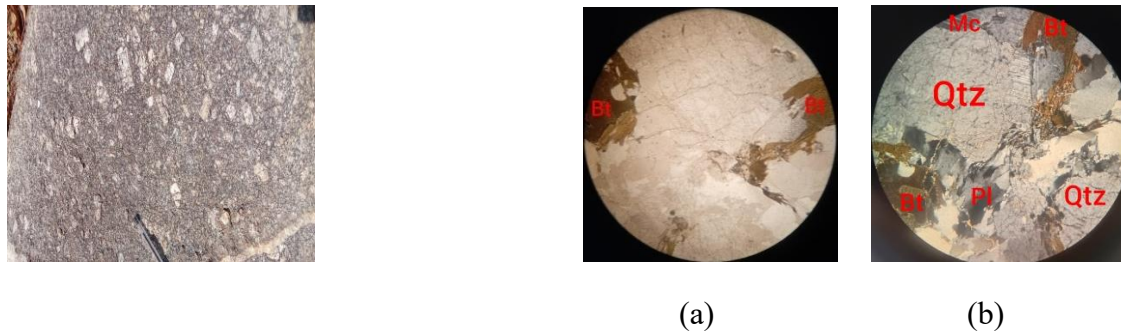


Figure 4 Hand Specimen of Porphyritic Granite. Porphyritic Granite Under PPL (a) and XPL (b) with visible feldspar phenocrysts

The porphyritic texture of the granite indicates two-stage cooling history, with early crystallization of feldspar phenocrysts at depth followed by more rapid cooling of the groundmass. The mineral assemblage (quartz + K-feldspar + plagioclase + biotite) is characteristic of calc-alkaline, syn-tectonic Pan-African granites derived from crustal sources with possible mantle contributions (Dada, 2006).

The basalt mineralogy (plagioclase + pyroxene + olivine) reflects rapid solidification of mafic magma at or near the surface. The presence of olivine and absence of quartz confirm its undersaturated character, typical of within-plate basaltic magmatism associated with the Cameroon Volcanic Line (Fitton, 1980).

The dominant NNE-SSW joint trends in granite and NNW trends in basalt reflect regional tectonic stresses during and after emplacement. These systematic orientations facilitated fluid ingress and weathering, explaining the more extensive joint-controlled weathering in granite compared to the more massive basalt exposures. The abundance of quartz veins in granite indicates late-stage hydrothermal activity along pre-existing planes of weakness.

3.3 ENGINEERING PROPERTIES

The result of the strength, Hardness, soundness, flexural strength, porosity, water absorption, density and specific gravity tests are presented in Table 2

Table 2 Result Summary of Tests of the Rock Types

| Property | Porphyritic Granite | Basalt |
|---------------------------------------|---------------------|--------|
| Specific Gravity | 2.95 | 2.85 |
| Density (kg/m^3) | 2695 | 2695 |
| Porosity | 0.065 | 0.071 |
| Water Absorption (%) | 0.63 | 0.68 |
| UCS (N/mm^2) | 34 | 31 |
| ACV (%) | 22.26 | 19.15 |
| AIV (%) | 26.15 | 26.71 |
| Soundness (% loss) | 7.45 | 7.20 |
| Flexural Strength (N/mm^2) | 10.24 | 9.45 |
| Hardness (Mohs) | 6.4 | 6.1 |

SG; Specific Gravity, WA; Water Absorption, UCS; Uniaxial Compressive Strength, ACV; Aggregate crushing value, AIV; Aggregate Impact Value

The specific gravity obtained for the porphyritic granite is 2.95, while that of the basalt is 2.85.

The density of the porphyritic granite was determined to be 2695 kg/m^3 , while the basalt recorded the same value of 2695 kg/m^3 . The porosity of the porphyritic granite sample was determined to be 0.065, while that of the basalt was slightly higher at 0.071. Test results shows that the porphyritic granite recorded a water absorption value of 0.63%, while the basalt recorded 0.68%. The UCS test results show that the porphyritic granite has an average compressive strength of 34 N/mm^2 (MPa), while the basalt records an average value of 31 N/mm^2 .

The ACV obtained for the samples is 22.26% for porphyritic granite (A) and 19.15% for basalt (B). The AIV obtained for the samples is 26.15% for porphyritic granite (A) and 26.71% for basalt (B). The results obtained show weight losses of 7.45% for porphyritic granite (A) and 7.20% for basalt (B) after 12 cycles in sodium sulphate solution. The results show that the porphyritic granite has a flexural strength of 10.24 N/mm^2 , while basalt records a slightly lower value of 9.45 N/mm^2 . The hardness values obtained are 6.4 for the porphyritic granite and 6.1 for the basalt.

Both rocks exhibit specific gravity values (2.85-2.95) within the range for sound crystalline rocks (2.5-3.0). The granite's slightly higher value (2.95) reflects its quartz-feldspar-biotite assemblage, while basalt's lower value (2.85) may result from localized weathering effects despite its mafic composition. Both fall within the "high" category (2.75-3.0) indicating dense, durable materials suitable for heavy structures

(ISRM, 1981). Identical density values (2695 kg/m^3) place both rocks in the "medium" category (2550-2750 kg/m^3), indicating good quality suitable for general construction (Bell, 2007).

Both rocks exhibit very low porosity ($<0.08\%$) and water absorption ($<0.7\%$), classifying them as having "very low" porosity ($<1\%$) with excellent durability and low permeability (ISRM, 1981). Basalt's marginally higher values (0.071%, 0.68%) compared to granite (0.065%, 0.63%) reflect its finer-grained texture and microfracture development, consistent with field observations of more pronounced weathering in basaltic outcrops.

UCS values place both rocks in the "medium strong" category (25-50 MPa) according to ISRM (1979). Granite (34 MPa) outperforms basalt (31 MPa) by ~9%, attributable to its coarser interlocking quartz-feldspar framework providing better resistance to crack propagation. This aligns with Adeyemi (1995) who reported superior strength in granitic rocks compared to associated mafic rocks. The higher USC value of granite in comparison to basalt is in contrast to the work of Zainil, (2023) where basalt possesses a higher compressive strength than granite.

ACV results show basalt (19.15%) performs better than granite (22.26%) as aggregate, though both are below the 30% limit for high-quality aggregates (BS 812, 1990). Basalt's superior crushing resistance reflects its fine-grained, uniform stress distribution, consistent with Smith & Collis (2001). AIV results (26.15-26.71%) fall within the "medium" category (20-30%), indicating moderately tough aggregates acceptable for most works.

Soundness test results (7.20-7.45% loss) classify both rocks as "good" (5-10% loss), indicating durable materials for most engineering applications (ASTM C88). Basalt's marginally better performance (7.20% vs 7.45%) may reflect its more uniform fabric resisting chemical attack, consistent with Afolagboye et al. (2016).

Flexural strength values (9.45-10.24 MPa) place both rocks in the "moderate to high" category (5-20 MPa), with granite showing ~8% higher resistance due to its coarser

interlocking texture. This indicates that granite can withstand greater strength than basalt and it agrees with the common observation that the tensile strength of rocks is generally much lower than their compressive strength, typically around 5 to 10% of the UCS value (Zainil, 2023). The hardness values (6.1-6.4) classify both rocks as "hard" (6-7 on Mohs scale), suitable for construction applications (Bell, 2007).

3.4 COMPARATIVE EVALUATION

The comparative analysis reveals:

| Property | Superior Rock Type | Attribution |
|---------------------------|--------------------|--|
| Specific Gravity | Granite | Quartz-feldspar dominance |
| UCS | Granite | Interlocking coarse texture |
| Flexural Strength | Granite | Grain interlocking |
| Hardness | Granite | Quartz content |
| ACV | Basalt | Fine-grained uniform stress distribution |
| Soundness | Basalt | Uniform fabric resisting chemical attack |
| Porosity/Water Absorption | Comparable | Both dense crystalline |

These differences reflect intrinsic mineralogical and textural controls. Granite derives strength from quartz-feldspar interlocking (Mallo & Sani (2012), while basalt's uniform fine-grained fabric provides better resistance to crushing and chemical weathering (Wu et al., 2010). The results

obtained in these tests are within the lower range because the rocks have been affected by chemical weathering impacting their strength.

Conclusion

The comparative evaluation of the porphyritic granite and basalt within the study area demonstrates that both lithologies possess competent engineering characteristics typical of strong igneous rocks, while also exhibiting distinct geological and geotechnical differences that influence their relative suitability for specific construction applications. Petrographically, the porphyritic granite is distinguished by a coarse-grained, quartz-feldspar dominated assemblage characterized by prominent feldspar phenocrysts, interlocking crystalline textures, and accessory ferromagnesian minerals, all of which contribute significantly to its mechanical competence. In contrast, the basalt is fine-grained, dense, and mafic in composition, consisting predominantly of plagioclase and pyroxene with minor olivine and opaque minerals, reflecting a more uniform and compact mineral fabric.

Geotechnical assessment further reveals notable contrasts in engineering behavior between the two rock types. The porphyritic granite generally exhibits superior performance in specific gravity, hardness, uniaxial compressive strength, and flexural strength, reflecting the influence of its silica-rich mineralogy and well-developed interlocking framework, which enhance resistance to compressive and tensile stresses. Conversely, the basalt shows slightly better performance in aggregate crushing value and soundness, indicating greater resistance to gradual crushing loads and durability under repeated wetting-drying or weathering cycles, properties attributable to its dense and homogeneous texture. Despite these differences, both lithologies fall within acceptable international standard limits, classify within the medium-strength rock

category, and record water absorption values well below 1%, signifying low porosity and favorable durability characteristics.

From an engineering perspective, these differences suggest complementary rather than competing applications. The porphyritic granite, owing to its higher compressive and flexural strength, greater hardness, and lower water absorption, is particularly suitable for high-strength concrete aggregates, structural dimension stone, foundation materials, and other load-bearing applications requiring resistance to deformation and long-term durability.

The basalt, with its superior crushing resistance and soundness characteristics, is more appropriate for road base aggregates, railway ballast, pavement construction, and engineering works exposed to cyclical weathering conditions. Overall, the study confirms that both rock types constitute viable construction materials, with their optimal utilization dependent on the specific engineering demands and service conditions of the intended application.

References

- Adeyemi, O.O. (1995). The influence of weathering on the engineering properties of some rocks in Ibadan, Nigeria. *Journal of Mining and Geology*, 31(2), 151-158.
- Afolagboye, L.O., Talabi, A.O., and Akinola, O.O. (2016). Evaluation of selected basement complex rocks from Ado-Ekiti, SW Nigeria as source of road construction aggregates. *Bulletin of Engineering Geology and the Environment*, 75(3), 853-865.
- Ajayi, L.A., and Balogun, L.A. (1988). Geotechnical properties of some lateritic soils in Nigeria. *Proceedings of the 2nd*

International Conference on Geomechanics in Tropical Soils, Singapore, 1, 121-128.

Ajibade, A.C., Woakes, M., and Rahaman, M.A. (1987). Proterozoic crustal development in the Pan-African regime of Nigeria. In C.A. Kogbe (Ed.), *Geology of Nigeria* (pp. 57-69). Rock View.

Akinbinu, V.A. (2015). Geotechnical properties of crushed stone aggregates for road construction in southwestern Nigeria. *Journal of Engineering Research*, 20(2), 1-12.

Annor, A.E. (1998). Structural and chronological relationship between the low-grade schist and the gneissic complex in the Nigerian Basement. *Journal of Mining and Geology*, 34(1), 13-22.

ASTM C88 (2014). *Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*. ASTM International.

ASTM C97 (2015). *Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone*. ASTM International.

Bell, F.G. (2007). *Engineering Geology* (2nd ed.). Elsevier.

BS 812 (1990). *Testing Aggregates*. British Standards Institution.

Choi, H. B., Park, J., Kim, T., and Lee, K. (2021). Mechanical Properties of Basalt-Based Recycled Aggregate Concrete for Jeju Island. *Materials*, 14, 5429. 10.3390/ma14185429.

Dada, S.S. (2006). Proterozoic evolution of Nigeria: Evidence from geochronology. *NGSA Bulletin*, 42, 29-43.

Fitton, J.G. (1980). The Benue Trough and Cameroon Line: A migrating rift system in West Africa. *Earth and Planetary Science Letters*, 51(1), 132-138.

Goodman, R.E. (1989). *Introduction to Rock Mechanics* (2nd ed.). John Wiley & Sons.

Grundmann, G., and Scholz, H. (2015). Preparation methods in Mineralogy and Geology: The preparation of thin sections, polished sections, acetate foil prints, preparation for elutriation analysis and staining tests for the optical and electron microscopy.

He, M., Yang, Q., Asteris, P. G., and Zhao, Q. (2025). A comparative study of three types of strength criteria for rocks. *Rock Mech. Lett.* 2(1), 57 -65.

Hoek, E., and Brown, E.T. (1980). *Underground Excavations in Rock*. Institution of Mining and Metallurgy.

ISRM (1979). Suggested methods for determining the uniaxial compressive strength and deformability of rock materials. *International Journal of Rock Mechanics and Mining Sciences*, 16(2), 135-140.

ISRM (1981). *Rock Characterization, Testing and Monitoring: ISRM Suggested Methods*. Pergamon Press.

Neville, A.M. (2011). *Properties of Concrete* (5th ed.). Pearson Education.

Obaje, N.G. (2009). *Geology and Mineral Resources of Nigeria*. Springer.

Oyediran, I.A., and Adeyemi, G.O. (2011). Geotechnical characteristics of some basement complex rocks in Ikere-Ekiti, southwestern Nigeria. *Journal of Mining and Geology*, 47(2), 153-164.

Mallo, S. J., and Sani, S. D. (2012). Influence of Mineralogy and Fabric on the Engineering Properties of the Miango Granite Porphyry, North Central Nigeria. *International Journal of Modern Engineering Research*, 2(6), 4600-4608.

Rahaman, M.A. (1988). Recent advances in the study of the Nigerian Basement Complex. In P.O. Oluyide (Ed.), *Precambrian Geology of Nigeria* (pp. 11-43). Geological Survey of Nigeria.

Smith, M.R., and Collis, L. (2001). *Aggregates: Sand, Gravel and Crushed Rock Aggregates for Construction Purposes* (3rd ed.). Geological Society of London.

Wu, S., Zhu, J., and Wan, L. (2010). "Relationship between petrographical and physical properties of aggregates." *Journal of Wuhan University of Technology-Mater. Sci. Ed.*, 25, 678-681.

Wright, E.P. (1976). The geology of the Jos Plateau. *Geological Survey of Nigeria Bulletin*, 32, 1-111.

Zainil, H., Madun, A., Heng, M. G., and Khalid, M. A., (2023). A Comparative Analysis of Mechanical Properties Between Granite and Basalt Rock Core Samples. *Journal of Sustainable Underground Exploration*, 3(2), 7-12.