**THE SUITABILITY OF GRANITE AND GRANITE-GNEISS OF PART OF MINNA SHEET 164 SW NORTH-CENTRAL NIGERIA AS CONSTRUCTION AGGREGATES**

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**ABSTRACT**

Selected geotechnical tests were performed on granite and granite-gneiss rock samples of parts of Minna sheet 164 SW north-central, Nigeria to know their suitability as construction aggregates. Eight (8) rock samples were selected after field geological mapping for the geotechnical test and standard test methods were followed. The properties of the rocks tested were Porosity, impact value, specific gravity and absorption capacity. The results determined from the geotechnical test give the average porosity values for the samples as 0.21, 0.12, 0.30, 0.10, 0.25, 0.25, 0.24 and 0.11 respectively for L1, L14, L15, L19, L21, L23, L25 and L29 indicating the samples have normal porosity except sample L15 which is highly porous and not suitable as construction aggregate. Average impact value for the rock samples shows they are suitable for wearing surface course in road and bridge construction except for samples L14 and L19 with an average impact value of 32.8 and 34.9 respectively indicating their suitability as bituminous macadam for the maximum value for this is 35%. Sample L1 is not suitable as construction aggregates because it exceeds the maximum value specified for that purpose. The average specific gravity of the rock samples determined from the lab are L1=2.68, L14=2.65, L15=2.65, L19=2.67, L21= 2.63, L23= 2.71, L25=2.65, and L29=2.69 respectively and which make them suitable as normal weight materials for construction. The average absorption capacity values of the rock samples are 0.20%, 0.2%, 0.50%, 0.10%, 0.25%, 0.10%, 0.50% and 0.20% respectively for samples L1, L14, L15, L19, L21, L23, L25, and L29. This makes the samples generally suitable as construction aggregates material except for few considered to be weak due to the impact of weathering on them.

**Keywords**: Geotechnical test, Construction Aggregates, Granite, Granites-Gneiss, Minna, Nigeria

1. **INTRODUCTION**

Igneous rocks tend to produce strong aggregates with a degree of skid resistance and are hence suitable for many road surfacing applications, as well as for use in the lower parts of the road pavement [1]. Granite and Granite-Gneiss rocks are predominantly abundant in the study area and can serve as natural construction aggregate for engineering geological projects. Construction aggregate according to Egesi and Tse [8], is the sized or crushed and sized rock materials used in asphalt and concrete which make up most of the bridges, highways, houses and other engineering works.

Many properties of the aggregate such as mineral and chemical composition, petrological characteristics, strength, hardness, specific gravity, pore structure, physical and chemical stability, and colour, however, depend entirely on properties of parent rock for the reason that all aggregate particles originally formed a part of a larger mass and may have been fragmented by the natural process of weathering or artificially by crushing [14]. Other properties possessed by aggregates such as surface texture, particle size and shape, and absorption capacity of the parent rock also have considerable influence on the quality of the concrete product. A wide variety of product from mining and crushing of rocks form primary raw materials in many industrial applications [9].

Egesi and Tse [8] carried out studies on rocks and stated that rocks are exposed to a variety of stresses in various ways they are used, and the response of the structure in which it is used will largely depend on the properties of the aggregate. The quality of the coarse aggregates is essential when considering the quality of the concrete itself [16]. Selecting the right aggregate material is important to overcome the problem of frequent pavement failure in engineering geological projects. Anosike [2]; Duggal [7] and [10] classified aggregate based on the source (Natural and artificial aggregates); According to mineralogical composition, aggregate may be classified as siliceous or calcareous; According to the mode of preparation, in this situation distinction is made between aggregates reduced to its present size by natural agents and crushed aggregates obtained by a deliberate fragmentation of rock; According to size, it is divided again into coarse and fine aggregates.

Kourd and Hammad [12] also carried out research and discovered that the resistance of an aggregate to a sudden Impact or shock differs from its resistance to a slope compressive load. Aggregates should be hard and tough enough to resist crushing, degradation, and disintegration from any associated activities. This research, therefore, studies the geotechnical properties of rock samples of granite and granite-gneiss in parts of Minna for their suitability as construction aggregates.

1. **MATERIAL AND METHODS**

**2.1 Geotechnical Analyses of Rock Samples**

All the samples were tested for geotechnical properties at the civil engineering laboratory of the Federal Polytechnic Bida (FPB), Nigeria and following all the standard procedures using the specific laboratory equipment. The impact values of the rock aggregate were determined following the method as explained in [3] and [11]while the specific gravity of the rock samples was determined following the method in [4]. The absorption capacity of the rock samples was determined from the procedure of [13]. The rocks porosity was determined in a standard procedure in [6].

**3 RESULTS AND DISCUSSION**

**3.1 Results of Geotechnical Properties of the Rock Samples**

Results of laboratory test conducted on the selected rock samples are presented in table 2, 3, and 4 while the sample locations, rock type and their descriptions are presented in table 1.

Table 1 Sample locations, coordinates and description of the rock samples and the rock types

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S/No** | **Locations** | **Coordinates** | **Rock type** | **Description of location** |
| **1** | Kwalkwata |  09⁰ 37ˈ 37.7"N006⁰ 30ˈ 15.0"E | Granite | Biotite granite with visible joints, faults and exfoliation undergoing weathering. Common texture is coarse grain |
| **2** | UP Hill(Beside NTA Station) 1 | 09⁰36ˈ30.6"N 006⁰33ˈ32.7" E  | Granite | The rock sample shows visibly K-feldspars and minor Biotite. The Texture is coarse to medium grain |
| **3** | UP Hill (Beside NTA Station) 2 | 09⁰36ˈ29.7"N 006⁰33ˈ30.4"’E | Granite gneiss | The sample has minor joints and fractures and the presence of phenocryst. It has a coarse grain texture. |
| **4** | Dutsen Kura (London Street) 1 | 09⁰38ˈ07.1"N 006⁰31ˈ14.3" E  | Granite | Large quartz intrusion in granite rock. The rock is weathered and shows minor joints within the rock. |
| **5** | Dutsen Kura (Mawo School) | 09⁰37ˈ55.6"N 006⁰31ˈ13.4" E  | Granite | The rock is mostly weathered from the surface and characterised with minor cross joints and a quartz vein intrusion. The texture is medium-coarse grain.  |
| **6** | Shannu Gidan Kuka 2 | 09⁰36ˈ47.1"N 006⁰30ˈ15.8"E | Granite | Many fractures and quartz intrusion characterised the outcrop. |
| **7** | Talba Estate 1 | 09⁰34ˈ48.5"N 006⁰30ˈ28.1"E | Granite gneiss | Pegmatite intrusion in granite-gneiss outcrop. The outcrop is highly weathered and has been metamorphosed. |
| **8** | Talba Estate 5 | 09⁰34ˈ40.5"N 006⁰30ˈ31.1"E | Granite | Both pegmatite and quartz veins are common in the outcrop. The texture is medium-coarse grain. |

Table 2 Impact Value Test Result

|  |
| --- |
| **Locations Samples** $M\_{1}\left(g\right) M\_{2}$**(g)** $M\_{3}\left(g\right) M\_{4}$**(g) AIV (%)** |
| L1 Granite 684.40 975.00 290.60 150.70 52.10L14 Granite 684.40 976.70 292.30 95.80 32.80L15 Granite-gneiss 684.40 975.10 290.70 76.60 26.40L19 Granite 684.40 958.20 273.80 95.50 34.90L21 Granite 684.40 979.50 295.10 64.70 21.90L23 Granite 684.40 973.50 289.10 70.10 24.40L25 Granite-gneiss 684.40 967.10 282.70 84.10 29.80L29 Granite 684.40 962.70 278.20 70.60 25.50 |

***M1***= Weight of cylinder, ***M2***= Weight of cylinder + Sample, ***M3***= Weight of sample, ***M4***= Weight of fraction passing 2.36., **AIV**= Average impact value.

Table 3 Specific Gravity Test Result

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Locations** | **Samples** | $$M\_{1}(g)$$ | $ M\_{2}$**(g)** | $$M\_{3}\left(g\right)$$ | $ M\_{4}$**(g)** | **ASG** |
| **1** | **2** | **1** | **2** | **1** | **2** | **1** | **2** |
| L1L14L15L19L21L23L25L29 | GraniteGranite-gneissGraniteGraniteGraniteGraniteGranite-gneissGranite | 290.0290.8290.9290.0290.9290.0290.9290.9 | 284.1284.0284.0283.9284.0284.0284.2284.0 | 390.0390.0390.0390.0390.0390.0390.0390.0 | 384.1384.0384.0383.9384.0384.0384.2384.0 | 842.9842.5842.4843.1842.2843.5842.9843.2 | 844.7844.4844.6844.9844.3844.8845.0845.5 | 779.9780.4780.1780.6780.4780.3780.2780.7 | 782.5782.5782.4782.2782.3782.0783.2782.4 | 2.682.652.652.672.632.712.652.69 |

*M1*= Weight of gas jar + glass plate, *M2*= Weight of gas jar + glass plate + sample, *M3*= Weight of gas jar + glass plate + sample + water, *M4*= Weight of gas jar + glass plate + water, *ASG*= Average specific gravity.

Table 4 Porosity Test Result

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** | **L1** | **L14** | **L15** | **L19** | **L21** | **L23** | **L25** | **L29** |
| Samples | Granite | Granite | Granite-gneiss | Granite | Granite | Granite | Granite-gneiss | Granite |
| Ɣ(kg/$m^{3})$ | 2148.05 | 2361.5 | 1912.98 | 2418.57 | 2048.47 | 2046.71 | 2044.27 | 2422.71 |
| Ɣd(kg/$m^{3})$ | 2117.62 | 2341.83 | 1902.25 | 2406.43 | 2044.59 | 2041.85 | 2034.62 | 2409.69 |
| M (%) | 1.44 | 0.86 | 0.55 | 0.5 | 0.18 | 0.26 | 0.49 | 0.54 |
| $$V\_{s}(m^{3})$$ | 0.00001808 | 0.00001818 | 0.00001256 | 0.00001501 | 0.00002181 | 0.00002893 | 0.00001929 | 0.00001753 |
| $$V\_{v}(m^{3})$$ | 0.00000487 | 0.00000238 | 0.00000543 | 0.00000164 | 0.00000739 | 0.00000947 | 0.00000657 | 0.00000208 |
| SƔ(kg/$m^{3})$ | 2327.45 | 2456.8 | 2184.57 | 2614.42 | 2266.72 | 2288.39 | 2266.75 | 2514 |
| E | 0.27 | 0.13 | 0.43 | 0.11 | 0.34 | 0.33 | 0.34 | 0.12 |
| N | 0.21 | 0.12 | 0.30 | 0.1 | 0.25 | 0.25 | 0.24 | 0.11 |

Ɣ= Bulk density, Ɣd=Dry density, M= Moisture content, $V\_{s}$= Volume of solid, $V\_{v}$= Volume of void, SƔ$=$ Saturated density, E= Void ratio, N= Porosity.

Table 5 Absorption Capacity Test Result

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **L1** | **L14** | **L15** | **L19** | **L21** | **L23** | **L25** | **L29** |
| Samples | Granite | Granite | Granite-gneiss | Granite | Granite | Granite | Granite-gneiss | Granite |
| Number of experiment | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD(g) | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| OD(g) | 199.90 | 199.90 | 199.90 | 200.00 | 199.80 | 199.90 | 199.10 | 199.90 |
| $W\_{w}$(g) | 205.60 | 205.80 | 203.70 | 204.00 | 205.90 | 203.10 | 203.00 | 204.80 |
| SSD(g) | 200.30 | 200.30 | 200.90 | 200.20 | 200.30 | 200.10 | 200.10 | 200.30 |
| SM (%) | 2.65 | 2.75 | 1.49 | 2.29 | 2.79 | 1.49 | 1.45 | 2.25 |
| MC (%) | 0.05 | 0.05 | 0.05 | 0.00 | 0.10 | 0.05 | 0.50 | 0.20 |
| ABC (%) | 0.20 | 0.20 | 0.50 | 0.10 | 0.25 | 0.10 | 0.50 | 0.20 |

AD= Air dry, OD= Oven dry, $W\_{w}$= Wetted weight, SSD= Saturated surface dry, SM= Surface Moisture, MC= Moisture Content, ABC= Absorption Capacity.

Table 2 and figure 1 shows the variations in the impact value of the aggregates samples. The average impact values are 26.4, 21.9, 24.4, 29.5, and 25.5 (%) respectively for samples L15, L21, L23, L25, and L29. These show that the aggregates are suitable for wearing surface course in road and bridges construction. Aggregate sample from location 14 and 19 have an average impact value of 32.8 and 34.9 respectively indicating they are suitable for bituminous macadam as the maximum value for this is 35%. Sample L1 is not suitable for construction purposes as it exceeds the maximum value specified for construction materials, thus the use of crushed rock aggregates for engineering construction depends on the strength and durability characteristics of the aggregates [15]. The high strength and attrition resistance of certain igneous rocks result in their use as railway ballast [5].

The specific gravity values derived from the aggregate samples ranges from 2.63-2.71. This shows that the aggregate samples from all the locations are within the range of 2.6-3.0 thus, can be used as normal weighted materials for construction [14]. Figure 2 show that sample L23 has the highest specific gravity value while sample 21 has the least specific gravity value.

Results derived from the porosity test table 4 and figure 3 shows that the aggregates sample collected from all the locations are porous. Sample L19 has the least porosity value and sample L15 has the highest porosity value. A highly porous aggregate may lead to low durability as asphalt mix.

The absorption capacity test results for the aggregate sample of all the locations show that they conform to the standard specification limit for normal-weight aggregates used in concrete which is 0 to 8% (ACI, 1999). The absorption capacity of aggregates depends on the source and geological nature of the aggregates. Figure 4 shows sample L15 and L25 have the highest absorption capacity while sampleL19 and L23 have the least.

The relationship between porosity and absorption capacity was plotted and a positive correlation exists between them figure 5. The R2 value is thus 0.3515.

The summary result of the geotechnical analysis of the rock samples collected in the study area is in table 6.

Table 6 Summary Results of Geotechnical Studies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Locations** | **Impact Value Test** | **Specific Gravity Test** | **Porosity Test** | **Absorption Capacity Test** |
| L 1 | Weak | Normal Weight | Porous | Moderate |
| L 14 | Tough | Normal Weight | Porous | Moderate |
| L 15 | Tough | Normal Weight | Highly Porous | High |
| L 19 | Tough | Normal Weight | Least porous | Low |
| L 21 | Tough | Normal Weight | Porous | Moderate |
| L 23 | Tough | Normal Weight | Porous | Low |
| L 25 | Tough | Normal Weight | Porous | High |
| L 29 | Tough | Normal Weight | Porous | Moderate |

**4. CONCLUSION**

The geotechnical analysis carried out on the rock aggregate samples in the study area revealed that the rocks have mostly normal impact and absorption capacity values and are suitable as construction aggregates. On the bases of weight, the rocks have normal weight. However, based on toughness, five-rock samples are tough, two are moderately tough and one is exceptionally weak. Therefore, the rock aggregates around the study area can be used as normal-weight materials for construction, wearing surface course materials for roads and bridges construction, and other concrete work such as a building.

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