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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

Geotechnical tests were performed on granite and granite-gneiss rock samples of parts of Minna to know their suitability as construction aggregates. Eight rock samples were selected for porosity test, impact value, specific gravity and absorption capacity. The average porosity of the samples is 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 which shows they are normal except L15 with a high porosity. Average impact value of the samples show they are suitable for wearing surface course in road and bridge construction, except samples L14 and L19 with average impact value of 32.8 and 34.9 respectively making them suitable only as bituminous macadam (maximum value = 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 rocks 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%, 0.20%, 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. All testing followed the respective ASTM standards.

Keywords: Geotechnical testing, construction aggregates, granite, granite-gneiss, Minna, Nigeria.

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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 (Adeyi et al., 2019). 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 (2012) 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 (Neville, 2011). 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 (Ellen, 2000).

Egesi and Tse (2012) 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 (Rozalija and David, 1997). Selecting the right aggregate material is important to overcome the problem of frequent pavement failure in engineering geological projects. Anosike (2011); Duggal (2008); Ezeokwonkwo (2014) 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 (2010) also carried out research and discovered that the resistance of an aggregate to a sudden impact or shock differs from its resistance to an increasing compressive load (the capacity of a material or structure to withstand loads tending to reduce in magnitude). 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.

2. 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 relevant laboratory equipment. The impact values of the rock aggregate were determined following the method as explained in ASTM (2016) and FMWH (1997), while the specific gravity of the rock samples was determined following ASTM (2015). The absorption capacity of the rock samples was determined from the procedure of Murat and Erhan (2019). The rocks porosity was determined in a standard procedure in Davood and Reza (2018).

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 Tables 2, 3, 4 and 5 while the sample locations, rock type and their descriptions are presented in Table 1.

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

S/No	Locations	Coordinates	Rock type	Description of location
1	Kwalkwata	09° 37' 37.7"N 006° 30' 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	09°36'30.6"N 006°33'32.7"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	09°36'29.7"N 006°33'30.4"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	09°38'07.1"N 006°31'14.3"E	Granite	Large quartz intrusion in granite rock. The rock is weathered and shows minor joints within the rock.
5	Dutsen Kura (Mawo School)	09°37'55.6"N 006°31'13.4"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	09°36'47.1"N 006°30'15.8"E	Granite	Many fractures and quartz intrusion characterised the outcrop.
7	Talba Estate 1	09°34'48.5"N 006°30'28.1"E	Granite gneiss	Pegmatite intrusion in granite-gneiss outcrop. The outcrop is highly weathered and has been metamorphosed.
8	Talba Estate 5	09°34'40.5"N 006°30'31.1"E	Granite	Both pegmatite and quartz veins are common in the outcrop. The texture is medium-coarse grain.

Table 2: Impact value test results.

Locations	Samples	$M_1(g)$	M_2(g)	$M_3(g)$	M_4(g)	AIV (%)
L1	Granite	684.40	975.00	290.60	150.70	52.10
L14	Granite	684.40	976.70	292.30	95.80	32.80
L15	Granite-gneiss	684.40	975.10	290.70	76.60	26.40
L19	Granite	684.40	958.20	273.80	95.50	34.90
L21	Granite	684.40	979.50	295.10	64.70	21.90
L23	Granite	684.40	973.50	289.10	70.10	24.40
L25	Granite-gneiss	684.40	967.10	282.70	84.10	29.80
L29	Granite	684.40	962.70	278.20	70.60	25.50

M_1= Weight of cylinder, $M2$= Weight of cylinder + Sample, $M3$= Weight of sample, M_4= Weight of fraction passing 2.36., AIV= Average impact value.

Table 3: Specific gravity test results.

Locations	Samples	$M_1(g)$		M_2(g)		$M_3(g)$		M_4(g)		ASG
		1	2	1	2	1	2	1	2	
L1	Granite	290.0	284.1	390.0	384.1	842.9	844.7	779.9	782.5	2.68
L14	Granite-gneiss	290.8	284.0	390.0	384.0	842.5	844.4	780.4	782.5	2.65
L15	Granite	290.9	284.0	390.0	384.0	842.4	844.6	780.1	782.4	2.65
L19	Granite	290.0	283.9	390.0	383.9	843.1	844.9	780.6	782.2	2.67
L21	Granite	290.9	284.0	390.0	384.0	842.2	844.3	780.4	782.3	2.63
L23	Granite	290.0	284.0	390.0	384.0	843.5	844.8	780.3	782.0	2.71
L25	Granite-gneiss	290.9	284.2	390.0	384.2	842.9	845.0	780.2	783.2	2.65
L29	Granite	290.9	284.0	390.0	384.0	843.2	845.5	780.7	782.4	2.69

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 results.

Locations	L1	L14	L15	L19	L21	L23	L25	L29
Samples	Granite	Granite	Granite-gneiss	Granite	Granite	Granite	Granite-gneiss	Granite
γ (kg/m^3)	2148.05	2361.5	1912.98	2418.57	2048.47	2046.71	2044.27	2422.71
γ_d(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
Sγ(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

γ= Bulk density, γ_d=Dry density, M= Moisture content, V_s= Volume of solid, V_v= Volume of void, Sγ= Saturated density, e= Void ratio, n= Porosity.

Table 5: Absorption capacity test results.

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= Wet 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, 29.8, 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 acceptable value for this use 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 (Okeke and Iwuaha, 2005). The high strength and attrition resistance of certain igneous rocks result in their use as railway ballast (BGS, 2013).

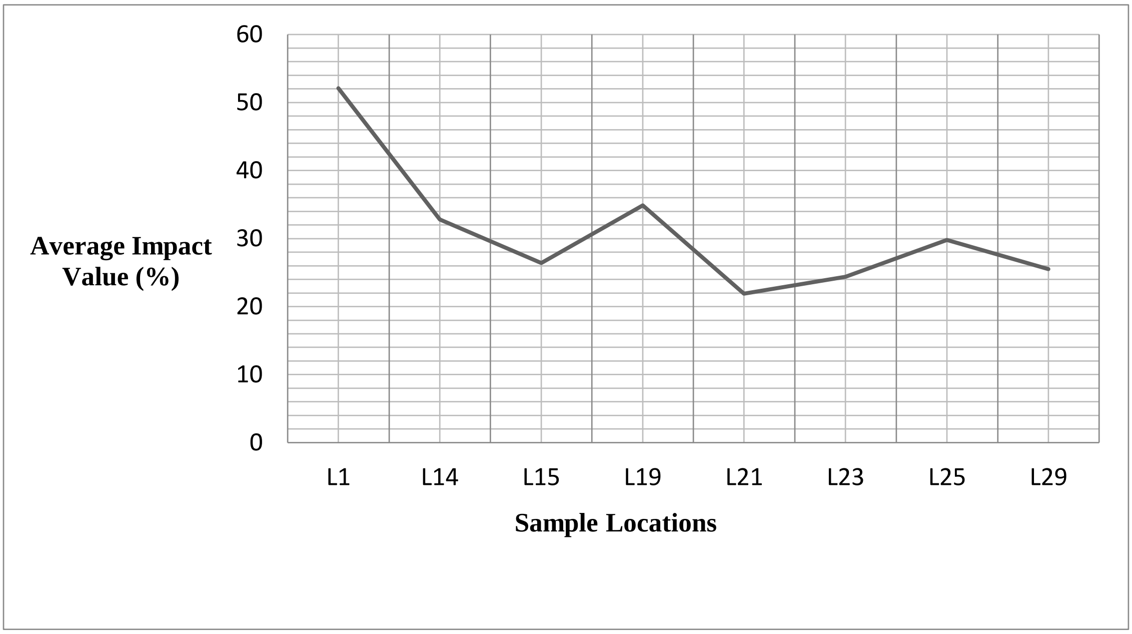

Figure 1: Average aggregate impact value test results.

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 (Neville, 2011). Figure 2 show that sample L23 has the highest specific gravity value while sample 21 has the least specific gravity value.

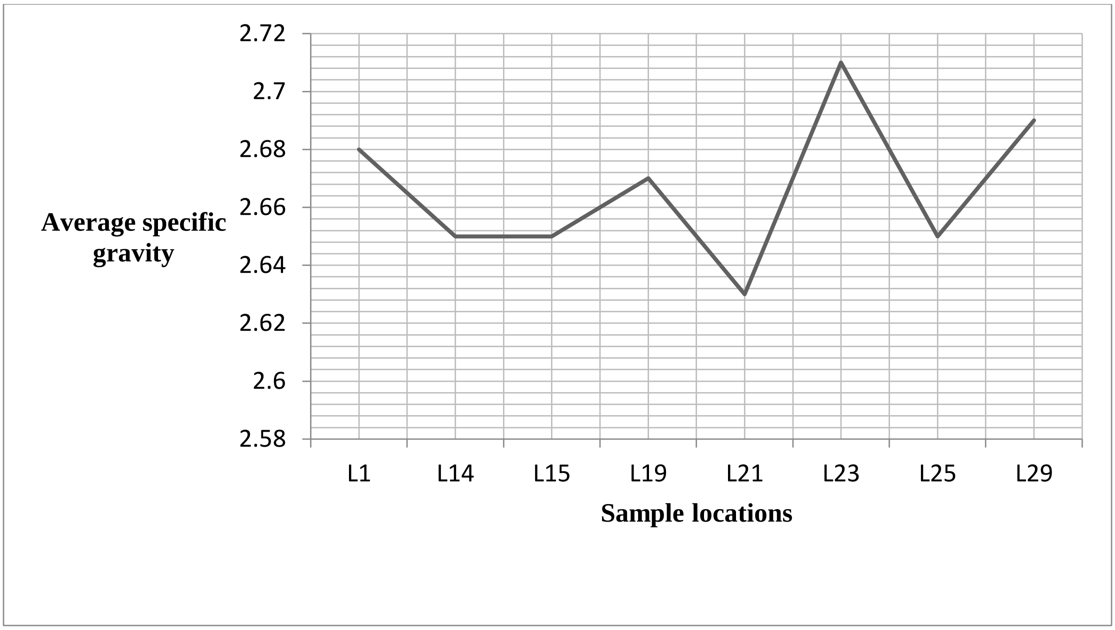

Figure 2: Average specific gravity test results.

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.

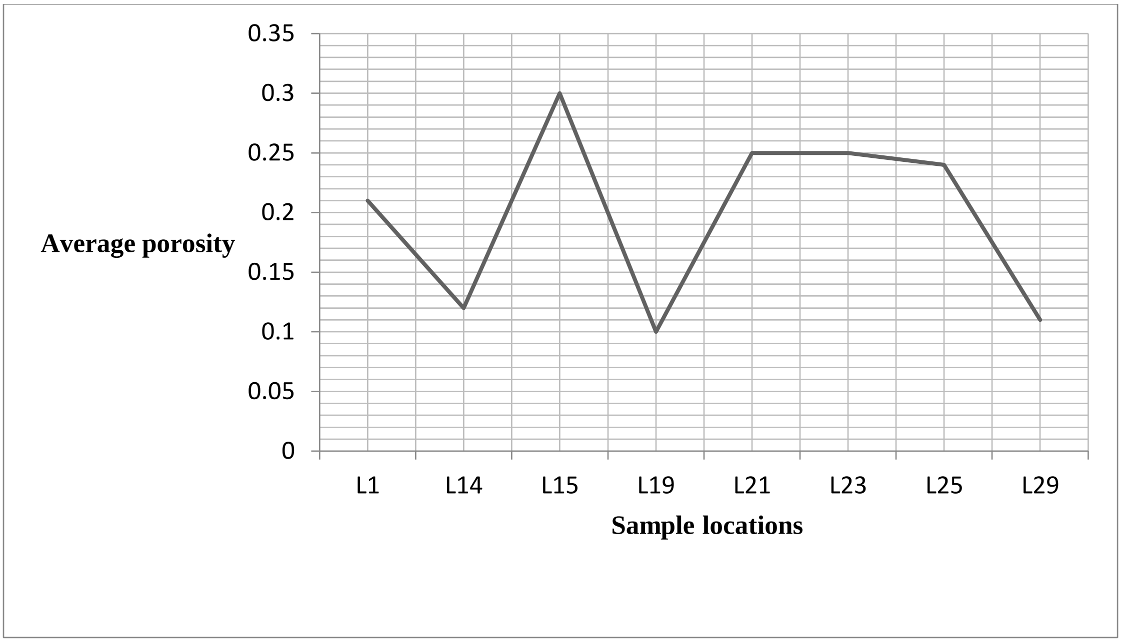

Figure 3: Average porosity test results.

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 sample L19 and L23 have the least.

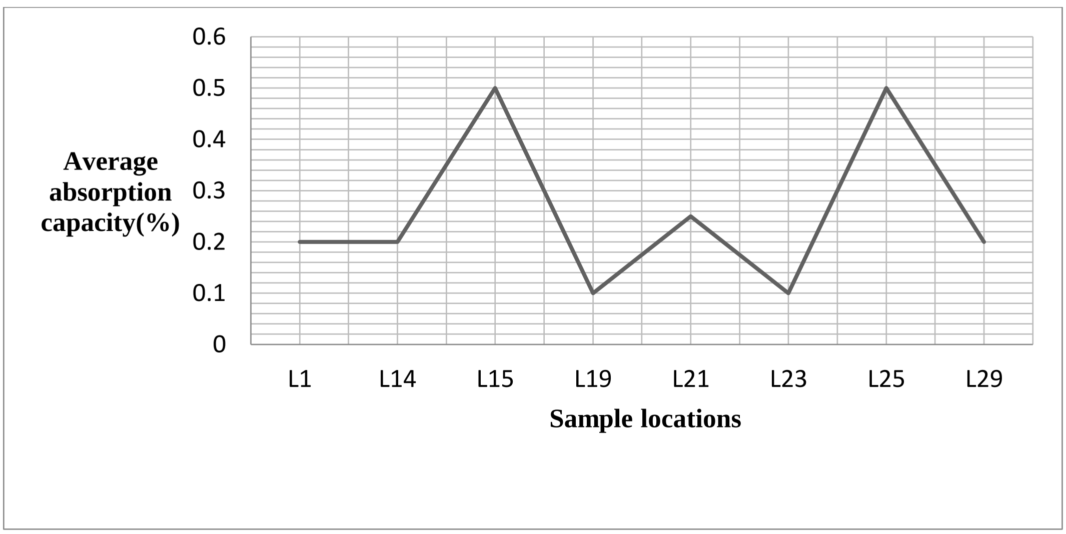

Figure 4: Measured average absorption capacity of the rock samples.

The relationship between porosity and absorption capacity was plotted and a weak correlation exists between them Figure 5. The R^2 value is thus 0.3515. As known, the capacity to accommodate water by rocks greatly depends on the porosity of rock materials (Zhou *et al.*, 2017). This, however, is not the situation in this case as the relationship between the porosity and absorption capacity is very weak and may indicate the rocks porosity have been altered possibly due to weathering.

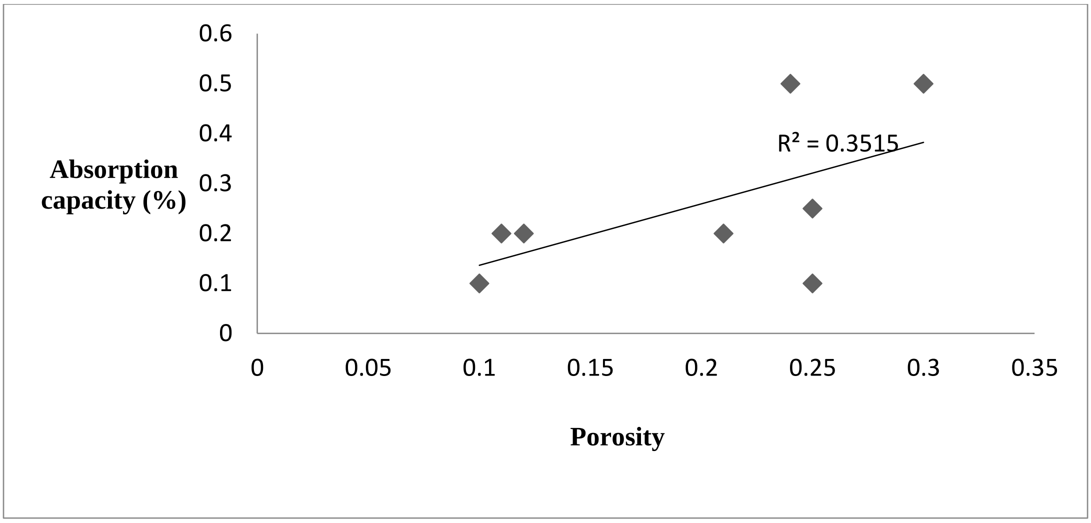

Figure 5: Relationship between porosity and absorption capacity.

The summary of geotechnical testing results for the rock samples collected in the study area, are summarised in Table 6.

Table 6: Summary of geotechnical testing results for the rock samples.

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 basis 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 reinforced concrete applications for concrete structures like buildings.

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