Usability of Pyroclastic Rocks as Construction Materials; Example from Nigeria

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O.P. Aghamelu and C.O. Okogbue

Abstract

Geotechnical properties of pyroclastic rocks from Nigeria have been assessed to determine their usability as construction materials. Modal analysis on the rock samples shows fine-grained to porphyritic textures. Petrographic analysis indicates high amount of plagioclase, pyroxene and groundmass, which consists of chlorite and glassy material. Comparison with construction standards indicates that the pyroclastic rocks would yield aggregates that are marginally suitable for use as road aggregates, as the tested samples fail a number of requirements as road aggregates; their Los Angeles abrasion and flakiness index values are quite outside the recommended limits. The rocks would also perform marginally as concrete aggregate, due to the poor flakiness index results. These situations may further diminish to poor as high amount of weak and deleterious minerals (especially chlorite and glassy material) are recorded in the samples, and would cause material deterioration over engineering time. Study suggests caution when the Abakaliki pyroclastic rocks are used in most engineering projects, as it is obvious that fine-grained texture and volcanic origin, although influenced their properties, but do not guarantee their good performance as construction materials.

Keywords

Geotechnical performance • Mineralogy • Petrographic analysis • Pyroclastic rocks • Texture

240.1 Introduction

The demand and utilization of rocks in various construction projects have continued to increase proportionally to infrastructural development. In the Abakaliki area of southeastern Nigeria (Fig. 240.1), construction aggregates are produced from crushing of pyroclastic rocks, commonly referred to as the 'Abakaliki pyroclastics'. Due to their perceived hardness, arising primarily from fine-grained to porphyritic texture and igneous origin, the connection between the performance of the rocks in service and structural failure of projects in which they are used are of major concern. This research attempts to employ basic but standard laboratory tests to assess the usability of the Abakaliki pyroclastics as construction aggregates.

240.1.1 Geology

The Abakaliki pyroclastic rocks consist of a sequence of tuff, mafic lavas, pyroclastic flows, agglomerates and amygdaloidal lavas of basaltic composition, alkaline in nature (Ofoegbu and Amajor 1987), which extruded the Albian Abakaliki Shale (see Fig. 240.1). The light grayish tuffs and unstratified lavas, however, form the dominant lithology (Aghamelu and Okogbue 2013).

O.P. Aghamelu (✉)
Department of Physics/Geology/Geophysics, Federal University, Ndufu-Alike, Ikwo, P.M.B. 1010, Abakaliki, Nigeria
e-mail: aghameluokeey@gmail.com

C.O. Okogbue
Department of Geology, University of Nigeria, Nsukka, Nigeria
e-mail: celeokogbue@yahoo.com

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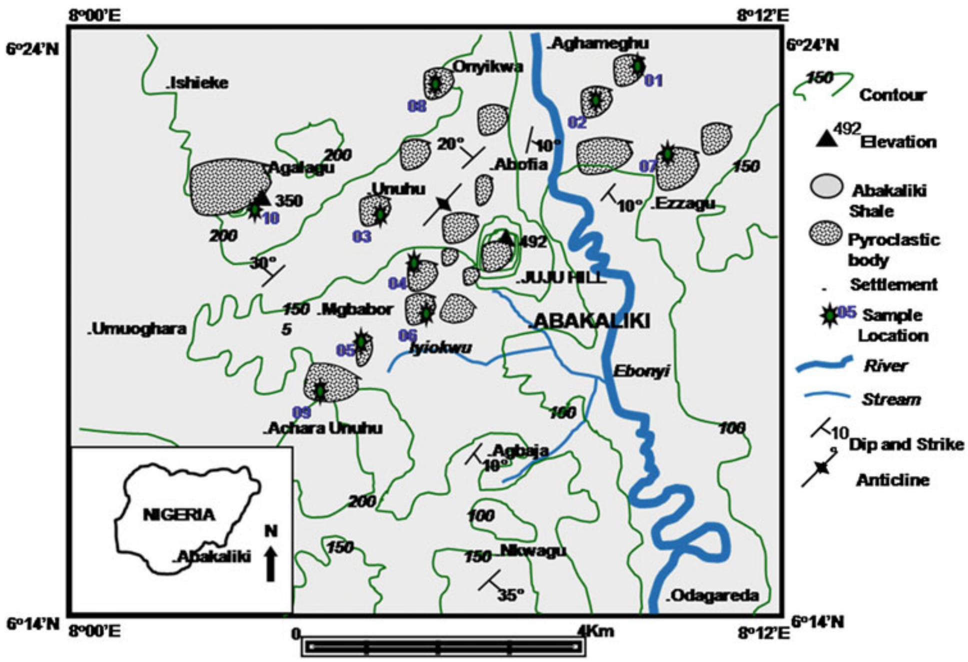

Fig. 1 Geological map of the Abakaliki metropolis showing studied pyroclastic suites (Modified after Aghamelu and Okogbue 2013)

240.2 Methodology

240.2.1 Sampling and Testing

A total of ten fresh representative samples from different pyroclastic rock bodies within the Abakaliki metropolis (Fig. 240.1) were collected and tested. The aggregate tests followed standards specified by British Standard Institution (BS 812 Parts 100 and 110 1990a, b), and American Society of Testing and Materials (ASTM C 127 1990; C 535 1988). The tests include petrographic modal analysis, water absorption, specific gravity (SG), Los Angeles abrasion (LAAV), aggregate crushing (ACV), aggregate impact value, ten percent fines (TFV) and flakiness index. Petrographic analysis was carried out in accordance with standard procedure given by ISRM (1978).

240.3 Results and Discussion

240.3.1 Modal Analysis

The results of the petrographic modal analyses are summarized in Table 240.1. The textures of the samples are between fine-grained and porphyritic. Presence of some weak materials such as chlorite in aggregates can render them deleterious. It is safe to assume that samples of the pyroclastic rocks with very significant contents of lithic fragment and glassy groundmass will be susceptible to faster alteration and material deterioration. Low quartz (≤4 %) in the Abakaliki pyroclastics may mean that they are 'hydrophobic' (i.e., higher affinity for bitumen than water), hence, would not be susceptible to stripping.

240.3.2 Water Absorption (W_a)

The results of W_a analysis are presented in Table 240.2. The amount of water aggregates can absorb tends to be an excellent indicator as to their strength, in other words, their weakness. According to ASTM C 127 (1990), W_a of construction aggregate should be less than 2.5 %. The tested samples have low W_a (all below 2.5 %) and may be an indication of very low porosity and degree of weathering. Feldspathic minerals and glassy materials in the rocks on weathering could increase secondary porosity, as well yield clay, which in turn increases their W_a capacity.

240.3.3 Specific Gravity and Los Angeles Abrasion

The Abakaliki pyroclastics have mean *SG* of 2.64 (Table 240.2), and on the basis this could be judged fairly suitability as a construction material. Aggregates with high *SG* values, usually ≥2.65, are generally suitable in construction. The appreciable *SG* of the Abakaliki pyroclastics may have resulted from significant amount of pyroxene and iron oxides, which predominate the opaque minerals (Aghamelu and Okogbue, 2013). *SG*, however, is likely to drop, in service, as appreciable weak minerals (especially chlorite) are recorded and are prone to deterioration when exposed to weathering conditions. The samples Abakaliki Pyroclastics have their *LAAV* all above 15 % (see Table 240.2), despite

Table 240.1 Results of modal analyses on the samples of the Abakaliki pyroclastics

No.	Texture	Major constituents (%)						
		Plagioclase	Pyroxene	Calcite	Quartz	Opq*	Lithic fragment	Groundmass
01	Prc	41	6	2	+	7	29	14
02	Prc	40	7	6	1	3	15	11
03	Fg	40	8	2	+	3	32	28
04	Fg	40	12	10	+	8	14	16
05	Fg	42	10	4	1	7	18	18
06	Prc	57	8	6	2	5	11	14
07	Prc	43	8	4	2	8	17	21
08	Fg	43	10	1	3	6	20	17
09	Fg	44	8	4	2	8	13	21
10	Fg	52	6	2	3	6	16	15

*opaque minerals, prc porphyritic, fg fine grained, + indeterminate

Table 240.2 Results of geotechnical tests on the Abakaliki pyroclastic rocks

No.	Texture	Parameter					
		Water absorption (%)	Specific gravity	Los Angeles abrasion value (%)	Aggregate crushing value (%)	Ten percent fines value (kN)	Flakiness index (%)
01	prc	1.3	2.61	15	14	104	30
02	prc	1.0	2.65	18	11	110	25
03	fg	1.1	2.64	20	8	122	22
04	fg	1.2	2.59	22	15	118	28
05	fg	1.2	2.58	23	12	120	24
06	prc	1.1	2.63	20	10	106	30
07	prc	0.8	2.74	15	11	180	22
08	fg	0.7	2.78	18	13	200	20
09	fg	1.2	2.62	19	12	110	31
10	fg	1.4	2.56	22	12	108	30

prc porphyritic, fg fine grained

being fine-grained to porphyritic, and not coarse-grained. According to Waltham (1994), fine-grained rocks usually yield crushed aggregates with low *LAAV* (below 15 %) while coarse-grained rocks yield higher values. Hence, 'trap rocks' (i.e., basalt and its likes) have their *LAAVs* within acceptable limits, generally less than 10 % (Waltham 1994), and are desired in most construction projects.

240.3.4 Aggregate Crushing and Ten Percent Fines

The results of ACV tests on the studied samples are presented in Table 240.2. Generally, fine-grained rocks yield aggregates with higher crushing resistance than coarse-grained rocks that yield aggregates with lower crushing resistance, thus, the lower the ACV the stronger the aggregate, in terms of its ability to resist crushing. The ACV of the studied samples compares fairly well that recorded on basalt (ACV of 14 %) by Waltham (1994); both rocks are classified generally as fine-grained and basic. Waltham (1994) had also noted that an aggregate with ACV below 5 % would usually serve well as a construction material, while that with ACV above 35 % would most likely perform poorly. The tested samples all have their *TFV* between 102 and 202 kN (see Table 240.2). Fine-grained variety, however, yielded *TFVs* that are slightly higher than that recorded on the porphyritic variety, indicating that texture variation could have resulted in *TFV* variation within the pyroclastic suite.

240.3.5 Flakiness Index (FI)

The results of *FI* tests on the studied samples are presented in Table 240.2, and revealed that the tested samples contained low to moderate percentage of flaky aggregates (*FI* 20–31 %). A flaky aggregate has low density under compaction and less strength than a cubical or an angular

Table 240.3 Comparison of the Abakaliki pyroclastic rocks with general road stone specification

Aggregate property	Road stone standard (Waltham 1994)	Abakaliki pyroclastics	Remarks
Aggregate impact value (%)	<10	15–29	*Likely to be marginally satisfactory as road stone*
Los Angeles abrasion value (%)	<10	11–25	
Ten percent fines value (kN)	>100	102–202	
Flakiness index (%)	<3	18–32	
Water absorption (%)	<2	0.7–1.5	

NB: Underlined values do not meet specification

aggregate. Waltham (1994) has pointed out that aggregates with *FI* value of 20 % and below will serve well as a construction aggregate; for use as road stone *FI* should be below 3 %. Volcanic rocks commonly yield aggregates with moderate to high *FI* value.

240.4 Conclusions

(1) Petrographic modal analyses indicate significant difference in the mineralogy and texture of the tested samples from the Abakaliki pyroclastic rocks. This is likely due to the variation in the magmatic and depositional processes that occurred during the emplacement of the volcanic suites. Presence of chlorite, shaley to muddy lithic fragment and glassy groundmass are recorded in all the tested samples. In most cases, samples with fine-grained texture and low glassy groundmass gave better engineering properties.

(2) The pyroclastic rocks yielded aggregates with marginal performance in road projects. This is due to the fact that although the aggregates meet the ten percent fines value and water absorption specifications, they fail to meet a number of other requirements as a road stone, such as aggregate impact value, Los Angeles abrasion value and flakiness index (Table 240.3).

(3) This study suggested that similarity in mode of formation, mineralogy and texture are not enough for common rating and predicting of the geotechnical behaviour of all rock types, Abakaliki pyroclastic rocks as an example.

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