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Petrochemical Characterization and Geotechnical Evaluation of Syenite Rock Samples FromIgarra, Southwestern Nigeria

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ABSTRACT: *Despite the abundance and availability of rocks that could be used for different construction purposes in Nigeria, sparse information or data is available about the physicomechanical properties of these rocks as it relate to their industrial applications. Syenite rock samples from Igarra, southwestern Nigeria were investigated with the aim of investigating its compositional features, physical and mechanical properties that may be related to its industrial application. Five samples of this basement rock were analysed for major elements using the X-ray Fluorescence Spectrometer technique. The X-ray diffractograms (XRD) pattern of the representative pulverized rock samples were also determined. The various physical and mechanical tests followed standards specified by International Society of Rock Mechanics and the American Society for Testing and Materials. Petrographic examination indicates microcline, albite, hornblende, biotite and quartz as the minerals occurring in the rock. Microcline is the dominant mineral. The XRD results show that the diffraction trace for the syenite rock is dominated by albite, hornblende, quartz and microcline. Furthermore, from analytical result, SiO_2, Al_2O_3, K_2O and Fe_2O_3 accounts for a substantial percentage of the oxides in the rocks. Result of physical tests including specific gravity range between 3.12—3.14; dry unit weight between 27.44 – 28.11 kN/m^3, compressive strength 163.98 to 164.2 MPa; water absorption capacity 0.65 – 0.7 %; porosity 0·99 and 1·02 % and pH 7.76–7.81. The results of physico-mechanical tests on syenite rock show that these rocks may be suitable for building stone as the tests are generally within the recommended standard values for general building purpose. However, the relatively high water absorption capacity of the syenite rock may affect the long-term performance of the rock as building stone.*

KEYWORDS*: Building Stone, Syenite, Precambrian Rocks, Water Absorption, Unconfined Compressive Strength*

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I. INTRODUCTION

Rocks of the Precambrian basement complex underlie major parts of South-West Nigeria and consist of heterogeneous composition of different rock types like granites, syenites, pegmatites, schists, gneisses and quartzites. The abundance and ready availability of these rocks is one prominent factor in their utilization as a major raw material in most construction industries. These rocks also serve as hosts for numerous economic minerals. The modal composition, petrographic characteristics and texture of these rocks vary significantly. According to Åkesson et al., (2001) and Räisänen (2004), mineral constituent, texture and degree of weathering of a rock unit control their quality as construction materials. Hence careful petrographic, geochemical and geotechnical studies are therefore necessary prior to utilization of these rocks for any construction purpose. Unfortunately, data on geochemical, properties, geotechnical parameter or petrographic studies on these rocks are rarely available before they are used for any construction purposes.

In the past, a series of geotechnical investigations and petrological assessment of some rocks, which constitute part of the Precambrian basement complex of SW Nigeria, have be conducted to assess their use as source of construction materials/aggregates (Eze 1997; Adebisi and Akintayo 2012; Akinola and Talabi 2012; Afolagboye et al. 2016). Akinola and Talabi (2012) indicated, “The gneisses, quartzite, epidiorite and granite have compressive strength values within the limits required for use as foundation material and building stones”. Afolagboye et al. (2016) however observed, “Not all the Precambrian basement rocks would yield aggregates that are satisfactory for use as road construction aggregates". These previous studies also gave an insight on how texture and mineralogical characteristics of these rocks affect their properties, which in turn dictate the kind of construction purpose they can be used for. However, few studies occur in literature that report the compositional features/characteristics and physical/geotechnical properties of syenite vis-à-vis their industrial usage or engineering usage. This work become necessary because most users of these rocks do not realize that they are similar but not identical in mineralogy and texture. Hence, the rocks may not have the same physical and mechanical properties and, therefore, may not be suitable for the same construction purpose. In this study the geochemical characteristics and physical properties of syenite from Igarra, SW Nigeria are determined, analyzed and evaluated in terms of their suitability as construction materials. Fresh samples of these rocks were collected from an active quarry in Igara SW Nigeria.

II. LOCATION AND GEOLOGICAL SETTING

Igarra Schist belt is one of the schist belts within Southwestern Nigeria and it is defined by Lat. 7°15' N – 7°28' N and Long. 5°00' E – 5°15' E.(Fig.1), It occupies the most south-eastern portion of the region. The schist belt trends NNW with a length of about 50km joining the NW trending Owo belt (Turner 1983). The earliest known detailed works on Igarra environs are those of Odeyemi (1976, 1977) and Rahaman (1989). Several other authors have since reported on the area with varied interests, These interests include among others geology (Oyewole and Ofuyah (2017); Akinola et al.,(2017)) economic geology (Akinola and Olaolorun 2020; Obasi and Anike (2012); Odokuma-Alonge and Adekoya(2013)) and structural geology (Ocan,(2016); Efosa and Oden(2016); Obiadi et al.,(2015); Oden and Efosa (2014); Oden (2012)). The geology and evolution of Igarra area as an integral part of southwestern Nigeria is well described in the works of Odeyemi (1988)(Fig. 1) and Rahaman (1989). The basement rocks of the schist belt represent that of a typical high grade metamorphic terrain with polyphase deformation. The metamorphic rocks are the migmatites, gneisses and schists with intercalations of amphibolites, cataclasites and quartzites. These underlying basement rocks in the area of study have been intruded by Pan African granites such as the Igarra batholiths and other minor intrusive including Pegmatite, Aplite, Dolerite, Lamprophyre and Syenite, the focus of this research. The Syenite is located in the N7° 13.544´ and E6° 08.204´ of Auchi NW (Sheet 226). The rock occurs as low-lying hills which extend for several meters and has a height of above 250 metres above sea level. Mapping was carried out to the left on a traverse off Auchi - Igarra road and samples were obtained in an active quarry (Anthony quarry) cite which granted the opportunity of obtaining fresh,un-weathered and uncontaminated samples from the well exposed outcrop in-situ,

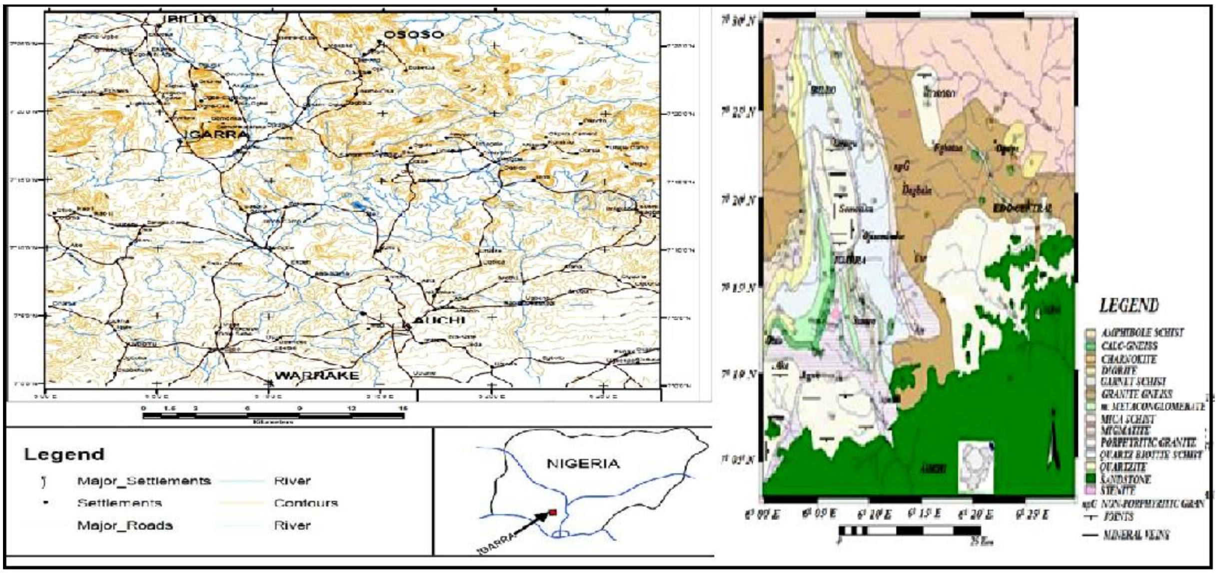

Fig.1: Topographical (Left) and Geological Maps of Igarra Area(after Odeyemi, 1988)

The syenite ismassiveand light grey on physical inspection. Appreciably large chunks of the syenite samples were collected and preserved immediately in labelled sample bags, each giving the location or point of procurement within the quarry. A few simple pegmatites were found in association with the rock.

III. METHODOLOGY/LABORATORY TESTS

Rock samples used for the work were collected from an active quarry. This gives the opportunity to obtain fresh and unweathered samples free from observable fractures. The obtained samples were divided into two: one part was crushed and pulverized and the second part was crushed and saved as coarse aggregates for further studies. Representative samples from the pulverized material were used for chemical analysis and XRD (Fig.2) while coarse aggregates were used for petrography studies, strength test and other physical properties. Three samples were chosen and prepared into thin sections for optical examination. The mineralogical analysis of the selected samples was studied by identifying the minerals in the slide according to their optical characteristics under crossed polar. Point counting method was applied to obtain the modal composition of the rock sample. The X-ray diffractograms (XRD) pattern of the representative pulverized rock samples were recorded using a RayonsPANalytical EMPYREAN DY 1032 X-ray diffractometer. The samples were scanned from 0 to 90° under Cu-Kα alpha radiation 40 kV, 30 mA at scanning rate of 2° 20 cm/min and time constant 4 sec. For geochemical analysis, collected rock samples were oven dried at 60 °C, crushed, pulverized and sieved with sieve size 75µm. The samples were then analyzed by X-ray Fluorescence Spectrometer for major and trace elements measurement. The various physical and mechanical tests followed standards specified by International Society of Rock Mechanics (ISRM 1979, 1981), and the American Society for Testing and Materials (ASTM C127 1990, C535 1989). These tests include specific gravity (ASTM C127, 1990), unconfined compressive strength (ISMR, 1981), dry unit weight, water absorption capacity and porosity.

IV. RESULTS AND DISCUSSION

Petrography

Microscopically, the Igarrasyenites are holocrystalline consisting of microcline, albite, hornblende, biotite and quartz (Fig.2 right).The textures of the rocks are found to be medium and hypidiomorphic. Microcline is the dominant minerals and their size ranging from 0.2 to 1.5 mm in length and about 5 to 6 mm in width. The ferromagnesium minerals range between 2.0 and 4.0 mm long. The average modal composition of the syenite is 65.95 % which is light colored alkali feldspars. The microcline form about 5.53 %,the dark colored minerals (biotite and amphiboles) and quartz form about 28.55 % of the total modal percentage of the mineral assemblage.Biotite is pleochroic, varying from brown to greenish brown. Albite is grey colored with inclusion of biotite within it. Microcline exhibits-stained brownish color while the hornblende looks milky to transparent in the thin sections. According to Bandini and Berry (2013) and Räisänen (2004), the textural characteristics of a rock control or influence their mechanical properties hence their effectiveness as construction materials. In addition, the presence and amount of weak or hard minerals in a rock also control its mechanical properties.

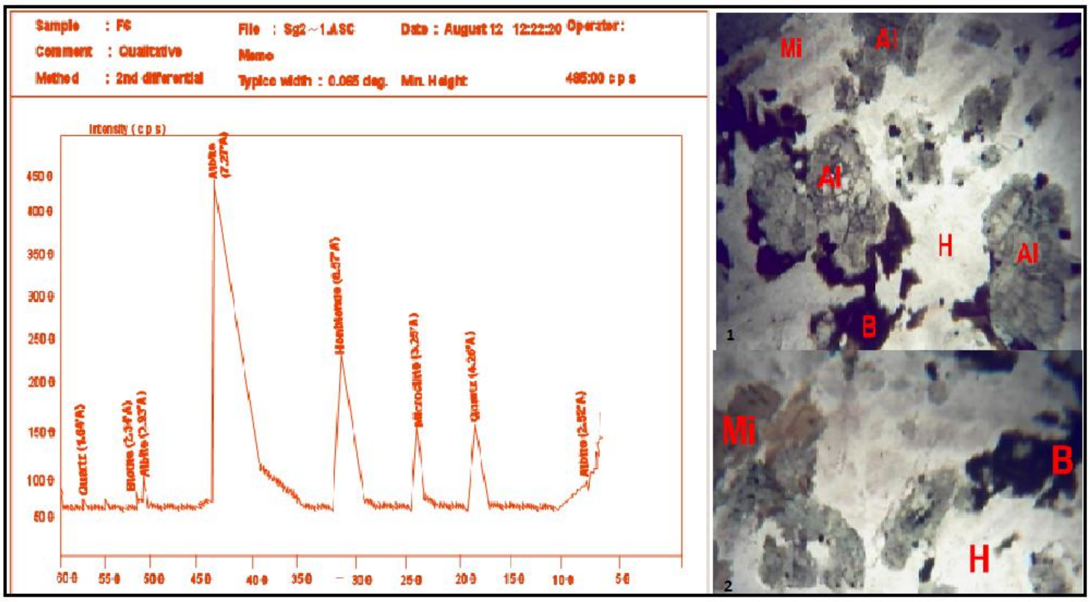

Fig. 2:XRD tracesand Syenite mineralslides (A-albite,B-biotite,M-microcline,H-hornblende)

A rock with mineral grains that are hard and rounded can take significant stress without breaking. On the other hand, a rock with weak mineral grains will suffer fragmentation when subjected to stresses due to the cracking of the minerals grains and shearing of asperities (Melbouci et al. 2008). Except quartz, which is a stable mineral during the weathering process, other minerals such as olivine, calcic felspar, augite, hornblende, sodicfelspar, biotite and muscovite are less stable compared with quartz and eventually weathers to clay minerals (Robin et al. 2015). The average modal composition of the minerals is presented in Table 1. The sensitivity of the syenite to alteration and disintegration is assumed to be relatively lower owing to the relatively low percentage of plagioclase and mafic minerals.

XRD Results

The X-ray diffraction (XRD) traces of the syenite rocks is presented Figure 2. The results show that the diffraction trace for the syenite rock is dominated by albite, hornblende, quartz and microcline, where albite constitute 65.92 %, hornblende 20.45 %, quartz 7.96 %, microcline 5.53 % while biotite is about 0.14 % in the mineralogy. Hence, the XRD analysis results also confirmed the results obtained from the petrological studies.

Geochemical Features

Geochemical result (

Table 1) shows that average SiO_2 content of all the rocks samples are high and with an average of 60.05 %. The high amount of SiO_2 present in the rock shows there is a significant amount of silicate minerals present in the rock samples. The rock samples are also rich in Al_2O_3, Fe_2O_3 and K_2O. The K_2O content more than twice MgO and CaO are high in value than Na_2O. The percentage composition of the aforementioned oxides shows the unusual mineralogical composition of the rock. The relatively lower amount of CaO may be a reflection of low amount of secondary minerals in the syenite. Substantial amount of Na_2O and K_2O confirm the classification of the rock samples as alkali. In addition, the chemical classification of the rock samples in the TAS diagram (total alkali vs SiO_2, after Cox and adapted by Wilson) show that the date fall in the syenite field. Fe_2O_3 and MgO constitute a substantial part of the major oxides of the rock samples and this may likely influence the specific gravity of the rocks. The syenite is whitish/greyish in color and due to the presence of substantial amount of Fe_2O_3, the rock may change or alter into shades of pink, red, brown or yellow as a result of hydration of iron oxides with time (Bell 2007).According to Sayat and Gonconglu (2009), the LOI serves as an indication of the degree of alteration and presence of secondary volatile and carbonate phases. The low LOI values recorded in the rock samples shows the absence of secondary carbonate and volatiles.

Table 1: Major oxide concentration of the rock

Major Oxides	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	P_2O_5	K_2O	MnO	MgO	Na_2O	LOI
*Oxide in %	60.05	15.42	5.09	0.8	3.74	0.36	6.69	0.09	3.72	2.77	0.5

* Average of seven samples

Physical Properties

Specific Gravity

The specific gravity of a rock depends on the density of its mineral constituents and the amount of water in the pores. The specific gravity (Table 2) of the rocks range from 3.12—3.14. These values are higher than the minimum value (> 2.5) suggested by ASTM specifications C—503 and 568. Freshness of the rock samples, compactness of the rocks or possibly the high amount of heavy minerals present in the rock may be attributed to the higher specific gravity values recorded in the rocks. Afolagboye et al. (2016) attributed the relatively high specific gravity of some Precambrian basement rocks in Nigeria to relatively high contents of iron-rich minerals that are present in the rocks. Although specific gravity is not usually considered as a primary means of determining the durability of rock for a construction purpose but specific gravity greater than 2.55 are generally considered to be suitable for heavy construction work (Blyth and De Freitas 1974).

Table 2: Physico-mechanical properties of the rock

S/N	UCS (MPa)	Porosity (%)	Specific Gravity	Dry Unit Weight (KN/m^3)	Water Absorption Capacity (%)	PH
1	163.98	0.99	3.12	27.71	0.65	7.78
2	164.03	1.01	3.12	28.11	0.69	7.81
3	164.20	1.00	3.13	27.45	0.68	7.76
4	164.07	1.02	3.14	27.44	0.64	7.77
5	164.08	1.01	3.13	27.49	0.70	7.76
6	164.08	1.01	3.13	27.64	0.67	7.80

Dry Unit Weight

As remarked by IAEG (1979): *"Unit weight is an important indicator of the physical properties of rock material and correlates well with mineral composition, porosity and strength"*. The unit weight gives information about the mineralogical or grain constituents of a rock (Goodman 1989). High moisture content, high amount of pore spaces and abundance of weak minerals (such as clay minerals) are factors that could make a rock have a low unit weight. The dry unit weight ranges between 27.44 and 28·11 kN/m^3 (Table 2). The unit weight can thus be classified as high to very high according to the International Association for Engineering Geology and the Environment (IAEG 1979). Thus, the absence of voids and low moisture contents are probably the cause of high dry unit weight of the tested samples. The significantly higher unit weight value of the syenite rocks, when compared with the mean unit weight values of common rocks used as construction materials may indicate good quality as construction materials (Carmichael 1984).

Porosity

Porosity describes the relative proportion of solids and voids in a rock. It is an important rock physical property that influenced key properties such as durability, strength, hydraulic conductivity and deformability (Martins et al. 2016; Tugrul 2004; Zalooli et al. 2017). However, porosity won't provide any details on the distribution of pore spaces within a rock that is the numbers fine of pores which may facilitate absorption by capillary tension, or a smaller number of coarse pores (Harrison and Bloodworth 1994; Quick 2002). The values of porosity obtained for the syenite rock range between 0·99 and 1·02 % (Table 2) and can be grouped as low to very low according to the IAEG (1979). The low to very low porosity of the tested rocks may be as a result of their tight interlocking crystalline texture. Porosity to a large extent is the main indicator of a rock resistance to weathering (Dearman 1981) while Waltham (2009) pointed out that the rate and extent to which a rock is dissolved or attacked by an acid is controlled by mineralogy and porosity. The tested rock may not weather easily because of the low to very low porosity of the rock. Due to the fact that porosity controls flow of fluid in a rock, it is assumed that the syenite rock samples may not be prone to acid attack and dissolution when used for outdoor construction purpose especially when polished. In addition, the durability of the rock samples will likely be high. Martins et al. (2016) show that rocks with high porosity have low durability in laboratory tests compared to rocks with low porosity. Overall, rock that are chemically non-reactive and sound rocks with low porosity are considered as durable.

Water Absorption Capacity

According to Çobanoğlu et al. (2009), water absorption value is a significant parameter which influence the physical and mechanical properties of rocks. Quick (2002) gave the definition of water absorption as "the proportion of water able to be absorbed by stone under specific immersion conditions". Water absorption is directly related to the effective porosity and controls the durability, stain resistance and strength of rock (Goudie 1999; Mann 2006; Erdoğan and Özvan 2015; Zalooli et al. 2017a). Generally, a rock with high water absorption is less durable, possesses less stain resistance and more liable to salt and frost attack. According to Benavente et al., (2007) a rock with high water absorption will deteriorate faster because water will act as a catalyst during the weathering process. In addition, low water absorption restricts the movement of deleterious solution (Mann 2006). Table 2 shows that the water absorption of the rock samples varies from 0.65 % by weight to 0.7 %. These values are greater than the ASTM specification C – 615 (less than 0.40 %). The relatively high values may be attributed to the presence of micro-fractures and the porosity of the rock samples.

Unconfined Compressive Strength (UCS)

The UCS values of the tested samples range from 163.98 to 164.2 MPa (Table 3). The UCS of the syenite rocks fall within the 'high strength' category of strength classification (ISRM 2007). Waltham (2009) pointed out that a stone with UCS value above 50 MPa is likely to perform favorably well as construction material. The UCS values of the rock samples are well above 50 Mpa, hence they are likely to perform well as construction material. In addition, the rock may also be suitable as cladding stone because their UCS are above 100 MPa (Waltham 2009). The UCS of syenite rock falls within a narrow range. This may be attributed to the uniformity in the texture and the mineralogy of the tested rock samples.

Suitability of the Syenite Rock as Dimension Stones

According to Harrison and Bloodworth (1994) the suitability of a rock as dimension stones is influenced by properties such as attractive appearance (color and texture), durability (physical and chemical stability), strength and consistency of quality. Other important factors according to the authors are "costs of quarrying, processing and transportation, and the availability of alternative sources of supply. Overall, the selection of a rock is determined by the by aesthetic appeal and the preferences of architects and design engineers". Compiling and comparing the petrographic and preliminary laboratory tests with the limiting values stated by various standards and specifications to reveal the engineering performance of the rocks in term of dimension stones suitability, the limiting values specified for dimension stones are generally those given in ASTM standards and other related standards (

Table 3).

Table 3: Typical acceptance values for dimension stones

Properties	Values	Acceptance Value	Source
Specific Gravity	3.12 – 3.14	-	
Unit Weight (KN/m^3)	27.44 – 28.11	25.60	ASTM C 615 (2001)
Porosity (%)	0.9 – 1.02	-	
WAC (%)	0.65 – 0.7	< 0.4	ASTM C 615 (2001)
UCS (MPa)	163.98 – 164.2	131	ASTM C 615 (2001)

For a rock to serve as building stone, such rock must be sound, spalls free, free of cracks or seams and other defect that are likely to affect its integrity in its proposed used. The field observation and specimen observation show that this rock formation is free of these defects and are likely to serve as good building stone. In addition, the rock has a uniform and consistence appearance, light colored and uniform texture. Rocks with these properties are generally used as building stone. According to the petrographic study, the rock is also free from minerals that can lead to staining when exposed to long unfavorable climatic condition. The results of physico-mechanical tests on syenite rock show that the rocks may be suitable for building stone as the tests are generally within the recommended ASTM standard values for general building and structural purposes (

Table 3). However, the syenite rock samples shows a higher water absorption than the ASTM recommended values. The relatively high-water absorption capacity of the syenite rock may affect the long-term performance of the rock as building stone. The factors affecting the outdoor usage of rock include the ease of solubility and presence of defects in the rock mass. These factors are largely affected by micro or macro-structures and mineralogy of the rock. The study reveals the presence of macro and micro-structures, though small, in the samples tested. Ozcelik and Ozguven (2014) stated that “durability is a complex criterion determined by inherent strength, water absorption and pore space”. The relatively high-water absorption capacity may make the stone liable to strength deterioration and have less stain resistance after prolong exposure climatic condition.

V. CONCLUSION

This study revealed that the Igarrasyenite is holocrystalline consisting of microcline, albite, hornblende, biotite and quartz. The syenite has high percentage of SiO_2, Al_2O_3, Fe_2O_3 and K_2O. Physico-mechanical properties of the basement rock indicate that it possesses relatively high specific gravity, unit weight, compressive strengths, relatively high-water absorption capacity and low porosity. The results and assessment of the physico-mechanical characteristics presented in this study shows that syneniterock generally satisfies the basic properties of building stone. The relatively high-water absorption capacity of the rock may make them liable to strength deterioration and have less stain resistance after a prolonged exposure to climatic condition. Besides knowing the most physico-mechanical properties of the rock deposits, it is also required to define how the syenite are affected by the heat and examine water absorption and dehydration of the rock against time. This is in addition to the short- and long-term durability of the rock samples. Understating these properties is very essential when selecting these rocks for building stones. The authors intend to study the long-term durability of this rock against prolong wetting–drying cycles and accelerated weathering. In addition, it will also examine water absorption and dehydration of the rock against time in a future research.

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REFERENCES

[1]. Adebisi NO, Akintayo FO (2012) Geotechnical properties of natural composite rock in Ibadan, Nigeria. Pacific J SciTechnol 13:448–453

[2]. Afolagboye LO, Talabi AO, Akinola OO (2016) Evaluation of selected basement complex rocks from Ado-Ekiti, SW Nigeria, as source of road construction aggregates. Bull Eng Geol. Environ 75:853–865. doi: 10.1007/s10064-015-0766-1

[3]. Åkesson U, Lindqvist J, Göransson M, Stigh J (2001) Relationship between texture and mechanical properties of granites, central Sweden, by use of image-analysing techniques Bull EngGeol Environ 60:277–284. doi: 10.1007/s100640100105

[4]. Akinola OO, Talabi AO (2012) Petrochemical characteristics and geotechnical properties of crystalline rocks in the archean-proterozoic terrain of Ijero-Ekiti, southwestern Nigeria. RMZ— Mater Geoenvironment 59:347–362

[5]. Bandini A, Berry P (2013) Influence of Marble’s Texture on its Mechanical Behavior. Rock Mech Rock Eng 46:785–799

[6]. Bell FG (2007) Engineering geology, 2nd edn. Oxford, Elsevier
[7]. Benavente D, Cueto N, Martínez-Martínez J, et al (2007) The influence of petrophysical properties on the salt weathering of porous building rocks. Environ Geol 52:215–224
[8]. Blyth FGH, De Freitas MH (1974) A geology of engineers. London, ELBS/ Arnold
[9]. Carmichael RS (1984) Handbook of physical properties of rocks, Vol. 3, 3rd edn. CRC Press, Boca Raton, Florida
[10]. Çobanoğlu İ, Çelik SB, Dinçer İ, Alkaya D (2009) Core size and time effects on water absorption values of rock and cement mortar samples. Bull EngGeol Environ 68:483–489. doi: 10.1007/s10064-009-0215-0
[11]. Dearman WR (1981) General report, session I: Engineering properties of carbonate rocks.
[12]. Bull IntAssocEngGeol 24:3–17. doi: 10.1007/BF02595246
[13]. Egbuniwe IG, Ajibade AC, Umeji AC (Eds.). Precambrian Geology of Nigeria (1):1-23.
[14]. Erdoğan O, Özvan A (2015) Turkey)., Evaluation of strength parameters and quality assessment of different lithotype levels of Edremit (van) travertine (eastern Turkey).
[15]. African Jour. Earth Sci 106:108–117. doi: 10. 1016/j.jafrearsci.2015.03.018
[16]. Eze EO (1997) Geotechnical assessment of some charnockites from Nigeria as construction materials. Q J EngGeol 30:231–236
[17]. Goodman RE (1989) Introduction to Rock Mechanics, 2nd, 2nd edn. Wiley, New York
[18]. Goudie A (1999) A comparison of the relative resistance of limestones to frost and salt weathering. PermafrPeriglac Process 10:309–316. doi: 10.1002/(SICI)1099-1530(199910/12) 10:4<309::AIDPPP330>3.0.CO;2-C
[19]. Harrison DJ, Bloodworth AJ (1994) Industrial minerals laboratory manual: construction materials BGS technical report WG/94/12
[20]. IAEG (1979) Classification of rocks and soils for engineering geological mapping part I:rock and soil materials. Bull IntAssocEngGeol 19:364–371
[21]. ISRM (International Society for Rock Mechanics) (2007) The complete ISRM suggested methods for rock characterization, testing and monitoring: 1974–2006. In: Ulusay R, Hudson JA (eds) Suggested methods prepared by the commission on testing methods. KozanOfset, Ankara, Turkey, p 628
[22]. Mann J (2006) The four basic keys to successful stone selection. Discov Stone 10:34–38
[23]. Martins L, Vasconcelos G, Lourenço PB, Palha C (2016) Influence of the freeze-thaw cycles on the physical and mechanical properties of granites. J Mater CivEng 28:04015201-1-04015201-13. doi: 10.1061/(ASCE)MT.1943-5533.0001488
[24]. Melbouci B, Bahar R, Cambou B (2008) Study of the Behavior of Schist Grains Under Crushing,. Bull EngGeol Environ 67:209–218
[25]. Obiadi I. I, Obiadi C. M, Ajaegwu N. E, Anakwuba E. K, Onuigbo N. E, Maduewesi U. V, Okolo C. M,Ezim O. E (2015) Structural evidence for Pan-African Event in the SW Basement block of Nigeria: the Igarra example. J Basic App Res Int 3(2):66–74
[26]. Oden, Michael I. and Udinmwen, Efosa (2015) Strain analysis and Tectonite Classification usingpolymicticmetaconglomerates in the Igarra schist belt, southwest ernNigeria.*Journal of AppliedGeology and Geophysics (IOSR-JAGG) e-ISSN: 2321– 0990, p-ISSN: 2321–0982.Volume 2,*
[27]. Odeyemi I. B. (1976). Preliminary report on the field relationships of the basement complex rocks around Igarra, Mid-West. Geology of Nigeria. Rock View 1:57-63
[28]. Odeyemi I. B. (1977).On the basement rocks of Bendel State of Nigeria. Unpublished Ph. D. Thesis, University of Ibadan 1:1-246.
[29]. Ozcelik Y, Ozguven A (2014) Water absorption and drying features of different naturalbuilding stones. Constr Build Mater 63:257–270. doi: 10.1016/j.conbuildmat.2014.04.030
[30]. Quick G. W (2002) CSIRO - Selective guide to the specification of dimension stone. Discov Stone 8–21.
[31]. Rahaman M. A, (1976). Review of the Basement geology of Southwestern Nigeriain Geology of Nigeria (Kogbe, CA (Ed.) Elizabethan publishing Company, Lagos 1:41-58
[32]. Rahaman M. A (1988). Recent advances in the study of the Basement Complex of Nigeria. In: Oluyide, P. O, Mbonu, W. C, Ogezi, A. E,Räisänen M (2004) Relationships between texture and mechanical properties of hybrid rocks from the Jaal–Iitti complex, southeastern Finland. EngGeol 74:197–211
[33]. Robin F, MacGregor P, Stapledon D, et al (2015) Geotechnical engineering of dams, 2nd edn. CRC Press/Balkema, London
[34]. Sayat K, Gonconglu M (2009) Geochemistry of mafic rocks of the Karakaya Complex, Turkey.; evidence for plumenvolvement in the Palaeotethyan extensional regime during the middle and late Triassic. Int J Earth Sci 98:367–385.
[35]. Tugrul A (2004) The effect of weathering on pore geometry and compressive strength of selected rock types from Turkey. EngGeol 75:215–227.
[36]. Turner DC (1983). Upper Proterozoic Schist belts in the Nigerian Sector of the Pan-African province of West Africa. Precambrian Resources 21:55-79.
[37]. UdinmwenEfosaand Michael Oden, (2016) Strain analysis and tectonite classification usingpolymicticmetaconglomerates in the Igarra schist belt, southwestern Nigeria Arab JGeosciences 9:534 Waltham T (2009) Foundations of Engineering Geology, 3rd edn. Spon Press, London
[38]. Zalooli A, Khamehchiyan M, Nikudel M (2017a) The quantification of total and effective porosities in travertines using PIA and saturationbuoyancy methods and the implication for strength and durability. Bull EngGeol Environ. doi: https://doi.org/10.1007/s10064-017-1072-x
[39]. Zalooli A, Khamehchiyan M, Nikudel MR, Jamshidi A (2017b) Deterioration of travertine samples due to magnesium sulfate crystallization pressure: examples from Iran. GeotechGeolEng 35:463–473

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