PHYSICAL AND MECHANICAL EVALUATION OF MARBLE IN ELEBU IN KWARA STATE

BY

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Certification

This is to certify that this project was carried out and submitted by **JAMIU, MUHAMMED** of Matric number **ND/23/MPE/FT/0049** to the Department of Minerals and Petroleum Resources Engineering, Kwara State Polytechnic, Ilorin in partial fulfilment of the Requirement for the Award of National Diploma in Minerals and Petroleum Resources Engineering Technology.

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Dedication

I am delighted to dedicate this project to Almighty GOD, the creator of all universe who gave me the grace and opportunity to complete my ND program and this research, may His name be glorified.

Acknowledgements

I give all the glory and adoration to Almighty GOD, the beginning and the End, for his greatest protection and love given to me as a privilege to start and complete this research work.

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Abstract

Physical and mechanical evaluation along with the economic potential of marble deposit from Elebu, in Moro Local Government Area of Kwara State were examined for their possible industrial applications. Five (5) samples were taken to laboratory for treatment and standard laboratory preparation prior to physical and mechanical analysis at Civil laboratory, University of Ilorin. The physical analysis include specific gravity, bulk density, porosity, compressive strength and aggregate abrasion value. It is evident for all the samples that the specific gravity may be credited to low degree of weathering and are suitable for heavy construction work. The lower density values can be attributed to the presence of impurities, especially in the country rocks. These factor contribute to a decrease in the overall density. Based on porosity, the marble is not prone to dissolubility, acid attacks and are less porous and dense along with the effect of weathering which have been of insignificant implication. The relatively lower values of water absorption can also be attributed to factors such as porosity and weathering or even high percentage of impurities including allied minerals. The UCS of all rock samples are not good in the production of floor tiles and cladding stone based on low Uniaxial Compressive Strength. The abrasion values of Elebu marble are compared to the minimum acceptable value specified in the ASTM C503 (2001) standard which suggest that all the samples are above the minimum required standard. Based on this, Elebu marble is not only suitable for fluxing steel but as chips which are crushed in pieces that are produced according to consumers' size demand and needs. Chips give gardens or landscapes exquisite cool look. It can also be used as marble fittings of high strength materials that are fitted in places where hard substances impervious to moisture are demanded.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Marble is one of the industrial rocks that is presently gaining prominence in the manufacturing sector of the Nigerian economy. The wide range of application of marble and associated lime-rich rocks especially in construction, recent upsurge in urban development and new opportunities in the solid minerals development has induced local as well as foreign entrepreneurs' to show a keen interest in the exploitation of marble deposits in Nigeria and what determines the suitability of a marble deposit for the production of cement and construction purposes is largely its physical and chemical characteristics, hence the justification of this study. Elebu area lies within the Precambrian Basement Complex of Northcentral, Nigeria. The Basement rocks notably the migmatite gneiss complex, schist (metasediment), older granite and late intrusives. The schist occurs as a supracrustal cover on the Basement and consists of mica schist, metaconglomerate, calc-gneiss and marble and quartz biotite. The marble in Elebu area occurs in large deposit, yet very little data are available on its physical and mechanical properties. The exploration for marble started in the year 1970 (Alabi*et al.,* 2013). The Occurrence and exploration of variety of marble deposits found within the Nigerian Basement terrain e.gBurum-Takalafia in the Federal Capital Territory (F.C.T), Abuja; kwakuti in Niger State; EtobeAjaokuta and Jakuti in Kogi State; Ukpilla in Edo State and Igbetti in Oyo State and Ukpilla in Edo State have been studied by many researchers and authors (Oluyide and Okunlola 1995). These deposits have various morphologies within the Schist belts and exhibit different physico-chemical characteristics that render them economically attractive. Marble also has numerous applications for structural and decorative purposes. It is utilized for outdoor sculpture, external walls, floor covering, decoration, stairs, and pavements. The majority of prehistoric monuments were made of marble. Marble has decorated the corridors of palaces and historical places e.gTajMahal Palace in India. This study therefore presents physical and mechanical properties of Elebu marble with the purpose of appraising its economic potentials and industrial applications.

1.2 Aim of the study

The aim of this study is to evaluate the physical and mechanical properties of marble for construction purposes.

1.3 Objectives of the study

The objectives of the study are as follows;

i. to determine the physical properties of marble in the study area.

ii. to determine the mechanical and strength of marble for construction purposes.

1.4 Problem Statement

Nowadays various engineering distress and concern have been observed due to the use of poor material for construction (i.e. material with less or poor engineering properties). It is very important to evaluate the physical and mechanical application of marble as it applies to construction purposes.

1.5 Scope of the study

This study is restricted to physical and mechanical characterization of marble. Samples collected from the study area was subjected into specific gravity, bulk density, porosity, water absorption while the mechanical properties includes uniaxial compressive strength and Los Abrasion analysis.

1.6 Justification of the study

Evaluation of marble deposits is vital for construction purposes and a keen interest in the exploitation of marble deposits in the study area is what determines the suitability of marble deposit for the production of cement and construction is largely its physical and mechanical characteristics.

CHAPTER TWO

LITERATURE REVIEW

2.1 Review of Previous work

Several authors has reported physio-mechanical properties of marble in Nigeria. Among these authors are Thuro and Scholz (2004) demonstrated that weathering in marble rock type has deep impacts on both physical and mechanical properties of the rocks as well as of the rock masses. The changes in mineral content and the increase of pore volume promote the action of mechanical disintegration and chemical decomposition.

Egesi and Tse, (2011) noted that understanding the mineralogy, grain size, texture and weathering states which could be related to the geological processes that form the rock also help in assessing the rock as dimension stone hence determining the rock's suitability and availability for production

Daku et al. (2017) reported Engineering Properties of Jakura Marble and Its Suitability for Tiles Production and concluded exploitation of marble for tiles production will be a huge developmental growth for the Nigerian economy, considering their good engineering properties.

Ogunsola et al. (2019) reiterated the effect of petrographic and geochemical characteristics on rock strength and especially the relationships between the engineering properties and specific petrographic transformations which take place during weathering process which are very common in marble. This is very necessary, to enhance the understanding of the effect of the internal mechanism of rock structure and its engineering properties.

Akinola et al. (2020) studied physic-mechanical and compositional features of metamorphosed carbonate rock in Igue, Southwestern, Nigeria: Implication for Industrial Use as Dimension and noted that the marble deposit are pure to relatively pure deposits and the physio-mechanical characteristics satisfy the basic properties for dimension stones. However, it was also noted that the marble is affected by heat and the understanding these properties is quite essential when selecting and determining the maintenance requirements of these marble used as dimension stones.

2.2 Geology of Nigeria

The Pre-Cambrian basement complex of Nigeria lies between the West African Craton in the west and the Congo Craton in the east. The rocks of the basement complex of Nigeria are loosely categorized into three main groups which are;

The migmatite gneiss complex: The migmatite gneisses are the most abundant rocks of the basement complex. They are divided into two types. These are the biotite gneiss and banded gneiss (Falconer, 1911).

Petrogenetic and field evidences (De Swardt, 1953) show that the migmatite gneiss originated through silica potash metasomatism of ancient metagranulites mainly between 2.8-2.0 Ga. However older dates of about 3.0 Ga have been reported (Dada, Brique, and Birck, 1998) who believed that such relict signatures indicate that the Precambrian terrain was part of an Archean proto-shield affected by Proterozoic crustal activities. Field evidences and radiometric dating have shown that the Nigerian basement complex bears the imprints of the major Orogenies in the earth history dating back to 3000 Ma and it undergone its most pervasive deformation and remobilization during the Pan African (< 600 Ma).

The schist belt: The schist belt occurs prominently within the western half of the country. Though a few have been recently highlighted in central and southeastern parts (Elueze, 1992). They are mostly regarded to be of Proterozoic age (0.6-2.5Ga). Various types and grades of schists occur in the basement complex. They include mica schists, phyllite and biotite schist. They form lowland between quartzite ridges and are rare as continuous massive outcrops. The schist belts, which some author classified as metasediments shows distinctive petrological, structural and metallogenic features.

The schist belts in the southwestern part of Nigeria include Iseyin, igarra, Egbe-isanlu, ifewara-ilesha (Rahaman et.al. 1983, Elueze, 1992, Annor et.al, 1996). The lokoja- Jakura belt (Okunlola, 2001) and the southeastern belts (Ekwueme, 1987) are the recently highlighted belts. Although there seems to be some lack of consensus on locational delineation, geologic nomenclature, geodynamic setting and geochronological characteristics. The schist belt is of metamorphosed pelitic and sandy assemblages. The schist belt is of particular interest in that it is associated with a widespread occurrence of marble deposits in Nigeria. It is dominated by low-grade metasediments remnants of supracrustal cover during the Pan-African orogeny (Mc Curry 1976).

The Pan-African granitic series and associated minor rocks: According to Rahaman, Emofurieta, and Caenachet, (1983) the older granites are the most visible part of the Pan-African orogeny in Nigeria. The older Granites were first distinguished from the younger or plateau tin-bearing alkalic granite (Falconer, 1911). They range in size from plutons to the environment in which the granite is emplaced. Circular to elliptical bodies occurs in schist environment and more elongate bodies in migmatite Gneiss terrains.

The older granites are the most obvious manifestation of the pan African Orogeny and constitute about 40- 50% of the basement complex outcrop. They include rocks of a wide range of composition including tonalities, granites, granodiorites, adamallites, quartz Monzonites, syenites, and pegmatites, granitic – granodioritic compositions are the most common texturally, they vary from strongly foliated gneiss varieties to undeformed rocks. Under the granitic granodioritic rocks, (Jones, and Hockey, 1964) recognized three main groups of granites, an early phase comprising granodiorites and quartz diorites, a main phase comprising homogenous granites, syenites and coarse porphyritic biotite granite and a late phase comprising homogenous granites, dykes, pegmatites, and aplite.

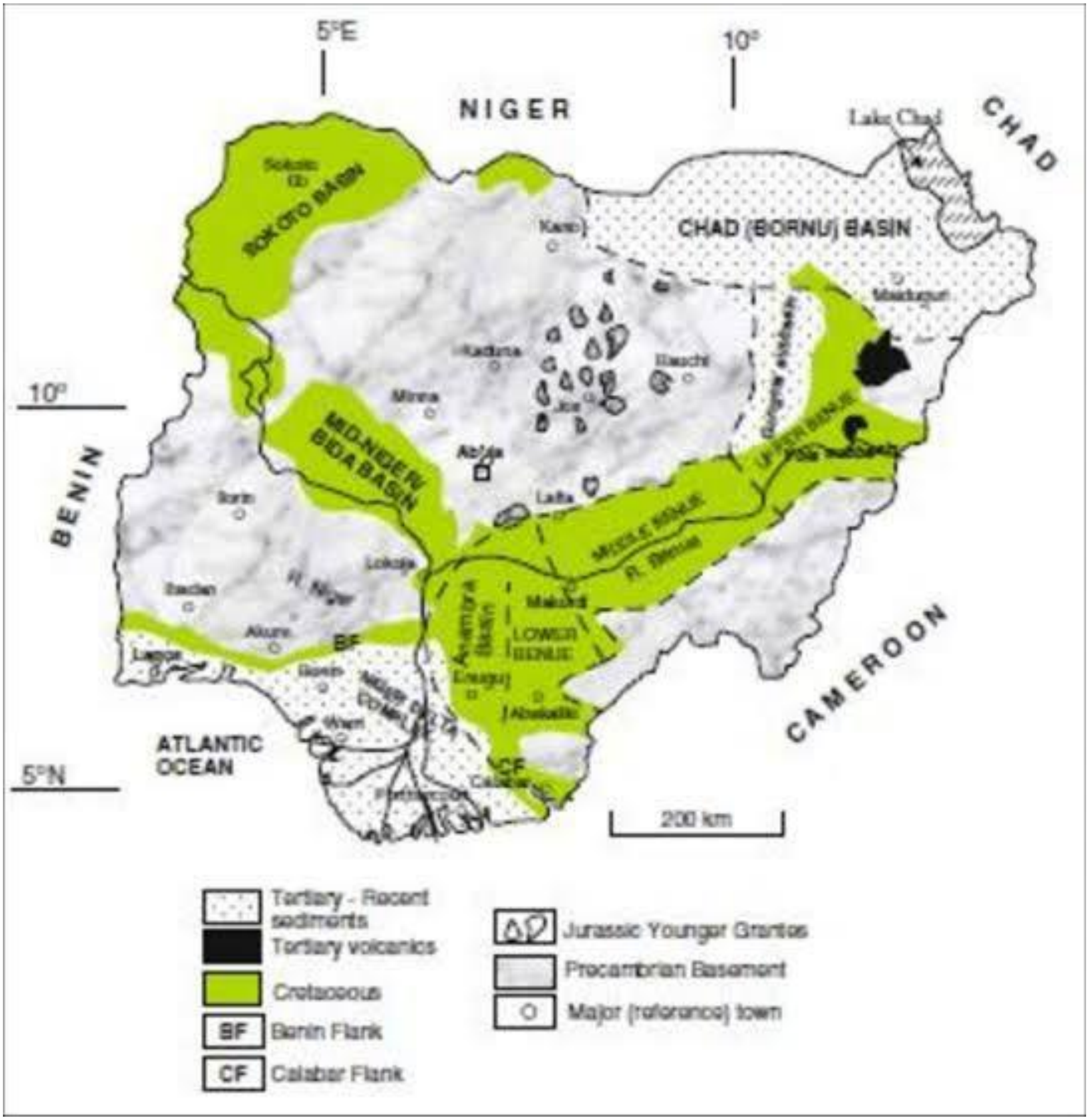

Figure 2.1: Geological Map of Nigeria (Obaje, 2009)

2.3 Geology of the study area

Elebu in Kwara State have been studied by many researchers and authors. These deposits have various morphologies within the Schist belts and exhibit different physical and mechanical characteristics that render them economically attractive. The Elebu area (Fig. 2.2) consist of fine to-medium grained granite and biotite-muscovite granite. It is underlain by migmatitic, augen and granitic gneiss along with quartzites and marble, (figure 2). Elebu marble occurs as low-lying outcrops along valley of River Abupata and is surrounded by quartzite ridges. The marble is grey in colour, medium grained in texture and occurs as two separate bands about 2 kilometers northwest of Elebu. According to Odewumi (2008) the exposure of the western band is approximately 3m x 30m in size while the eastern band which is about 800meters to the western band is approximately 5m x 200m in size while the modal estimates of the mineralogy are essentially dolomite 97%, tremolite 2% and quartz 1%. The dolomite is medium-grained and it occurs as irregular crystals with a variable shapes. Tremolite and quartz occur as accessory silicate minerals. The mean annual rainfall is 1500mm and the mean annual relative humidity is about 80%.The mean annual temperature is about 26.6^{o}C (Emofurieta, 1984).

Dendritic drainage pattern is prevalent in the area. The study area is also covered mainly by tall palm trees and grasses typical of rain forest vegetation. The vegetation is thick and has been greatly affected by human interference through farming, bush burning with the development of seasonal forests in some of the area.

Figure 2.2. Location of the study area

2.4 Strength of Marble

The strength of marble is the measure of its capacity to resist stresses and it depends on the rift, hardness of grains, state of aggregation and degree of cohesion and interlocking of grains.

The surface of marble crumbles readily when exposed to a moist, acid atmosphere, but marble is durable in a dry atmosphere and when protected from rain (Fatoye and Gideon, 2013). The purest form of marble is statuary marble, which is white with visible crystalline structure. The distinctive luster of statuary marble is caused by light penetrating a short distance into the stone and then being reflected from the surfaces of inner crystals. Calcite (CaCO3) of which marble is composed is highly susceptible to attack by acid agents. Marble is readily dissolved by acids, even very dilute acid. However, dolomite marble is much more resistant to acid attack than calcite marble.

2.5 Uses of marble

Marble is used for interior or exterior design of a house or building. In addition, marble can also be used as raw material for crafts or sculpture. Marble has been used as a decorative building stone since ancient times and is widely appreciated for its beautiful colours, structure, and high gloss on polished surfaces. The Marble has been commonly used for different purposes like flooring, cladding etc., as a building material since the ancient times. Marble finds wide spread application as raw material in many industries depending mostly on their purity or chemical content. Therefore, prior and concise chemical characterizations are necessary before any industry application. Nigeria is a developing nation with abundant minerals resources, especially meta-carbonate which occur in an estimated proportion of 60% dolomite marble and 40% calcitic marble. These meta carbonate deposit usually occur within the Schist belt (Muotoh et al., 1998; Okunlola, 2001), marble is one of the industrial rocks that gain prominence in the manufacturing sector of the Nigerian economy.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Sample collection

The methods used for this research work consist of field study and laboratory analyses. The field study exercise involved collection of six (6) fresh samples of marble. The marble was obtained from Elebu, Moro Local Government Area in Kwara State. The materials used in obtaining the samples include geologic hammer, chisel and sample bags while the compass-clinometer and global positioning system was used for direction. The Global positioning system (GPS) was used to take the coordinate of the study area.

3.2 Laboratory analysis

The laboratory analysis involved sample preparation for both physical and mechanical analysis. The laboratory analysis was undertaken at the Civil Engineering Laboratory, University of Ilorin

3.2.1 Sample preparation

The samples of marble obtained from the field were taken to Civil Engineering Laboratory, University of Ilorin for further analyses. The rock samples were carefully selected and processed at the laboratories in preparation for physical and mechanical analysis. The physical analysis that was carried out involves specific gravity, bulk density, porosity, water absorption while the mechanical properties includes uniaxial compressive strength and Los Abrasion analysis.

3.2.2 Procedures for Specific Gravity

The Bulk or Apparent specific gravity, Gb is the ratio of the dry weight, Wd of a rock to the weight, W of water equal to the total volume of rock including voids. The rock sample was dried for 24 hours in an oven at a temperature of 1050C to expel all water present in the rock sample. It was allowed to cool and the dry weight, Wd determined. The rock sample was completely immersed in water to enable it attained saturation for 48 hours and the saturated weight Ww was measured and recorded. The rock sample still in a soaked condition was weighed (Ws) while suspended in water. This can be mathematically represented as: G= Wd

Ww - WS

The essence of heating and then saturating is to determine the amount of water in the pore spaces of the sample.

3.2.3 Procedures for Density

The density of the rock sample was determined by multiplying the specific gravity, G with the density of water. Therefore, the rock sample density was calculated as follows: = 1000G (Kg/m3) Where is the density of water =1000Kg/m3

3.2.4 Procedures for Porosity

The sample was dried to a constant weight at a temperature of 105°C in an oven and cooled for 30 minutes in a desiccator. The porosity n, was determined by dividing the volume of water filling the pores (Ww-Wd) by the total volume of the rock sample, v. This is expressed in percentage as follows: n = %

3.2.5 Procedures for Water Absorption Test

The ASTM C97 procedure was adopted where the specimens were soaked in water for 48 hours, wiped dry, and weighed again. The difference in weights was divided by the dry weight and multiplied by 100 to give the percentage of water absorption. This is expressed mathematically as: Wsw = 100

3.2.6 Procedures for Uniaxial Compressive Strength

To determine the compressive strength, the sample was cut into a cube of 5cm and loaded gradually, one at a time, on the base of a Universal Testing Machine (UTM). The loading was continued till the first crack appears in the test specimen indicating beginning of failure. The load at failure (F) divided by the area of cross-section (A) of the sample gave the unconfined compressive strength of the sample:

Co = Where Co is crushing Strength F = Total load at failure A = Cross sectional area

3.2.7 Procedures for Los Angeles (L.A) Abrasion Test

The standard L.A. abrasion test subjects a coarse aggregate sample (retained on the No. 12 (1.70mm) sieve) to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres. ASTM method C131-66 was used for the LA abrasion test. The samples were oven-dried at 105–110°C for 24hrs and then cooled to room temperature before they were tested. After drying, the samples were sieved into individual size fractions, and recombine to one of two specified grading that most nearly represents the aggregate gradation. The total sample mass was about 5000g. Six steel spheres were placed in a steel drum along with the 5000g of aggregate sample. The drum was rotated for 500 revolutions at a rate of 30–33 rev/min. After the revolution was completed, the sample was sieved through the 1.7 mm sieve (Sieve No 12). The amount of material passing the sieve is expressed as a percentage of the original weight. The LA abrasion loss or percentage loss was calculated as follows:

W = Where W is the abrasion loss (%) P1 is the initial weight (g) P2 is the weight passing through sieve no 12 (g).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results of specific gravity

The results of specific gravity for Samples A is 2.50, Sample B is 2.53, Sample C is 2.62, and Sample D is 2.54 while Sample E is 2.65. It ranges from 2.50 to 2.65 with an average of 2.57.

Table 4.1. Result of Specific gravity

Sample Number	Specific Gravity
Sample A	2.50
Sample B	2.53
Sample C	2.62
Sample D	2.54
Sample E	2.65
Average	2.57

4.2 Discussion on Specific Gravity

The average specific gravity (SG) of Sample A, B, C, D and E (Table 4.1) suggest 2.57. Generally, the high Specific Gravity (SG) of marble may be credited to low degree of weathering and freshness of rocks (Akintola*et al.*, 2020). The slightly higher value in the marble may be attributed to the presence of ferromagnesian minerals. The relatively high specific gravity of some rocks in Nigeria has been associated to relatively high contents of iron – rich minerals present in rocks (Afolagboye*et al.*, 2016). However, the Specific Gravity is not usually consider as a primary means of determining the durability of rocks for construction purpose but Specific

Gravity greater than 2.55 are generally considered to be suitable for heavy construction work (Blyth and De Freitas, 1974). Hence, the specific gravity of all the samples is suitable for construction works.

4.3 Results of Density (Kg/m^3)

The result of density values is shown in table 4.3. The density for Sample A is 2510 Kg/m^3, Sample B is 2586 Kg/m^3, Sample C is 2520 Kg/m^3 and Sample D is 2560 Kg/m^3 while Sample E is 2570 Kg/m^3. The density for all the samples ranges from 2510 Kg/m^3 to 2586% with an average of 2549Kg/m^3.

Table 4.2. Result of Density (Kg/m^3)

Sample Number	Density (Kg/m^3)
Sample A	2510
Sample B	2586
Sample C	2520
Sample D	2560
Sample E	2570
Average	2549

4.4 Discussion on Density

Generally, bulk density is influenced not only by porosity but also by mineral density of the components and the filling materials in the voids. Quick (2002) remarked that higher water absorption, porosity and lower density suggest less durable and less stain resistant and more susceptible to salt attack. According to the ASTM 503C (2008) standard, the minimum density required for marble to be used as a dimension stone is 2595 kg/m^3. These values indicate that all density values are below the required standard (Table 4.2). The Elebu marble has significantly lower density values which can be attributed to the presence of impurities, especially in the country rocks. These factors contribute to a decrease in the overall density of Elebu marble.

4.5 Results of Porosity (%)

The results of percentage porosity is shown in table 4.3. The values for Sample A is 0.51%, Sample B is 0.54%, Sample C is 0.50% and Sample D is 0.59% while Sample E is 0.52%. The porosity test falls within 0.50% and 0.59% with an average of 0.53%.

Table 4.3. Results of Porosity test (%)

Sample Number	Porosity test (%)
Sample A	0.51
Sample B	0.54
Sample C	0.50
Sample D	0.59
Sample E	0.52
Average (%)	0.53

4.6 Discussion of Porosity (%)

Porosity has a direct and indirect impact on the physical properties of rocks, and is mostly measured as a vital rock parameter. An increasing porosity has an unfavourable influence on the weathering characteristics. The porosity values as shown in Table 4.5 suggest that the studied samples ranges between 0.51% and 0.54%. Studies based on Martins et al. (2016) have shown that higher porosity has resulted in lower durability compared to low – porosity rocks. Dearman (1981) stated that microporosity with percentage of pores with an effective diameter of less than of less than 0.005mm is a better indicator of carbonate rocks resistance to weathering than strength. Since porosity is known to control fluid flow, the Elebu marble is not prone to dissolubility and acid attacks, thus increasing its suitability as building stone. According to ISRM classification, the marbles are compact (Table 4.4) which suggest that all the samples are less porous and dense and the effect of weathering will be of little implication hence, it is compact (Moos and De Quervain, 1948)

Table 4.4. Classification Scheme for porosity of rocks (Moos and De Quervain, 1948)

S/n	Porosity	Classification
1.	< 1%	Compact
2.	1 – 2.5%	Few pores
3.	2.5 – 5%	Slightly porous
4.	5 – 10%	Significantly porous
5.	10 – 20%	Many pores
6.	< 20%	A lot of pore space

4.7 Results of Water Absorption Capacity

The water absorption for Sample A is 0.32%, Sample B is 0.29%, Sample C is 0.28% and Sample D is 0.25% while Sample E is 0.27%. The water absorption for all the samples (Table 4.5) ranges from 0.25% to 0.32% with an average of 0.28%.

Table 4.5. Result of Water Absorption Capacity

Sample Number	Water Absorption (%)
Sample A	0.32
Sample B	0.29
Sample C	0.28
Sample D	0.25
Sample E	0.27
Average	0.28

4.8 Discussion on Water Absorption

Water absorption is an important pointer of rock durability (Daka*et al.*, 2009). The water absorption values vary for different locations. These values are compared with the maximum value recommended by the ASTM 503C (2008) standard for the use of marble in dimension stone, which is 0.2%. Based on this comparison, it is clear that the average value of all the samples in the study area is relatively good for dimension stone. However, Samples A (0.32%)

do not meet the recommended value for water absorption, making them unacceptable (Table 4.5). According to Mann (2006) the higher water absorption capacity allows for a higher stain holding capacity. The variation in water absorption values and the relatively lower values can also be attributed to factors such as porosity, fracturing, shearing, weathering or even high percentage of impurities including allied minerals like biotite which tend to increase the water absorption capacity of the marble.

4.9 Results of Compressive Strength

The results of compressive strength of marble is shown in table 4.6 below. The values for Sample A is 13.22N/mm^2, Sample B is 12.73N/mm^2, Sample C is 11.63N/mm^2 and Sample D is 12.98N/mm^2 while Sample E is 12.27N/mm^2, The porosity test falls within 11.63N/mm^2 and 13.22N/mm^2 with an average of 12.57N/mm^2

Table 4.6. Results of Compressive Strength of Marble

S/N	Weight (kg)	Density (kg/m^3)	Ultimate Future load (kN)	Area (mm^2)	Compressive Strength (N/mm^2)
A	1.131	2953	68000	5130	13.22
B	1.146	2690	68000	5342	12.73
C	1.212	2746	68000	5843	11.63
D	1.145	2543	68000	5237	12.98
E	1.234	2854	68000	5543	12.27
	Average				12.57

4.10 Discussion of Compressive Strength

According to Moos and De Quervain, 1948 the International Society of Rock Mechanics (ISRM, 1978) classify rocks in the range of extremely strong to extremely weak depending on the compressive strength as shown in the table 4.8 below. ASTM 503C (Table 4.7) also reported

52MPa (52N/mm^2) as the required standard value for marble. The results obtained from the crushing strength have a range of values between 11.63N/mm^2 and 13.22N/mm^2 with an average of 12.57 N/mm^2. This value does not meet the minimum required standard as specified by ASTM 503C (2008) as can be seen in Table 4.9. Therefore all rock samples are not good in the production of tiles and cladding stone because their UCS were below 100 Mpa (Waltham, 2009) only if only the compressive strength is to be considered. Although, the UCS of Elebu marble appears to be depending more on mineralogy than grain size or texture. This may be attributed to the presence of calcite, dolomite, tremolite and quartz (Odewumi*et al.*, 2012).

Table 4.7. Classification of Unconfined Compressive Strength (Mpa or Nmm^2)

S/n	Classification	Unconfined Compressive Strength (Mpa or Nmm^2)
1.	Extremely Strong	> 250
2.	Very Strong	100 – 250
3.	Strong	50 – 100
4.	Medium Strong	25 – 50
5.	Weak	5 – 25
6.	Very Weak	1 – 5
7.	Extremely Weak	< 1

Table 4.8. Physico-mechanical Properties of Marble (ASTM C503 2001)

Properties	Specification
Unconfined Compressive Strength (MPa)	52
Abrasion Resistance	10
Water Absorption Capacity (%)	0.20
Bulk Density (g/m^3)	2.6
Apparent Porosity	-
Specific Gravity	2.5

4.11 Results of Los Angeles Abrasion test (%)

The results of Los Angeles Abrasion test (%) is presented in table 4.9. Los Angeles Abrasion test for Sample A is 44.1%, Sample B is 42.2%, Sample C is 45.5% and Sample D is 43.7% while Sample E is 46.1%. The Los Angeles Abrasion test ranges from 33.7% to 38.2% with an average of 44.32%.

Table 4.9. Results of Los Angeles Abrasion test (%)

Sample Number	Los Angeles Abrasion test (%)
Sample A	44.1
Sample B	42.2
Sample C	45.5
Sample D	43.7
Sample E	46.1
Average	44.32

4.12 Discussion on Los Angeles Abrasion

Abrasion resistance represents the resistance of rock surface to wear as stated earlier, and are usually caused by pedestrian traffic, the wheels of trolleys and the legs of furniture. Therefore, a lower Los Angeles Abrasion values indicate rock samples that are tougher and more resistant to abrasion. The abrasion values of Elebu marble are compared to the minimum acceptable value specified in the ASTM C503 (2001) standard. However, all the samples are above the minimumrequired standard and the abrasion test range of values is also above the values of 28% and 40% which is acceptable standard based on the ASTM C1353.

This variation in abrasion resistance values is due to low or minimal of tectonic forces which could have resulted to minimal joints and shearing, which are not pronounced in the studied area. These factors positively affect the overall abrasion resistance of the marble resulting in higher values.

Nevertheless, the marble in the study area can be used for indoor/interior and outdoor/exterior use. The indoor use of Elebu marble includes tiles for walls, sculpture and pupits while the exterior use could include monuments and gravestone. Also, the physio-mechanical tests on Elebu marble deposit shows that these rocks may be suitable for dimension stone as the tests, generally, are not and above the recommended ASTM standard values for general building and structural purposes. However, marble suggest a higher water absorption than the ASTM recommended values. The major requirements for most interior use include adequate polishing quality, and strength and uniform colouration. Elebu marble suggest that the deposits is closed to these conditions and are likely to serve as indoor dimension stones. Nevertheless, the relatively low water absorption capacity and the presence of impurities in some of the marble variety may affect the long term performance of the marble as dimension stone.

Ozcelik and Ozguven (2014) reported that durability is a complex criterion determined by inherent strength, water absorption and pore space. Due to the relatively high-water absorption capacity, the deposits may be prone to strength deterioration and have less train resistance after a long exposure to unfavourable climatic condition. The durability of the marble deposit both as indoor or outdoor use could be enhanced through appropriate technology such as coating.

4.13 Economic Importance of Elebu Marble

Finely ground white calcite marble serves as good fillers, extenders and coating pigment. They stabilize the paint and act as a weather resistant (Obasi and Isife, 2012). As paper filler, it imparts high brightness to the sheets, surface smoothness and ink receptivity to printing. In plastic manufacturing, marble filler provides necessary reinforcements for greater impact strength, rigidity and stiffness. Physical tests indicate that the Elebu marble has high strength properties that could be applied in a variety of industries to produce tiles, chips and fittings. Marble chips are crushed pieces that are produced according to consumers' size demand and needs. Chips give gardens or landscapes exquisite cool look. Marble fittings are high strength materials that are fitted in places where hard substances impervious to moisture are demanded. Results of physical and mechanical properties such as specific gravity, bulk density, porosity, compressive strength and abrasion value show that the marble bodies could be used for fluxing steel. They could also be useful in glass making, whiting and as fillers in papers and paints manufacture. In construction, it is widely used for road stabilization, aggregates, and as ornamental stones where it is polished into decorative slabs and masonry.

CHAPTER FIVE

Conclusion and Recommendation

5.1 Conclusion

The physical and mechanical data obtained from marble samples were compared to the standard criteria established by the ASTM standards. The specific gravity may be credited to low degree of weathering and are suitable for heavy construction work. The lower density values can be attributed to the presence of impurities, especially in the country rocks which however contribute to a decrease in the overall density. The porosity of the marble is not prone to dissolubility, acid attacks and are less porous and dense along with the effect of weathering which have been of insignificant implication. The relatively lower values of water absorption can also be attributed to factors such as porosity and weathering or even high percentage of impurities including allied minerals. The UCS of all rock samples are not good in the production of floor tiles and cladding stone based on low Uniaxial Compressive Strength. The abrasion values suggest that all the samples are above the minimum required standard. Based on this, Elebu marble is not only suitable for fluxing steel but as chips which are crushed in pieces that are produced according to consumers’ size demand and needs.

5.2 Recommendations

i. Further research should be conducted that will focus on the ornamental rock industry and demonstrate the optimum mining methods to save the raw materials.

ii. Adequate experimental works should be done on marble in Nigeria so as to ascertain their suitability of marble for different construction works.

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