CHARACTERIZATION OF MARBLE IN ISALE-OSIN KWARA STATE

BY

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CERTIFICATION

This is to certify that this research study was conducted by MAMUD AHMED DANJUMA with Matric No: ND/22/MPE/FT/026, Department of Minerals and Petroleum Resources Engineering Technology, Kwara State Polytechnic, Ilorin, carried out this project work in partial fulfillment of the requirements for the award of ORDINARY NATIONAL DIPLOMA (OND) in Mining Engineering Technology.

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DEDICATION

This project is dedicated to Almighty Allah my creator, our strong pillar, our source of inspiration, wisdom, knowledge and understanding. He has been the source of strength throughout this programme and on His wings only have I soared.

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ABSTRACT

This study assessed the marble deposits from Isale-Osin, Kwara State, Nigeria, to determine their industrial potential. Laboratory tests were conducted on five samples to evaluate their physical and mechanical properties, including specific gravity, density, porosity, compressive strength, and abrasion resistance. The results showed that the marble samples had suitable properties for heavy construction work, were resistant to dissolution and acid attacks, and met the minimum standard for abrasion resistance. However, the samples had low uniaxial compressive strength, making them unsuitable for producing floor tiles and cladding stones. The study concluded that Isale-Osin marble is suitable for use as fluxing agents in steel production, decorative chips for landscaping, and high-strength materials for construction projects requiring durability and moisture resistance.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Marble are generally metamorphic derivatives of sedimentary carbonates. they have been known to be relatively impermeable during metamorphis (Neb lelek,1991) a review of the economic utilization of carbonate therefore to some extent takes into consideration aspects of the mineralogy, physical and chemic al properties of the marble deposits (Onismisi et *al.,* 2013). Marble is a meta morphic rock produced from limestone by pressure and heat in the earth crust due to geological processes. The pressure and temperature essential to produc e this stone generally eliminate any fossils that exist in the initial rock due to these forces, the texture of limestone is changed impurities in the limestone affect the marble mineral composition (Mason, 1996).

Marble is beautiful - no one can dispute that. Its characteristics from patterns to colors are what make the stone special, it is understandable why p eople choose to have marble kitchen countertops, there are number of stone c olors available in granite although none can match the beauty of a veined whi te marble. Marble has long been the stone of choice from castles of old to c ommercial application of the finest quality. Monuments to ballroom floors, win dow sills to sophisticated foyers, it is a stone that rarely competes with each other elements for attention, though it can blend in or serve as the centerpiece of a room, depending on its pairings (Mason, 1996). Marble is available in v arious colors due to the variety of minerals present in the marble like clay, sa nd, and silt. it is widely utilized as a building material, in monument and scu lptures, and in numerous other applications. Marble are suitable for internal an d external applications however, due to modern-day environmental pollution, th e polish on marble used for external application may not be durable (Odokum a, 2019).

Marble is susceptible to chips or stains, as it is a softer stone, it is a susceptible to etching, meaning that any acids (Lemon juice, Tomato Juice, w ine) that is not cleaned right away, may etch the surface of the stone making it dull, if it is a honed or leather finish the etching is masked within the sur face. On a polished finish once the etching overwhelming after year of use, th e entire surface can be re-polished bringing it back to its original beauty (Odu kuma-Alonge,2019).

Marble is metamorphic rock mainly composed of calcite and /or dolo mite. Marble with different color, texture and patterns (macrostructure) were e xtensively used during ancient times in many archaeological sites, some of w hich are still buried. It is still an attractive natural stone used to inside and o utside decorations of buildings, as architectural and building purposes, gravest one, ornamental stone in turkey and all over the world. Due to adverse envir onmental conditions, marble may contain soluble salts which originate from th e ground, street, atmosphere, jointing material, and backing materials (Schaffer, 1972).

1.2 STATEMENT OF THE PROBLEM

The forces of nature may produce a decaying effect on the effect on the loo and structural reliability of marble. These agents include temperature, rain, wind and atmospheric pollutants. Weathering agents normally act in combinati on with other agent to increase the deterioration of marble. In a given area li ke increase in temperature, wind, and other atmospheric pollutants has reduced the quality or standard of marble deposit in the region.

1.3 AIM OF THE STUDY

The aim of this project is to determine the physical and mechanical properties of marble in Isale-Osin, Ifelodun Local Government Area, Kwara State, Nigeria

1.4 OBJECTIVE OF THE STUDY

·Determination of the physical properties of marble

.Determination of the mechanical properties of marble.

1.5 JUSTIFICATION

This is an attempt to assess the physical and mechanical properties of marble in a given area. The topic of study will help to establish the effect of geological variable on marble. deposits, for Example, temperature, rain, wind.

1.6 SCOPE OF THE STUDY

This scope covered Isale-Osin town, Ifelodun Local Government within Kwara State, where there is a marble deposits. It dealt with active marble deposit where mining and extraction is ongoing this was due to accessibility.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Marble

Marble is a metamorphic rock composed essentially of calcite and dolomite or a combination of the two, with a fine to coarse-grained crystalline texture (Serra, 2006). 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. (Herbert, 2005).

The metamorphic rocks form in two types of setting: it could be formed convergent plate boundaries where crustal rocks are buried deeply and experience high pressure and temperature due to the moving plate where there is no direction of high pressure and foliation typically develops and it is called regional metamorphism because it affect very large area. The second setting is formed at the vicinity of igneous intrusion where the surrounding rocks are heated by the ascending hot magma and this kind of metamorphism is known as contact metamorphism, describe marble as a metamorphic rock that forms when limestone is subjected to pressure and heat in the earth crust to the geological processes. The pressure and temperature required to produce this marble generally eliminate any fossils that exist in the initial rock (Herbert, 2005).

Many industries like paints, chemical, pharmaceutical and cosmetics utilize marble as major raw materials. It is also used as ornamental stone and raw material to manufacture cements and magnesium oxide for refractories (Herbert et al, 1990).

Marble can be used as soil treatment since calcite has numerous uses as neutralizer of acids due the spreading of marble powder into the field during crushing. It is also used in the

production of abrasive and ceramic, shop, fitting, tiles, asbestos and terrazzo. (Herbert et al, 1990).

Marble is also suitable for water softening, acid water neutralization and reduction of bacterial load in municipal water treatment, plus water acidity reversal and silica and phosphate in municipal water treatment, plus water acidity reversal and silica and phosphate removal from sewage effluents. (Elueze, 1993).

Because of the way marble forms, it occurs in large deposits worldwide. It's economical to mine this common, useful rock on a large scale.

Most marble is used in the construction industry. Crushed marble is used to build roads, foundations of buildings, and railroad beds. Dimension stone is made by cutting marble into blocks or sheets. Dimension stone is used to make buildings, sculptures, paving stones, and monuments. The statue of Lincoln in the Lincoln Memorial is made of white marble from Georgia, while the floor is pink Tennessee marble, and the exterior facade is marble from Colorado. Marble is susceptible to acid rain and weathering, so it wears down over time.

Marble results from the metamorphism of limestone, a carbonate sedimentary rock formed at the bottom of lakes and sea as silt and organic matter settle from the water body to the bottom. Marble deposits all over the world are only confined to metasedimentary belts. Examples include the Sax on deposit in Germany (Ihenyen, 1992). Atakora units in Benin Republic (Affaton et al, 1978), Igbeti, Ososo, Jakura, Burum-Toto marble deposits of Nigeria (Okunlola,1996).

2.2 Formation and Occurrence of Marble.

Marble bodies are widely distributed within the Precambrian Basement Complex of Nigeria and are commonly associated with the schist belts which may be regarded as folded belts into the multiple deformed and variable metamorphosed migmatite-gnesis-quartize complex (McCurry, 1976., Grant., 1978., Rahaman, 1988). Associated with the major petrological units are other localized minor rocks units namely: Quartz-biotite gnesis, Quartz-biotite-hornblende-pyroxene gnesis and Quartz-biotite-garnet gnesis. The pressure and temperature required to produce this marble generally eliminate any fossils that exist in the initial rock (Horbart, 2005).

The word "Marble" derives from the Ancient Greek mármaros, "crystalline rock, shining stone". Marble is a metamorphic rock formed when limestone is subjected to high pressure or heat. In its pure form, marble is a white stone with a crystalline and sugary appearance, consisting of calcium carbonate ($CaCO_3$). Usually, marble contains other minerals, including quartz, graphite, pyrite, and iron oxides. These minerals can give marble a pink, brown, gray, green, or variegated coloration. While true marble forms from limestone, there is also dolomitic marble, which forms when dolomiteundergoes metamorphosis (Acton and Johnny,et al 2006).

Limestone, the source material for marble, forms when calcium carbonate precipitates out of water or when organic debris (shells, coral, skeletons) accumulates. Marble forms when limestone experiences metamorphism. Usually, this happens at a convergent tectonic plate boundary, but some marble forms when hot magma heats limestone or dolomite. The heat or pressure recrystallizes calcite in the rock, changing its texture and color of marble. Over time, the crystals grow and interlock to give the rock a characteristic sugary, sparkling appearance.

Other minerals in marble also change during metamorphism. For example, clay recrystallizes to form mica and other silicates. Marble is found all over the world, but four countries account for half of its production: Italy, China, Spain, and India. Probably the most famous white marble comes from Carrara in Italy.

Marble, a major raw material for industries, is a crystalline non-foliated metamorphic rock formed from limestone or dolomite due to the action of heat and pressure. For practical purposes, pure marble (high calcium marble) is composed primarily of the mineral calcite or aragonite with total CaCO3 content of between 97-99% and pure dolomite is composed of 45.7% and 54.3% CaCO3 or 30.4% lime (CaO) and 21.8% magnesia (MgO) (Boynton,1980).

2.3 Physical Properties of Marble

The physical properties of Marble depends on its formation, Physical properties of rocks play an important role in determining its applications in various fields. Rocks are rated on Mohr's hardness scale which rates the rocks on the scale from 1-10. Rocks with hardness 1-3 are soft rocks, 3-6 are medium hardness rocks while 6-10 are the hard rocks. The hardness of marble is 3-4, whereas its compressive strength is $115.00 N/m^2$. Streak is the color of rock when it is crushed or powdered. The streak of marble is white, whereas its fr acture is not available. Luster of marble is the interaction of light with the sur face of marble. Luster of marble is dull to pearly to subvitreous. Marble cleav age is perfect. The specific gravity of marble is 2.86-2.87. Marble is opaque in nature whereas its toughness is not available. At a high temperature, rarer cal cium minerals such as lignite, Monticellite and rankine forms in the marble. If water is present, serpentine, tale and other hydrous minerals may be produced (Sarpun et al, 2005).

Physical Properties of Marble

·**Colour**: White, pink

·**Derived**: Limestone, dolomite

·**Grain** size-medium grained; can see interlocking calcite crystals with the naked eye.

·Hardness-hard, although component mineral is soft (calcite is 3 on Moh's scale of hardness)

Structure: Massive

Group: Metamorphic Rocks

Texture: Granoblastic, granular.

Formation: Regional or contact metamorphic

·**Acid Reaction**: Being composed of calcium carbonate, marble will react i n contact with many acids, neutralizing the acid. It is one of the most effective acid neutralization materials. It is often crushed and used for acid neutralization in streams, lakes, and soils.

·**Hardness**: Being composed of calcite, marble has a hardness of three on the Moh's hardness scale. As a result, It is easy to carve, and that m akes it useful for producing sculptures and ornamental objects. The tra nslucence of marble makes it especially attractive for many types of sc ulptures.

· **Ability to Accept a Polish**: After being sanded with progressively finer abrasives,It can be polished to a high luster. This allows attractive piec es of marble to be cut, polished,and used as floor tiles, architectural p anels, facing stone, window sills, stair treads,columns,and many other p ieces of decorative stone.

·**Major minerals of Marble:** Calcite

·**Accessory minerals of Marble**: Diopside, tremolite, actinolite, dolomite.

2.4 Petrographic characteristics of Marble

The physical and chemical Feature of stone depend to petrographic compos ition .These Features help to know the environment and Situation of stones for mation very much and provides main and basic information to do engineering plans (Lucas 2010). Because uniform structure and composition of marble, alwa ys the physical features and engineering characteristics are related to each other. Calcite minerals in the sample occur as equi-granular crystals, most of them s howing perfect rhombohedra cleavage and twinning. The carbonate phase of the se marbles is more commonly whitish to grayish white in colour.

Thin section is used for mineral identification, petrographic analysis to classify rocks and textual analysis to describe how a rock is formed. Thin section can also be stained to identify specific minerals.

The petrographic characteristics of rocks such as texture, mineralogical composition, orientation, micro cracking, grain size, streakage and colour are determined from the thin section of rock. The properties are essential because they are in turn related to geological settings and subsequently modification of rocks due to tectonic and hydrothermal factors.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Sample collection

This research utilized a combination of field study and laboratory analysis. During the fieldwork, six fresh marble samples were collected from Isale-Osin in the Ifelodun Local Government Area of Kwara State. Tools such as a geological hammer, chisel, and sample bags were employed for collecting the samples, while a compass-clinometer and global positioning system (GPS) were used for orientation. The GPS specifically helped in obtaining the coordinates of the study area.

3.2 Laboratory analysis

The laboratory analysis included preparing samples for both physical and mechanical examinations, and it was conducted at the Civil Engineering Laboratory at the University of Ilorin.

3.2.1 Sample preparation

The marble samples collected in the field were transported to the Civil Engineering Laboratory at the University of Ilorin for further analysis. The rock samples were meticulously chosen and prepared for physical and mechanical testing. The physical analysis included evaluating specific gravity, bulk density, porosity, and water absorption, while the mechanical properties assessed consisted of uniaxial compressive strength and Los Abrasion tests.

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:

$$G = \frac{Wd}{Ww - Ws}$$

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 Bulk 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 Sample A is 2.62, and Sample B is 2.54 while Sample C is 2.65. It ranges from 2.54 to 2.65 with an average of 2.60.

Table 4.1. Result of Specific gravity

Sample Number	Specific Gravity
Sample A	2.62
Sample B	2.54
Sample C	2.65
Average	2.60

4.2 Discussion on Specific Gravity

The average specific gravity (SG) of Sample A, B, and C (Table 4.1) suggest 2.60. 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 Bulk density (Kg/m^3)

The result of density values is shown in table 4.3. The density for Sample A is 2520 Kg/m^3 and Sample B is 2560 Kg/m^3 while Sample C is 2570 Kg/m^3. The density for all the samples ranges from 2520 Kg/m^3 to 2570% with an average of 2550Kg/m^3.

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

Sample Number	Density (Kg/m^3)
Sample A	2520
Sample B	2560
Sample C	2570
Average	2550

4.4 Discussion on Bulk 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 Isale-Osin 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 Isale-Osin marble.

4.5 Results of Porosity (%)

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

Table 4.3. Results of Porosity test (%)1

Sample Number	Porosity test (%)
Sample A	0.50
Sample B	0.59
Sample C	0.52
Average (%)	0.54

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 Isale-Osin 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 0.28% and Sample B is 0.25% while Sample C is 0.27%. The water absorption for all the samples (Table 4.5) ranges from 0.25% to 0.28% with an average of 0.28%.

Table 4.5. Result of Water Absorption Capacity

Sample Number	Water Absorption (%)
Sample A	0.28
Sample B	0.25
Sample C	0.27
Average	0.27

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 (0.28%) 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 11.63N/mm^2 and Sample B is 12.98N/mm^2 while Sample C is 12.27N/mm^2, The porosity test falls within 11.63N/mm^2 and 12.98N/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	1.212	2746	68000	5843	11.63
B	1.145	2543	68000	5237	12.98
C	1.234	2854	68000	5543	12.27
	Average				12.29

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 12.98N/mm^2 with an average of 12.29 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 Isale-Osin 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 45.5% and Sample B is 43.7% while Sample C is 46.1%. The Los Angeles Abrasion test ranges from 43.7% to 46.1% with an average of 45.1%.

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

Sample Number	Los Angeles Abrasion test (%)
Sample A	45.5
Sample B	43.7
Sample C	46.1
Average	45.1

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 Isale-Osin marble are compared to the minimum acceptable value specified in the ASTM C503 (2001) standard. However, all the samples are above the minimum required 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 Isale-Osin marble includes tiles for walls, sculpture and pupits while the exterior use could include monuments and gravestone. Also, the physio-mechanical tests on Isale-Osin 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. Isale-Osin marble suggest that the deposits are 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 Isale-Osin 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 Isale-Osin 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, Isale-Osin 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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