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# Analyzing the Influence of Mineralogy on Strength Properties of Carbonate Rock in Sagamu and Ewekoro, Ogun State, Nigeria

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***ABSTRACT*****:** *The research analyzed the influence of mineralogy on strength properties of carbonate rocks in Sagamu and Ewekoro in Ogun State, Nigeria. The research was conducted using the rock samples collected from the two locations. Sagamu has coordinate (latitude $6^{0}45^{1}$N and longitude $3^{0}35^{1}$E) and Ewekoro has coordinate (latitude $6^{0}35^{1}$N and longitude $3^{o}12^{1}$E).The result of modal analysis from the thin section shows that Sagamu has the mineralogical composition of 79.5% calcite, 13.5% quartz and 7.0% opaque while Ewekoro has 77.5% calcite, 17.0% quartz and 5.5% opaque. The rebound hardness result shows that Sagamu has an average value of 32.3 while Ewekoro rebound hardness value has an average of 35.1. The result of uniaxial compressive strength as estimated from the correlation chart between average density and Schmidt hardness shows that Sagamu has average strength of 61.8 MPa while Ewekoro has an average uniaxial compressive strength of 72.4 MPa. The point load strength index for Sagamu has an average value of 1.6 MPa while Ewekoro has an average value of 1.8 MPa. The tensile strength as estimated from point load strength index for Sagamu has an average value of 2.5 MPa while Ewekoro has an average value of 2.7 MPa. The results show that sagamu has higher percentage of calcite, lower percentage of quartz and higher percentage of opaque mineral compared with Ewekoro with lower percentage of calcite, higher percentage of quartz and lower percentage of opaque mineral. Ewekoro has higher hardness and strength values compared with sagamu and these can be attributed to higher percentage of quartz.*

**Keywords**: *Mineralogy, Schimdt hardness, Uniaxial compressive strength, Point load strength index and Tensile strength.*

## I. INTRODUCTION

Rocks exhibit a vast range of properties which reflect vast varieties of structures fabric and compound, some basic properties measurements which are essential for describing rocks are physical and mechanical properties (Bell, 1992). Intact rock strength is a major rock property of rock material and governs the behaviour of a rock mass to the force field of its physical environment. Standard determination of rock strength is by means of Unconfined or Uniaxial Compressive Strength (UCS) test. In most rock mass classification systems, analytical and numerical determination of intact rock strength is essential for characterizing intact rock strength (Robert and Marco, 2002). The strength of intact rock is one of the prime parameters used to classify the quality of rock mass and the determination of rock strength by the in-situ test is the most preferable and reliable method of testing (Zainab *et al*., 2008). Mechanical properties of rock are characterized by the reaction of rocks to the effect of a force of its environment and it depends on the nature of rock substance, the stratigraphy of rock, rock defects and testing methodology. Mechanical strength of a rock is the property of opposing destruction by an external force, either static or dynamic. The rocks give maximum resistance to compression normally, as the tensile strength is not more than 10 or 15% of the compressive strength. This is due to the fragility of rocks, to the large quantity of local defects and irregularities that exist and to the small cohesion between the particles which they are constituted. Examples of mechanical rock properties are: Hardness (the resistance of rock to abrasion), Elasticity (the ability of rock to change form or volume under the effect of external force and return to original form shape when the force is removed), tensile strength (maximum stress, a rock under tension can withstand until it disintegrates) and compressive strength (maximum stress that a rock under compression can withstand until it disintegrates).The rock strength fundamentally depends on its mineralogical composition. The mineral strength depends upon the size of the crystals and diminishes with their increase.

Uniaxial Compressive Strength (UCS) of an intact rock is a basic parameter for rock classification and rock mass strength criteria. Therefore, the strength characteristics of rocks are usually considered to be necessary for design of rock structures, stability of rock excavations and working of mine rocks (Ojo and Olalaye, 2002).

## II. Material and Methods

### 2.1 Location of the Study Area

The study areas are Sagamu and Ewekoro both in Ogun State. Ogun State lies within the latitude 6.2 °N and 7.8 °N and longitude of 3.0 °E and 5.0 °E. Sagamu has coordinates of 6°45'N and 3°35'E while Ewekoro has latitude of 6°35'N and longitude 3°12'E. This is as shown in Figure 1.

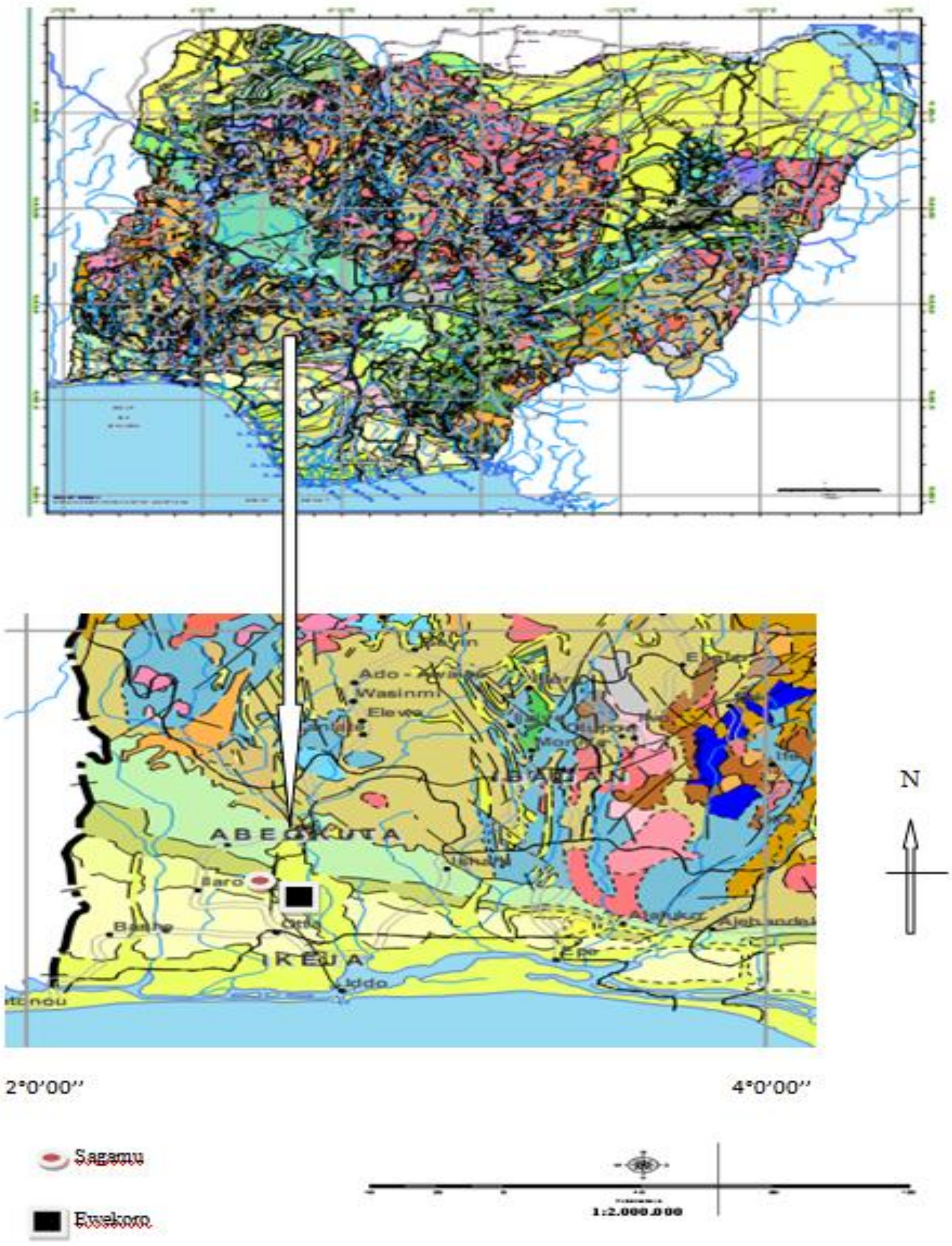



Figure 1: Geological Map of Sagamu and Ewekoro Deposit Extracted from Geological Map of Nigeria

**2.2 Sample Collection, Preparation and Testing**

Rock samples were collected at the Sagamu and Ewekoro mine faces after the fragmentation of limestone. The samples were taken for laboratory analysis for the determination of mineralogical composition and strength properties. Sagamu samples were labelled S1 to S5 while Ewekoro samples were labelled E1 to E5. Preparations of these samples were done according to ISRM and ASTM standards.

**2.3 Mineralogical Composition**

The laboratory work involved preparation of thin section of the samples, study of the thin section under the microscope and taken the photomicrograph of the samples. The procedures for thin section preparation are: impregnating, cutting, trimming, grinding, lapping, mounting, further grinding, lapping, further trimming, covering, washing, drying and labelling. The slides were then carefully studied under microscope to identify the mineralogical composition of the samples. The modal analysis technique was used to estimate the percentage of each mineral present in the samples. The modal analysis (Tables 1 and 2) of the samples involve taking three different count of each mineral from different part of the slide and adding all the count to calculate the percentage of each mineral present in the rock sample. Also, photomicrographs of the slides were taken to show features of geological interest as shown in Fig. 2 and 3.

**2.4 Determination of Hardness**

The determination of the hardness of the samples involves the use of Schmidt hammer on lump of the rock samples. The rebound value of the Schmidt hammer was used as an index value for the intact strength of the rock material. The measured test values for the samples were ordered in descending order. The lower 50% of the values were discarded and the average upper 50% values obtained as the Schmidt Rebound hardness. The procedures followed the standard suggested by ISRM (1989) and the results presented in Tables 3 and 4.

**2.5 Determination of Uniaxial Compressive Strength**

The Schmidt hammer was first used on the samples to determine the rebound number. The values obtained were arranged then correlated using Deere and Miller (1966) chart to determine the uniaxial compressive strength of the rock. The results obtained are presented in Tables 3 and 4.

**2.6 Determination of Point Load Strength**

The point load strength values were determined in accordance the procedures suggested by ISRM (1985) using equations 1, 2, 3 and 4.

$$I_s = P/{D_e}^2 \tag{1}$$

where $I_s$ is the point load strength index (MPa), P is the failure load (KN) and $D_e$ is the equivalent diameter (mm).

$${D_e}^2 = \frac{4A}{\pi} = \frac{4DW}{\pi} \tag{2}$$

where $D$ is the distance between load contact points (mm), $W$ is the width of the sample (mm) and $A$ is the minimum cross-sectional area of the loading points.

$$F = \left(\frac{D_e}{50}\right)^{0.45} \tag{3}$$

where F is the correction factor.

$$I_{S(50)} = FI_S \tag{4}$$

where $I_{S(50)}$ is the corrected point load strength index.

The results obtained are presented in Tables 3 and 4.

2.7 Determination of Tensile Strength

The tensile strength of the rock samples was estimated based on the relationship suggested by Brook (1993) and ISRM (1989) which shows the general relationship between the point load strength ($I_s$) and the tensile strength ($T_o$) as expressed in equation 5 and the results presented in Tables 3 and 4.

$$T_o = 1.5I_{s50} \tag{5}$$

## III. Results and Discussion

### 3.1 Results

Table 1: Modal Analysis of Samples from Sagamu

| Mineral Present | 1st Count | 2nd Count | 3rd Count | Total | Percentage (%) |
|---|---|---|---|---|---|
| Calcite | 40 | 47 | 37 | 124 | 79.5 |
| Quartz | 5 | 6 | 9 | 21 | 13.5 |
| Opaque | 3 | 4 | 4 | 11 | 7.0 |
| Ground Total | | | | 156 | 100 |

Table 2: Modal Analysis of Samples from Ewekoro

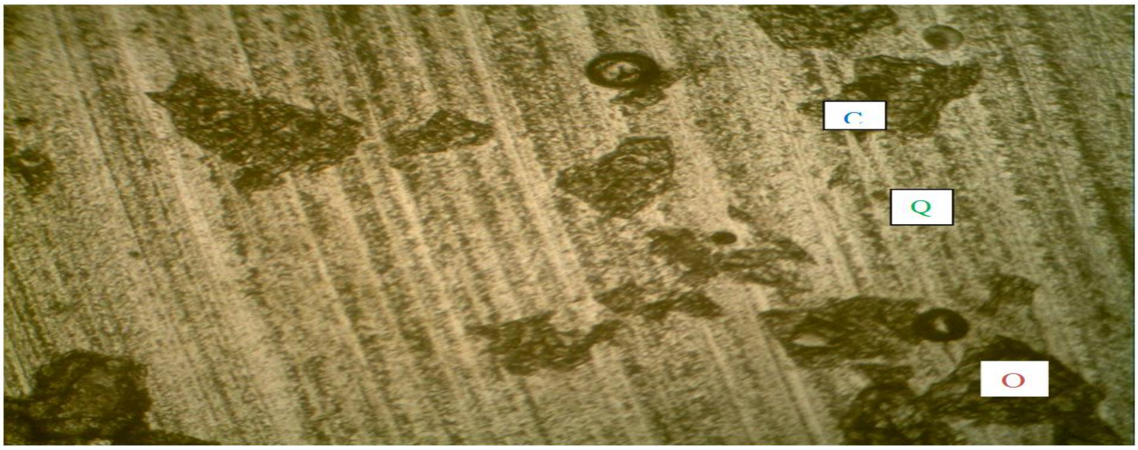
| Mineral Present | 1st Count | 2nd Count | 3rd Count | Total | Percentage (%) |
|---|---|---|---|---|---|
| Calcite | 40 | 40 | 37 | 117 | 77.5 |
| Quartz | 6 | 8 | 12 | 26 | 17.0 |
| Opaque | 2 | 2 | 4 | 8 | 5.5 |
| Ground Total | | | | 151 | 100 |

Table 3: Experimental Results of Strength Properties of Samples from Sagamu

| Rock code | Rebound Hardness | Point Load Strength (MPa) | Tensile Strength (MPa) | Uniaxial Compressive Strength (MPa) |
|---|---|---|---|---|
| S1 | 33.7 | 2.185 | 3.278 | 63.6 |
| S2 | 32.3 | 2.061 | 3.092 | 63.5 |
| S3 | 32.3 | 1.604 | 2.406 | 61.9 |
| S4 | 32.2 | 1.241 | 1.862 | 60.4 |
| S5 | 32.1 | 1.104 | 1.656 | 59.4 |

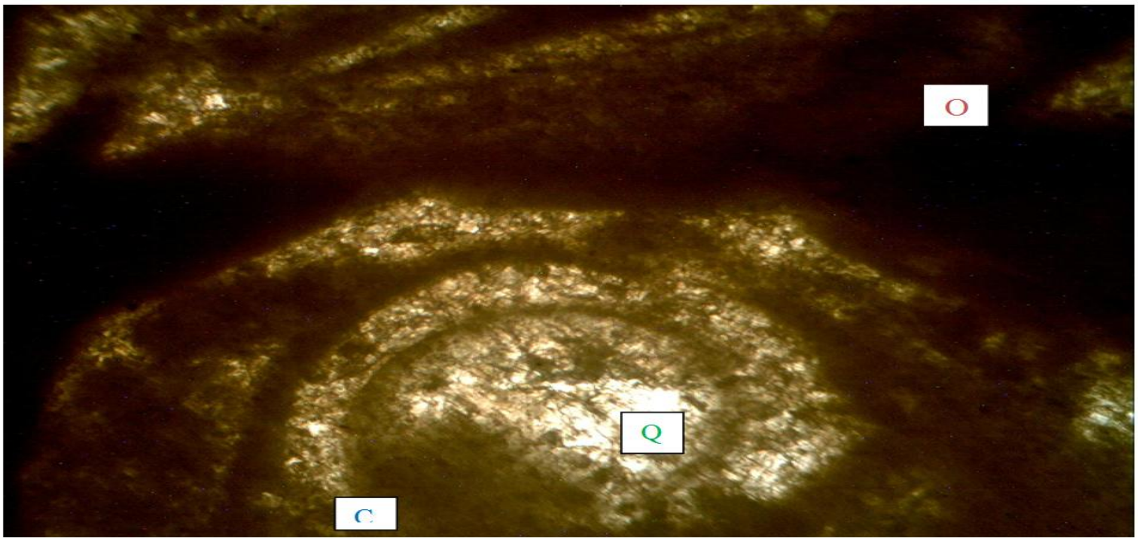
Table 4: Experimental Results of Strength Properties of Samples from Ewekoro

| Rock code | Rebound Hardness | Point Load Strength (MPa) | Tensile Strength (MPa) | Uniaxial Compressive Strength (MPa) |
|---|---|---|---|---|
| E1 | 36.4 | 3.363 | 5.045 | 77.2 |
| E2 | 36.4 | 1.609 | 2.414 | 75.5 |
| E3 | 34.8 | 1.453 | 2.180 | 74.8 |
| E4 | 34.0 | 1.238 | 1.857 | 70.8 |
| E5 | 34.0 | 1.194 | 1.791 | 63.7 |




C – Calcite, Q - Quartz, O- Opaque

Figure 2: Sagamu Photomicrograph




C – Calcite, Q - Quartz, O- Opaque

Figure 3: Ewekoro Photomicrograph

### 3.2 Discussions

The analysis of minerals shows that Sagamu sample has 79.5% calcite, 13.5% quartz and 7% opaque while Ewekoro sample has 77.5% calcite, 17% quartz and 5.5% opaque as shown in Tables 1 and 2. The high quartz content of Ewekoro accounts for its high strength value. The Schmidt hammer rebound number for Sagamu samples varies from 32.1 to 33.2 as shown in Table 3 and Ewekoro sample has rebound number of 34.0 to 36.4 as shown in Table 4.

The uniaxial compressive strength of the samples was estimated from the chart named after Deere and Miller, (1966). The uniaxial compressive strength of Sagamu varies from 59.4 MPa to 63.6 MPa as shown in Table 3. The strength classification is of moderate to high strength. The uniaxial compressive of Ewekoro sample varies from 63.7 MPa to 77.2 MPa as shown in the Table 4. The strength classification is of high strength.

The point load strength index is obtained from the laboratory results are shown in Tables 3 and 4. The point load strength index for Sagamu samples varies from 1.104 MPa to 2.185 MPa and that of Ewekoro samples varies from 1.194 MPa to 3.363 MPa. The strength classifications fall within the range of moderate to high strength class.

The tensile strength is obtained from uniaxial compressive strength and the results are shown in Table 3 and 4. The values for Sagamu samples range from 1.656 MPa to 3.278 MPa. The tensile strength values for Ewekoro samples range from 1.791 MPa to 5.045 MPa.

## IV Conclusions

This research has analyzed the influence of mineralogical composition on strength properties of carbonate rocks in Sagamu and Ewekoro in Ogun State, Nigeria. Sagamu has the mineralogical composition of 79.5% calcite, 13.5% quartz and 7.0% opaque while Ewekoro has 77.5% calcite, 17.0% quartz and 5.5% opaque. The rebound hardness result shows that Sagamu has an average value of 32.3 while Ewekoro rebound hardness value has an average of 35.1. The result of uniaxial compressive strength as estimated from the correlation chart between average density and Schmidt hardness shows that Sagamu has average strength of 61.8 MPa while Ewekoro has an average uniaxial compressive strength of 72.4 MPa. The point load strength index for Sagamu has an average value of 1.6 MPa while Ewekoro has an average value of 1.8 MPa. The tensile strength as estimated from point load strength index for Sagamu has an average value of 2.5 MPa while Ewekoro has an average value of 2.7 MPa. The results show that sagamu has higher percentage of calcite, lower percentage of quartz and higher percentage of opaque mineral compared with Ewekoro with lower percentage of calcite, higher percentage of quartz and lower percentage of opaque mineral. Ewekoro has higher hardness and strength values compared with Sagamu and these can be attributed to higher percentage of quartz. This type of research should be carried out on other type of rocks.

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