Establishing Relationships between Some Engineering Properties of Granitic Rock Types in Selected Quarries in South-West, Nigeria

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Abstract
Evaluation of some engineering properties of granitic rock types were carried out in selected quarries in Ekiti and Ondo states, Nigeria. The Rock Quality Designations (RQD); Uniaxial Compressive Strength (UCS); and Aggregate Crushing Value (ACV) of the rocks were determined both in the laboratory and on the field using international standard procedures. Subsequently, relationships were established between the determined rock strength parameters. From the results of the investigation, the granite rocks from the study areas were quantitatively evaluated and classified into different strength categories. The RQD of the rocks varies between 65.11% and 89.19% which reveal that the rocks range between fair and good in quality. The UCS varies from 65.65 MPa to 105.38 MPa which indicate that the rocks range from medium to high strength. The ACV varies from 21.99% to 28.31%. The result showed that the higher the RQD and UCS values, the lower the ACV. It was equally established that there are strong relationships between the values of RQD, UCS and ACV. The work will serve as additional database and help in optimizing the engineering design processes involving the use of the determined rock properties before and during excavation of the rock type.

Keywords: strength characteristics, granitic rock, relationship, regression analysis

INTRODUCTION
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). The UCS of intact rock samples of homogeneous and isotropic rocks such as granite, sandstones, basalt had been well published. Substantially, all the findings were based on the study conducted on a single rock type that range from hard to weak rocks. Unfortunately, little study has been conducted on anisotropic and non-homogeneous rock to address the complexity of the tropically weathered sedimentary to metamorphic rock mass (Zainab et al. 2007). UCS values are often determined from laboratory test using equation (1).

\[
UCS = \frac{P_{\text{max}}}{A} = \frac{P_{\text{max}}}{\pi (\frac{D}{2})^2} \quad (1)
\]

where \(P_{\text{max}}\) is the maximum load on sample (N); \(A\) is the cross sectional area of sample (m²); and \(D\) is the average sample diameter (mm).

Aggregate Crushing Value (ACV) indicates the ability of an aggregate to resist crushing. The lower the value, the stronger the aggregate, hence, the greater is its ability to resist crushing (Summers, 2000). The factors affecting the ACV include petrography, texture, grain size, cementing materials, hardness of the constituent minerals, and shape of the grains. Verwaal and Mulder (2000) gave the equation (2) for determination of ACV.

\[
ACV = \frac{B}{A} \times 100 \% \quad (2)
\]

where \(A\) is the mass of surface dry sample (g) and \(B\) is the mass of the fraction passing the 2.36 mm sieve (g).

The ACV gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load.

Rock Quality Designation (RQD) is a modified core recovery index expressed as a percentage of the ratio of the total length of core greater than or equal to 100 mm to the total length of the core run. This is expressed in equation (3).

\[
RQD = \frac{100 \sum_{i=1}^{n} x_i}{L} \quad (3)
\]
where \( n \) is the number of consolidated fractured pieces; \( \chi \) is the core \( \geq 100 \text{ mm} \); and \( L \) is the total core run in (m).

Deere developed the RQD index to provide a quantitative estimate of rock mass quality from drill core logs (Hartman and Handley, 2002). In practice, a high rock RQD value does not always translate to high quality rock (Milne et al., 2008). They further stated that it is possible to log 1.5 m of intact clay gouge and describe it as having 100% RQD. This may be true based on the original definition of RQD, but is very misleading and gives the impression of competent rock. To avoid this problem, a parameter called ‘Handled’ RQD (HRQD) was introduced (Robertson, 1988). The HRQD is measured in the same way as the RQD, after the core has been firmly handled in an attempt to break the core into smaller fragments, during handling, the core is firmly twisted and bent, but without substantial force or the use of any tool.

According to Hartman and Handley (2002), the RQD can be misleading in rock masses where discontinuities in the rock are widely spaced and contain either infilling or weathered material. They therefore concluded that RQD is thus proven to be valuable as a component of more sophisticated rock mass rating schemes. Today, RQD is used as a standard parameter in drill core logging and forms a basic element value of the major mass classification system: Rock Mass Rating (RMR) and Q-system, Wikipedia (2008).

MATERIALS AND METHODS

Location of the Study Area

Figure 1 depicts the geological map of Nigeria showing the study areas.

![Generalized Geological Map of Nigeria after Rahaman (1988) Showing the Study Areas](image)

LEGEND
- Afo
- Iwaro
- Ado Ekiti
- Ikere Ekiti

Sample Collection, Preparation and Testing

Granite rock samples taken from the granite deposits of the various quarries in the study locations were prepared to the standard suggested by International Society of Rock Mechanics Commission (ISRM, 1989) for the strength test. The length-to-diameter ratio of the cores used for the entire UCS test is 2.5-3.0:1 which is in accordance with the ISRM standard. This ordinarily took care of one of the problems arising from using strength values based on UCS laboratory tests as stated by Robert and Marco (2002). The UCS of the rocks was calculated using equation (1) and the results presented as Figure 2. Samples for the determination of the ACV were prepared in line with ISRM (1989), tested and calculated using equation (2) and the results presented as Figure 3. The measurement of the number of fractured pieces of the cores from the core run was taken on the field at the rock mass locations after core drilling operations. This is in agreement with Lanaro et al. (2003). The RQD values were determined using equation (3) and the results presented as Figure 4. The RQD was found to be difficult to establish per lithology as observed by Hack (2002). In the rock mass studied, lithology identification was difficult to establish because there were no clear cut demarcations between the different lithologies of each rock mass.
The average discontinuity frequencies of drill rock cores obtained from granite deposits in Afo, Iwaro, Ado, Ikere are 2, 2.3, 3 numbers respectively.

RESULTS AND DISCUSSION

Results
Table 1 shows the UCS and RQD values obtained from the rocks of the various study areas and their qualitative descriptions and ratings.

Table 1: Qualitative Description of Granite Rocks from the Study Areas

<table>
<thead>
<tr>
<th>Location of Deposit</th>
<th>Strength Classification</th>
<th>UCS (MPa)</th>
<th>Class of Strength</th>
<th>RQD (%)</th>
<th>Rock Quality</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afo</td>
<td>Medium</td>
<td>91.23</td>
<td>85.73</td>
<td>Good</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Iwaro</td>
<td>High</td>
<td>105.38</td>
<td>89.19</td>
<td>Good</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Ado</td>
<td>Medium</td>
<td>84.87</td>
<td>82.66</td>
<td>Good</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Ikere</td>
<td>Medium</td>
<td>65.65</td>
<td>65.12</td>
<td>Fair</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

Figures 1-3 depict the average UCS, ACV and RQD values for all the granite rock samples from the various study locations.

DISCUSSION

The granite rocks from the study areas were classified into different strength categories according to Ramamurthy (2003), based on UCS values obtained. From Figure 1, granite rock from Iwaro was classified ‘high strength’ with UCS value of 105.38 MPa while the rocks from Afo, Ado and Ikere with UCS of 91.23MPa, 84.87MPa and 65.65 MPa respectively were classified as having medium strength.

Generally, the result of the aggregate crushing values for all the tested samples followed a negative trend pattern of the uniaxial compressive strength values. Iwaro rock sample which has the highest UCS values conversely have the lowest ACV of 21.99% while Ikere which has the least UCS values, has the highest aggregate crushing value of 28.31% as shown in Figure 2. This is to say that the higher the UCS, the more difficult it is to crush the rock because of the corresponding low ACV.

The RQD values were greatly influenced by the interaction of the intact rock blocks with the discontinuities. It was observed physically that discontinuities were less in Iwaro granite while it was more in Ikere granite as measured from the drill rock cores on the field. The qualitative description of the rocks was done in accordance with Deere and Miller (1966) and Bieniawski, (1979) as shown in Table 1. This classification agrees with Milne et al (2008) that a high RQD value does not always translate to high quality rock.

CONCLUSION

The experimental results and qualitative evaluations of the Uniaxial Compressive Strength (UCS), Aggregate Crushing Value (ACV) and Rock Quality Designation (RQD) values of Iwaro, Afo, Ado and Ikere granite rocks have been presented. This would
provide good database knowledge for mining engineers and granite quarry operators in working the rocks in the study areas for aggregate productions.

REFERENCES


