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Influence of fabric and mineralogy on the mechanics of dolomitic rocks

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ABSTRACT

A detailed study into the engineering mechanics of rocks is very crucial due to their nature and widespread applications as well as the fact that they are encountered in the daily activities of practicing engineers and designs and constructions are made in and/or on them. Comprehensive investigations have been made into the influence of fabric and mineralogy on the behavior of dolomitic rock by conducting a series of laboratory tests. Also, extensive analyses have been made to determine suitable indices to predict parameters needed for engineering design and construction particularly at the beginning of projects when data may not be readily available. The parameters considered were porosity, rebound hardness, strength, and modulus and the indices considered were fabric (particle shape, packing density) and mineralogical indices (quartz and dolomite). The rock is characterized by low porosity (0.64-1.50%), medium durability (65.4-73.3%), heterogeneous and sub-angular particles (0.60-0.77) with very few voids. The mineralogy comprises quartz (0-64%), dolomite (10-87%), and other minerals. The strength varies from low to relatively high strength (12-43 MPa). The variability of parameters and indices of dolomitic rock is low except for quartz. Although mineralogy has little influence on the porosity of samples, fabric and mineralogy have a significant influence on the mechanics of dolomitic rock. It is very interesting to observe that fabric and mineralogical indices can be used to predict physical and mechanical parameters of dolomitic rock based on significant regression statistics. The fabric and mineralogical indices are suitable and are recommended for practitioners working on the materials.

Keywords: *Dolomitic rock, fabric, mechanical properties, mineralogy, physical properties*

1. Introduction

Investigating the mechanics of rocks is very essential due to their applications in mining and civil engineering projects (e.g., tunneling and underground space excavations, buildings, dams, and highways). To estimate the strength and deformability of rock needed for engineering design and constructions, the determination of intact rock parameters (e.g., uniaxial compressive strength UCS) is very important [1-3]. Several studies have been conducted on the mechanical behavior of different rock types and classes encountered by practicing engineers worldwide [4-7]. However, few such studies were on the dolomitic rock [8]. Also, many attempts have been made to provide empirical equations to predict the parameters required for engineering design and analysis [9-12]. The majority of the studies on mechanical behavior and development of empirical equations for predicting design parameters were on igneous rocks, for example, granite [13-16], basalt [17-19], and sedimentary rocks, for instance, limestone [20-22], sandstone [23] and coal [24]. However, similar studies on the dolomitic rock are very scanty compared to other types of rock. In addition, the physical and mechanical properties of the rock are influenced by mineralogical composition and fabric characteristics [25]. Although some studies have been conducted on the relationship between mineralogical and fabric characteristics on rock properties, the majority of such studies were on igneous rocks and mostly granitic rocks [26-27]. The investigation on the effects of fabric and mineralogy on dolomitic rocks is still limited and no study has ever linked particle shape index with mechanics as used here to the best of our knowledge.

Apart from applications in engineering constructions, rocks are used in the manufacturing of detergents, steel, paints, ceramics, and sheet glass and they are called industrial rocks. Dolomitic rock is an example of industrial rock due to its numerous engineering applications. In addition, where these rocks exist, they are used for engineering purposes, and engineering design and constructions are made in/on them. Their behavior may vary even in the same geological formation due to mode of formation, its composition, texture, and structure as well as other geological processes. However, the knowledge about the behavior of this material is still scanty due to very few studies on them.

This study investigates the mechanics of dolomitic rock in order to provide further insight into the mechanical behavior of carbonate rocks and the influence of fabric and mineralogy on physical and mechanical behavior. Also, statistical analyses have been performed to generate empirical relationships to predict the mechanical behavior of rock using fabric and mineralogical indices. This is achieved by conducting physical tests (e.g., porosity, unit weight, Schmidt hammer rebound test), petrographic analyses, mineralogical analyses, and mechanical tests (e.g., uniaxial compression). This study is new and very important for this material due to its consideration as an alternative construction material as a result of massive engineering infrastructural development in Africa and the world at large as well as the design challenge they pose when encountered during excavation of valuable ore minerals. It is also novel the way in which fabric and mineralogical indices are related to physical and mechanical properties. The relationships obtained can be used as a guide to estimate parameters needed for engineering design especially at the preliminary design and construction stages when the availability of data might be a problem.

2. Materials and methods

The samples used were dolomitic rocks. The samples were collected

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as several lumps from different locations. Based on the objectives of the research, samples were taken from quarry face at four different locations. The samples are labeled as A, B, C, D, and the details are given in Table 1. The quarry face is located at Ikpeshi, Akoko Edo Local Government, Edo state, south southern, Nigeria. Ikpeshi hosts different companies due to this massive deposit and wide range of applications of the rock. At location A, samples were collected at five different depths. The sampling depth was 10m and samples were retrieved at two (2) meters intervals. The samples were collected using a geological hammer and chisel from the quarry face and then labeled accordingly. Samples from this location are whitish in color. The samples from locations B, C, and D were not retrieved at a particular depth but were rather taken at different points. The samples were collected considering physical appearances (color). Samples from location B were whitish similar to those from location A, those from location C were off-white and those from location D were greyish. This was done to put considerations into the diverse nature of the deposit.

Table 1. Details of samples tested

Location	Acronym	Depth (m)	Color
A	A1	2	white
	A2	4	white
	A3	6	white
	A4	8	white
	A5	10	white
B	B	-	white
C	C	-	off-white
D	D	-	grey

The samples collected lie between 07°14'005"N, 06°12'27"E and 07°14'030"N, 06°12'33"E. Ikpeshi covers an area of about 110.5 km^2 and it is located within the southwestern part of Nigeria basement complex. It is underlain in the north by the Precambrian basement complex and in the south by Cretaceous and Tertiary sediments. The northern part is rich in industrial and metallic minerals.

The unit weight of the samples was computed by determining the weight using weight balance of least count of 0.01 g and volume by estimating sample dimension (length, width, and height) using a digital vernier caliper. The durability of samples was determined by computing slake durability index according to ISRM [28]. The porosity of the samples was determined using the saturation and caliper technique as suggested by ISRM [28] for samples of regular dimensions. Porosity was computed as the ratio of pore volume to the bulk volume of the samples. The hardness of the samples was determined by computing rebound number (R_N) using a portable Schmidt hammer of N-type. The rebound tests were performed based on the methods suggested by ISRM [29-30]. However, the R_N value reported for each sample in this work is the average of ten rebound number values.

The fabrics of samples were studied by preparing thin sections from rock samples as suggested by ISRM [31]. The fabrics used here include a degree of grain sorting, grain size, shape and distributions, pores, and packing density. Apart from qualitative descriptions through observation of micrographs, it is also essential to describe the fabrics quantitatively. The grain shape and packing density were estimated in a numerical manner for the samples.

The empirical chart proposed by Krumbein and Sloss [32] and which has been used by other studies [33-34] was used to determine the grain shape. The three-grain shape descriptors used are roundness (R), sphericity (S), and regularity (ρ). The R is the ratio of the average radius of curvature of the surface feature to the radius of the largest sphere inscribed in the grain and S is the ratio between the radius of the inscribed sphere in the grain to the radius of the smallest circumscribed sphere to the grain. The ρ is the arithmetic mean of R and S. The descriptors were determined by selecting 25 grains in a random manner from the photomicrograph obtained from the thin section of each sample. The packing density (ρ_P) was determined using the relationship suggested by Zorlu et al [35].

The mineralogy of samples was investigated using X-ray diffraction (XRD). A Shimadzu XDS 2400H diffractometer equipped with JCPDFWIN software was used. The equipment operated at 40 kV and 55 mA. The minerals were identified in the range of $5° \leq 2\theta \leq 70°$ with Cu-Kα radiation. The samples were scanned at an interval of 0.02°/0.30 s. The analyses were conducted on samples in powder form.

The uniaxial compressive strength (UCS) was determined by conducting tests according to the testing procedure suggested by ISRM [36]. Thirty-five tests were conducted on the samples. Young's modulus was determined from the stress-strain curve as suggested by ISRM [37].

3. Results and discussions

3.1. Physical properties

Fig. 1a presents the unit weight of the samples. Data points for other locations are put arbitrarily at 1 m depth for clarity. The details of the physical properties are given in Table 2. The values range between 26 and 27.53 kN/m^3 similar to other rocks [5, 8], and the samples can be classified as having high unit weight. The unit weight is increasing with depth and the relationship is represented by the regression line. The slake durability was determined for samples from three locations and the values range between 65.4 and 73.3%. The slake durability increases with strength, similar to what has been found by related studies [37]. The values are close and the durability of samples can be classified as the medium based on ISRM classifications [36].

Table 2. Summary of physical and mechanical properties

Sample	γ (kN/m³)	Id$_2$ (%)	n (%)	R_N	UCS (MPa)	E (GPa)
A1	27.27	-	1.02	47.10	27.81	15.61
A2	27.17	-	1.02	47.60	34.65	19.93
A3	27.27	-	1.01	47.50	22.88	17.24
A4	27.40	-	1.04	46.50	20.14	10.86
A5	27.53		1.02	48.50	30.17	19.53
B	26.00	65.40	1.50	44.12	11.80	6.49
C	26.90	69.60	0.89	46.68	18.12	10.76
D	27.50	73.30	0.64	47.52	21.00	12.71

γ unit weight, Id$_2$ slake durability index, n porosity, R_N rebound hardness value, UCS uniaxial compressive strength, E Young's modulus.

The profile of porosity of the samples is shown in Fig. 1b and the trend line shown is an average line due to lack of particular trend with depth. Within the same location, the values of porosity are close and there are small variations compared to other locations. The values are similar to those reported for other rocks [38-39]. The samples generally have very low porosity. Fig. 1c presents rebound hardness values of the samples using an N-type Schmidt hammer. The values vary between 44.12 and 48.5. The R_N values increase with depth and the relationship is represented by the regression line. This is similar to what has been reported by other studies [40-41]. Based on ISRM [28] classifications, samples belong to slightly strong and strong rocks.

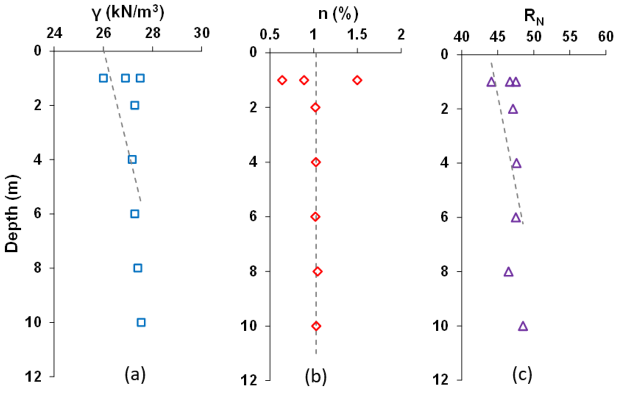

Fig. 1. Profiles of physical properties; (a) unit weight, (b) porosity, and (c) rebound hardness value

3.2. Fabric and mineralogy

Fig. 2 presents the photomicrographs of the samples from location A. The fabrics are characterized by grains of different sizes with very few inter grain voids. The grains are not sorted and they are not arranged in any particular way. In general, samples are characterized by heterogeneous fabric with very few voids. The details of quantitative grain shape descriptors are presented in Table 3. The average values of descriptors for each sample are given in the table. However, regularity, which is a function of roundness and sphericity is used as an overall index for particle shape. The values are close and this indicates the grains are fairly similar, similar to what has been found for related geomaterials [41]. The grains are sub-angular. The packing density, defined as the space occupied by grains in a particular area, was determined using an empirical equation that relates packing density with uniaxial compressive strength [33-34]. The ρ_p values range between 4 and 12% and as expected, it increases with the strength of the samples, similar to other studies [37].

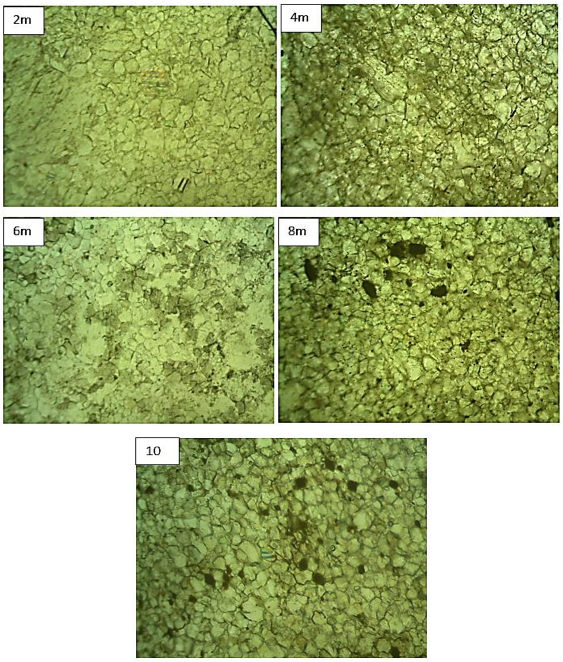

Fig. 2. Photomicrographs of a thin section of the samples

Table 4 shows the mineralogy of the samples for three locations as obtained from XRD. The samples comprise dolomites, quartz, and other accessory minerals (e.g., calcite, feldspar, biotite, and muscovite). They are generally dominated by dolomite minerals and quartz. The proportions of minerals vary but a sample from location B has the highest percentage of dolomite mineral and least percentage of quartz and a sample from location A2 has the highest proportion of quartz. The sample with the highest percentage of dolomite has the least strength value and the sample with the highest value of quartz has the highest strength value. This is similar to what has been reported by other studies [42-43].

Table 3. Details of fabric indices

Sample	ρ_p	ρ
A1	18.82	0.60
A2	25.02	0.63
A3	14.61	0.60
A4	11.12	0.64
A5	20.91	0.60
B	6.19	0.77
C	10.79	0.65
D	13.07	0.61

ρ_p packing density, ρ regularity

Table 4. Details of mineralogy

Samples	Mineralogy (%)		
	Quartz	Dolomite	Others
A1	44.90	19.96	35.14
A2	64.19	-	35.81
A3	31.12	40.63	28.25
A4	18.93	58.82	22.25
A5	51.59	10.10	38.31
B	0.40	87.47	12.13
C	17.00	57.81	25.19
D	26.20	50.97	22.83

3.3. Mechanical properties

The stress-strain behavior of samples is shown in Fig. 3. The plots are shown for a few samples. The behavior is characterized by the non-linearity of curves at very small strain and this can be attributed to the closure of the pre-existing micro cracks or voids as the stress is applied. The initial non-linear stress-strain behavior is common in weaker and more porous rocks. This is followed by a monotonic increase of axial stress with axial strain to a well-defined peak. After the peak, the samples have undergone strain softening and the axial stress is reduced with axial strain.

The properties of rock in uniaxial compression are very important in the design and construction of engineering projects. The properties determined in this work are uniaxial compressive strength (UCS) and Young modulus (E) and the details of average values of mechanical properties are given in Table 2. The UCS of samples from location A ranges from 20 to 43 MPa and is classified as high strength. While UCS values of samples from locations B and C vary from 12 to 19.5 MPa and can be classified as moderate strength, samples from location D have high strength and UCS varies between 20 and 21.7 MPa. The strength values are similar to those reported by related studies and similar materials [44-46]. Fig. 4 presents the estimation of UCS for some samples. The estimated average values are presented in the figure and the samples can be classified as high-strength rock. Young's modulus (E) values generally range between 6 and 20 GPa. The moduli are similar to those reported by related studies and similar materials [45-46]. The variations of mechanical properties (UCS and E) with depth are presented in Figure 5 and the relationships are represented by regression lines in the plot. The properties have a similar trend of increasing value. Generally, samples with lower UCS have lower E (Figs. 5a and 5b).

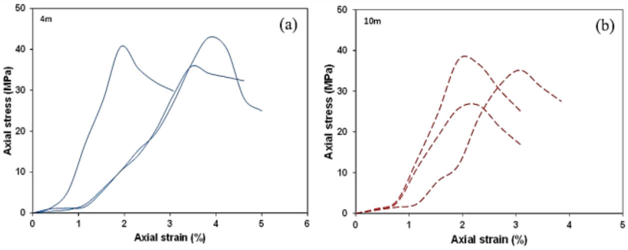

Fig. 3. Typical stress-strain behavior of samples; (a) 4m and (b) 10m

3.4. Effects of fabric and mineralogy on physical and mechanical behavior

The influence of fabric and mineralogy on mechanics was studied by relating fabric and mineralogical indices to the physical and mechanical properties of rock. Predicting the physical and mechanical parameters needed for geotechnical engineering design and analysis can be very crucial particularly at the beginning of a project where data may not be readily available. Attempts are made here to find suitable approaches for predicting the parameters that might be needed for design and construction analyses using fabric and mineralogical indices. The common practice is relating parameters with depth, which is very useful from a practical point of view of an engineering practitioner. However, parameters can be related to other indices because depth cannot be regarded as an index per se. The parameters considered are porosity (n), rebound hardness value (R_N), uniaxial compressive strength (UCS), and

Young modulus (E). The indices used are fabric indices (particle shape (ρ) and packing density (ρ_P)) and mineralogical indices (quartz (Q) and dolomite (D)). This was achieved by conducting regression statistics. However, the aim of providing correlations is to act as a guide for engineers to identify likely values at the beginning of projects and interpolate between the data available and not to serve as an alternative to the good quality field and laboratory testing. Other indices that can have effects on the mechanics of dolomitic rock are the amount and type of cementation, water content, permeability, and presence of microfractures. However, they were not considered due to the unavailability of data.

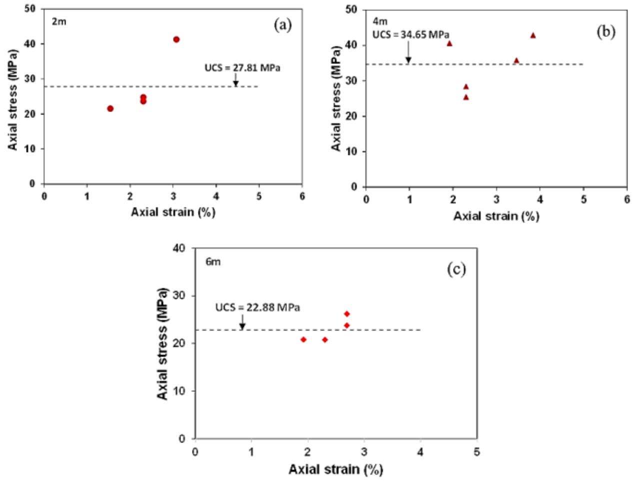

Fig. 4. Uniaxial compressive strength of samples; (a) 2m, (b) 4m, and (c) 6m

Regression statistics are used to provide the relationships between the mechanical parameters and the indices. The statistics properties used are correlation coefficient (r) and p value. The quantitative strength between the parameters and the indices is defined by the correlation coefficient and the p value is the probability of a true relationship between parameters and the indices. A relationship is said to be statistically significant if the correlation coefficient is high and the p value is low. The correlation statistics are classified based on systems used by Okewale and Coop [47] and Okewale [48]. The correlation coefficient between 0 and 0.19 is classified as very weak; between 0.20 and 0.39 is weak; between 0.40 and 0.59 is moderate; between 0.60 and 0.79 is strong, and between 0.80 and 1.0 is very strong. In this work, the relationships with reasonable correlations are presented.

The availability of variability of geotechnical data allows the designer to select appropriate factors and also, it allows more robust estimation of geotechnical variability by combining prior information from the available data using an advanced technique (e.g., Bayesian method). In addition, presenting variability values will assist design practitioners in understanding the likely range of inherent variability in the overall estimation of geotechnical design parameters. In this study, the attempt was made to determine the variability of mechanical parameters needed for engineering design and construction, and physical indices, fabric indices, and mineralogical indices required to estimate mechanical properties. The variability was determined using the coefficient of variation (CV), which is the ratio of standard deviation (σ) to the mean (μ) of the parameters and the indices. For the mechanical parameters, the variability is low and the values of CV are close. The physical indices also have low variability but the values are relatively higher than those of mechanical parameters. The variability of fabric indices is low. The mineralogical indices have variable values but it is observed that dolomite minerals have low variability and quartz has very high variability.

3.4.1 Influence of fabric on physical properties

Fabrics of rock have been found to have influenced the mechanical parameters needed for engineering design and construction. It is therefore important to provide a quantitative relationship between rock parameters and fabric properties.

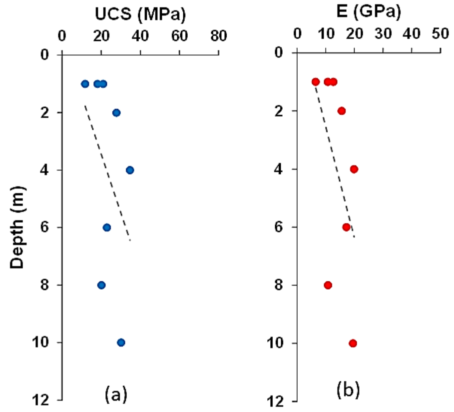

Fig. 5. Profiles of mechanical properties; (a) uniaxial compressive strength and (b) Young's modulus

The fabric properties are termed indices and they are determined in a numerical way. The fabric indices used in this study are grain shape, which is represented by regularity (ρ) and packing density (ρ_P). Fig. 6 presents the variation of porosity with fabric index. The only index that shows a good relationship with porosity is shown. The relationship is represented by the model equation and regression line. The regression statistics are also provided in the plot. Porosity is a very important property and it is combined with stress in most cases to describe the behavior of geomaterials. The less angular samples are more porous and the particle shape index increases with porosity. The relationship between porosity and particle shape index (ρ) is linear with strong correlation statistics (r = 0.75, p value = 0.02). Also, packing density (ρ_P) reduces with porosity but the correlation is weak (r = 0.28, p value = 0.48). This shows that ρ has an influence on porosity and can be used as a predictor of the physical property of the rock. The empirical equation is;

$$n = 3.0326\rho - 0.9228 \tag{1}$$

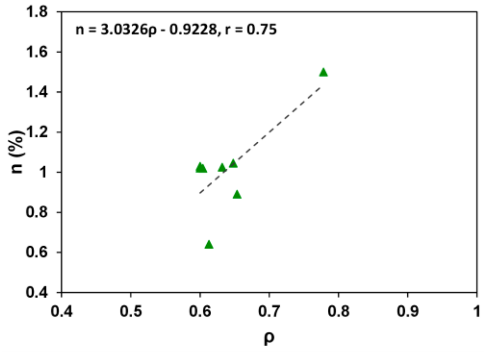

Fig. 6. Variation of porosity with a particle shape index

Fig. 7 presents the variation of rebound hardness value with fabric indices. The Schmidt hammer rebound test is a quick, cheap, and non-destructive method of measuring the hardness in rock. Again, the relationships are represented by model equations and regression line(s), and the regression statistics are also provided in the plot. The rebound hardness value increases with packing density (ρ_P) (Fig. 7a). Rebound hardness values (R_N) have linear relationships with ρ_P, and the regression statistics (r = 0.76, p value = 0.02) are very significant. Also, the R_N reduces with particle shape index (ρ) (Fig. 7b). Again, the relationship is linear with very strong regression statistics (r = 0.94, p value = 0.0004). The R_N gives an indirect measurement of strength and as expected, the strength will increase with packing density and reduce with particle shape index. This shows that fabric indices have an influence on rebound hardness value and both packing density and particle shape index could be a good predictor but ρ is the best index.

The relationships can be expressed as;

$$R_N = 0.1617\rho_p + 44.504 \quad (2)$$

$$R_N = -20.572\rho - 60.129 \quad (3)$$

Attempts are also made to determine the overall most suitable fabric indices by determining the average value of statistics properties. This was achieved by setting a criterion ($r \geq 0.70$) based on the classifications of Okewale and Coop **[47]**. The average values of r and p for the fabric indices are 0.84, 0.01 and 0.76, 0.02 for ρ and ρ_p respectively. The particle shape is the best fabric index for predicting the physical property of dolomitic rock.

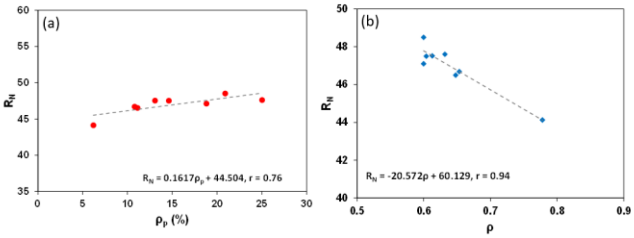

Fig. 7. Variations of rebound hardness value with fabric indices; (a) packing density ρ_p and (b) particle shape index ρ

3.4.2 Influence of fabric on mechanical properties

Fig. 8 presents the relationship between strength and fabric indices. The strength increases with packing density, similar to related work [33] (Fig. 8a). The increase in the packing of rock grains leads to an increase in strength. The relationship is linear with very strong regression statistics (r = 0.99, p value = 2.58E-07). Fig. 8b shows the relationship between strength and particle shape index and the strength reduces with particle shape. The relationship is statistically significant (r = 0.71, p value = 0.04) and linear. This behavior is similar to that of rebound hardness although with different correlations. This shows that both fabric indices have an influence on strength of dolomitic rock. Both packing density and particle shape can be used to predict the strength of the rock and the equations can be represented as;

$$UCS = 1.1797\rho_p + 5.5431 \ (MPa) \quad (4)$$

$$UCS = -87.448\rho + 79.383 \ (MPa) \quad (5)$$

The packing density is the best fabric index for predicting the strength of dolomitic rock.

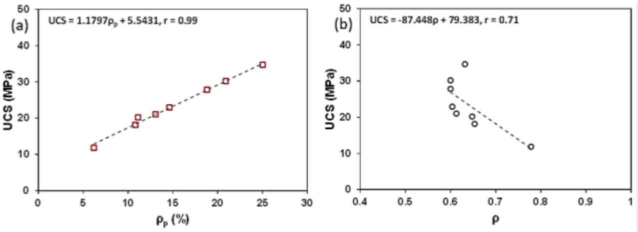

Fig. 8. Variations of strength with fabric indices; (a) ρ_p and (b) ρ

Fig. 9 shows the variation of Young's modulus with fabric indices. Fig. 9a presents the variation of modulus with packing density. As for packing density increases, the modulus also increases and the relationship is linear. The correlation properties r = 0.93 and p value = 0.0005 shows that correlation is very strong and the probability of a true relationship is very high. The resulting equation can be written as;

$$E = 0.7245\rho_p + 3.2268 \quad (GPa) \quad (6)$$

The relationship between modulus and grain shape is presented in Fig. 9b. The modulus reduces with regularity, which indicates a reduction in mechanical properties as grain shape is moving from being angular to round. The relationship is linear and the statistics (r = 0.77, p value = 0.02) are very significant. The empirical equation is;

$$E = -61.822\rho + 53.777 \quad (GPa) \quad (7)$$

This indicates that packing density and grain shape have an influence on the modulus and both can be used as a predictor of the modulus of the rock. The overall performance of fabric indices is estimated and the average values of r and p are 0.96, 2.5E-04 and 0.74, 0.03 for packing density and particle shape respectively. Packing density is the best fabric index for predicting the mechanical behavior of dolomitic rock.

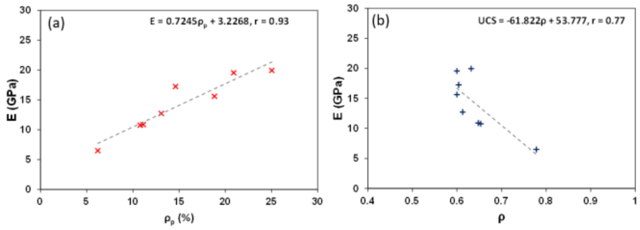

Fig. 9. Variations of Young's modulus with fabric indices; (a) ρ_p and (b) ρ

3.4.3 Influence of mineralogy on physical properties

Mineralogy can have a great influence on physical and mechanical properties used in rock engineering projects and the construction industry. It is therefore essential to study the relationship between physical and mechanical parameters and the mineralogy of rock. The variation of physical properties with the mineralogy of rock is presented in Fig. 10. Only rebound hardness value is presented and the variation of porosity with mineralogy is not shown because of weak regression statistics. The mineralogies are quartz (Q), dolomite (D), and others (e.g., calcite), and only Q and D are shown in the plot. Porosity reduces with quartz content and increases with dolomite content but the relationship is statistically weak. It can be seen that rebound hardness increases with quartz (Fig. 10a) and rebound hardness reduces with dolomite (Fig. 10b). The relationship between R_N and quartz is linear and the correlation statistics (r = 0.82, p value = 0.0003) are very significant and it is interesting to see that quartz mineral content can be used to predict the rebound hardness of this rock using the equation;

$$R_N = 0.0614Q + 45.084 \quad (8)$$

Similarly, the relationship between rebound hardness and dolomite is linear with strong correlation (r = 0.75, p value = 0.03). This indicates that dolomite mineral can be used as a predictor of rebound hardness of the rock using the relationship;

$$R_N = -0.1894D + 25.983 \quad (9)$$

This is an indication that both quartz and dolomite contents have an influence on rebound hardness and quartz is the best mineralogical index for predicting the physical property of dolomitic rock.

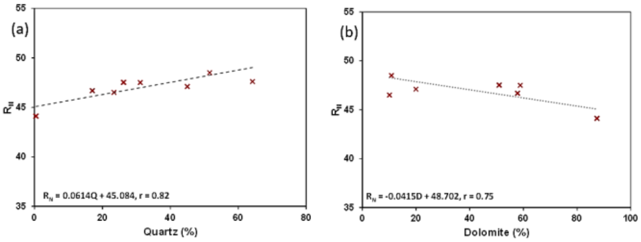

Fig. 10. Variations of rebound hardness value with mineralogical indices; (a) Quartz and (b) Dolomite

3.4.3 Influence of mineralogy on mechanical properties

The variation of strength with the mineralogy of rock is presented in Fig. 11. The quartz content increases with strength (Fig. 11a) and dolomite content reduces with strength (Fig. 11b). The increase in quartz content with strength is similar to other related studies [42] and this is expected because quartz is the strongest of the rock-forming minerals. Dolomite mineral is weak and in this rock, the sample with the highest dolomite mineral has the least quartz content.

The relationship between strength and quartz is linear and the correlation statistics (r = 0.99, p value = 2.1E-13) are very significant and it is interesting to see that quartz mineral content can be used to predict the strength of this rock using the empirical relation;

$$UCS = 0.356Q + 11.03 \quad (MPa) \tag{10}$$

Similarly, the relationship between strength and dolomite is linear with very strong correlation (r = 0.82, p value = 0.0005). This indicates that dolomite mineral can be used as a predictor of the strength of the rock using the relationship;

$$UCS = -0.177D + 28.771 \quad (MPa) \tag{11}$$

This shows that mineralogy (quartz and dolomite) influences strength and quartz content is the best mineralogical index for predicting the strength of dolomitic rock.

Fig. 12 presents the relationship between Young modulus and mineralogy. The relationships give direct similarities to those of strength and mineralogy but with different regression statistics. The statistics are r = 0.99, p value = 1.98E-08 and r = 0.74, p value = 0.003 for relationship with quartz and dolomite respectively. Quartz and dolomite contents influence modulus and could be used as a predictor using the equations;

$$E = 0.2253Q + 6.8678 \quad (GPa) \tag{12}$$

$$E = -0.1133D + 17.779 \quad (GPa) \tag{13}$$

Overall performance of mineralogical indices are determined and the average values of r and p are 0.99, 9.9E-09, and 0.75, 0.0017 for quartz and dolomite respectively. This shows that quartz content is the best mineralogical index for predicting the mechanical properties of dolomitic rock.

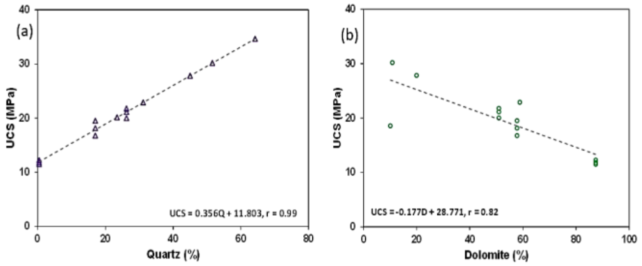

Fig. 11. Variations of strength with mineralogical indices; (a) Quartz and (b) Dolomite

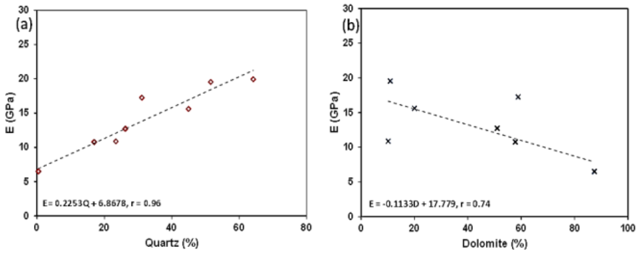

Fig. 12. Variations of Young's modulus with mineralogical indices; (a) Quartz and (b) Dolomite

In order to determine the overall best indices (fabric and mineralogy) with great influence on the behavior and which can serve as the best predictor for physical and mechanical properties, average values of regression statistics (r and p value) are estimated. For the physical properties, only rebound hardness is considered because mineralogical indices have little influence on porosity. The average regression statistics for fabric indices are r = 0.84 and p value = 0.010, and the average regression statistics for mineralogical indices are r = 0.78 and p value = 0.015. The fabric indices have more influence on rebound hardness and it is the best for predicting the physical property of the rock. For the mechanical properties, fabric indices have an average r and p value of 0.85 and 0.015 and mineralogical indices have average r and p values of 0.88 and 0.0008. Both indices have close value and perform very well. It is very interesting to see that mineralogical indices have an overall higher influence on the mechanical behavior of dolomitic rock.

4. Conclusions

The mechanics of physical, fabric, mineralogical and mechanical behavior of dolomitic rock and the influence of fabric and mineralogy on mechanics have been studied. The applicability of different indices to predict the physical and mechanical parameters needed for engineering design and construction has been investigated. Rock samples were collected along with a vertical profile and also from different locations in order to study the behavior vertically and horizontally. This was achieved by conducting physical, petrographical, mineralogical, and mechanical tests as well as performing comprehensive statistical analyses.

The dolomitic rock has high unit weight and medium durability. The porosity is low and the rebound hardness value can be classified as slightly strong. The fabrics are heterogeneous and characterized by grains of different sizes with very few inter-grain voids. The grains are not sorted and they are not arranged in any particular way. The grain shapes are fairly similar and sub-angular. The packing density increases with the strength of the samples. The samples were composed of dolomites, quartz, calcite, feldspar, biotite, and muscovite. They are generally dominated by dolomite minerals and quartz and calcite are in small proportions.

The stress-strain behavior is dominated by initial non-linear followed by the monotonic increase of stress and strain to the peak. The mechanical properties (uniaxial compressive strength) range from moderate to high strength. Due to the medium durability and relatively high strength of dolomitic rock, care should be taken in their application in mining and civil engineering projects. The physical indices have low variability, the variability of fabric indices is low, the mineralogical indices have variable values but dolomite minerals have low variability and quartz has very high variability and mechanical parameters also have low variability.

Fabric and mineralogy have an influence on the physical and mechanical properties of rock. Mineralogy has little influence on the porosity of samples. Different fabric and mineralogical indices that can be used to predict and characterize the parameters needed in engineering design have been studied. It is interesting to observe that fabric and mineralogical indices are suitable predictors of the behavior of dolomitic rock. The empirical equations provided can be used to estimate mechanical parameters required for engineering design particularly in the preliminary stages when data availability may be limited. For the porosity, the fabric index (particle shape) is the only suitable predictor. Rebound hardness can be successfully predicted by particle shape, quartz content, packing density, and dolomite content in that order. The strength will be successfully predicted by quartz content, packing density, dolomite content, and particle shape. The suitable predictors for modulus are quartz, packing density, particle shape, and dolomite content in that order. The fabric indices have more influence on rebound hardness and it is the best for predicting the physical property of the rock. Both the fabric and mineralogical indices have very good performance. It is very interesting to observe that mineralogical indices have an overall higher influence on the mechanical behavior of dolomitic rock.

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Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Notations

D	dolomite
E	Young's modulus

Id_2	slake durability index
n	porosity
Q	quartz
R	roundness
R_N	rebound hardness value
S	sphericity
UCS	uniaxial compressive strength
γ	unit weight
ρ	regularity
ρ_P	packing density

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