Analysis of the Potential of Some Nigerian Rocks to Wear Drill Bit

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Abstract

The potential of some selected Nigerian rock samples to wear drill bit was investigated. In order to achieve this, the point load strength for the three rock samples were tested using point load testing machine and tensile and compressive strength were estimated from the point load strength. The rebound values for the samples were determined as a measure of hardness using Schmidt hammer. Also, the mineral compositions of the samples were determined using thin – section. The results obtained were used to evaluate wear potential of the samples. The compressive strength, tensile strength, point load strength, hardness have values ranging from 209.30 – 244.85 Mpa, 11.40 – 12.95 Mpa, 6.97 – 8.16 Mpa and 47.50 – 52 respectively. Also, Vickers Hardness Number of Rock of 534.36, 895.10 and 898.71 kg/mm^2 were obtained for samples A, B and C respectively. Equivalent Quartz Content of 41.5%, 66.2% and 69.18% were obtained for samples A, B and C respectively. These show that the three samples have potential to wear drill bit but sample C has highest potential because it has the highest Vickers Hardness Number of Rock as well as Equivalent Quartz Content.

Keywords: *equivalent quartz content, strength, hardness, mineral composition.*

Introduction

Rocks are aggregates of crystals and amorphous particles joined by varying amounts of cementious materials. Bell (1992) confirmed that they are made up of more or less invariable composition bounded together by forces of molecular interaction (cohesion) that arise either at the sites of direct contact of mineral with one another or at sites of their contact with mineral particles extraneous cementing substances. Blair and Cook (1998) were of the view that rocks materials that fractures through growth and coalescence of micro cracks. In addition, rocks are heterogeneous aggregates of grains varying in shape, size and strength with varying contact relationships between the grains in either the distribution, size or quality of the contact, with various binding agents between the grains whose properties are often largely different from those of the grains and with many planar or triaxial discontinuities (Bell 1992).

Percussive drilling penetrates rock by the effects of successive impacts applied through the bit. The application in the percussive drill is a chisel-shaped or button studded tool, which impacts the rock with a hammer – like blow (Hartman 1968). The boring tool strikes the face and breaks the rock under the blade. Drilling the interval between each strike, the application turns through a small angle thereby ensuring circular shape of boreholes. The stress effective in breaking the rock is applied by the impact blow essentially in an axial direction and in a pulsating manner. He also, observed that in rotary drilling, the boring tool rotates around an axis, which coincides with axis of the boreholes and at the same time supplied energy to the bit by rotating action and thrust for the breaking of the rock. The thrust or the pull down weight is obtained from the calculation of the limit of durability or rock to stress at the area of contact of cutting blade of boring tool with the rock with this, there is a systematic shearing or sliding fracture. In addition, rotary percussive drilling is characterized by continuous rotation – comparable to rotary drilling as well as high feed pressure, the drilling bit is always tight to the bottom of the borehole. The torques are much stronger, crushing work is carried out also by shearing between the impacts (Hartman 1968). Moreover, properties of rock are important for describing and quantifying response of rock to mechanical tool.

Wear phenomenon are results of complex tribosystems. According to German Standard DIN 50320, a tribosystem consists of a solid body (objects which is affected by wear), and interacts with the counter body (object causing the wear) under a certain environment. All materials and processes involved in the system interact with and influence each other. All these have certain effect on the wear of the solid body.

Wear refers to the loss of dimension, weight, shape of cutting element in the bit unit time or length of hole (Bell 1992). Generally, Bit wear has been described as micro spalling (Montgomery 1968 and Engel 1976). But the types of wear experienced by drag-bit are abrasion, adhesion and surface fatigue (Tandanad 1973; Czichos 1978). Thuro(1997) observed that wear in percussion drilling occurs mainly as impact wear and drag - bit rotary drilling as abrasion wear with mixed effect. In rock drilling process tool interact with the rock under certain loads, rotation, and temperature and in abundance of a flushing fluid, typically water (Plinninger *et al.* 2002). The wear type describes the specific form of wear observed on the tool. It can be described qualitatively by use of a wear classification system. The wear rate describes the velocity of material removal from the tool. The wear rate is a basic factor for the calculation of tool consumption and wears costs. It is obtained on site from measurements on single tools or calculations based on stock lists and delivery notes. The objectives of this paper are to establish parameters influencing drill bit wear and the ability of some Nigerian rocks to wear drill bit.

Materials and Methods

Samples Collection

The rock samples were collected from three separate locations. Sample A was taken from Oke-Ogbon Ile-Ife ($07^0\ 34^l\ 30^{ll}$ N, $004^0\ 36^l 14^{ll}$ E) sample B was taken from Oke-Ijetu ($07^0\ 39^l\ 15^{ll}$ N, $004^0\ 32^l\ 03^{ll}$ E), Osogbo and Sample C from Awo ($07^0\ 40^l\ 03^{ll}$ N, $004^0\ 23^l\ 44^{ll}$ E). However, the three samples fall within South Western Nigeria basement complex.

Equipment

The equipment used for testing the samples includes; Point load testing machine, Schmidt hammer, polarized microscope, Rock cutting machine.

Point Load Strength

Lump size samples collected from Ile-Ife, Oke-Ijetu, and Awo respectively from aggregate production quarries and were machined to block size samples for point load strength index. Thuro and Plinninger (2001) confirmed that in rock mechanics and engineering geology, the point load is regarded as a valuables field tool to give an estimate of the unconfined compressive strength. Therefore, ten samples each were prepared and tested to standard suggested by International Society of Rock Mechanics Commission (ISRM 1985). The formulae suggested by Brook (1985) and ISRM (1985) for both determination of point load strength index and size correction (for blocks and irregular lumps) were used as shown in Eqs. (1) and (2) below, the results are presented in Table 1. Here,

$$I_s = F/W.D, \qquad (1)$$

where: I_s = point load index; F = failure load; W = width of samples; and D = thickness of rock sample. Also,

$$I_{s(50)} = f\,(F/D_e^2) = f\,(\pi.F/4.W.D), \qquad (2)$$

where: $I_{s(50)}$ = point load index at diameter D = 50 mm; f = correction factor; and D_e = equivalent core diameter.

Equation 2 contains the size correction factor, f,

$$f = (D_e/50)^{0.45}, \qquad (3)$$

where: f = correction factor; and D_e = equivalent core diameter.

The general relationship between tensile strength (T_o), the point load strength (I_s) and compressive strength (C_o) are expressed in Eqs. (4) and (5)

$$C_o = 20T_o = 30I_s, \qquad (4)$$

$$T_o = 1.5\, I_s. \qquad (5)$$

The uniaxial compressive and tensile strength was estimated using Eqs. (4) and (5), respectively, and the mean values are presented in Table 1.

Rock Samples Rebound Values

Test were performed with L-Type hammer and all test were conducted with hammer held vertically downward at right to horizontal faces of large rock blocks. ISRM (1981) test procedure was used for the determination of rebound values for the rock samples hardness. The test method was repeated at least three times on the rock samples and the mean values were recorded as rebounds number as shown in Table 2.

Modal Analysis

The study of the thin-section was carried out on the slides prepared from the rock samples and these slides were viewed with the aid of polarizing microscope. Also, the mineral composition of the rocks were estimated using modal analysis, the percentage of each mineral and their forms were also determined as presented in Table 3.

Determination of Equivalent Quartz Content and Vickers Hardness Number

Equivalent Quartz Contact (*EQC*) was obtained by multiplying percentage of minerals present in rock by Rosiwal abrasiveness value (Thuro 1997)

$$EQC = \sum_{i=1}^{n} A_i\, R_i (\%), \qquad (6)$$

where: A = mineral amount (%), R = Rosiwal abrasiveness (%); and n = number of minerals.

In addition, Vickers Hardness Number of Rock (*VHNR*) of the samples were obtained by multiplying Vickers Hardness Number, *VHN* (kg/mm^2), by amount of minerals

$$VHNR = \sum_{i=1}^{n} VHN_i\, A_i, \qquad (7)$$

where: *VHN* = Vickers Hardness Number (kg/mm^2), A = amount of minerals; and n = number of minerals. Equations (6) and (7) were used to establish wear parameters as shown in Table 3.

Results and Discussion

Strength Parameters

Table 1 presents the values of tensile strength (T_o), compressive strength (C_o) and point load strength ($I_{s(50)}$), for samples *A*, *B* and *C*, respectively. Sample *C* has the highest compressive strength, tensile strength and point load strength of 244.85 Mpa, 12.95 Mpa and 8.16 Mpa, respectively. The result indicates that sample *C* most competent among the three samples investigated.

Table 1. Mean of Tensile (T_o), Compressive (C_o) and Point Load Strength ($I_{s(50)}$).

Samples	T_o (mpa)	C_o (mpa)	$I_{s(50)}$
A	11.4	209.3	6.97
B	12.7	242.5	8.08
C	12.95	244.85	8.16

Rock Hardness Index Parameter

Table 2 shows that the Schmidt hammer rebounds values varies from 47.50 to 52, this is a measure of hardness of the samples. Moreover, the results presented in Table 3 show the percentage composition of each mineral in the rock samples, the values of Equivalent Quartz Content (*EQC*) and Vickers Hardness Number of Rock (*VHNR*).

The equivalent quartz content and the Vickers hardness number for rock are 41.5%, 66.2%, 69.18% and 534.36 kg/mm^2, 895.1 kg/mm^2, 898.71 kg/mm^2, respectively, for samples *A*, *B* and *C*. It can be seen that both values of Equivalent Quartz Content (*EQC*) and Vickers Hardness Number (*VHNR*) takes the highest value in sample *C*.

Table 2. Result of mean Schmidt Hammer rebound values.

Samples	Compressive strength (C_o) (Mpa)	Tensile strength (T_o) (Mpa)	Point load strength Mpa $I_{s(50)}$	Mean rebound values	Equivalent quartz content (*EQC*) (%)	Vickers hard no. of rock (*VHNR*) kg/mm^2
A	209.3	11.4	6.97	47.5	41.5	534.36
B	242.5	12.7	8.08	51.5	66.2	895.10
C	244.85	12.95	8.16	52.0	69.18	898.71

Table 3. Vickers hardness number and equivalent quartz content.

Sample	Minerals	Amount (%)	*VHN* (kg/mm^2)	*VHNR* (kg/mm^2)	Rosiwal (%)	*EQC*
A	Biotite	38.6	110	42.46	11	4.20
	Quartz	26.3	1060	250.16	100	26.3
	Microcline	15.8	730	115.34	35	5.50
	Plagioclase	15.8	800	126.40	35	5.50
	Σ			534.36		41.50
B	Hornblende	7.7	600	46.2	20	1.50
	Plagioclase	35.9	800	287.2	35	12.60
	Orthoclase	2.6	730	18.98	35	0.90
	Quartz	51.2	1060	542.72	100	51.20
	Σ			895.1		66.20

Table 4. Summary of the measure of rock samples to wear drill bit.

Sample	Schmidt hardness (type *L* - hammer) value	Term
A	47.5	Very strong
B	51.5	Extremely strong
C	52	Extremely strong

Summary of Measures of the Potential Selected Rock Samples to Wear Drill Bit.

Table 4 presents the summary of all the parameters that could be used to measure ability of rocks to wear drill bit. It could then be inferred from Table 4 that sample *C* has the highest potential to wear drill bit, since all the wear parameters are highest in the sample.

Conclusion

The paper has analyzed the potential of three rock samples to wear drill bit. The selected wear indices include point load strength, compressive strength, tensile strength and hardness of the rock. Also, other wear parameters were established for the samples using the percentage composition of minerals in the samples. The results from the study show that sample *C* has the highest potential to wear drill bit than the others.

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