Geo- Mechanical Properties of Okaba Coal Deposit for Pillar Support System

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Abstract

This paper investigated the Geo-mechanical properties of Okaba Coal deposit for pillar support system in an underground mine, in which the unit weight of sandstone being the roof rock is 2 450 kg/m3, average Uniaxial Compressive Strength (UCS) value for sandstone sample is 58.65 MPa while the coal sample indicated a UCS value of 4.11 MPa. The Rock Quality Designation of sandstone sample is 76 % while that of coal is 35 %. The Rock Mass Rating (RMR) of sandstone is 74 while that of coal is 36. The RMR was used in the system of pillar dimension whose height is 2.6 m, width of 7.8 m and length of 32 m arranged in form of chain along the roadways to support the roof, and the panel is dimensioned to 200 m width and 1200 m length surrounded by roadways of 4 m width. The choice of the pillar dimension is purely based on the fact that it is the only one that satisfies the requirement of factor of safety of 1.6 which is sufficient enough to ensure stability of the roadways in the mine.

keywords

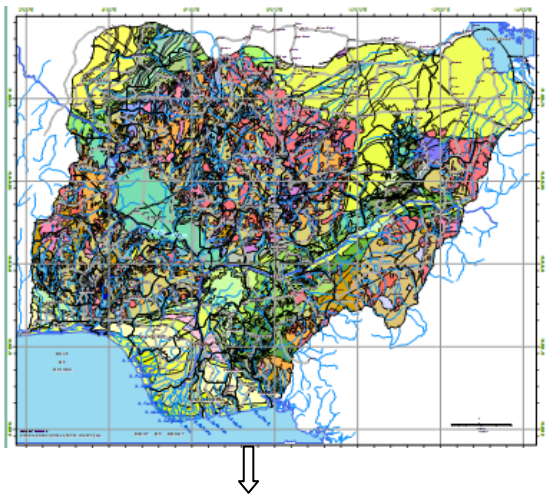
Geo-mechanic; Pillar; Panel; Overburden; Roadway; Rock Quality Designation.

Introduction

Coal, a fossil fuel combustible sedimentary rock, is composed mainly of organic materials such as carbon, hydrogen and oxygen, other constituent including nitrogen (Robert, 1993). Coal, a combustible, opaque (except in very thin slices), non-crystalline solid which varies from brown to black in colour as well as from dull to brilliant in luster, has a low specific gravity (1.0 to 1.8). Rock mass classification, preferable used to classify the rock quality for design and construction of the excavations using empirical rating system (Palmstrom *et al.*, 2001), was developed to create some order out of the chaos in site investigation procedures (Wikipedia, 2011). The physical and mechanical properties of rock are very important parameters for geological engineering design and construction. For instance, in coal mining industry many geological disasters induced by mining were associated with misunderstanding of rock mechanical properties (Han and Peng, 2002). These properties include density and porosity, Poisson's ratio, and rock strength e.t.c. These parameters can be obtained from laboratory experiments of core samples or from in-situ tests. The other characteristics of rocks include time-dependent rheological and creep behaviours (Wang *et al.*, 2001). When the rock samples are not available, such as oil and gas drilling and mining at deep depth, the well log data and geophysical data can be used to analyze and interpret rock physical and mechanical parameters (Peng, 1999). Pillars can be defined as the rock between two or more underground openings. Parameters such as: depth of the overburden, thickness of roof layers, the overburden unit weight, panel width or face length, entry width, pillar length, thickness of the coal seam and the state of in-situ stress will affect the optimum design of chain pillar size (Oraee *et al.*, 2010).

Materials and Method

The study area covers Okaba coal deposit, Okaba in Kogi state of Nigeria located on Latitude N7^0 30′ 00″and Longitude E7^0 53′ 38.8″ (MSMD,2006) which is represented in FIG. 1.



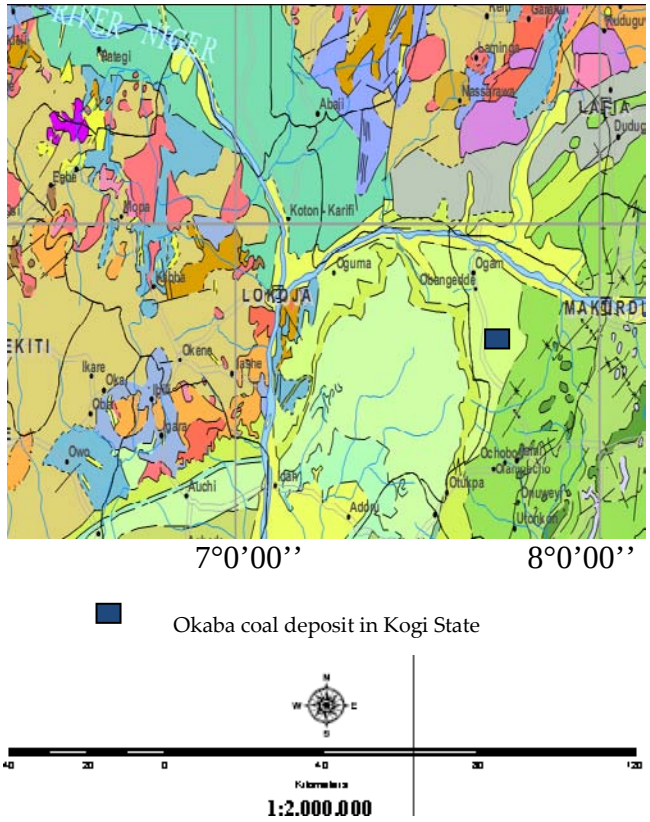


FIG. 1 EXTRACTED GEOLOGICAL MAP OF NIGERIA SHOWING OKABA COAL DEPOSIT

Geo- Mechanical Properties

Geo-mechanical properties investigated included unit weight of overburden, Uniaxial Compressive Strength, Rock Quality Designation (RQD) and Rock Mass Rating (RMR). All the tests and calculations were carried out in accordance with the standard suggested by ISRM (1989). The strength of the coal and sandstone was calculated using Equation 1 and the indicated strengths were corrected using Equation 2.

$$UCS(C) = \frac{P}{A} \quad (1)$$

$$c_o = \frac{c}{0.788 + 0.222(D:L)} \quad (2)$$

Where Co is Corrected Compressive Strength (MPa)

C is Indicated Compressive Strength (MPa)

P is Peak Load at Failure (kN)

A is Cross Sectional Area (mm^2)

D is Diameter of the Specimen (mm)

L is Length of the Specimen (mm)

The unit weight of roof rock was calculated using Equation 3.

$$\rho = \frac{Dry\ Mass}{Volune} \quad (3)$$

The rock Quality Designations of the rock samples were calculated using Equation 4.

$$RQD = 115 - 3.3J_v \quad (4)$$

where J_v is number of joints per unit length for all joint (discontinuity) sets.

The Rock Mass Rating for both samples was calculated using Equation 5

$$RMR = i + ii + iii + iv + v + vi \quad (5)$$

Where *i* is uniaxial compressive strength of rock material

ii is Rock Quality Designation (RQD)

iii is spacing of discontinuities

iv is conditions of discontinuities

v is groundwater conditions

vi is orientation of discontinuities

The Geo-mechanical properties of Okaba Underground Coal Mine are given in Table 1

Geometrical Parameters

The cubical strengths of coal pillar were calculated using Equation 6.

$$\sigma_p = 7.18h^{-0.66}Wp^{0.46} \quad (6)$$

Where *h* is mining height and *Wp* is pillar width.

The Geometrical parameters are as shown in Table 2 respectively.

Results and Discussion

The results are shown in Tables I and II.

TABLE I GEO-MECHANICAL PROPERTIES OF OKABA COAL MINE

PARAMETERS	VALUE
Strength of coal	4.11 MPa
Strength of roof rock	58.65 MPa
Unit Weight of rook rock	24.50 kN/m^3
Rock Quality Designation of coal	35
Rock Quality Designation of roof rock	76
Rock Mass Rating of coal	36
Rock Mass Rating of roof rock	74

The unit weight of sandstone is 2 450 Kg/m^3. The average UCS value for sandstone sample is 58.65 MPa while the coal sample has a UCS value of 4.11 MPa. The Rock Quality Designation of sandstone sample is 76 % while that of coal is 35 %, and the Rock Mass Rating of sandstone is 74 while that of coal is 36. The wide difference in the UCS value for sandstone and coal is among the factors responsible for sharp difference in the RQD and RMR of sandstone and coal.

The results show that the UCS value of sandstone is 58.65 Mpa which is classified as high strength compared to the UCS of coal which has low strength classification as a result of UCS value of 4.11 MPa. The RQD classification for sandstone is good while that of coal is poor because of their respective RQD values. The RMR classification for sandstone is also good while that of coal is poor. This points to the fact that there is a direct relationship between RQD and RMR which is also a function of the UCS which as well reflects the influence of moisture content on mechanical strength of rock. The lower UCS, RQD and RMR values as against high moisture content agree with the works of (Stavrogin and Karmanski, 1993), (Vasarhelyi and Van, 2006), (Fahamifar and Soroush, 2007) and (Ergular and Ulusay, 2008).

TABLE II GEOMETRICAL PARAMETERS OF OKABA COAL MINE

PARAMETERS	VALUE
Pillar Height	2.6 m
Pillar Length	32 m
Overburden depth	150 m
Cross Cut width	4 m
Entry width	4 m
Number of Entries	2

The depth of overburden is 150 m while the average mining height which is also the coal thickness is 2.60 m. The roadway is 4 m width with an arc of radius 1 m. The panel is dimensioned to 200 m width and 1 200 m length to be surrounded by roadways of 4 m width, and the pillar dimension is 2.6 m height, 7.8 m width and 32 m length arranged in form of chain along the roadway to support the roof. The choice of the pillar dimension is purely based on the fact it is the only one that satisfies the requirement of factor of safety of 1.6 which is sufficient enough to ensure stability of the roadways.

Okaba Coal Mine Pillar Design

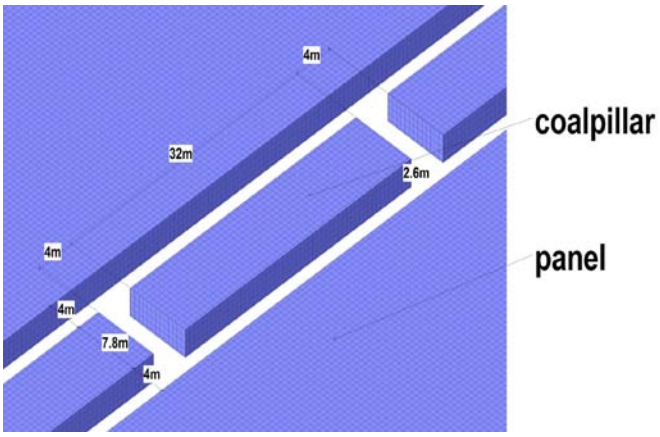


FIG. 2 3D MODELING OF TWO-ENTRY SYSTEM WITH AUTOCAD

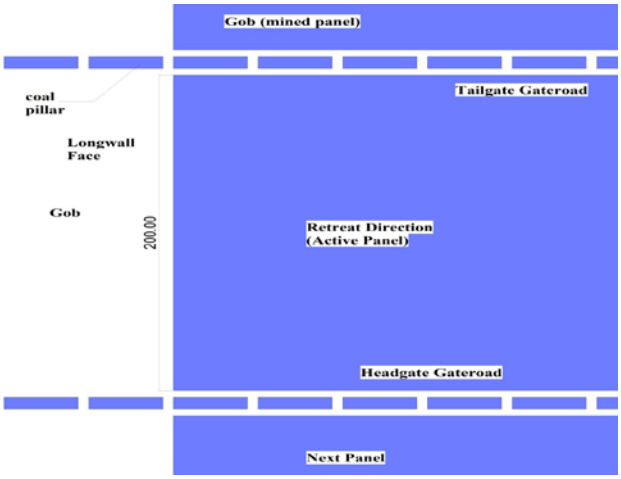


FIG. 3 3D PLAN SHOWING THE LAYOUT OF THE PANEL AND COAL PILLAR

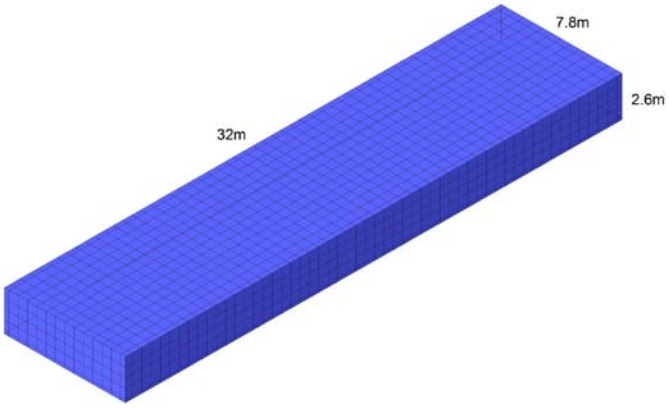


FIG. 4 3D MODELING OF OKABA COAL PILLAR WITH AUTOCAD

FIG. 2 is the 3D modeling of the Two-entry method of panels of 200 m width by 1,200 m length using AutoCAD, and the method means that a single chain of pillars separates two panels leading to two roadways which have been selected based on the

safety requirement of the roadways. As noted earlier, the roadway width is 4 m and cross cut width is 4 m. FIG. 3 is the 3D plan showing the layout of the panel, coal pillars, the mined-out portion and direction of mining which is hidden in FIG. 2. FIG. 4 is the 3D modeling of an Okaba coal pillar with AutoCAD showing the pillar dimension of 32 m length, 7.8 m width and 2.6 m height which is sufficient to support the mine with safety.

Conclusions

The presented results of geo-mechanical properties of sandstone and coal sample of Okaba coal deposit during physical and mechanical strength tests offer original design data necessary to carry out mining activities. The various results have indicated that sandstone is significantly stronger than coal because of its lower affinity for water compared to that of coal.

The Geo- mechanical properties determined helped in design of Okaba coal pillar system and this could be used as a guide for other deposits of similar geological characteristics.

ACKNOWLEDGMENT

I sincerely thank the staff of the Federal Ministry of Mines and Steel, Lokoja, Nigeria who gave me approval to carry out research at the Okaba Coal deposit.

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