Design of a Powered Support System in Enugu Coal Mine

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Abstract
The main aim of this research work is to design the power support system that will create a safe working environment for Enugu Coal mine. The project involves the analyses of the geological characteristics of the Enugu Coal Deposit. This includes the angle of dip of the deposit, the condition of the roof and the floor, hydrogeological condition; seam thicknesses are considered during the design of the powered support. A powered support system is designed for the longwall face using the application of the Polish system of design. The average carrying capacity $15.42 \text{ t/m}^2$, the working heights $h_{\text{max}} = 2 h_{\text{min}}$ and the area of the face to be supported $19.30 \text{ m}^2$ are calculated using practical formulae.

Keywords: longwall, dip, deposit, roof, floor, hillside, coal seam, adit, tunnel.

INTRODUCTION
At first, people found coal washed up on a beach or in coal seams in a hillside. This coal was easy to find. When it was used up, miners had to get the coal below the ground. Some dug tunnels, called adit mines, into coal seams on the sides of hills. Coal can also be dug out until the roof fell in or by digging down into bell pits for coal. Coal exploitation can be achieved by digging a hole or shaft, three to six metres deep and thus cut out the coal around the bottom of the shaft, so that the shaft looked like a bell. The first coal miners soon found out that coal mining was dangerous when tunnels fell in with the weight of the rocks above and thus called for the need to find a safer way of digging for coal. One good idea was to leave half the coal standing as pillars of rock to hold up the tunnels. This is called “room and pillar” mining (Philip, 1987).

Miners sometimes used another way of mining in order to mine more coal that is by “longwall method.” This is the most popular method of mining coal deposits (Wikipedia, 2009). Many miners worked together to take the coal seam at the same time. They built stone walls and used timber posts or props to hold up the roof as supports (Nwude and Mallo, 2003).

Presently, steel longwall supports are used and the mechanized (powered) supports will be extensively discussed in this project.

Brief History of Coal Mining in Nigeria
Coal mining in Nigeria started in 1915 following the discovery of sub-bituminous coal near Enugu by the then Mineral Survey of Southern Nigeria. Since then, other coal sequences have been discovered, but Enugu coal field remains one that has the most extensive coal deposit. Enugu coal sequence lies below a north-south trending regional escarpment, and has an estimated total coal reserve of 200 million tonnes (Dialah, 1984). Like other parts of the world, coal is the oldest commercial fuel, dating in Nigeria from 1916 when 24,000 tons were produced. Production peaked at near one million tons in 1959, before declining to the present insignificant level. This is due to the reduction in the demand for coal arising from dieselisation of rail transportation, and switching from coal to gas for thermal power generation (Grainger and Gibson, 1981). Now, Nigeria ranks low in worldwide coal production, with less than 10,000 tons of coal production in 2005 (Table 1.1).

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Anthracite &amp; Bituminous (million tonnes)</th>
<th>Sub-bituminous &amp; Lignite (million tonnes)</th>
<th>Total (million tonnes)</th>
<th>Global Rank (# &amp; %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Proved Coal Reserves (2005)</td>
<td>21</td>
<td>169</td>
<td>190</td>
<td>27(0.02%)</td>
</tr>
<tr>
<td>Annual Coal Production</td>
<td>0.008</td>
<td>0</td>
<td>0.008</td>
<td>30(0.0001%)</td>
</tr>
</tbody>
</table>

Source: EIA (2007)

LITERATURE REVIEW
Geologic Characteristics Of Coal In Nigeria
The geological characteristics of coal should be critically considered before any design can take place. This will determine the nature of the design. Examples of such characteristics are: seam thickness, conditions of the roof and floor, hydro geological conditions of the deposit, volatile content and so on.
The geology of coal is characterized by the following factors:

1. **Angle of dip of the coal seam:** Coal seams occur at varying angles of dip from 0° to 90° and are generally classified as moderately or gently dipping, semi-steep or steep seams. In gently dipping seams, broken coal remains at their sites but in steeply dipping seams, they may roll down. Mining methods to be selected for working in steep seams must therefore take into consideration the various effects of dips. For example, in steep deposit, room and pillar method of mining will not be successful. Enugu coal deposit has an average angle of dip of about 1°–3° which implies that the deposit is gently dipping.

2. **Geological Conditions of the Roof and floor:** Coal seams may have shale, sandstone or combination of both as their roof or floor. If the floor is weak, there is limitation to the kind of mining equipment to be used. For example, tyre mounted machines cannot be operated on weak floors. Similarly, if the roof is weak, its stability will be very poor making room and pillar method of mining impossible because it requires numerous roads which should have stable roofs. Figure 2.1 shows lithological section of the deposit which is also indicating the roof and floor of seam #3 and #4.

![Fig. 2.1: Lithologic data of Exploration Borehole BH 16 in Enugu deposit Source: Egboaka and Uma, (1985)](image)

Table 2.1: Summary of the Geologic Features of Seams 3 and 4 in the Enugu coal mine

<table>
<thead>
<tr>
<th>Features</th>
<th>Seams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (m)</td>
<td>1.24</td>
</tr>
<tr>
<td>Volatile Content (%)</td>
<td>32.3 – 36.3</td>
</tr>
<tr>
<td>Ash Content (%)</td>
<td>0.3 – 13.7</td>
</tr>
<tr>
<td>Calorific Value (%)</td>
<td>23,860 – 26,680</td>
</tr>
<tr>
<td>Sulphur Content (%)</td>
<td>0.56 – 1.15</td>
</tr>
</tbody>
</table>

Source: Akande (1984)

3. **Seam Thickness:** Enugu coal has about five seams. Seam #1 has a thickness of about 1.3 m, seam #2 has 0.32 m, seam #3 is 1.24 m, seam #4 is 0.86 m and #5 is 0.13 m (Akande, 1984).

For the purpose of this project, seam #3 would be considered.

4. **Hydro-geological Condition of the Coal Deposit:** Groundwater is an integral chemical component in Acid Mine Drainage (AMD) formation and it serves as contaminant transport medium (Udosen and Eshiett, 2009). Therefore, prediction of post mining drainage quality requires the knowledge of a surface mine with groundwater hydrogeology. If the hydrogeological regime of the coal formation to be mined is known, then the groundwater inflows can be predicted well in advance and it can then be possible to design suitable drainage systems that will minimise the potential for mine flooding.
prerequisite for successful longwall mining. Furthermore, due to the large number of units required, the capital invested for the powered support usually accounts for more than half of the initial capital for a longwall face. Therefore, from both technical and economic points of view, the powered support is a very important piece of equipment in a longwall face.

Figure 2.2: Powered Longwall Supports [(a) & (b): Side views; (c) Plan view

Parts Of Powered Supports
According to Cemal and Ergin (1983), all powered supports, regardless of type, consist of a canopy, a base, hydraulic legs and control system.

1) **CANOPIES**: The canopy size ranges from 1.61 to 9.4 m² with maximum roof pressure at yield about 4.2-33.2 kg/cm². Solid roof canopies have been found to maintain an average of 41% contact area with the roof; contact area increases to an average of 68% when an articulated canopy is used.

2) **BASES**: Bases are available in any size. Generally, bases for frame supports are split into two halves, whereas solid bases are used for chock and shield supports. A solid base provides better stability. Each base is provided with skids; the most popular design is a combination of a rear skid and a single split forward skid. Guide bars are used to transfer the ram jack force to guide the support units during advance without undue side loads. The optimum size of the base for a specific seam floor is such that its unit loading pressure at yield is less than the bearing capacity of the floor rocks.

3) **LEGS (JACKS)**: The bore diameter of the hydraulic legs of powered supports ranges from 10 to 30 cm with operating pressures of the hydraulic pump. When the legs are raised against the roof, the total load exerted on the roof is

\[ P = P_i \times A \times n \]  

Where: \( P \) = total setting load, in kilograms  
\( P_i \) = operating hydraulic pressure, in kilograms per square centimetre  
\( A \) = cross-sectional area, in square centimetres  
\( n \) = number of legs

Thereafter, when the roof starts to cave, the hydraulic legs are forced to retreat and hydraulic pressure in the legs increases. The pressure at which the yield valve will open is called the yield pressure; the corresponding load applied on the roof is called the yield load. Most support capacities are designed to incorporate the yield loads.

4) **HYDRAULIC POWER SUPPLIES**: There are four types of hydraulic fluids for powered supports: 1) 5% soluble oil-in-water emulsion; 2) 40% water-in-oil emulsion; 3) 50% glycol-in-water solution; 4) refined petroleum based oil. The basic requirements for powered support hydraulic fluids are low cost, low viscosity, non-flammability, and high resistance to chemical change upon contact with air. Also, the fluid should be highly resistant to foaming. Lubricity and corrosion protection is also important to protect moving parts.

5) **CONTROL SYSTEMS**: Supports can be controlled in various ways: 1) individual support manually; 2) individual support manually from the neighbouring unit; 3) manually from selected points at the face; 4) automatic control from the gateway.

Types of Powered Supports
According to Cemal and Ergin (1983), there are four major types of powered supports which are designed for various conditions. These are Chock: Frame, Shield and Chock-shield types of supports.

1. **Chock Powered Supports**
   The chock type of powered support is the earliest used. It is hydraulic in nature. The old type of chock powered support is composed of a block (chock) of one horizontal and four vertical pistons. The vertical pistons support the roof and the horizontal piston pushes the conveyor. Currently, there are chock powered supports having six legs (Fig. 2.3). The back of the chock is protected from caving blocks and the rigid canopy has elongations to cover the roof after the cutting machine has passed.
1. hinge; 2. hydraulic control assembly; 3. leaf-spring thrusters; 4. centre base; 5. footplates with centering base; 6. shifting cylinder; 7. leg; 8. articulated canopy.

3. Shield Powered Supports

Shield supports were developed in order to keep up with easily caving faces. The shield supports consist of an inclined plate whose lower end is hinged to a horizontal base plate that sits on the floor, while the upper end is hinged to a horizontal roof canopy in contact with the roof (Fig. 2.5). Due to various developments made on shield supports, we have three types of shield supports: (i) The “Calliper” shield, (ii) The “Lemniscate” Shield and (iii) The Four-leg Support Shield.

Advantages of Powered Supports

a) Low Convergence: Hydraulic systems control the roof very efficiently. Large canopies hold the roof effectively.

b) High Production: Owing to mechanization, the systems are able to advance as much as 5-6 m a day. This increases the production (more than 1500-2000 tons), decreases the number of faces required, and obtains concentration in the mine workings.

c) Safe Production: Effective roof control has minimized accidents caused by roof falls.

d) High Efficiency: The output per conventional man shift has increased tremendously compared to the output of conventional supporting systems.
Disadvantages of Powered Supports

a) **Capital Cost:** Powered supports require high capital expenditure. Unless there are large panels available, they may not be justified.

b) **High Cost of Upkeep:** The cost for upkeep is much higher than the cost for conventional supports.

c) **Qualified Labour:** Powered support systems do require highly qualified labour.

d) **Geological Specifications:** Geological specifications are difficult to meet. Large panels, small fluctuations in seam thickness, and conditions of mechanical workability should be met.

MATERIALS AND METHODS

Among the types of powered support discussed, the Frame type of powered support is selected and designed in this project.

**Design of Frame Powered Support**

The design of the powered supports depends majorly on the geological and stress conditions of the coal strata. For example, if low-yield-capacity supports are used in a strong roof, hardly caved, the pressures will not be met by the supports, the roof will not cave as the face advances, and excessive pressures will result in heavy upkeep expenses on supports.

Conversely, if a high yield support is used in a weak roof, there will be intrusions to the roof, and the unnecessary use of high-cost powered support increases the expense. Thus, the correct capacity of powered supports should be chosen to meet the conditions.

There is no established set of formula or systems in designing powered supports. Almost every country has established her own systems. Thus, the Polish system will be applied in this project.

**Important Dimensions Related to Supporting**

**Yielding Pressure:** This is given by the formula:

\[ P_y = 1.25 P_i \]  

Where, \( P_y \) = yielding pressure, in kg/cm\(^2\)  
\( P_i \) = operating or setting pressures, in kg/cm\(^2\)

**Distance between supports:** this depends on the roof and floor conditions, bearing capacity of the support, gob conditions (caving), and rate of advance. It is usually taken as 1.2 m from centre to centre. It is shown as ‘c’ in Fig. 2.2.

**Unsupported face distance:** This is the small distance between the coal at the face and the end of the canopy. This distance increases as the winning machine cuts. It is shown as \( l_o \) in Fig. 2.2.

**Load Density:** Load density is given by the formulae:

\[ n = \frac{F}{(l_i + l_o) c} \]  

where, \( n \) = load density, in tonnes per square metre.

**Maximum and Minimum Heights:** Maximum and minimum define the working heights of the supports according to the geological conditions and convergence evaluation of the face. Some coal is left at the roof owing to changes of the seam thickness (see Fig. 3.1). The working heights are given by the following expressions:

\[ \log \frac{h_{\text{max}}}{1.1 h_{\text{min}}} = \frac{1.704 m'}{m_{av}} \]

where, \( h_{\text{max}} \) = maximum height, in metres  
\( h_{\text{min}} \) = minimum height, in metres  
\( m_{av} \) = average thickness, in metres  
\( m' \) = geological deviations in thickness, in metres  
\( c \) = average convergence, in millimetres per metre  
\( l \) = width (supported span) of the face, in metres

**Application of Polish System in the Design of Powered Supports**

The Polish system of calculating powered supports is based upon the openings at the face. Considering fig. 3.2, where three units are used to support the average bearing capacity of an area; the average carrying capacity can be calculated from the formulae:

\[ P_o = \frac{(P_1 + P_2 + P_3) n}{F} \]

Where, \( P_o \) = average carrying capacity, in tonnes per square metre  
\( P_1 \) = nominal load of one unit, in tonnes  
\( P_2 \) = load on the unit when advancing, in tonnes, taken as zero.  
\( P_3 \) = carrying load of the unit just set, in tonnes  
\( F \) = the area of the face covered by three supports, in square metres  
\( n \) = efficiency factor of supports, taken around 0.8
RESULTS AND DISCUSSIONS

Based on the design calculations carried out, the results are presented in the table below. This would help in the construction of the powered supports.

**Powered Supports**

The parameters derived from the design calculations of the powered supports are shown in Table 4.1

<table>
<thead>
<tr>
<th>S/N</th>
<th>Determined Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Working heights, ( h_{\text{max}} ) and ( h_{\text{min}} )</td>
<td>( h_{\text{max}} = 2.0 \times h_{\text{min}} )</td>
</tr>
<tr>
<td>2.</td>
<td>Face Width</td>
<td>4.60 m</td>
</tr>
<tr>
<td>3.</td>
<td>Nominal Carrying Load, ( P_1 )</td>
<td>70 t per leg</td>
</tr>
<tr>
<td>4.</td>
<td>Advancing Load, ( P_2 )</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td>Carrying Load of unit newly set, ( P_3 )</td>
<td>23 t per leg</td>
</tr>
<tr>
<td>6.</td>
<td>Number of legs</td>
<td>4</td>
</tr>
<tr>
<td>7.</td>
<td>Area of Face to be supported, ( F )</td>
<td>19.30 m²</td>
</tr>
<tr>
<td>8.</td>
<td>Average Carrying Capacity, ( P_0 )</td>
<td>15.42 t/m²</td>
</tr>
</tbody>
</table>

Table 4.1: Parameters to design the Powered Support

The table above indicates that Powered supports meet all conditions at a longwall face especially when compared with other means of support such as friction props, hydraulic props and rigid chocks.

**CONCLUSION AND RECOMMENDATIONS**

**CONCLUSION**

The design calculations are carried out in order to determine pressure loads exerted by the rock above the powered supports at the face. These pressure loads therefore determine the dimensions to be used for the designs. Longwall method of mining should be adopted with a properly designed powered support system for the longwall face making it safe for mine workers and machineries to work efficiently. Also, longwall will yield higher production and profit at a minimum cost.

**RECOMMENDATIONS**

In order to have one of the best coal producing nation in the world, highly mechanized underground coal mine is needed to be set up. This mechanized mine involves effective support underground access roadway, hydraulically supported mining faces and which are well ventilated to ensure maximum safety for workers. Currently, coal mining in Nigeria is at its lowest state. To revive the coal mining industries in Nigeria, the following recommendations should be considered and seriously acted upon:

1. It must be ensured that before any design or construction is carried out, the geological characteristics of the deposit must be put into consideration.
2. Future exploration on mineral deposits should provide sufficient and reliable details or data and not just assumptions.
3. Research works on mineral deposits and their exploitation should be highly encouraged.
4. Longwall method of mining should be applied in mining coal deposits since it ensures safety of workers and high productivity.
5. The roofs of longwall faces should be well supported with well designed powered supports.

**REFERENCES**

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