

DESIGN OF A HAULAGE WAY IN AN UNDERGROUND COAL MINE

¹Akande, J. M. And ¹A. I. Lawal

¹Department of Mining Engineering, The Federal University of Technology, P.M.B. 704, Akure.
Email: akandejn@yahoo.com, abiounismail18@yahoo.com

ABSTRACT

The research work examines the design of a haulage way in an underground coal mine in Enugu, Nigeria. To achieve the set objectives the following factors were put into consideration: angle of dip of the deposit, condition of the roof and floor, hydro-geological condition, seam thickness. The design of the haulage way was carried out based on the geological characteristics of the area. In the design of the haulage way, rigid arch support was selected to control the roof and has a span or width of 3.65 m, height of 1.20 m and 1.3 m spacing between the arches. The pressure load (5.931t/m), maximum moment is (-2.64 t.m) and absolute stress value (14000 t/m²) were determined using practical formulae.

Keywords: Haulage way, underground coal mine, angle of dip, hydro-geological condition, arch support, pressure load, absolute stress, seam thickness.

1.0 INTRODUCTION

1.1 Brief History of Coal 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 the Enugu coal field remains the one that has the most extensive coal deposit. The 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. Now, Nigeria ranks low in worldwide coal production, with less than 10,000 tons of coal production in 2005 (Table 1).

Table 1: Nigeria's Coal Reserves and Production

Indicator	Anthracite & Bituminous (million tonnes)	Sub-bituminous & Lignite (million tonnes)	Total (million tonnes)	Global Rank (# & %)
Estimated Proved Coal Reserves (2005)	21	169	190	27(0.02%)
Annual Coal Production	0.008	0	0.008	30(0.0001%)

1.2 Haulage Ways in Underground Mining

Access haulage ways or entries are the tunnels giving access to longwall faces. Extraction cannot take place without access haulage ways, the provision and maintenance of these is a major cost

item of the mining system (Grainger and Gibson, 1981).

Extraction of coal from the longwall face requires the driving of pairs of roads which link with pairs of access roads into the area being worked. These access roads in turn link with the pair of mine

shafts. Access is required for the transport of men and equipment into and out of the mine, for the transport-out of coal and rock from the mining operations and for the maintenance of good healthy environmental working conditions.

According to Akande (1984), haulage way is constructed for the following reasons:

- i. To transport extracted mine mineral or rock from the faces.
- ii. To transport materials and mine machinery.
- iii. For the arrangement and movement of mine workers.
- iv. Allowing the flow of air necessary for ventilating the faces.
- v. For the removal of underground water.
- vi. For transportation of energy to the machines and mechanisms being used.

In a longwall system of mining, access haulage ways are constructed depending on the kind of mining direction employed (Grainger and Gibson, 1981).

In *advancing longwall faces*, roads are continuously extended at each end of the face as it advances away from the main haulage way. The haulage ways are formed from the extraction zone at the sides of the longwall excavation, and the useful part of the haulage way is generally in a zone of high stress.

In *retreating longwall faces*, the roads are first formed to the boundary of the coal panel which is to be extracted; the face is then started at the far end and is worked back to the main road. The haulage ways are driven before mining and the useful part of the haulage way is always in front of the retreating face. Because of this, the haulage way is generally in a zone of relatively low stress.

According to Akande (1984), the following should be taken into consideration when designing and constructing a haulage way or a tunnel: 1) Form and dimensions of cross sectional area of the haulage way, 2) Technological diagram of the construction, 3) Positioning of the tunnelling machine, 4) Technical details of support, 5)

Diagram of ventilation, 6) Diagram of organisation of work, 7) Table showing the machineries used, and 8) Technical-economical indices.

The design and construction of haulage ways are the same as the design and construction of tunnels in Civil Engineering. Therefore, the term 'tunnel' will frequently be used to refer to haulage way in this research work.

1.3 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 $0-90^{\circ}$ and are generally classified as moderately or gently dipping, semi-steep or steep seams. In gently dipping seams which are broken, remain at their sites but in steeply dipping seams, they may roll down. Mining methods, which are 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 $1 - 3^{\circ}$ 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 1 shows lithological section of the deposit which is also indicating the roof and floor of seam #3 and #4.

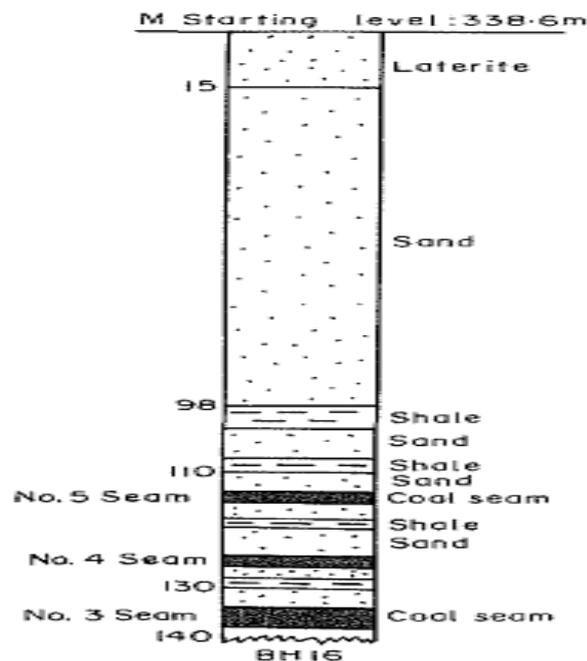


Fig. 1: Lithologic Data of Exploration Borehole BH 16 in Enugu deposit

Source: Egboka, 1985

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. 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 spoil 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 mine flooding.

Table 2: Summary of the Geologic Features of Seams 3 and 4 in the Enugu Coal Mine

Features	Seam #3	Seam #4
Thickness (m)	1.24	0.86
Volatile Content (%)	32.3 – 36.3	33.0 – 34.5
Ash Content (%)	0.3 – 13.7	0.6 – 14.1
Calorific Value (%)	23,860 – 26,680	24,150 – 26,530
Sulphur Content (%)	0.56 -1.15	0.41 – 1.05

Source: Akande (1984)

1.4 Location and Reserve Estimation of Nigeria Coals

Nigeria's coal resources are located in the Cretaceous Anambra and Makurdi Basins, and Afikpo Syncline and occur in two levels: the lower Mamu Formation and the upper Nsukka Formation. Coal seams occur in three main stratigraphic levels (Ogunsola, 2008):

- i. The brown coals (lignite) of Ogwashi-Asaba Formation of Miocene to Pliocene ages.
- ii. The upper and lower sub-bituminous coal measures of Maastrichtian age.
- iii. The bituminous coals of the Agwu shales of Coniacian age.

Nevertheless, Nigeria's coal reserves are large, over 2 billion metric tonnes, of which 650 million tonnes are proven. From North to South, the reserves from seams over one metre thick are; Ogboyoga (100 million tonnes), Okaba (70 million

tonnes), Orukpa (60 million tonnes), Ezimo (50 million tonnes), and Enugu (50 million tonnes). (NOGO, nd).

Coal seams also occur at Gombe in Gombe State. Mine production capacities after full rehabilitation and privatisation could attain the following levels: Oyeama and Okpara (150,000-400,000 tonnes/year), Owukpa (2,500 tonnes/year), and Okaba (15,000-300,000 tonnes/year). Nigerian sub-bituminous coal has a high calorific value (5,000-6,000 cal/g or 5,500-6,500 airdried), low ash and low sulphur contents, with good storage characteristics.

Nigeria has the largest lignite deposit (a type of coal) in Africa, with reserves of about 50million tonnes. The Nigerian lignite belt, of mid-Tertiary age, extends from Oriu in the South-east, through Urnuezeala, Umuahia, Nnewi, Oba, in a 20 to 40 km-wide belt across the Niger, to Ogwashi, Asaba, Mgbiiigliba and Adiase-Uti in Delta State. It has not yet been exploited. Figure 2 indicates the major areas where coal deposits are located in Nigeria.

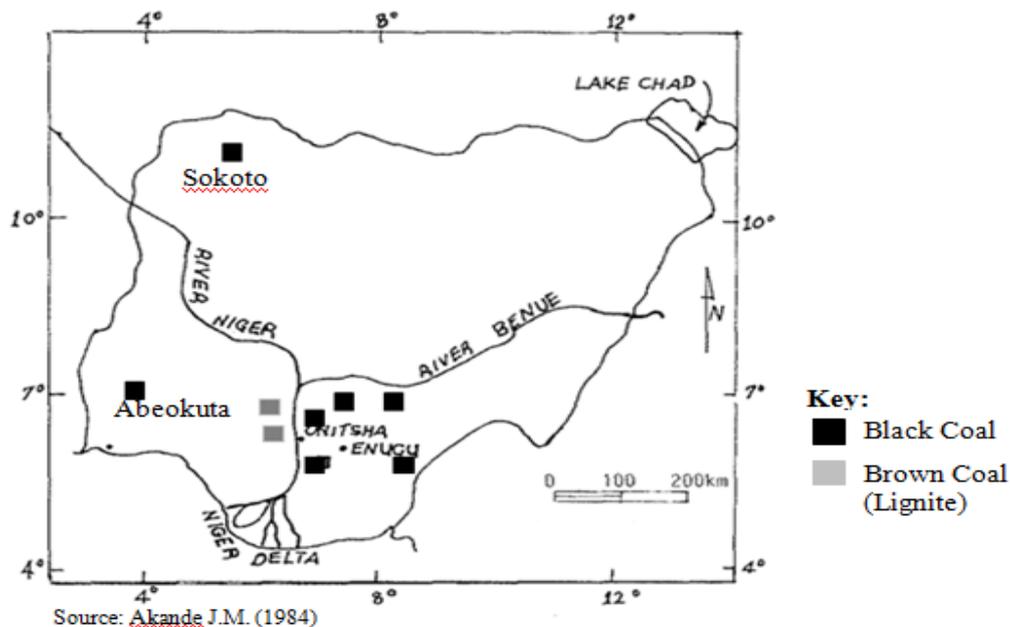


Fig. 2: Nigeria's Major Coal Field (Source: Akande, 1984)

3.0 MATERIALS AND METHODS

3.1 DESIGN OF THE HAULAGE WAY

Based on the advantages of Tunnel Boring Machines (TBMs) over the conventional drilling and blasting method of tunnelling, the TBM is selected to excavate the rock.

Also, based on the geological characteristics of coal studied, the haulage way is designed by using

practical mathematical formulas with standard numerical examples.

In designing the haulage way, the Rigid Arch method is selected based on the design requirements and designed as follows:

Given the static analysis in Fig. 3;

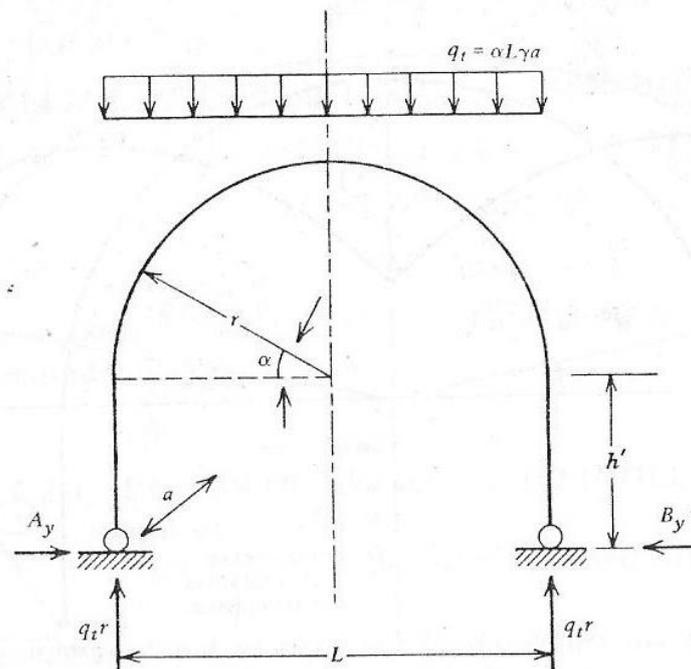


Fig. 3: Static Component of a Rigid Arch

3.1.1 Stress Evaluation:

$A_y = B_y$ = Side reactions, in tonnes

h' = vertical distance of the arch, in metres

r = radius of the arch, in metres

α = angle from horizontal, in degrees

q_t = uniform roof load, in tonnes per metre

M = moment, in tonnes. metre

N = normal force to the profile, in tonnes

$$\text{The Side Reactions, } A_y = B_y = \frac{(0.785h' + 0.666r)q_t r^3}{0.666h'^3 + \pi r h'^2 + 4h' r^2 + 1.57} \quad (1)$$

$$\text{The moment, } M = 0.5q_t r^2 \sin^2 \alpha - A_y (h' + r \sin \alpha); \text{ for } 0 \leq \alpha < \pi \quad (2)$$

$$M = -A_y X; \text{ for } 0 \leq \alpha < h \quad (3)$$

$$\text{The Normal Force, } N = -q_t r \cos^2 \alpha - A_y \sin \alpha \quad (4)$$

The maximum moment must be determined if a rigid arch is to be designed.

By differentiating Eq. (2) with respect to α , and equate to zero, we have;

$$\frac{\delta M}{\delta \alpha} = \cos \alpha (q_t r^2 \sin \alpha - A_y r) = 0 \quad (5)$$

$$\text{then, } \cos \alpha = 0, \alpha = \pi/2 \quad (6)$$

$$\text{and } q_t r^2 \sin \alpha - A_y r = 0 \quad (7)$$

$$\sin \alpha = A_y / q_t r, \alpha = \sin^{-1} A_y / q_t r \quad (8)$$

The values of M_{\max} and N are for values of α of Eqs. (6) and (8) as follows:

$$M_{\max} = 0.5 q_t r^2 - A_y (h' + r) \quad (9)$$

$$M_{\max} = -A_y [h' + 0.5 A_y / q_t] \quad (10)$$

$$\text{Also, } N = -A_y \quad (11)$$

$$N_1 = -q_t r \quad (12)$$

The stress should be determined as follows:

$$|\sigma| = \frac{\text{normal load}}{\text{profile area}} + \frac{\text{maximum moment}}{\text{section modulus}}$$

$$|\sigma| = \frac{q_t r}{F} + \frac{A_y (h' + 0.5 A_y / q_t)}{W} \leq \sigma_{sf} \quad (13)$$

Where, $|\sigma|$ = absolute stress value, in tonnes per square metre

F = section area of the profile, in square metres

W = section modulus of the profile, in cubic metres

σ_{sf} = allowable stress in steel for mine supports, 1400 kg/cm² or 14000 t/m².

According to DIN specifications;

$$\text{The section area, } F = 0.149W + 9.780 \quad (14)$$

$$\text{Therefore, } |\sigma| = \frac{q_t r}{0.149W + 9.780} + \frac{A_y (h' + 0.5 A_y / q_t)}{W} \leq \sigma_{sf} \quad (15)$$

4.0 RESULTS AND DISCUSSIONS

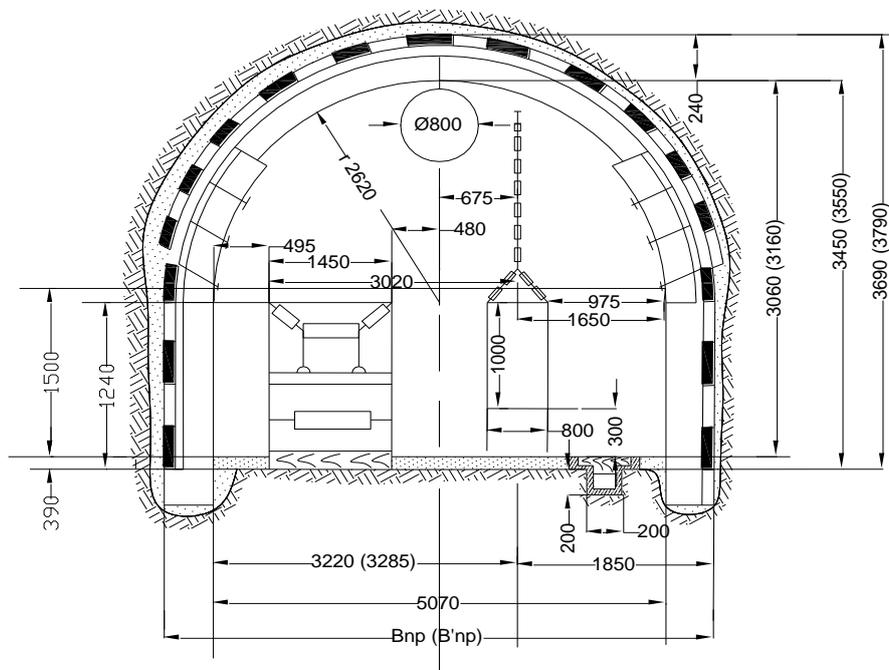
Based on the design calculations, the results obtained are tabulated below. This would help in the construction of the haulage way.

4.1 HAULAGE WAY CONSTRUCTIONS

After designing the rigid arch, using calculated design parameters. The parameters shown in Table 3 are used to construct the haulage way and its support.

Table 3: Parameters Required to Design the Rigid Arch

S/N	Determined Parameters	Values
1.	Uniform Roof Load, (q_t)	5.931 t/m
2.	Side Reactions (A_y or B_y)	1.938 t
3.	Maximum Moment (M_{max})	-2.64 t.m
4.	Normal Force (N)	-9.93 t
5.	Absolute Stress Value (σ_{sf})	14000 t/m ²
6.	Section Modulus (W)	188.7 cm ³



CROSS SECTION OF HAULAGE WAY (M 1:50)

Fig. 4: Cross Section of Haulage Way

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The design calculations are required in order to determine pressure loads exerted by the rock above the haulage way. These pressure loads therefore

determine the dimensions to be used for the designs as indicated in Table 3.

5.2 RECOMMENDATION

The method of arch support for the roadway should be adopted because of the strength of the steel material used for the arch. Also, because of the large amount of roof load to be supported. Also,

rigid arches have varieties of cross-sectional area

which provide opportunity for selection.

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