

Appraisal of Some Nigerian Coals

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Abstract-Coal has served man well from earliest time till date. It is basically of sedimentary origin and is widely found in Nigeria within the Cretaceous Mamu and Nsukka Formations within the Anambra depositional basin. Coal has found application as fossil fuel in the generation of electricity, for heating of the home and in steel production. Proximate analysis for fixed carbon content, sulfur content, moisture content, and ash content shows Nigerian coal to be best in use for energy generation, having high carbon content and low sulfur and ash content. Atterberg limit and shrinkage limit tests carried out on the samples showed low plastic and liquid limits values (24.6% - 31.7% and 29.5% - 37.2%) and linear shrinkage (2.9% - 6.4%) respectively, which satisfy engineering standard of stability with insignificant reduction in size or distortion of shape. Being inert, the stabilization of the coal was achieved using clay, thereby enhancing its potential for production of durable bricks. Coal ash (waste) generated from power generation and steel production plants could be used for brick making without direct or indirect impact on the environment and human health. Standard laboratory tests were carried out to determine the engineering properties of the coal in its natural state and after treatment with increasing percentages of Portland cement and the results indicated a significant improvement in the engineering properties of the coal with a reduction in plasticity and shrinkage, as well as increase in the strength and bearing capacity with the addition of 2% Portland cement. The resulting brick met most Nigerian construction specifications for fills, embankment and sub-base. On account of its being non-cohesive naturally, other additives with high plasticity serve as bonding/cementing material for coal.

I. INTRODUCTION

Coal deposits composed primarily of carbon and other elements including sulfur are readily combustible black-brownish rock of plant remains, form in an environment where plant remains are saved by mud and water from oxidation and biodegradation. Composed of carbon and other elements including sulfur, it is source of carbon dioxide emissions due to its use in electricity generation which results in global warming. Waste products from coal usage include fly ash, bottom ash, boiler slag, and flue gas desulfurization, which contain heavy metals, raising health concern in areas with poor air pollution controls (Wikipedia, 2003). Total world reserves of coal is estimated to be about 998 billion tones and most loss is to fire due to spontaneous combustion or mine fires (Brian, 1983). The sequence of coal formation, Peat-lignite-bituminous coal-anthracite (Harvey, 1982) shows several progressive changes taking place, resulting in the formation of many power plants. High volatile bituminous coal is found within

the Turonian-Santonian Awgu Formation in the Anambra Different kinds of coal from peat lignite – sub bituminous - Bituminous and anthracite, following the process of coal formation from cellulose as it progresses from one rank to another.

Deposits of clay, silt or sand on coal, eventually become part of the coal, constituting the ash content of the coal. Peat becomes coal when subjected to the pressure of overlying layers of sedimentary rocks of sandstone, shale and limestone. Some heat is generated by the overburden helping the coal-making process. The physical and chemical changes in the peat gradually result in the slow transition first to lignite and then to higher ranks of bituminous and anthracite coal (Jesen and Bateman, 1979). Gradual expulsion of water results in bedding plane cleavage. Changes in density, color and luster occur as the coal progresses through the various ranks. The time required for chemical and physical changes depend upon the intensity and nature of the pressure and heat which cause the changes. Older coals have been deeply buried over longer time, and are usually of higher rank.

The most economical method of coal extraction from coal seams depends on depth and quality of the seam. Coal mining processes are generally differentiated by whether they operate on the surface or underground, however both require that coal be washed.

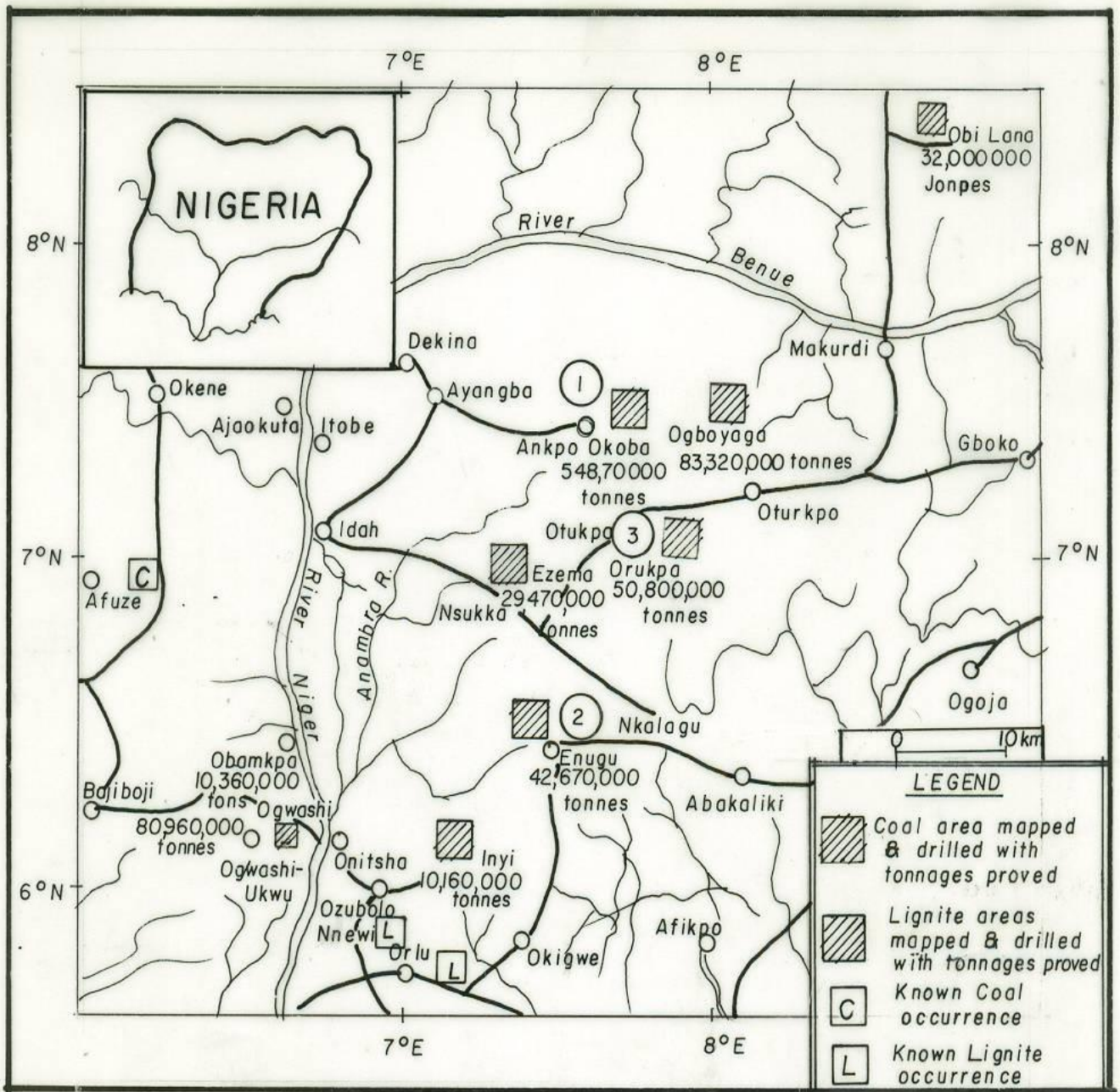
Primarily coal is used as solid fuel to produce electricity and heat through combustion, coking of coal which is a solid carbonaceous residue derived from low-ash, low sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven without oxygen. This ensures that fixed carbon and residual ash are fused together and are used in smelting iron ore in a blast furnace as a reducing agent. Coal could also be useful in the conversion through the process of gasification, using high temperature and pressure. Steam and oxygen produce syngas, mainly consisting of carbon monoxide and hydrogen as alternative fuel. Processes such as liquefaction and methanation also make use of modern processes converting coal to liquid fuel like gasoline or diesel.

Estimates of the national coal reserve are put at 2.75 billion tonnes with occurrence spreading over 13 states of the country (Obaje, et. al.1998). Coal deposits occur within Enugu, Orukpa - Benue and Okaba – Kogi (Behre, 2005 and Ofor, 1997), within the Cretaceous Anambra depositional basin (Fig 1). Nigerian coal is noted to be suitable for boiler fuel, calorific gas production, domestic heating, briquettes, coking coal for steel production. Having characteristic properties of low sulfur, low ash content and low thermoplastic properties, the coal attains the sub-bituminous rank of coal and is thereby made fit for use by electric

basinwhile upper Benue contains lignite and sub-bituminous coal in the Maastrichtian Gombe sandstone Formation (Obaje, et al, 1998). This suggests that the sub-bituminous coal in the lower and upper Benue are optimum for combustion and sub optimum for liquefaction, while the high volatile bituminous coal in the middle Benue (Anambra Basin) are suitable for liquefaction and prove to be good raw material for coke making (carbonization) in steel production. The stabilization of Nigerian coal with Portland cement (gypsum + limestone) gave effective results, indicating that the stabilized coal has potential for use for various construction purposes (Okagbue and Ocholor, 2004).

In order to assess the quality and composition of the coal deposits, samples of coal were collected from the three locations (Enugu, Orukpa and Okaba), and subsequently taken to the laboratory for analysis. The coal samples were subjected to proximate analysis to determine the moisture, ash, sulfur and fixed carbon content (Ward, 1984). Additional tests carried out include caloric value (CV) and specific gravity (SG). Since the use of coal is determined by the quality, it is attempted in this study to evaluate the potential of coal in brick making in a sustained environmentally friendly manner

Fig. 1: Map of proved coal reserve showing sample locations (1, 2 & 3) Source: Ofor '97



II. METHOD OF STUDY

Fresh samples of coal were collected from the various locations and well packaged in polythene bags to preserve the moisture content, labelled and transported to the laboratory for analysis. The samples were pulverized and subjected to assessment of the Atterberg limits and shrinkage limits, adopting British Standard B.S 1377(1990) for testing of soil.

Proximate test on the samples was also done to determine coal quality using British Standard B.S.1016 part 3 (1973) as standard procedure for analysis to determine the moisture content, ash content, sulfur and fixed carbon content.

A. Linear Shrinkage

Linear shrinkage measured the reduction in size on loss of moisture after heating for 24 hours at 110°C in an oven. To successfully achieve this, clay was added as a bonding material since coal is not cohesive in its natural state.

B. Fixed Carbon

The determination of fixed Carbon (FC) content was done using British Standard B.S 1016 part 3 (1973), and calculation was done using the formula

$$FC = \frac{\text{Weight difference}}{\text{Weight of sample}} \times 100 = \% \text{ Organic matter} \times 1.72$$

Using the Rapid Titrimetric Method, 1g of pulverized coal sample was oxidized with potassium dichromate in the presence of concentrated sulphuric acid for 15 minutes on the hot plate. The oxidized residue was made up to 10m with distilled water and 20m of the solution was titrated with ferrous ammonium sulphate in the presence of barium diphenylamine sulphate indicator. It was further repeated for other samples, while a blank was also prepared with dichromate and sulphate acid. The calculation of titre value was done using the following formula:

$$\frac{18.2 \text{ titre value} - 10.0 \text{g of sample} \times .2 \times .3}{\text{Weight of sample} (.1)} = FC \times 4$$

C. Moisture Content

Moisture is an important property of coal as total moisture is analyzed by loss of mass between an untreated sample and the sample once analyzed. Placing small quantity of pulverized sample in a container with the weight recorded and then oven dried for 12 hours in an oven temperature of 105°C, then weighed again when removed from oven and cooled. The moisture content is determined using the formula

$$\frac{\text{Mass of water}}{\text{Mass of solid soil}} \times 100$$

D. Ash Content

Ash content of coal is the non-combustible residue left after coal is burnt. This represents the bulk mineral matter after carbon, oxygen, sulfur and water have been driven off during combustion. Analysis is fairly straight forward, with the coal thoroughly burnt and the ash material expressed as a percentage of the original weight.

$$\frac{\text{Initial weight} - \text{residual weight}}{\text{Initial weight}} \times 100$$

III. RESULTS AND DISCUSSION

The results for the liquid limit, plastic limit, plasticity index and linear shrinkage for samples from Enugu, Okaba in Kogi and Orukpa in Benue, are shown in table 1 below.

Table 1: Atterberg's Limits of the various coals

Test type	Enugu	Orukpa	Okaba
Liquid limit (%)	37.2	31.1	29.5
Plastic Limit (%)	31.7	24.2	26.2
Plasticity Index (%)	5.5	6.9	3.3
Linear Shrinkage (%)	6.4	5.7	2.9

Table 2: Proximate test result of the coals

Test type	Enugu	Orukpa	Okaba
Fixed Carbon (%)	82	80.6	80.2
Moisture Content (%)	5.0	5.1	5.2
Ash Content (%)	12.0	13.2	13.5
Sulphur (%)	1.0	1.1	1.1

The Atterberg limits test carried out on the coals showed that the samples are not cohesive, difficult to work with, and particularly did not absorb water upon mixing after pulverizing.

To achieve best result and in line with British Standard B.S 1377 (1990) for geotechnical soils, Clay a cohesive soil was added as a bonding or cementing material for the coal in a ratio 2:5, for its potential to absorb water and also mix well with coal.

Though coal is not cohesive, the addition of clay increased its workability and its potential expansiveness; and it recorded low swelling potential upon comparison with a standard for swelling potential for soil (Ola, 1982), having low plasticity index (<15%).

Table 3: Plasticity of Coal in relation to Swelling (after Ola, 1982)

Plasticity index %	Swelling Potential
0-15	Low
15-25	Medium
25-35	High
>35	Very High

Clay in the coals enhanced their plastic behaviour, making them best for brick production that is stable. Low water absorption character will enhance brick making, thereby eliminating tendency towards structural failure due to expansion on absorption of water or contraction and loss of moisture due to heated climate change.

The linear shrinkage values for the coals are generally low and suggest that they do not lose water and show negligible reduction and distortion in the shape and size of the final brick.

A. Proximate Test Result.

The proximate test results for the coal samples collected from Enugu, Orukpa and Okaba were as follows high fixed carbon, low sulfur, low moisture content and low ash content as most of the coal is burnt implying that much energy can be got from its use for power generation as shown by absorption of 4 times more dichromate by the coal samples.

Sulfur content is low meaning that for its use in brick production its effect has to be completely eliminated. Obaje et. al. (1998) showed from their work that to eliminate the effect of sulfur, limestone could be added for safe usage without health implication.

Low ash content in the coal is indicative of best coal quality according to world coal institute and is a critical factor in selecting coals for steam power generation.

The low moisture content indicates that bricks produced will be stable as no loss of water occurs thereby giving a stable structure.

IV. CONCLUSION

The various coal samples have liquid limits of 37.2%, 31.1%, 29.5% for Enugu, Orukpa and Okaba respectively, showing that they are between intermediate and low in plasticity and compressibility.

The plastic limit for the coals were 31.7%, 24.2% and 26.2% with plasticity index of between 3.3% and 5.5%, which gives the coals a good performance characteristics towards brick making. Assessment based on the Rigidity and stability of bricks produced, gave indication to the fact that the coals are:

- *Sufficiently strong and stable*
- *Resistant to rain penetration due to poor absorption of water*
- *Able to provide sufficient thermal insulation*
- *Dimensionally stable, ensuring freedom from cracking and distortion*
- *Durable*

The proximate test results show the coals to be high in carbon content implying they are best for energy generation, and good for brick making as thermal heat inherent in the bricks produce impact, fast baking to the bonding clay. And that coal by-product from power plant or steel production plant could be safely used for brick making thereby reducing waste production. The coals are found to be suitable for large scale usage in brick production for low income houses and they have the advantage of being available as well as cheap.

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