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Full Length Research Article

Assessment of Physicochemical Properties of some Bitumens from Nigerian Resources

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ABSTRACT: Bitumen is a cheap, common, and important material in today's technological world. Bitumens gotten at different locations on earth, and produced from different manufacturing processes, or crude feedstocks can however have wide variations in physico-chemical properties and levels of service performances. Hence reliability, handling, and modification in technological usage of different bitumens demands that proper information on a given harvested one should be consulted. Nigeria has large reserves of natural bitumen resources and potentials for sustained production of bitumen in large quantity, but basic applicable public information is lacking on bitumens at most locations of the resources. In this paper, proper test-obtained result of the properties is presented for three bitumen samples obtained from some important sources in the country. Assessment of the results vis-a-vis available information on bitumens elsewhere indicate that any clear surface or underground natural bitumen obtainable in the region of Agbabu village in Ondo State, and a manufactured type from Kaduna Refining and Petrochemical Company (KRPC) in the country are comparable with bitumens of good or acceptable qualities from other locations in the world. Bitumen from the region and the as-manufactured are therefore recommended to be producing in large available quantity and exploiting for different technological applications.
Keywords: Bitumen, resources at Agbabu and KRPC, quality, usage, properties, basic information.

INTRODUCTION

Bitumen is a mixture of organic liquids that are highly viscous, black, sticky and entirely soluble in carbon disulphide. Although no two bitumen are chemically identical and chemical analysis cannot be used to define the exact chemical composition of bitumen, elemental analysis indicates that most bitumen contain 79-88% carbon; 7-13% hydrogen, traces to 3% nitrogen; 8% sulphur; 8% oxygen by weight (UNEP and ILO, 2004).

Bitumens were used in ancient times as far back as over 3,500 BC for corpse preservation such as the Egyptian mummifications of the Pharaohs. It was also used for water proofing of baskets. It is primarily used today for paving roads and parking lots, roofing, corrosion protection, general industrial and special purposes. Oxidized bitumens are used for pipe coating, manufacture of paints, hydraulic applications, under sealing for concrete pavement (UNEP and ILO, 2004).

In Nigeria, natural bitumen has been found in Ondo, Lagos, Ogun, Edo, and Enugu States with a combined proven reserve of about 14.86 billion barrels. Geologically, the main bitumen belt in Nigeria occurs on the eastern margin of a coastal sedimentary basin known as the Benin Basin, which extends through Togo and Benin Republic to Western Nigeria. The crystalline basement rocks form the foundation of the whole area (Sheikh, 2003; FMSMD, 2006).

Ondo State is the most noted area of bitumen activities in the belt and has offices of Nigerian Bitumen Development Project located at Akure and Ore. Generally some distinct bitumen-impregnated hydrocarbon types of occurrence have been identified within the Nigerian bitumen belt from topsoil downwards and location to location as: Outcrop, rich sands, lean sands, shales and heavy crudes (FMSMD, 2006).

The average bitumen content of Nigerian tarsand is about 20% by weight. Very rich natural bitumen deposits are found in Ondo State around the region of Idiobilayo, Foriku, Agbabu, Okitipupa, and Aiyibi. Generally tarsands are composed of bitumen, water and some mineral accessories. Tarsands with 5 – 10% by weight bitumen content are designated as good or medium grade (Oshinowo, *et al*., 1982; FMSMD, 2006).

Personnel discussions with some KRPC staff have shown the company is the most important synthetic bitumen manufacturing outfit in Nigeria. The information also indicates that the company has an installed capacity for producing up to 4000 barrels of bitumen a day. The bitumen from the company is manufactured by blending Nigerian crude feedstock which is per se not suitable for bitumen production with imported suitable crudes such as; Lagomar from Venezuela, light Arabian from Saudi Arabia, Basra from Iran, and the Kuwaiti ones (Olarere, 1991). The social, economic and technological benefits these bitumen resources exploitation to the country are enormous (Sheikh, 2003)

Proper characterization of bitumen from a source provides information that enables prospective users of the bitumen to assess desired suitability levels for particular applications, select and use the material properly and efficiently from alternative bitumens. The critical issues in the characterization process are determination of the following:

i Chemical composition. Bitumen whose chemical composition deviates significantly from the generally known average composition for bitumens or most good ones from different sources can be considered to be of lower quality or standard.

ii Kinematic viscosity which gives an indication of adaptability or manipulatability of a bitumen for a purpose when it is at a given temperature.

iii Penetration, which is a property that indicates the quality and grade of a bitumen.

iv Flash point which indicates the fire-hazardousness of a bitumen.

v Softening point which is useful in determining the temperature susceptibility of a bitumen in its heating characteristics and knowledge of it useful as a safety guide in handling a bitumen while heating it.

vi Specific gravity which also determines the quality of a bitumen.

vii Weathering resistance. The significance of this is that the higher the resistance of a bitumen to deterioration with weather, the better it is. (Institute of Petroleum, 1980; Sarkar, 1998; Mummah and Muktar, 2001):

The objective of this paper is to provide some fundamental information required on bitumen resources from Agbabu village in Ondo State and KRPC-manufactured bitumen for, technological applications such as corrosion protection or research purposes.

MATERIALS AND METHODOLOGY

Materials

Two natural bitumen samples were collected from the richest bitumen spots at Agbabu village in Ondo State. One sample was from a standard extraction hole drilled by early explorers of bitumen in the village and the other from clear outcrop deposits in a waterlogged area on the outskirt of the village. The two samples were assigned identification names Ondo S-B and Ondo S-A respectively. Also a sample of bitumen manufactured using Basra crude blended with the Nigerian crude feedstock with identification name KPB was collected from KRPC.

Methods

Determination of Chemical Composition

The chemical composition by percentage elemental weight of each sample was determined principally by the Instrumental Neutron Activation Analysis (NAA) at CERT. High fluxes of neutron energy from the fission of uranium (^{235}U) produced by Nigeria Research Reactor-1 (NIRR-1) installed at CERT were bombarded onto each given bitumen sample. The chemical analysis of a sample was based on the principle that nuclear scattering amplitudes for neutrons do not vary uniformly with atomic number of each element bombarded. The nuclear energy from the reactor scatters each metallic element to respectively suitably more enriched isotope which has scattering amplitudes that are different but more identifiable according to the proportion of amount of each element in the bitumen sample. These characteristics were then determined by computerized instrumentation at the centre to reveal the types and amounts in parts per million (ppm) of some of the chemical elements present in the sample. The results were then converted to percentages of the elements. Up to 40 elements can be analysed by NAA (Jonah *et al*., 2006; Molnar, 2010).

Determination of Flash Point

Test cup, a thermometer, and a Bunsen burner were used for the experiment. Ondo S-A was poured into the test cup to a standard level, the thermometer was inserted into a cup and heated at the rate of 5^0C/min, with the Bunsen flame while periodically passing a small flame across the surface of the bitumen. The flash point was taken as the temperature at which the vapour given off from the bitumen ignites and continues to burn for five seconds. The procedure was repeated for Ondo S-B, and then KPB.

Determination of Penetration

Penetration is an empirical property of bitumen and is used for its quality control and grading. The method of determining it is based on how far a standard needle (specified by ISO 683/XIII and Rockwell hardness C54 – C60) penetrates vertically into a bitumen sample under standard conditions of load, temperature and time. The standard test conditions are 25^0C, 100g-load, and time period of five seconds. Ondo S-A was poured into a cylindrical flat-bottomed glass container immersed in a water bath containing water at a temperature of 25^{0}C for 30 min. The temperature and time were monitored by automatic temperature indicator on the bath and a watch respectively. The standard one-millimetre diameter needle with a load of 100g was allowed to touch the surface of the bitumen in the container. The needle was then released to fall under gravity on the sample for five seconds and the penetration value was obtained from its digital indicator. This was repeated with Ondo S-B and then KPB sample.

Determination of the Effect of Oxidation or weathering resistance

During weathering the rheolgical properties of a bitumen change and the bitumen becomes harder. This can be catastrophic with respect to its surface cracking. Tesst results from weatering resistance of bitumen are useful in its modification or processing (Sarkar, 1998; Srivastava and Roijen, 2000; Mummah and Muktar, 2001) The test was carried out to determine the effect of weather on each bitumen sample in accordance to the method used by Mummah and Muktar (2001). A portion of each of Ondo S-A, Ondo S-B, and KPB was heated to same suitable soft condition and poured to the same level into separate, transparent glass containers of similar cross-sectional sizes. The initial thickness of bitumen in each container was noted.

The containers were then exposed to ambient weather conditions on the fence top of the laboratory in February 2009 in Kaduna, Nigeria. Measurements were made to the thickness of the bitumen portion in each of the container every week for a period of five weeks using a ruler (Mummah and Muktar, 2001).

Determination of Softening Point

Ring balls, centering guides and a mercury-in-glass thermometer were used for the test. A portion of Ondo S-A was poured into the ring and allowed to cool, so that a flat disc of the bitumen was enclosed completely in the ring. The ring was fitted to an opening on a metal carrier and immersed in water at a temperature of 25^{0}C. A standard steel ball of 9.53mm in diameter was placed centrally on top of the bitumen in the ring. The water was then heated at a constant rate until the ball fell through a standard height of 25mm of the ring. The temperature at that instance was then recorded. The test was similarly repeated with Ondo S-B, and then KPB.

Relative density

A 250cm^3 glass container of 75mm internal diameter, an electronic digital weighing scale, a steel ruler, and a small steel slab that could be contained in the container were used. The slab was immersed in water poured to about half capacity of the container and the change in volume level of water in the container (V_1) determined in cubic centimetres. The container with its contents were then weighed using the scale and the resultant mass (M_1) noted. The slab was gently removed from the container and all water on it allowed to drip into the container. A small portion of Ondo S-A at room temperature was detached from the sample and placed on the slab, and the previous procedure repeated to obtain another volume (V_2) and mass (M_2). The relative density of Ondo S-A (ρ) was thus determined as,

$$\rho = \frac{M_2 - M_1}{V_2 - V_1}$$

This was similarly repeated for the case with Ondo S-B and then KPB.

Determination of Viscosity

The Saybolt viscometer was used in this experiment. A portion of Ondo S-A was heated in a closed container for three hours at a temperature above the one in which the viscosity was to be determined, whilst taking care to prevent local overheating and loss of volatile constituents. The portion was then allowed to cool to a temperature slightly above the one at which its viscosity was to be tested. After cleaning the viscometer cup with carbon tetrachloride, a cork was inserted in the bottom of the cup and the prepared portion poured into it to such a height that the leveling peg on the bath was just immersed in a KV bath when the bath was vertical. The viscometer was then immersed in the bath under controlled constant condition of the bath medium temperature that did not vary more than $\pm$0.01^{0}C over the length of the viscometer. The time in seconds it took the bitumen to rise to a standard level of 50ml as indicated by sections in the cylinder of the viscometer was recorded. The bath contained water and was heated electrically. The viscosities of the bitumen in Poise at 60 and 100^{0}C were recorded.

RESULTS AND DISCUSSIONS

The results of the chemical compositions and physicochemical properties of Ondo S-A, Ondo S-B and KPB are given in Tables 1-4. The chemical compositions of five natural bitumen samples from other locations in the Nigerian tarsand belt have been investigated, by Sheikh (2003). The chemical elements and percentage ranges of their contents by weight for the samples are as follows; The main difference between the compositons of the Ondo samples and those presented in Sheikh (2003) is the presence of trace elements of aluminium, magnesium, titanium, vanadium, in the Ondo samples. One reason that may be attributed to the presence of some of the trace elements in Ondo S-A and Ondo S-B, but not in bitumen reported by Sheikh (2003) presented compositions is in the methods of detection and analyses of the elements. The NAA is a quantitative and qualitative method of high efficiency for the precise determination of main-components and trace elements in different samples compared to most methods of analysis (Jonah *et al*., 2006; Jonah, 2007; Molnar, 2010).

Table 1: Elemental Composition by weight (%)

Element	Bitumen Sample used		
	Ondo S-A	Ondo S-B	KPB
Al	0.09	0.07	-
Mn	0.05	0.04	2.04
Ti	0.02	-	-
V	0.05	-	0.02

As can be observed from Table 2; the values of penetration, softening point and specific gravity of Ondo bitumen samples compare favourably with respective values of 116,34 and 0.91 obtained by Adebayo (2004) at another location in the Ondo tarsand. The penetration values obtained for KPB fall below 100mm, so coatings based on bitumen from the sample sources will not be associated with bad cracking (Adegoke, 1989; Mummah and Muktar, 2001). The penetration value of each bitumen sample also fall in the range of 80-120mm as reported by Mummah and Muktar (2001) and Adebayo (2004) for bitumen of acceptable grades. The flash point of each bitumen sample also lies in the range of 245-352^{0}C as given by Mummah and Muktar (2001) for most bitumen of good grade. The specific gravity of each bitumen sample also compares favourably with that for asphalt standard of 1.013 as given by Adebayo (2004).

Table 2: Control Properties

Property	Result obtained		
	Ondo S-A	**Ondo S-B**	**KPB**
Penetration (mm)	120	116	85
Flash point (^{0}C)	260	269	320
Softening Point (^{0}C)	36.5	37	45
Specific gravity	0.92	0.95	1.08

All bitumens weather at slow rates (Table 3). The trend and level of weathering resistance of each bitumen sample Ondo S-A, ondo S-B, and KPB, is comparable to that of some bitumen tested and asserted of good weathering levels and resistance by Mummah and Muktar (2001). At 20^{0}C the viscosities of some types of bitumen range from 10^3 to 10^8 Poise depending on the type; compared to water 10^{-2} Poise,diesel 10^{-1} Poise, and engine oil 10 Poise. The viscosities however decrease with increase in temperature (Jackson and Ravindra, 1996). This trend of behaviour is also observed with Ondo S-A, Ondo S-B, and KPB as can be seen in Table 4. KPB is the most viscous sample, followed by Ondo S-B, and then Ondo S-A.

Table 3: Oxidation Test Result

Time of Exposure	Thickness of Bitumen (mm)		
	Ondo S-A	**Ondo S-B**	**KPB**
0 week	2.9	2.9	2.9
First week	2.8	2.8	2.9
Second week	2.5	2.6	2.7
Third week	2.2	2.3	2.4
Fourth week	1.9	1.9	2.1
Fifth week	1.7	1.8	2.1

Table 4: Viscosities at specified temperatures

Sample	Viscosity (Poise)	
	@ 60 ^{o}C	@ 100 ^{o}C
Ondo S-A	5.19×10^4	1.2×10^4
Ondo S-B	5.20×10^4	1.25×10^4
KPB	6.27×10^4	2.49×10^4

CONCLUSIONS

The physico-chemical properties of natural bitumen samples from Agbabu village in Ondo State, and a manufactured sample from KRPC have been determined using routine physical and chemical methods. The results indicated that the bitumen from which the test samples were obtained are all comparable with bitumens of good or acceptable qualities from other locations in the world. The physico-chemical properties of the bitumens are however found to be different. Ondo S-A and Ondo S-B, are however much more close in properties while that of KPB is more or less different. The information presented is basic and a contribution towards utilizing the abundant bitumen resources at the two locations for technological applications.

RECOMMENDATION

The bitumen resources from Agbabu village in Ondo State and the KRPC-manufactured bitumen from Nigerian crude feedstock blended with Basra crude are recommended to be produced in large quantities and exploited for technological applications particularly in Nigeria.

REFERENCES

Adebayo, E.A. (2004). Extraction and Characterization of Bitumen from Ondo State Tarsand, proceedings of the 8th National Engineering conference of Kaduna Polytechnic, Nigeria PP. 82-88 `

Federal Ministry of Solid Minerals Development (FMSMD) (March, 2006). Technical Overview in Nigeria's Bitumen Belt and Development Potential. Report, PP. 1-14, Federal Ministry of Solid Minerials Development, Abuja, Nigeria.

Institute of Petroleum (1993). *Standard Methods for Analysis of Petroleum and Related Products Vol.1 and 2.* Published by Heyden and Son Ltd on Behalf of Institute of Petroleum London, England, PP 35-222.

Jackson, N. and Ravindra, K.D. (1996). *Civil. Engineering Materials.* Macmillan Press Limited, London, England, pp. 53-64.

Jonah, S.A. (2007). Application of Neutron Activation Analysis Technique, Technical Report, Centre for Energy Research and Training, ABU Zaria, Nigeria.

Jonah, S.A., Umar, I.M., Oladipo, M.O.A., Balogun, G.I., Adeyemo, D.J. (2006). Standardization of N.I.R.R-1 Irradiation and Counting Facilities for Instrumental Neutron Activation Analysis. *Applied Radiation and Isotopes*, **64(7):** 818-822.

Molnar, Z.S. (2010). Neutron Activation Analysis Retrieved on 12th January, 2012 from http://www.reak.bme.hu/wignercoursemanualsbudapest/.

Mumah, S.N. and Muktar, S. (2001). Improving Road Pavements with Natural Rubber. *Journal of Engineering Technology and Industrial Applications*, **1(3):** 208-220.

Olalere, A. (1991). Asphalt/Bitumen Production From Nigerian Crude. A HND Research Project, Unpublished, Department of Chemical Engineering, Kaduna Polytechnic, Nigeria.

Oshionowo, T., Ademodi, B., Adediran, A.S. (1982). Bitumenous Tarsands of Nigeria: Analysis of Oils Part I. *Journal of Nigerian Society of Chemical Engineers*, **1(1):** 44-48.

Pavia, D.L., Lapman, G.M., and Kriz, G.S. (1982). Introduction to Organic Laboratory Techniques- A Contemporary Approach, 2nd Edition, CBS College Publishing, New York, PP.585-596

Sarkar, G.N. (1998). Advanced Refining, Indian Oil Corporation Limited, Gujarat Refinery, Romesh Chander Khanna Publishers Nai Sarah, Delhi, India pp. 521 – 522.

Sheikh, G.M. (2003). Bitumen Exploitation and Development in Nigeria. A Paper Presented to the Nigerian Society of Engineers March.

Srivastava A. and Roijen R.V. (2000). Bitumen Performance in Hot and Arid Climates. A Paper Prepared for Pavement Seminar for Middle East and North Africa Region on Innovative Road Rehabilitation and Recycling Technologies, New Policies and Practices in Pavement Design and Education, Amman. Jordan. UNEP and ILO (2004). Concise International Chemical Assessment Document 59, Published Under the Joint Sponsorship of the United Nations Environment Programme, the International Labour Organization and World Health Organization, Geneva, Switzerland.