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An Examination of the Use of Liquid Asphalt Binders in Road Works in Nigeria

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Abstract: The significant role of liquid asphalt binders in the construction, maintenance and rehabilitation of bituminous pavements cannot be ignored. Incidentially, it is estimated that more than 98 % of Nigeria's over 40.000 km surfaced road network is bituminous-surfaced. The common experience in maintenance and rehabilitation of roads in Nigeria is that the pavements fail very soon after rehabilitation. In conducting research into the possible causes of these early failures, this study takes a look at the characteristics of the liquid asphalt binders used in maintenance and rehabilitation of roads in the country. The nearly exclusive use of cutback asphalt, even when asphalt emulsions would give higher returns in terms of performance and cost-effectiveness, is evaluated, the faulty processes of production of cutback asphalt are highlighted and appropriate recommendations are made.

Key words: Asphalt binder, cutback asphalt, asphalt emulsion, road works, Nigeria

INTRODUCTION

Liquid asphalt, beside road oils manufactured directly from the refinery, is produced when asphalt cement is blended or "cut back" with petroleum distillates or emulsified with water and an emulsifying agent. Liquid asphalt binders are used for variety of purposes in the paving industry including prime coat, surface dressing, seal coat, grouting or penetration work, soil stabilization and tack coat in overlay rehabilitation, amongst other uses.

There are two conventional types of liquid asphalt binders, namely cutback asphalt and asphalt emulsions. Foamed (expanded) asphalt can be described as a modern type of liquid asphalt binder and there is no record of its use in Nigeria so far.

At present, there is almost exclusive use of cutback asphalt in road works in Nigeria, even when asphalt emulsions would give higher returns in terms of performance and cost-effectiveness. A very large proportion of cutback asphalt used in road works in the country is self-blended and mixed just prior to usage on site. However, some fundamental flaws have been observed in the production of such cutback asphalt by the road contractors. These flaws, it is believed, contribute negatively to the performance of roads constructed/rehabilitated in the country.

This study evaluates the production and usage of cutback asphalt and asphalt emulsions in road works in the country. Some of the flaws in the production of cutback asphalt by road contractors are also highlighted.

TYPES AND GRADES OF CUTBACK ASPHALTS

Cutback asphalt is simply a combination of asphalt cement and petroleum solvent. Cutbacks are used because they have reduced binder viscosity for lower temperature uses (tack coats, fog seals, slurry seals, stabilization material, etc.). After cutback asphalt is applied the petroleum solvent evaporates leaving behind asphalt cement residue on the surface to which it was applied. Cutback asphalt is said to "cure" as the petroleum solvent evaporates to form the original asphalt cement.

Cutback asphalts are classified into three main types on the basis of the relative speed of evaporation of the solvents in them. The three main types of cutback asphalts are:

- Rapid Curing (RC) cutback asphalt, composed of asphalt cement and a solvent of a volatility similar to that of naphtha or gasoline, which evaporates at a fast speed.
- Medium Curing (MC) cutback asphalt, containing a solvent of volatility similar to that of kerosene, which evaporates at a medium speed and
- Slow Curing (SC) cutback asphalt, which contains an oil of relatively low volatility.

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According to Roberts *et al*. (1996), the use of cutback asphalts is decreasing (in developed countries) because of the following reasons:

Environmental regulations: Cutback asphalts contain volatile chemicals that evaporate into the atmosphere, unlike emulsified asphalts which evaporate water into the atmosphere.

Loss of high energy products: The petroleum solvents used require higher amounts of energy to manufacture and are expensive compared to the water and emulsifying agents used in emulsified asphalts.

In many (developed) countries, the use of cutback asphalt is restricted to patching materials in cold weather.

TYPES AND GRADES OF EMULSIFIED ASPHALTS

Emulsified asphalt (or asphalt emulsion) is simply a suspension of small asphalt cement globules in water, which is assisted by an emulsifying agent (such as soap) (Fig. 1). The emulsifying agent assists by imparting an electrical charge to the surface of the asphalt cement globules so that they do not coalesce (Roberts *et al*., 1996). Asphalt emulsions are used because they effectively have reduced binder viscosity for lower temperature uses (tack coats, fog seals, slurry seals, Bituminous Surface Treatments (BST), stabilization material, etc.).

Emulsified asphalts are divided into three major groups, namely, anionic, cationic and nonionic, on the basis of the electrical charges of the asphalt particles in the emulsion, as follows:

- An anionic asphalt emulsion has negatively-charged asphalt particles and is usually more suitable for use with calcareous aggregates (e.g., limestone), which tend to have positive surface charges.
- A cationic asphalt emulsion has positively charged asphalt particles and is usually more suitable for use with siliceous aggregates (e.g., river gravel), which tend to have negative surface charges.
- A nonionic asphalt emulsion contains asphalt particles that are electrically neutral. Nonionic asphalt emulsions are not used in pavement applications.

Asphalt emulsions are further classified into three main types on the basis of how quickly the suspended asphalt particles revert back to asphalt cement, a form in which it is actually needed as a binder. The three types are:

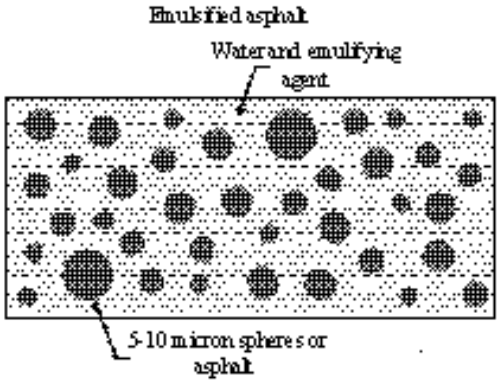

Fig. 1: Emulsified asphalt schematics
Source: Construction Standard Specification (1995)

- Rapid-Setting (RS) emulsion, designed to demulsify quickly (to break away from the emulsion form such that asphalt particles recombine) upon contact with an aggregate. It is best used in spraying applications where mixing is not required but fast setting is desirable.
- Medium-Setting (MS) emulsion, designed to have good mixing characteristics with coarse aggregates and to demulsify after proper mixing. It is suitable for applications where mixing with coarse aggregate is required.
- Slow-Setting (SS) emulsion, designed to be very stable in the emulsion form and is suitable for use where good flowing characteristics are desired or where mixing with fine aggregate is required. It is also suitable where long periods of storage are desired.

FOAMED (EXPANDED) ASPHALT

Foamed asphalt is formed by combining hot asphalt binder with small amounts of cold water. When the cold water comes in contact with the hot asphalt binder it turns to steam, which becomes trapped in tiny asphalt binder bubbles. The result is a thin-film, high volume asphalt foam with approximately 10 times more coating potential than the asphalt binder in its normal liquid state (WSDOT, 2003). This high volume foam state only lasts for a few minutes, after which the asphalt binder acquires its original properties. Foamed asphalt can be used as a binder in soil or base course stabilization and is often used as the stabilizing agent in full-depth asphalt reclamation.

ASPHALT CEMENT USED IN NIGERIA

Asphalt cement used in virtually all road construction and maintenance activities in Nigeria is the 60/70 pen

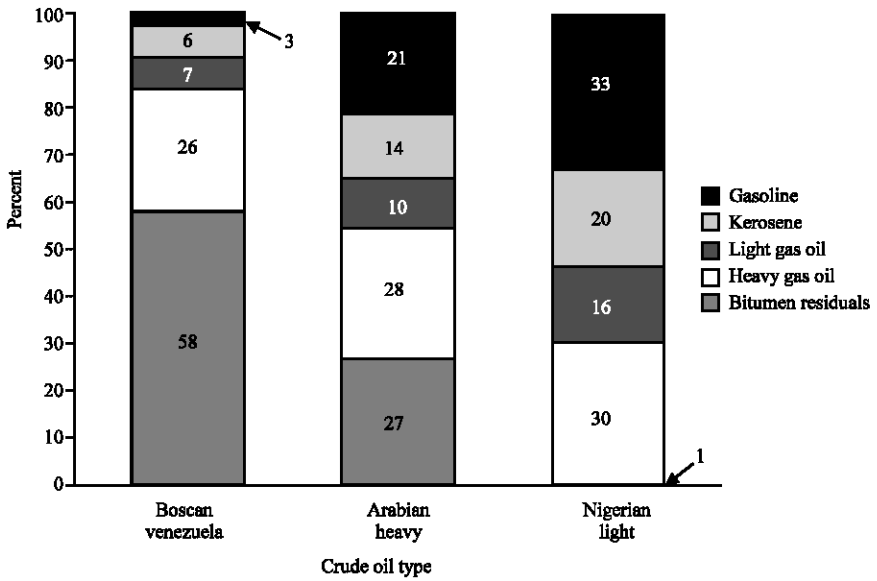

Fig. 2: Typical composition of some crude oils, WSDOT (2003)

asphalt. This is largely because the characteristics of grade 60/70 are very suitable for the prevailing temperature range in the country-being a tropical country. For hot climatic condition with a mean annual air temperature of 24°C or greater, the use of a 40/50 or 60/70 pen. asphalt is recommended (Asphalt Institute, 1991).

Currently, the 60/70 pen asphalt cement grade used in the country is exclusively imported from countries such as Venezuela, Cote d'Ivoire, Italy, South Africa, etc. The major reason for the exclusive importation is because the Nigerian Light Crude Oil can produce only about 1% fraction of bitumen, unlike Heavy Crude Oil of Venezuela which produces as high as 58% fraction of bitumen (Fig. 2).

The Kaduna refinery is one of the four refineries in Nigeria. The refinery started the distillation of heavy crude oil to produce bitumen in 1979. The heavy crude oil was imported from Venezuela under an exchange program-heavy crude oil of Venezuela was obtained in exchange for Nigeria's light crude oil. The Kaduna refinery was the only one out of the four refineries in Nigeria that had the capacity to refine both heavy and light crude oil.

At present, Kaduna refinery has stopped the production of bitumen since 1997 due to two major reasons-a fire outbreak that gutted the bitumen production section of the refinery in 1996 and pipeline vandalization. The heavy crude oil used to be imported into the country through the Escravos port in Warri and piped to Kaduna refinery for processing. Pipeline vandalization has made it impossible to transport the heavy crude oil using this medium.

LIQUID ASPHALT BINDERS IN USE IN NIGERIA

Evidence shows that different grades of cutback and emulsified asphalts have been used in road construction/maintenance in the country. Examples of such grades that have been used in the past as liquid asphalt binders include CRS2, RS1 and RS2 (emulsion); and MC1, MCO and S125 (cutback). CRS2 is cationic RS2 while S125 is a cutback asphalt blend popularly used as tack coat in the country. At present, only RS1, MC1 and S125 are in use.

Of the above three binders still in use, MC1 has the most predominant usage among road construction/ maintenance workers. There is decreasing patronage of emulsified asphalt over the years, even in the face of its better performance and lower purchasing costs. West African Bitumen Emulsion Company (WABECO), as the only current manufacturer of emulsified asphalt in the country, sells at a rate of 6 tonnes of cutback bitumen (MC1) to one tonne of bitumen emulsion.

Some of the reasons for bitumen emulsion's significantly reduced patronage include:

- The 'complexity' of its manufacturing process, storage and transportation to work site and the risk of the emulsified asphalt 'breaking' during the process. A specially designed colloid milling machine, among other things, is required for the production and only WABECO presently has such machine installed at Kaduna.
- Bitumen emulsion requires special equipment to apply on site.

Fig. 3: Stationary bitumen heater used for the production of MC1/S125 at lagos state asphalt plant

Fig. 4: A typical mobile bitumen heater at a road rehabilitation site, getting set to produce MC1/S125 at jibowu, lagos

- There is non-familiarity with its application and advantages among road contractors and engineers.
- Officials of ministries of work at federal and state levels insist on the usage of cutback asphalt, even when some road contractors show preference for the use of emulsion asphalt in road works. There is the belief among engineers that bitumen has to be heated for all its applications.
- There is absence of legislation to restrict the use of bituminous products that emit hazardous pollutants into the environment, as obtained in developed countries.
- Unwillingness of the government, through the ministries of works, to insist on the use of bitumen emulsion for certain categories of road construction.

Some of the reasons for the preference for cutback asphalt (MC1 and S125)among road contractors include:

- MC1 and S125 are produced from a simple blend of kerosene with bitumen.
- The only equipment required in the production is a pressure feed mobile distributor, which coulde stationary (at the yard-Fig. 3). The cutback asphalt is blended at the yard and then transported to work site in drums. For medium to large scale jobs, the cutback bitumen is conventionally blended in a pressure feed mobile distributor *in-situ* (Fig. 4).

IMPROPER PRODUCTION OF CUTBACK ASPHALT IN NIGERIA

Only two types of cutback asphalt are currently blended and these are MC1 and S125. MC1 and S125 are traditionally produced from a blend of bitumen and kerosene. As earlier stated, S125 is a cutback asphalt blend popularly used as tack coat in the country. The higher percentage of bitumen content in S125 production differentiates it from MC1. However, as a result of absence of regulations for the standard production and usage of liquid asphalt binders in the country, a large percentage of such binders used in road works are not properly blended. There are also conflicting mixing ratios of bitumen to kerosene and mixing temperatures among the various road contractors and asphalt mixing plants. Examples of varying mixing ratios of bitumen to kerosene used by some road contractors and the mixing temperatures are presented in Table 1.

The pressure feed mobile distributor employed by many road contractors in the blending of the cutback asphalt is really not designed for such purpose but to spray the product through its spray bar and also keep the blended cutback at required temperature during transportation to site and before spraying.

In addition to the problem of inconsistency in mixing ratios and temperatures, there is also the major problem of non-homogeneity of blending due to lack of required circulation process. Thorough and homogenous blending of bitumen and kerosene to obtain MC1 and S125 is achieved when the mixture has been allowed to circulate round. This process is further described in this study. It was also discovered that the mixing temperature for the MC1 and S125 could not be truly ascertained because the temperature gauge on many of the pressure feed mobile distributors employed for the blending were noticed to be non-functional.

However, in direct contrast to the widespread improper and inadequate blending of cutback asphalts among road contractors, some of the companies are

Table 1: Mixing ratios and blending temperatures for mc1 and s125 in Nigeria

Road contractors	MC1		S125		Mixing temperature (°C)
	Bitumen (%)	Kerosene (%)	Bitumen (%)	Kerosene (%)	
LOPEK Constr. Ltd, Lagos	50.0	50.0	87.5	12.5	100-120
Lagos State Asphalt Plant*	62.5	37.5	62.5	37.5	100-110
Julius Berger Ltd., Lagos	67.0	33.0	71.0	29.0	150-170
KOPEK Constr.Ltd, Ibadan	80.0	20.0	90.0	10.0	150-160
WABECO, Kaduna	64.0	36.0	88.0	12.0	140-160
RATCON Constr. Ibadan	60.0	40.0	70.0	30.0	110-140
FISKO Constr., Ijebu-Ode	71.5	28.5	80.0	20.0	150-180

* Only one type of cutback asphalt is produced and used for both MC1 and S125 applications

Fig. 5: A temperature dial gauge provided on the Bitumen tanker's side

Fig. 6: Inlet and outlet valves at back of a mobile bitumen tanker

observed to still produce cutback asphalts using standard procedure. Two of these companies are Julius Berger Euro 65 Yard, Lagos and West African Bitumen Emulsion Company (WABECO), Kaduna. The production process employed by these two companies is evaluated briefly in the following study.

STANDARD PRODUCTION OF CUTBACK ASPHALTS

The bitumen in the storage tank (fixed or mobile) is heated to a temperature range of 150-170°C (Fig. 5) for a period of about 12 h. The bitumen from the tanker moves out through the outlet valve (Fig. 6), flows through an inner pipe within a bigger pipe surrounded by hot oil and returns into the tanker through an inlet valve in a continuous cycle (Fig. 7). Heat is supplied from the hot oil to the flowing bitumen, thus direct contact of flame with the bitumen is avoided.

After liquefying the bitumen, the required proportion of the liquid bitumen is transferred into the MC1 (or S125) tank (Fig. 8) containing the required proportion of kerosene. The next stage in the production of MC1 or S125 is subjecting the mixture

Fig. 7: A view of pipes connections used to supply heat to flowing bitumen (Courtesy: Julius Berger Nig. Ltd.)

to continuous agitation through the process of circulating the mixture in and out of the blending tank. With the aid of a specialized pump (Fig. 9), the mixture is drawn out with pressure from the mixing tank through an outlet valve. The mixture is pumped continuously through the pipe network (Fig. 6) and returned into the blending tank. The blending temperature is kept around 50°C with the aid of the attached temperature gauge (Fig. 10).

Fig. 8: Tank designated for the production and storage of MC1

Fig. 9: Special pump used to circulate cutback asphalt mixture

Fig. 10: A temperature gauge attached to MC1/S125 blending tank

CHALLENGES IN THE PRODUCTION, STORAGE AND TRANSPORTATION OF EMULSIFIED ASPHALT

The primary requirements for manufacturing quality emulsified asphalt are:

- Use of high quality ingredients (asphalt-cement, water, emulsifying agents, etc.).
- Pre-mixing or otherwise conditioning those ingredients so that they will be introduced into the milling unit in the correct volume, temperature and homogeneity.
- Use of an emulsion milling unit which provides proper dispersion of asphalt globules within the soap solution at the asphalt content and production rate specified for the plant.
- Proper storage of the finished emulsions product to maintain its high quality until delivered to the final user.

The fundamental ingredients of any asphalt emulsion are clean water, alkali to adjust the pH of the water, emulsifying chemicals and raw asphalt cement (60/70 or 80/100 grade). Normally, raw bitumen is used with no treatment other than to bring it to the required consistent temperature within its storage tank before it enters the emulsion milling unit. Water and emulsifiers are mixed in the proper proportions to provide a soap solution having the correct pH, composition, homogeneity and temperature to be used with hot asphalt in preparing the finished emulsion.

Some properties of emulsified asphalt which can also become serious challenges when not properly understood and taken into consideration are viscosity, breaking, settlement, flocculation and coalescence. These are briefly described below:

Viscosity: This is defined as the resistance to flow of a fluid. The viscosity must be predictable and remain within certain limits throughout the storage life of the emulsion. Some of the most important factors that have an influence on the viscosity include bitumen content, temperature of the emulsion, droplet size distribution, type and storage of emulsifier and type and dosage of stabilizer.

Breaking: The main purpose of emulsifying bitumen is to transfer it to a fluid state at an ambient temperature. The emulsion should be stable during storage and transport but when applied on mineral aggregate or pavement surfaces, it should break. The rate of breaking is largely controlled by the type and dosage of emulsifier, the type of aggregates, the temperature and other climatic conditions.

Settlement: Settlement is a process where the bitumen phase of the emulsified asphalt moves towards the bottom of the emulsion container. Though an emulsion settles, it

does not necessarily mean that it is unstable-gentle agitation often brings the emulsion back to its original quantity. If however, the stability is poor, settlement may lead to coalescence and breaking of the emulsion. The degree of settlement of an emulsion gives an indication of is shelf life.

Flocculation: Flocculation is a process where the droplets start adhering to each other. Very often, there is a large central droplet with smaller droplets surrounding it. Flocculated droplets can often be separated again by agitation.

Coalescence: When droplets in an emulsion merge to form bigger droplets, it is called coalescence. Flocculation is often followed by coalescence. Coalescence can be started because of mechanical action such as agitation, pumping or vibration. Coalescence occurs in the breaking process and is dependant on the aggregate type.

Some of the challenges that have been encountered in the production and transportation of emulsified asphalt in Nigeria include the following:

- Emulsified asphalt 'breaking' prematurely as a result of contamination of the bitumen used for the production. The contamination may be due to impurities which cannot be detected by the conventional tests carried out on bitumen grades.
- Emulsified asphalts also break prematurely during long distance transportation from the manufacturing plant to work site. The perennial bad state of our roads imparts intense undesirable agitation to the bitumen being transported.
- Currently, the only means of transportation of emulsified asphalt is through the use of tanker trucks. Dubious tanker drivers have been known to siphon some of the product en-route and replace with other cheaper but deleterious sub-standard materials.
- Anionic emulsion breaks if it comes in contact with cationic emulsion and vice versa. This happens mostly when a tanker that has previously been used to transport cationic emulsion is subsequently used to transport anionic emulsion. When these products come in contact with each other, neutralization takes place.

APPLICATIONS OF BITUMEN EMULSIONS

Even though the use of bitumen emulsions in Nigeria is not as widespread and popular as cutback asphalt, bitumen emulsions are well suited for many road work applications. Some of the applications of emulsions include:

Tack coat: Tack coat is a light spray of bitumen emulsion, either hand or machine sprayed to ensure the bond between an old surface and a new asphalt mix layer. The tack coat must be very thin and must cover the entire surface evenly. The rate of application should be 0.8-1.0 litres m^{-2} depending on the surface being sprayed. Too much tack coat may create a slippage plane between the two courses as the bitumen may act as a lubricant. After spraying the tack coat, enough time must be allowed for complete breaking to occur before the overlay is placed. Traffic should be kept off the tacked area. Rapid Setting grade one (RS1) of bitumen content 55-60% is usually recommended.

Surface dressing: At surface dressing, a binder is sprayed on the road surface by a bitumen distributor or by hand. An aggregate cover follows immediately, laid by an aggregate spreader and the surface is then rolled as soon as possible. Surface dressing is performed either in single or multiple layers. It is laid on granular bases or existing pavements on many types of roads from low cost surfacing on rural roads to wearing course on roads with relatively high traffic. The importance of having a strong base or pavement under the surface dressing should be noted. Rapid Setting grade two (RS2) of bitumen content 60-68% is usually recommended. The emulsion is designed to give a good adhesion in a breaking time of less than 30 min. The road can then be opened to slow traffic.

Minor road repairs: Sealing of cracks is often done using bitumen emulsions. Cracks appear for several reasons and take many forms, from small hairline cracks to major cracks with 20-30 mm openings. Very small cracks are difficult to seal effectively. Large cracks are filled with emulsion mixed with fine sand, but leaving a short depth from the surface. After curing, the remainder is filled with pure emulsion. The surface is sealed with sand to prevent traffic pick-up.

Cold emulsion mixes are suitable for patching potholes and damaged areas. If small quantities are required, it may be mixed by hand at the worksite. Local aggregates can often be used. Also, the spray patch method is used for pothole repair. Here, the pothole is filled with aggregate up to the surfacing level and then sprayed over with bitumen emulsion, which penetrates into the aggregate. The surface is finally dressed with fine sand.

Other uses of emulsion include: Dust binding, Fog seal, Recycling, Penetration macadam and In-place stabilization.

PRICES OF ASPHALT CEMENT AND LIQUID ASPHALT BINDERS IN NIGERIA

The importation and usage of bitumen in the country is increasing on a yearly basis. This can be attested to by the records from WABECO (one of the three major importers of bitumen into the country), as given in Table 2. Apart from WABECO, OANDO and TOTAL Plc. are the other major importers of bitumen in the country. Thus by extrapolation, Nigeria can safely be said to be currently importing not less than 100,000 metric tonnes of bitumen annually at an estimated cost of over eight billion naira (Information on quantities of bitumen imported into the country by the other importers of bitumen visited could not be obtained).

In the U.S., an estimated 22 million tonnes of hot-mix asphalt cement concrete, an estimated 0.75 million tonnes of cutback asphalt and approximately 1.76 million tonnes of emulsified asphalt were sold in 1994 (Moulthrop *et al*., 1997). The cutback asphalt sold represents about 3% of sales of all asphalt binder types used in that year while the emulsified asphalt sold represents about seven percent of overall use of all asphalt types that year.

The current price list of bituminous materials as supplied by WABECO, Kaduna is given in Table 3. As can be seen from the table, the cost of purchase of asphalt emulsion is lower than that of cutback asphalts.

The use of emulsified asphalt in road construction and maintenance in Nigeria is fast declining despite its better suitability and lower purchasing costs when compared to cutback asphalt. While bitumen, cutback or emulsions can be used as binders for surface dressing (for example), emulsions have several advantages compared to the others and these include:

- Damp aggregate can be used.
- High binder temperature is not required.
- Fire hazard related to cutback is eliminated.

A number of states in the U.S. recognize the emission potential from the use of cutback asphalts and have established regulations limiting the amounts used and the time of year when they are used.

A very large proportion of cutback asphalt used in road works in the country is self-blended and mixed just prior to usage on site. However, some flaws have been observed in the production of such cutback asphalt by the road contractors. These flaws, it is believed, will definitely have negative impacts on the performance of roads constructed/rehabilitated. Some of the observed flaws include:

Table 2: Quantity of imported bitumen by WABECO into Nigeria

Year	Quantity imported (Metric tonnes)
2001	13.000
2002	20.000
2003	40.000
2004	46.000
2005	50.000
2006	50.000
January-May 2007	20.000

Courtesy: WABECO, Apapa Port, Nigeria

Table 3: Typical current price list of bitumen and bituminous materials in Nigeria

Sales		
Product	₦/Tonne	₦/Drum
RS	80,500.00	17,885.00
MC1	88,095.00	19,404.00
S125	89,880.00	19,761.00
MC0	90,013.00	19,787.60
60/70	69,000.00 (Lagos)	-
60/70	81,000.00 (Kaduna)	18,795.00 (Kaduna)

Courtesy: WABECO, Kaduna

- Incorrect mixing proportions of bitumen with solvent (kerosene).
- Inability to heat the mixture up to the recommended temperature range of 140-160°C without risking reaching the flash point and a possible fire hazard.
- Inability to achieve required circulation/agitation of bitumen and kerosene mixture during blending in order to ensure proper and quality blend.

CONCLUSION

Most probably, the popularized usage of cutback asphalt in the country in contrast to asphalt emulsion is due to the simplicity in the blending process. Unfortunately, this simplistic blending by large percentage of road contractors cannot achieve the level of miscibility required between bitumen and solvent (kerosene) to produce qualitative cutback asphalt. Asphalt emulsion, as binder medium in the construction and maintenance of roads has better return values compared to the poorly blended cutback asphalt.

RECOMMENDATIONS

- The Federal Government of Nigeria should, as a matter of urgency, look into the immediate repair of the vandalized pipeline formerly used in transporting bitumen from Escravos Port in Warri to the Kaduna refinery and urgently develop policies that would

bring about the revitalization of the Kaduna refinery so that it could commence the production of bitumen once again. This should definitely bring down the cost of bitumen and translate into lower construction/ maintenance costs of our roads.

- In the Federal Government's quest to encourage the setting up of private refineries, it should insist on the production of bitumen and other bituminous materials as part of the conditions to be met by the private investors.
- Government should also provide enabling environment and incentives for more private investors such as WABECO to set up plants for the production of quality bituminous materials. It is believed that if more bitumen emulsion plants are set up round the country, it would make the products more accessible to road contractors.
- The government and private investors should also be encouraged to research into the possibilities of locally producing some of the ingredients used in the production of emulsified asphalts such as emulsifiers and caustic soda.
- The Federal Ministry of Works (Highways Division) should encourage the use of emulsified asphalts where found to be more acceptable. This is the only way to break away from the mentality that bitumen must be heated before it can be used in any form for road works.
- A technical committee should be set up to adapt suitable current classification methods for asphalt cements and liquid asphalt, which are based on viscosity values.

There should be more stringent regulations in the production and usage of liquid asphalt binders in the country to; reduce emission of hazardous pollutants during construction and reduce the huge annual financial losses incurred from rehabilitated road sections that spoil soon after, due to the effect of badly prepared and applied liquid asphalt binders.

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