Effects of Candle Wax on the Physical Properties of Grade 80/100 Bitumen used in Asphalt Road Pavements in Nigeria

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ABSTRACT

Improving on the performance of bituminous concrete (i.e. a typical flexible road pavement) has been one of the major concerns in highway engineering, due mainly to the problems of temperature susceptibility and oxidation of bitumen as a road construction material. However, there are several methods and techniques in which this can be achieved ranging from quality of aggregates used to quality of binder, particularly bitumen used during construction. On this basis, this study was directed towards exploring techniques that will improve the performance of bitumen by modifying its physical properties using non-bituminous modifier (candle wax). The results revealed that the addition, of varying amounts of candle wax between 5-25% by weight of bitumen linearly improved the properties of the grade 80/100 bitumen considerably; thus providing bitumen that will enhance the overall performance of the asphalt road pavement.

Keywords: *Bitumen, Physical Properties, Candle Wax, Road Pavements.*

INTRODUCTION

Bitumen can be described as a viscous liquid or solid consisting essentially of mineral oil (having a variety of hydrocarbons with high molecular weight, which are asphaltic in nature and having small proportions of oxygen, nitrogen and sulphur), hydrocarbon derivatives (such as asphaltenes, maltenes), which are soluble in carbon disulphide and is substantially non-volatile and softens gradually when heated. Depending on its mode of derivation, it is either black or brown in colour, possessing water-proofing and adhesive properties and has a variable hardness and volatility (Encyclopedia of Science and Technology, 1965; Allison, 1980).

In usual commercial practice, bitumen is restricted to semi-solid or solid bitumen, which includes asphalts, tars and pitches. However, due to its binding and cementing property, it is used in road construction for paving road surfaces and also for a variety of uses such as in water-proofing to prevent leakages. It is also used for filling joints in construction works to prevent contractions and expansions. Furthermore, it is used for the reduction of the heat of hydration in Portland-cement concrete constructions. Its chemical composition is complex and varies depending, to a large extent, on the crude-oil used and the method of manufacture (Allison, 1980). Also, it is widely considered as a colloidal solution with the mineral oil acting as the dispersed as well as the control phase while the mixture of resins provides stability. Othmer (1963) observes that the limitations of bitumen as a road-paving material are associated with the problems of oxidation, which results in the cracking of the pavement and its instability with respect to temperature variations. Due to these problems, various forms of modifications of the physical properties of bitumen have evolved over the years using different materials like natural rubber (Van-Rooijen, 1938; Decker and Nijveld, 1951; Mason, Thrower and Smith, 1957; Mummah and Muktar, 2001), recycled polyethylene from grocery bags (Flynn,1993), recycled plastics composed predominantly of polypropylene and low density polyethylene (Collins and Ciesielski, 1993; Federal Highway Administration, 1993; Khan, Mohan and Raykar, 1999; Zoorob, 2000; Zoorob and Suparma, 2000) and processed plastic bags (Punith, 2001). However, there is a dearth of information on the use of candle wax as a modifier for bitumen which this study sought to investigate. In addition, it will compare the rates of changes that will occur in the physical properties of bitumen using polythene and candle wax of the same grade of bitumen.

MATERIALS AND METHOD

The materials used for the study were, bitumen and candle wax. Bitumen was obtained from the Rivers State Ministry of Works, while the candle wax was from Park 'n' shop Supermarket. After sampling the following laboratory tests were carried out to determine the physical properties of the unmodified and modified bitumen. (a) Penetration, (b) Ductility, (c) Softening point, and (d) Viscosity. Penetration of bitumen as presented in Emesiobi (2000) is defined as the distance in tenths of millimeter that a standard needle will penetrate into the bitumen under a load of 100g applied for 5seconds at 25ºC (77ºF).

The method of preparation involved the use of a penetrometer; where the hot bitumen in molten state was poured into a container and immersed in a water bath containing water at a temperature of 25ºC for 30 minutes. After which the bitumen was allowed to cool and a needle of 1mm in diameter weighing 100g was allowed to touch the surface of the bitumen. The needle was released under gravity to pierce through the bitumen surface for 5 seconds and the distance in unit of millimeters was recorded as the penetration value of the bitumen. For the modified bitumen, the same procedure was adopted except that the modifier (candle wax) was heated to molten state before pouring into the molten bitumen and then mixed thoroughly before carrying out the penetration test. The procedure was repeated for varying amounts of candle wax between 5-25% and the results obtained were recorded. Ductility of bitumen as presented in Mumah and Muktar (2001) is that property that measures the internal cohesion of bitumen under varying conditions of external loadings causing elongation of the sample. It is expressed as the distance that a standard semi-solid briquette will elongate before breaking. Similarly, Oglesby and Hicks (1984) posited that ductility is intended to provide assurance such that a completed pavement will fail by distortion rather than by cracking due to brittility.

However, when a pavement becomes too ductile, it is also subject to temperature changes resulting in bleeding or flushing of pavement (Oguara, 2005). The procedure involved pouring hot molten bitumen into a briquette mould immersed in a ductilometer (i.e., instrument that measures ductility) containing water for 11/2 hours. The ductilometer is then switched on to allow for elongation of the sample until failure occurred and the distance at which failure was recorded as the ductility of the bitumen. The same procedure was adopted for modified bitumen except that molten bitumen was premixed with the modifier (candle wax) in the molten form which was then allowed to cool and return to the viscous state. Afterwards the procedure as with the unmodified bitumen was repeated.

The procedure was repeated for varying amounts of candle wax between 5-25% and the results obtained were recorded. Softening point of bitumen as presented in Mumah and Muktar (2001) is that property which determines the temperature at which bitumen changes from semi-solid to liquid under heat variation. The method of preparation involved placing two 9.33mm diameter steel balls on viscous bitumen sample placed in a steel ring immersed in a water bath. Heat was then applied to the water and its temperature increased until the point when the bitumen sample was sufficiently soft to allow the balls to pierce through and fall through a height of 25mm. the temperature at which the steel balls fell through the sample was recorded as the softening point of the unmodified bitumen. For the modified bitumen, the same procedure was adopted except that the modifier (candle wax) was first heated to molten state and then premixed with molten bitumen. Afterwards the modified bitumen was allowed to cool and become viscous before placing the two steel balls, and then repeating the process as with the unmodified bitumen. The procedure was repeated for varying amounts of candle wax between 5-25% and the results obtained were recorded. Viscosity of bitumen as presented in Oguara (nd) and Emesiobi (2000) is that property that retards flow such that when a force is applied to the bitumen, the higher the viscosity, the slower the movement of the bitumen.

In short, it is the property that measures resistance to flow of bitumen. The method of preparation involved the use of a Saybolt Furol Viscometer measuring the time in seconds required for 60ml of the bitumen to flow by gravity from a completely filled cylinder. A cork was inserted into the air chamber below the orifice and preheated bitumen was poured into the cup until it filled the gallery. When temperature of the bath and cup were steady the thermometer was withdrawn from the gallery and the cork removed. After which 60ml of the binder was collected in a graduated receiving flask and the time taken in seconds at the temperature of testing recorded as the viscosity of the bitumen. For the modified bitumen, the same procedure was adopted except that the modifier (candle wax) was heated to molten state before pouring into the molten bitumen and then mixed thoroughly before carrying out the viscosity test. The procedure was repeated for varying amounts of candle wax between 5-25% and the results obtained were recorded. The results of the properties of both unmodified and modified bitumen are presented on table and charts.

RESULTS AND DISCUSSION

Changes in Penetration: From the results obtained in figure 1 it was observed that the value of penetration at 0% candle wax content was 84mm implying a grade 80/100 bitumen. However, the addition of varying amounts of candle wax between 5-25% revealed that penetration decreased linearly to a value of 13.5mm at 25% candle wax content. In similar study by Mummah and Muktar (2001), it was concluded that bitumen having penetration value above 100mm is associated with flushing or bleeding of road surfaces whereas cracking rarely occurs with bitumen having penetration value below 80mm. In contrast, Emesiobi (2000) posits that bad cracking of road pavement are also associated with bitumen having penetration values below 20mm and for values higher than 30mm cracking is reduced. The implication of their findings is that there is both upper and lower limit of cracking associated with bitumen in terms of penetration. That is, the limit of cracking is between 20-80mm. From figure 1 corresponding values of penetration at 20mm and 80mm occurs at 18.85% and 0.54% candle wax contents, thus modifying bitumen with candle wax between these values produce bitumen with penetrations having higher resistance to cracking of road surface pavement for grade 80/100 bitumen.

Changes in Ductility: From the results obtained in figure 3.2 it was observed that ductility of the bitumen at 0% candle wax content was 188mm. However, the addition of varying amounts of candle wax between 5-25% revealed that ductility decreased linearly to a value of 24mm at 25% candle wax content. Although the bitumen at 0% candle wax content (i.e. having ductility of 188mm) can be said to be more ductile, however higher ductility does not necessarily imply a binder with better quality. Oguara (2005) and Mumah and Muktar (2001) in their findings concluded that bitumen with ductility at least above 100mm are susceptible to temperature changes which results in bleeding and flushing of pavement. From figure 3.1 a ductility of 100mm is obtained at 4.1% candle wax content which becomes our limiting value of modifier, and less than this value will result in a pavement subject to flushing or bleeding.

Changes in Softening Point: It is desired that bitumen should be able to resist deformations (such as boiling) resulting from incremental temperature changes; therefore the need to increase the softening point of bitumen. From figure 3.3 results revealed that the softening point of unmodified bitumen (i.e. at 0% candle wax content) was 46.5°C. However, addition of varying amounts of candle wax between 5-25% resulted in linear increase of the softening point of the bitumen up to 82°C at 25% candle wax content. Therefore, it is concluded that the addition of candle wax to bitumen increases its resistance to boiling when subjected to incremental changes in temperature experienced during use of the pavement Mumah and Muktar (2001).

Changes in Viscosity: It is also intended that bitumen should resist flow under the influence of external load particularly traffic loads during use; therefore the need to increase that property that inhibits movement or flow of bitumen which is viscosity.

From figure 3.4 it was observed that the value of the unmodified bitumen at 0% candle wax content was 2seconds. However, addition of varying amounts of candle wax resulted in linear increase of viscosity up to 35seconds. Therefore, it is concluded that the addition of candle wax to bitumen increases its resistance to flow or movement during use of the pavement.

Table 1: Results of unmodified and modified properties of bitumen

Candle Wax Content (%)	Unmodified Bitumen (0% candle wax)	Modified Bitumen with candle wax				
		5%	10%	15%	20%	25%
Penetration (mm)	84	47	38.5	25	18.5	13.5
Ductility (mm)	188	81	61	40	32	24
Softening Point (°C)	46.5	48	57	65	73	82
Viscosity (Seconds)	2	9	15.5	21	27	35

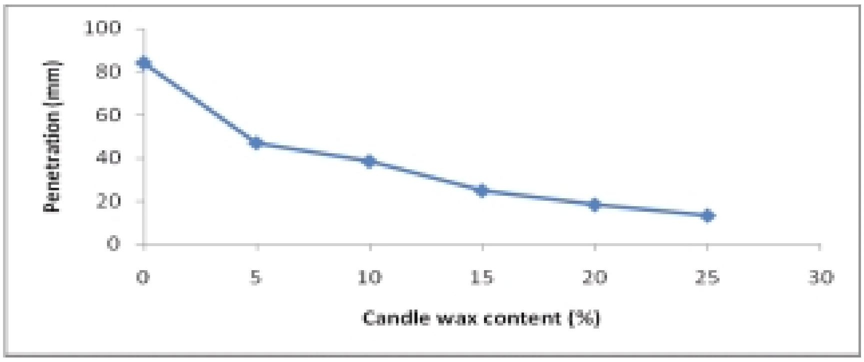

Fig. 1: Variation of penetration with candle wax content

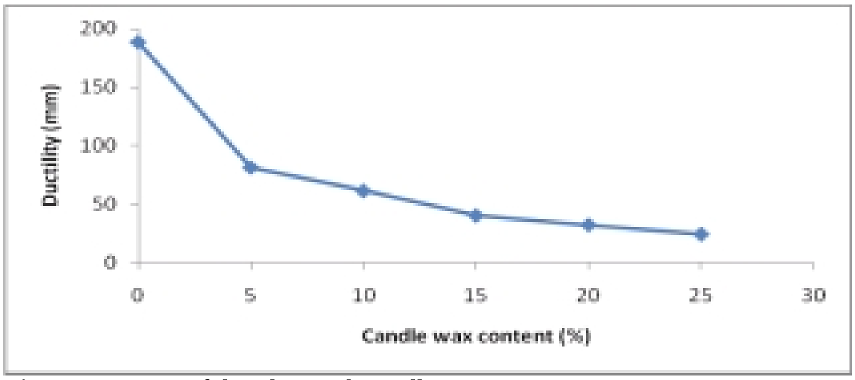

Fig. 2: Variation of ductility with candle wax content

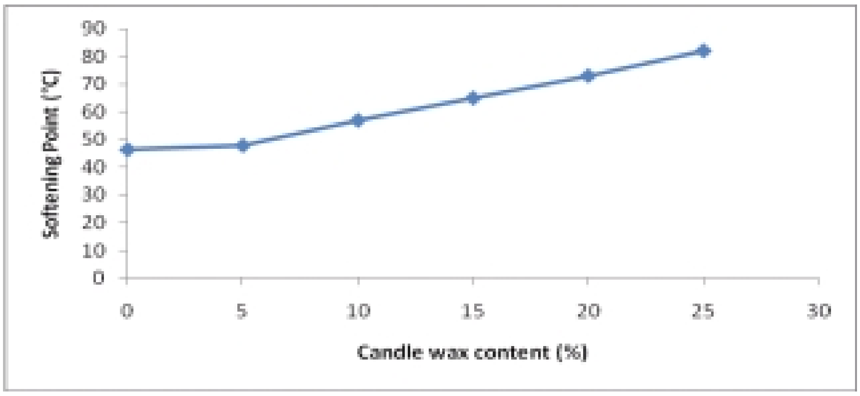

Fig. 3: Variation of softening point with candle wax content

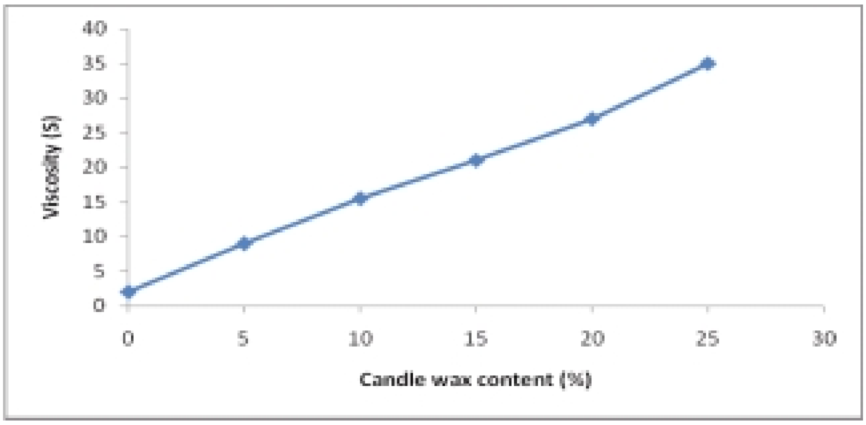

Fig. 4: Variation of viscosity with candle wax content

CONCLUSION

This study experimented the use of candle wax as a modifier for bitumen. In addition, it compared the rates of changes that occur in the physical properties of bitumen using polythene and using candle wax for the same grade of bitumen. From the findings based on the laboratory tests carried out, it is concluded that the addition of candle wax between 18.85% to 0.54% produce bitumen better than the unmodified bitumen in terms of penetration; that is a material that will not distort under external traffic loads. The addition of candle wax up to 4.1% and above will produce ductility in bitumen that will not flush or bleed when subjected to incremental changes in temperature, thus performing better than the unmodified bitumen. The addition of candle wax between 5-25% produce bitumen that is more resistant to boiling than the unmodified bitumen when both are subjected to incremental changes in temperature. The resistance to flow or movement of the modified bitumen under external loads of traffic was better than that of the unmodified bitumen due to the addition of candle wax.

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