Ground Tire Chips Influence on the Rheological Properties of Grade 60/70 Bitumen used in Flexible Road Pavements

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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. This study was an experimentation of the ground tire chips influence on the rheological properties of grade 60/70 Bitumen used in flexible road pavements. The major aim was to determine the penetration value of modified bitumen with tire chips contents. However, there are several methods and techniques in which asphalt concrete pavement can be enhanced ranging from the use of high quality of aggregates used, to quality of binder used during construction. Other methods of improving the quality of the wearing course (pavement material) is by increasing the level of compaction on the bituminous concrete which in turn reduces the level of voids in the pavement material thereby making it denser and stiffer. However, for the present study the technique used was directed towards modifying the physical or rheological properties of grade 60/70 bitumen using a non-bituminous modifier: ground tire chips. The results revealed that the addition, of varying amounts of ground tire chips made from condemned car tires between 5-25% by weight of bitumen linearly improved the properties of the grade 60/70 bitumen considerably; thus providing bitumen that will enhance the overall performance of the asphalt road pavement.

Keywords: *Bitumen, Rheological Properties, Ground Tire Chips and Flexible 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.

However, 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 tire chips as a modifier for bitumen which the present study sought to investigate. In addition, compare the rates of changes that will occur in the physical properties of bitumen using polythene as have been already studied and using tire chips as would be studied for the same grade of bitumen.

MATERIALS AND METHODS

This study adopted the experimental research design. The materials used for the study were, bitumen, tire chips and polythene bags. Bitumen was obtained from the Rivers State Ministry of Works, while the tire chips were obtained directly from old worn out tires, and the polythene used was obtained as littered wastes within the environment. After sampling laboratory tests were carried out to determine the physical properties of the unmodified and modified bitumen. For purpose of the study the following laboratory tests were carried out for both unmodified and modified bitumen (Penetration, Viscosity, Softening point and Ductility). 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; were 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 (tire chips) 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 tire chips between 5-25% and the results obtained were recorded.

Ductility of bitumen as presented in Mummah 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. 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. 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, no date).

The same procedure was adopted for modified bitumen except that molten bitumen was premixed with the modifier (tire chips) 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 tire chips 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 (tire chips) 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 the 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 Emesiobi (2000:p184) 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 the 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 (tire chips) 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 tables 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% tire chips content was 67mm implying a grade 60/70 bitumen. However, the addition of varying amounts of tire chips between 5-25% revealed that penetration decreased linearly to a value of 9mm at 25% tire chips 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 3 corresponding values of penetration at 20mm and 80mm occurs at 12% and 0% tire chips contents, thus modifying bitumen with tire chips between these values produced bitumen with penetrations having higher resistance to cracking of road surface pavement for grade 60/70 bitumen.

Changes in Ductility: From the results obtained in figure 2 it was observed that ductility of the bitumen at 0% tire chips content was 180mm. However, the addition of varying amounts of tire chips between 5-25% revealed that ductility decreased linearly to a value of 21mm at 25% tire chips content. Although the bitumen at 0% tire chips content (that is, having ductility of 180mm) can be said to be more ductile, however higher ductility does not necessarily imply a binder with better quality. Oguara (no date) and Mummah 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 1, a ductility of 100mm is obtained at 3.3% tire chips 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 results revealed that the softening point of unmodified bitumen (that is to say, at 0% tire chips 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 84°C at 25% tire chips content. Therefore, it is concluded that the addition of tire chips 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 4 it was observed that the value of the unmodified bitumen at 0% tire chips content was 4 seconds. However, addition of varying amounts of candle wax resulted in linear increase of viscosity up to 29 seconds. 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

Tire Chips	**Unmodified Bitumen**	**Modified Bitumen with tire chips**				
Content (%)	**(0% tire chips)**	**5%**	**10%**	**15%**	**20%**	**25%**
Penetration (mm)	67	28	22	17	12	9
Ductility (mm)	180	59	47	36	28	21
Softening Point (°C)	46.5	46	58	67	74	84
Viscosity (Seconds)	4	7.8	11	16	22	29

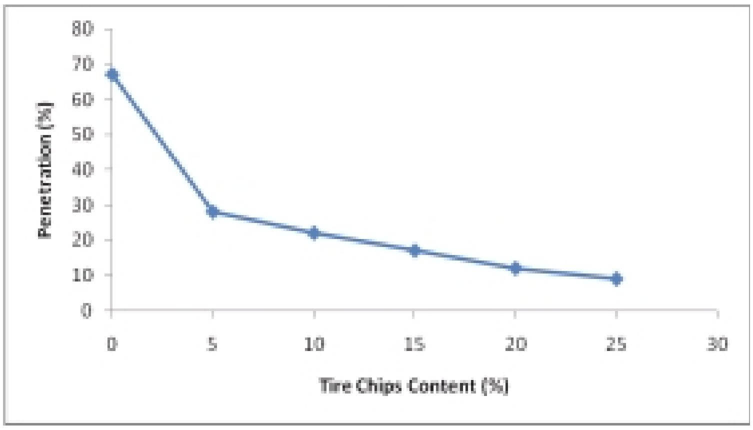

Fig. 1: Variation of penetration with tire chips content

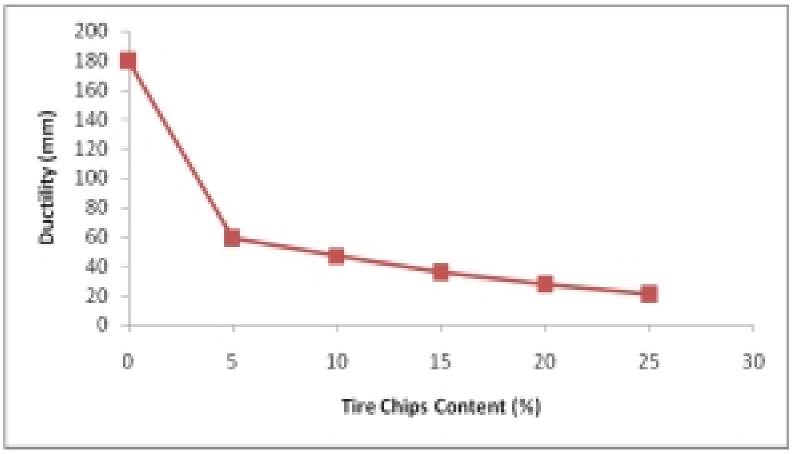

Fig. 2: Variation of Ductility with Tire Chips

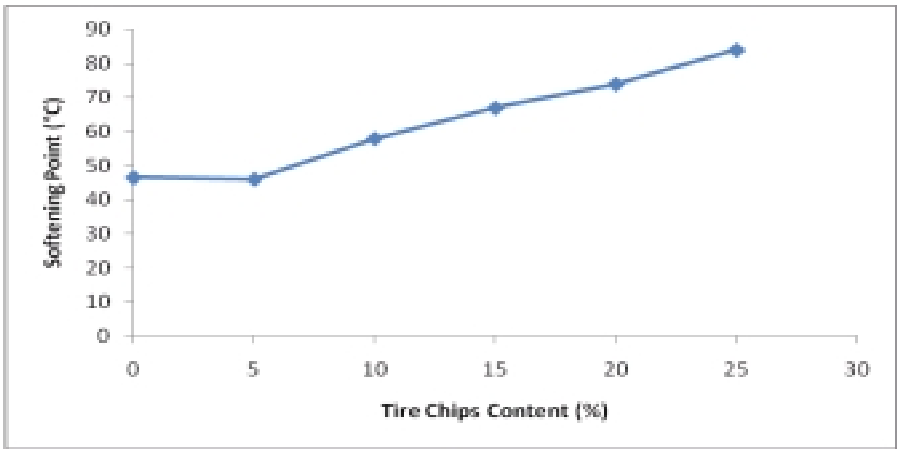

Fig. 3: Variation of Softening Point with Tire Chips Content

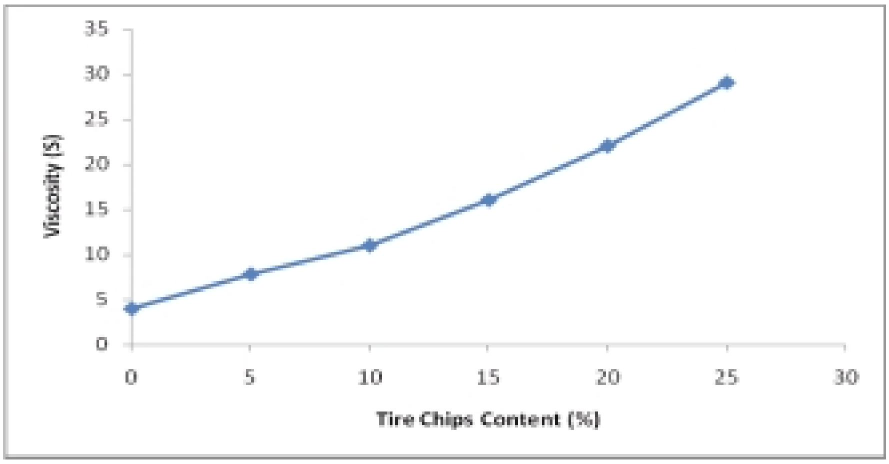

Fig. 4: Variation of Viscosity with Tire Chips Content

CONCLUSION

This study sought to investigate the dearth of information on the use of tire chips as a modifier for bitumen. Also, compare the rates of changes that will occur in the physical properties of bitumen using polythene as have been already studied and using tire chips as would be studied for the same grade of bitumen. From the findings of the work based on the laboratory tests carried out, the following conclusions are drawn:

i That the addition of tire chips between 12% to 0% produce bitumen better than the unmodified bitumen in terms of penetration; that is a material that will not distort under external traffic loads

ii That the addition of tire chips up to 3.3% 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

iii That the addition of tire chips between 5-25% produce bitumen that is more resistant to boiling than the unmodified bitumen when both are subjected to incremental changes in temperature

iv 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 addition of tire chips.

Therefore, it is recommended that the addition of tire chips should be used as bitumen modifier to increase its resistance to boiling when subjected to incremental changes in temperature experienced during use of the pavement (Mummah and Muktar, 2001).

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