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Evaluating the Physical Properties of Ground Waste Scrap Tyre Modified Bituminous Material use in Asphalt Concrete Production

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***Abstract*-- The possibility of incorporating automobile waste scrap-tyres into bitumen for the production of asphalt concrete in the construction of roads was evaluated. Several concentration of ground scrap tyres rubber were incorporated into bitumen samples at 5%, 10%, 15%, 20%, 25%, 30% by weight of bitumen. The samples were subjected to the following tests: penetration, viscosity, softening point, ductility and flash point. Control specimen of 0% ground scrap-tyre rubber was used to measure against the various concentrations. The penetration and ductility of bitumen decreases 51% and 84% respectively as the ground scrap tyre rubber content increases from 0 to 30%. The softening point and flash point of bitumen increases 50% and 59% respectively as the ground rubber content increases from 0 to 30%. The viscosity of bitumen increases as the ground scrap tyre rubber content increases. But stop flowing at 15% and 20% rubber content At test temperature of 130 ºC and 140 ºC respectively. The benefits in the area of environment, particularly solid waste management is significant.**

***Keywords*--Scrap tyre, asphalt concrete, Bitumen, Viscosity, Ductility**

I. INTRODUCTION

The rapid rate of urbanization has contributed to the ever-increasing size of solid waste, and its poor management has contributed in no small measure to the nuisance and damaging effects of solid wastes on the urban environment.

There is evidence of filthy urban environment within and around major cities in Nigeria such as Lagos, Abuja, Port Harcourt, Enugu, Ibadan, Onitsha, Aba, Kano, to mention a few. These cities which serve as commercial nerve centers with specific trade functions across the length and breadth of the country, experience rapid rate of solid waste generation and accumulation due to the rapid urban growth and development.

Due to the poor state of the Nigeria economy and imbalance in the provision of social infrastructure in the rural areas, due largely to political reasons, the rate of rural-urban migration has been unparalleled. For example, Sule, (2004) reported that, Lagos which has an estimated population of about 14 million people witnesses a daily erosion in the quality of life due to uncontrolled, unguided and poorly managed solid waste in the urban environment.

Other cities such as Ibadan, Port Harcourt, Onitsha, Aba, Kano, Enugu etc, are not left out in the aesthetic disaster of both public and private places in their respective urban environments.

Among these wastes generated are scrap tyres which are presently predominant in motor mechanic shops and spare parts villages located in areas such as Alaoji in Aba, Ikokwu in Port Harcourt, Nnewi, Onitsha, Ladipo automobile parts market in Mushin, Lagos, and a host of many other locations in Nigeria.

Due to the rapid growth of urbanization, and the relative increase in public and private transportation activities, scrap tyres have become predominant in many parts of the cities. The influx of second-hand imported vehicles (otherwise known as "Tokunbo"), have greatly increased the quantity of disposed scrap tyres.

Most apparent in our cities today is the deterioration of our urban environment in terms of irresponsible ways of dumping refuse and accumulated solid wastes which include scrap tyres. Asuquo (1979) stated that the unfriendly effects of these circumstances in our urban lives have often been cited and noted as contributing causes of the Nigeria urban decay. The problems of the urban decay have become more serious and acute today. It is taking a new dimension with traditional ways of life and gradually giving way to what we might call modern life. A reflection of this new life style is manifested in our pattern of consumption and how we generate solid waste.

This research is geared towards the suitability and effective utilization of recycled scrap tyres, by incorporating an adequate proportion into bitumen to enhance the mix proportion of asphalt for beneficial use in the construction industry and beyond. Past research works on incorporation of scrap tyres rubber in asphalt, concentrated on cold mix asphalt concrete with rubber pellets (chunk rubber) as aggregates and hot-mix asphalt concrete using finely grounded rubber particles as modifiers. However, there is a general paucity of research to ascertain the effect of varying concentration of ground scrap tyre on the consistency or flow properties of bitumen. This therefore constitutes the major objective of this study.

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It is believed that the results of this study will be of great importance to the construction industry in Nigeria and beyond.

II. Materials And Methods

2.1 Materials

Bitumen material used in this investigation was sourced from the bitumen depot of Julius Berger PLC, Port Harcourt and used in all sample and specimen preparation. Sample preparation was in accordance with AASHTO T48-T55; Standard method of test for bitumen. The scrap tyres used for this research were collected from a scrap tyre dump at Ikokwu automobile spares parts market in Port Harcourt City, Rivers State. The tyres were washed, cleansed and dried. The sections free from steel wires were grounded and the ground scrap tyre passing sieve 0.300mm was used.

2.2 Methods

This research work was realized through laboratory experimentation carried out in the laboratories. Sample collection and preparation, testing and analysis were carried out in accordance with the relevant international standards and specifications. Specimens were prepared in accordance with AASHTO T48–T55–Standard Methods of Tests for Bitumen. Scrap tyre rubber modified bitumen specimens were prepared for 5%, 10%, 15%, 20%, 25%, and 30% by weight of bitumen. While the unmodified sample with 0% rubber was used as the control specimen.

The penetration test involved the depth in tenth of mm of a bitumen sample at 25 ºC temperature with a standard needle under a load of 100g for 5 seconds. The test procedure used, was in accordance with standard methods (Bitumen) AASHTO-T49. The detailed results are shown in Table 1 and a graph of penetration against rubber content is shown in Figure 1. The viscosity test involved the measurement of time it will take fluid (bitumen) flowing through an orifice at a given temperature to fill a 50ml receiver. The Standard tar viscometer was used as specified by AASHTO-T50. The detailed results are shown in Table 1 and a graph of viscosity against rubber content is shown in Figure 2.

The softening point of the specimen was measured using the ring and ball softening point test as specified by AASHTO-T52. The detailed results are shown in Table 1 and a graph of flash point against rubber content is shown in Figure 3.

The method is described in “Standard Methods (Bitumen) (IP32/55) was used in carrying out the ductility test. The Pensky-Martens closed tester was used and the procedure was in accordance with AASHTO-T73. The detailed results are shown in Table 1 and a graph of ductility against rubber content is shown in Figure 4. The flash point of the specimen was determined based on the temperature at which the specimen during heating evolves vapour that will temporarily ignite or flash when a small flame is brought in contact with it. The detailed results are shown in Table 1 and a graph of flash point against rubber content is shown in Figure 5.

III. Results And Discussion

3.1 Effect of Ground Scrap Tyre Rubber on Penetration of Bitumen

In Table 1 and Figure 1, it can be seen that the penetration of the binder reduces with increase in rubber content. It shows that there is a linear relationship between penetration and rubber content. This trend and was also observed by Roque et al (2005). An average reduction in penetration of about 51% was observed for the rubber content range of 0 – 30%. From Table 1, it can be seen that, at 0% rubber content (normal bitumen), the penetration was 66.50 pen. Thus, the bitumen is grade 60/70 bitumen, which is suitable for rolled asphalt surfacing in tropical climates, such as in Nigeria. Based on the penetration values of rubber modified bitumen obtained, 15% to 30% rubber content of bitumen can serve as 20/50 penetration grade bitumen (mastic asphalt) which is suitable where traffic stresses are particularly high, for example, Bus-stops, Emesiobi (2000). Studies elsewhere show that, the reported values in this study fall within the range of values that have been reported for similar mixtures *by* Epps (1994).

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Table 1:
Result of Penetration Test

Rubber Content %	Penetration (pen)	Viscosity (sec)		Softening Point (ºC)	Ductility (cm)	Flash Point (ºC)
		130 ºC	140 ºC			
0	66.50	2.15	1.74	44.00	72.47	186.33
5	56.50	6.60	2.05	48.0	25.13	231.00
10	53.50	17.46	10.41	49.83	24.07	244.33
15	50.25	-	435.85	51.67	23.13	258.00
20	46.75	-	-	57.00	21.90	268.00
25	40.75	-	-	62.00	14.83	279.67
30	32.75	-	-	66.17	11.57	297.00

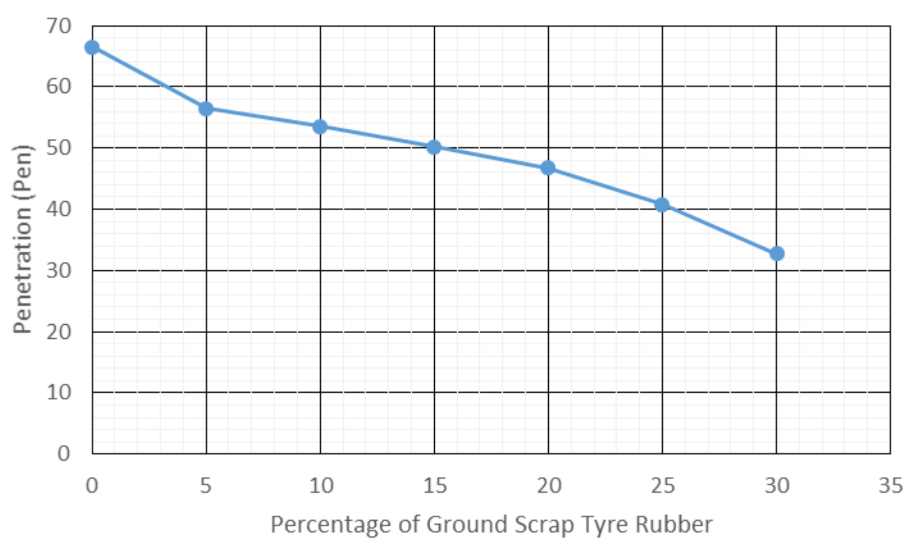

Figure 1: Graph of Penetration against percentage of Ground Scrap Tyre Rubber

3.2 Effect of Ground Scrap Tyre Rubber on Viscosity of Bitumen

The results of viscosity as a function of rubber content are presented in Table 1 and Figure 2, from where it can be seen that, the viscosity of the binder increases as the rubber content increases. Table 1 indicates that at 0% rubber content, the time of efflux was 1.74 seconds at 140 ºC. The time increased as ground rubber was added. At 5% rubber content, the time was 2.05 seconds. The trend continued for 15% rubber and stopped. From 20% upward the rubber-modified bitumen did not pass through the orifice.

While at test temperature of 130 ºC at 0% rubber content, the time of efflux was 2.15 seconds. The trend continued for 10% rubber content with time of 10.41 seconds and stopped because the modified bitumen stopped flowing as soon as 15% rubber content was achieved. In comparing the time of efflux of the specimens, it was noticed that the time of efflux increases as the temperature decreases. The findings is similar with the results of Roque et al (2005), who concluded that, the addition of crumb rubber to bitumen can dramatically increase the viscosity of the resultant asphalt rubber binder. It can be noticed that the graph of 140 ºC is above the graph 130 ºC.

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This means that the viscosity of the modified binder is affected by temperature. As the rubber modified bitumen temperature decreases, the viscosity increases. Relationship between viscosity increase and the increase in diluents is also affected by the reaction temperature.

Epps (1994) also reported that the benefit of increased viscosity of the bituminous rubber binder is that, additional binder can be used in the asphalt mix to cause a reduction in the reflective cracking, stripping and rutting, while improving the binder's response to temperature can be a long term durability.

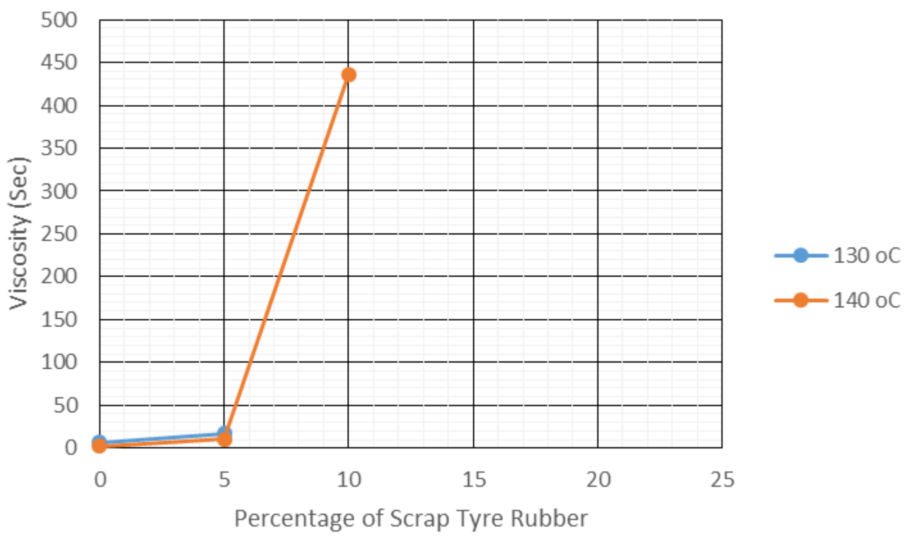

Figure 2: Graph of Viscosity against percentage of Ground Scrap Tyre Rubber

3.3 Effect of Ground Scrap Tyre Rubber on Softening point of Bitumen

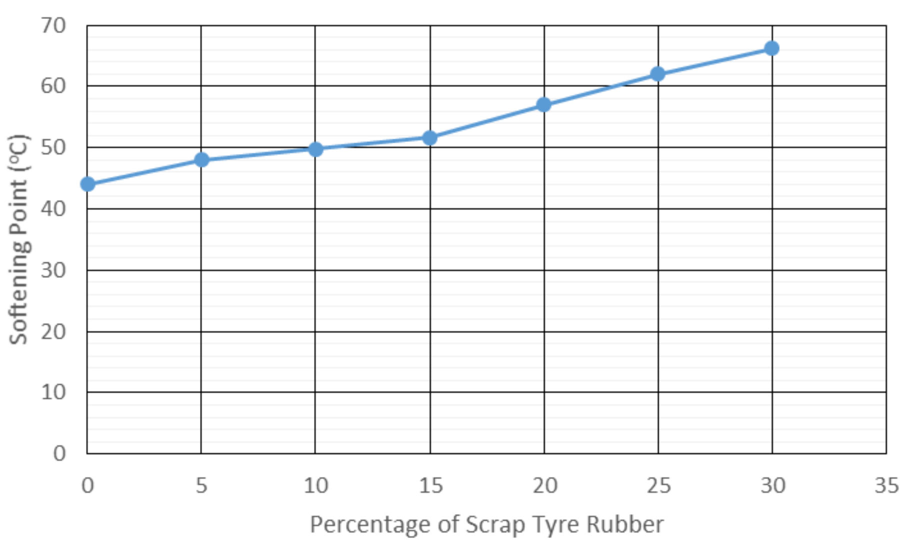

Figure 3: Graph of Softening Point against percentage of Ground Scrap Tyre Rubber

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Tables 1 and Figure 3 gives the results and graphical representation respectively. At 0% rubber content, softening point temperature was at 44^{0}C, then at 5% rubber content, the softening point of the rubber modified bitumen increased to 48.33^{0}C while at 15% rubber content, it was 51.67^{0}C. This trend continued, then at 30% rubber content, the softening point temperature was 66.17^{0}C. The results obtained are in conformity with Epps (1994), who reported in his findings that the addition of crumb rubber into bitumen increases its softening point. The result indicates a linear relationship between the rubber content and softening point temperature.

Also an increase of 50% in softening point was observed for the rubber content range of 0 – 30%. This increase in temperature will result in the reduction of rutting of the asphalt rubber products at elevated temperatures. Since ground tyre rubber modified bitumen has better binder elasticity than unmodified bitumen, it enhances the ability of asphalt rubber pavement to resist deformation and cracking. Robert et al (1989***)*** specified a minimum softening point of 54% for an asphalt rubber blend containing AC-20 asphalt and 15%-26% rubber. This shows that the result obtained is within the range as reported.

3.4 Effect of Ground Scrap Tyre Rubber on Ductility of Bitumen

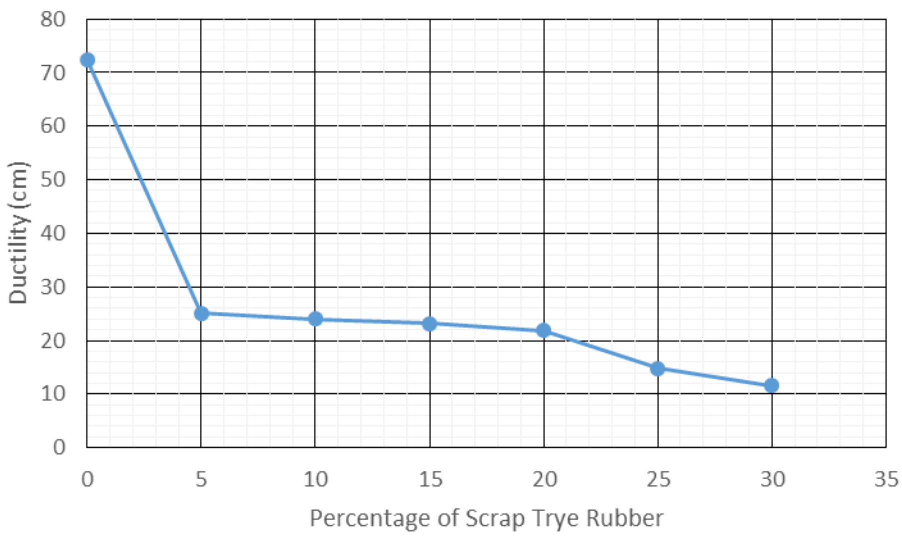

Figure 4: Graph of Ductility against percentage of Ground Scrap Tyre Rubber

From the results of ductility test shown in Table 1 and presented graphically in Figure 4, there is an indication that, at 0% rubber content, the ductility was 72.47cm, at 5% rubber content, the ductility decreased to 25.13cm, which is about 60% drop in ductility. This means that addition of ground rubber into bitumen greatly affects the ductility of the bitumen. With a 10% rubber content, the decrease in ductility was small compared to ductility at which ground tyre rubber was initially added to the unmodified bitumen. This trend continued as more ground tyre rubber was added to the modified bitumen, because at 30% rubber content, the ductility was recorded as 11.57cm the results above indicate that an average reduction in ductility of about 84% was observed for scrap tyre content range of 0 – 30%. The graph of Figure 4 shows a linear relationship between the rubber content and the ductility of the bitumen sample.

The graph indicates that as the ground tyre rubber content increases, the ductility decreases. The trend in Figure 4 is similar to the observations made by Roque et al (2005), who reported that there is a reduction of ductility because of drain-down and this makes the production of higher binder content mixtures possible.

3.5 Effect of Ground Scrap Tyre Rubber on Flash Point of Bitumen

Table 1 provides a detailed analysis of the results of flash point test on ground scrap tyre rubber. This is graphically presented in Figure 5, which indicates that as the rubber content of the bitumen increases, its flash point also increases. This is so because at 0% rubber content, the flash point temperature is 186.33 ^{o}C, at 5% and 10% rubber content, the temperature was 231 ^{o}C and 244.33 ^{o}C respectively.

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The trend continued because at 30% the flash point temperature increased to 297⁰C. The following result indicates that an increase in flash point temperature of about 59% was observed for the ground tyre rubber content range of 0 – 30%.

This Study is in conformity with Epps (1994) findings, which assert that the addition of crumb rubber elevated the flash point of the bitumen. In a related study, Roque et al (2005) concluded that addition of crumb rubber into bitumen results in higher temperature in asphalt concrete production.

The graph indicates an approximate linear relationship between rubber content and flash point. The flash point test is primarily a safety test although it can also be considered as indirect reflection of binder volatility. Emesiobi (2000**)** reported that the flash point indicates the maximum temperature to which the bitumen can be safely heated, because safe practice requires special precautions when temperatures in excess of the flash point are being used. From these results, it can be observed that asphaltic concrete can be produced at higher temperatures when crumb rubber modified bitumen is used as binder.

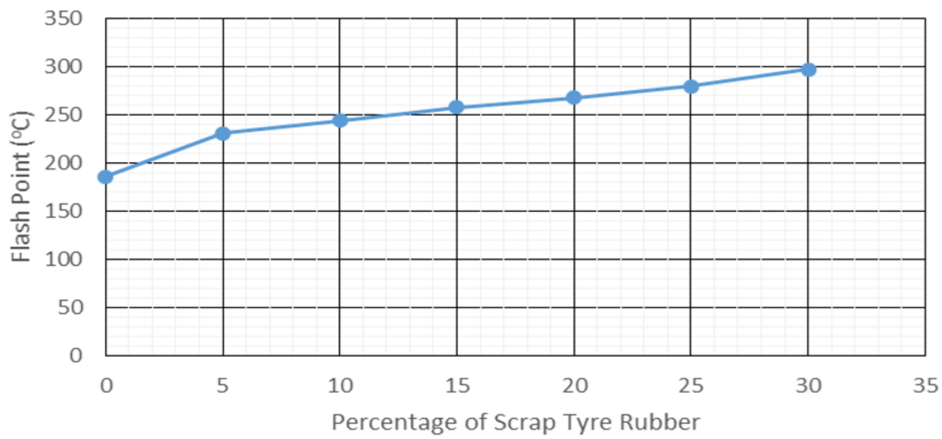

Figure 5: Graph of Flash Point against percentage of Ground Scrap Tyre Rubber

IV. Conclusion

The following conclusions are made based on the investigations carried out on the effect of ground scrap tyre rubber on the consistency of bitumen: The penetration and ductility of bitumen decreases 51% and 84% respectively as the ground scrap tyre rubber content increases from 0 to 30%. The viscosity of bitumen increases as the ground scrap tyre rubber content increases. At test temperature of 130 ºC, the modified bitumen stopped flowing at 15% rubber content while it stopped flowing at 20% rubber content at 140 ºC, The viscosity increased because the rubber additive prevented drain-down and made the production of higher binder content mixtures possible. The softening point and flash point of bitumen increases 50% and 59% respectively as the ground rubber content increases from 0 to 30%.

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