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ASSESSMENT OF THE PROPERTIES OF ASPHALT MODIFIED WITH USED TIRES

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ABSTRACT

This study investigates the properties of asphalt mix modified with ground tire. The ground tire was introduced into the asphalt in a melted form at varying percentages of 2%, 4%, 6%, 8% and 10% by weight of the asphalt. The properties of the asphalt mixed with the ground tire were then obtained through penetration, softening point, flash and fire point and ductility tests. These properties were then compared with those of the control asphalt to determine the effectiveness of the ground tire in improving the asphalt properties. The results showed that the ground tire additive improved the asphalt properties considerably.

KEYWORDS

Asphalt mix, ground tire, softening point, ductility test, ground tire

INTRODUCTION

Poor performance of bituminous mixtures under increased traffic volume and heavier axle load has led to the increased use and development of modified bitumen especially the use of discarded tires of vehicles in pavement construction. Modified binders generally exhibit decreased temperature susceptibility and potentially improved mix performances.

Researchers have demonstrated improved performance of bituminous mixes with shredded rubber. The advantages resulting in the use of used tire include: increased fatigue life or fatigue resistance, reduced reflective cracking and low temperature cracking, improved tensile strength, ductility, toughness, adhesion, resilience, tenacity, durability, and skid resistance [1].

Tires have limited lifespan and constitute a large volume in the environment such that adequate methods of disposal have not been developed or discovered. Hence they constitute an environmental nuisance. Recent research has been able to develop ways of recycling and reusing the used tires in road pavement construction.

The tire rubber can be modified into adequate asphalt binder through two processes namely the wet and dry process. Under the wet process, the ground rubber is added to the bitumen previously warmed at temperatures around 190 °C remaining in contact for a period of 1 to 4 hours [2]. The rubber particles, especially if in large quantities, swell in the bitumen due to absorption of some of the lighter bitumen fractions to form a viscous gel with an increase in the overall viscosity of the modified binder.

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Under the dry process, the rubber particles are first added to the preheated mineral aggregate, before the bitumen is added. The aggregates are heated at temperatures between 200 °C and 210 °C for about 15 seconds, resulting in a homogeneous mixture. Thereafter, the bitumen is heated at temperatures between 140 and 160 °C and added to the aggregate – rubber mixture [2-3].

Hence, this study assesses the properties of asphalt modified with used tire. The underlying objectives are to determine the properties of asphalt binder modified with used tire and to compare the performance of the asphalt modified mix with the performance of conventional asphalt mix and determine the effectiveness of the process.

Background Literature

Mainly petroleum refinery plants with the evolution of modern technology produce asphalt binders. It has been shown that most petroleum products consist of asphalt in which it exists in solution. The crude petroleum is refined by distillation to separate the various fractions. During this process, asphalt is recovered. The modern refined asphalt is better than the crude natural ones of the olden days for obvious reasons. This is because in some distances, the natural asphalt has become mixed with variable quantity of mineral matter, water and other substances. This can impair the properties of the asphalt. For the purpose of refinery (distillation) however, natural bitumen (natural asphalts) has been conveniently classified into three groups from practical point of view namely materials occurring in a fairly pure state, materials found with an appreciable proportion of mineral matter but with the bitumen predominant and mineral materials associated with relatively small proportions of bitumen [4].

Engineers are very interested in asphalt because of its properties. It is readily adhesive, highly waterproof, durable and has high strength. It is plastic in nature thereby giving controllable plasticity to mixtures of mineral aggregates when combined with them. It is unaffected by most acids, alkalis and salts. Asphalt may be readily converted to liquid form by applying heat or by dissolving it in petroleum solvents of varying volatility.

There is a wide interest in the use of rubber tire modified binders in pavement construction as several laboratories and field tests reported improved overall performance of pavements. The asphaltenes and the light fractions of conventional binders interact with the granulated rubber of the used types forming a film of gel on the rubber leading to an increase in the volume [5]. The granulated rubber and conventional bitumen do not react. The rubber acts as an additive and not as a modifier agent [6]. The results of the study indicate that there is a physical interaction between the rubber particles obtained from the used tires and the bitumen leading to a different final behavior of the bitumen.

In the wet or dry process, the interaction of conventional bitumen, rubber granules should not be made above temperature of 170 °C, in order to seize all the characteristics that the modified bitumen presents in the bituminous mixtures compared to the conventional bitumen. A proper dispersion of crumb rubber particulates into asphalt was achieved making crumb rubber compatible with modified asphalt with improvement both in high and low temperature properties, which can lead to reduced cracking, rutting, and raveling tendencies of the crumb rubber modified asphalt pavement [7]. The approach of the study was to join the crumb rubber and asphalt molecules with small bi-functional molecule called compatibilizers.

In terms of physical properties, tires consist of a rubber compound usually reinforced with steel and textile. Tires vary in design, construction and total weight depending on their size and usage. The weight of a used passenger car tire in Europe is about 6.5 kg and that of a truck tire is about 53 kg. Passenger car and truck tires make up approximately 85% of the total tires manufactured globally. In terms of chemical properties, approximately 80% of the weight of car tires and 75% of the weight of truck tires is rubber compound [8].

MATERIALS AND METHODS

The materials used in carrying out this study are bitumen, fine and coarse aggregates, filler and ground tire. 70-80 penetration grade bitumen was used as the base asphalt binder in this study. This bitumen was obtained from Samchase Bitumen plant along Akure-Ado Road in Nigeria. Figure 1 shows a sample of the bitumen.

Fig. 1 - Sample of the bitumen used.

The fine aggregate used for this experiment was obtained from Ogbese river in Ondo state, Nigeria. The sand was free from silt and and other organic materials that can reduce the strength or have any other negative effects on the asphalt made from it. Figure 2 shows a sample of the fine aggregate used.

Fig. 2 - Sample of the fine aggregate used.

The coarse aggregate used in this research was crushed rock obtained from Samchase quarry Akure, Ondo state, Nigeria. It was carefully selected to ensure that it was free of deleterious materials. Figure 3 shows a sample of the coarse aggregate used.

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Fig. 3 - Sample of coarse aggregate used.

The filler used for this experiment was obtained by sieving quarry dust obtained from Samchase quarry Akure, Ondo state with sieve no 200 (75 micron). Figure 4 shows a sample of the filler used.

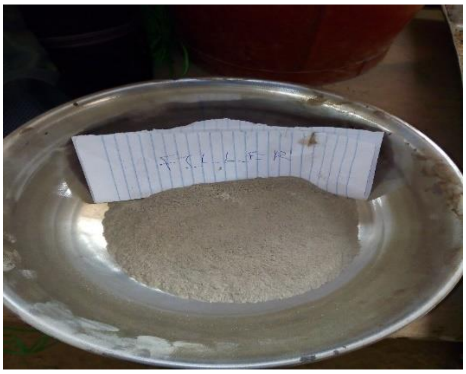

Fig. 4 - Sample of filler used.

Figure 5 shows a sample of the tire used in this study obtained by grinding used tire into powdered form.

Fig. 5 - Sample of ground tire used.

Tests Carried out

Tests were carried out on the fine aggregates, coarse aggregates, shredded crumb tire and asphalt binder (Bitumen) to determine their characteristic strength. Moisture content, particle size distribution and specific gravity test were carried out on the fine aggregate. Specific gravity, aggregate impact value (AIV), aggregate crusshing value (ACV) were carried out on the coarse aggregate. Moisture content, ductility, viscousity, softening point, flash and fire point and penetration tests were performed on the bitumen with and without the ground tire.

RESULTS AND DISCUSSION

In order to determine the asphalt mix design to use for the different tests at varying percentages of ground tire addition, the Marshall Stability test was carried out. The stability of the mixes was determined by multiplying the proofing ring factor (0.0328) value with the dial reading. Three mix designs with the highest stability were selected out of several from several mix designs and the average obtained. The results of the stability test are as shown in Table 1.

Tab. 1 - Results of Marshall stability test.

S/N	% CRUMB TIRE CONTENT	DIAL READING				STABILITY(KN)			
		A	B	C	Average	A	B	C	Average
1	0%	57	37.6	32.2	42.3	1.87	1.23	1.06	1.39
2	2%	26	19	17	20.7	0.85	0.62	0.56	0.68
3	4%	17.6	33.2	25.6	25.47	0.58	1.08	0.84	0.83
4	6%	51.0	47.6	43.0	47.2	1.67	1.56	1.41	1.55
5	8%	45.2	31.0	38.0	38.1	1.48	1.02	1.25	1.25
6	10%	45.6	36.0	46.8	42.8	1.50	1.18	1.54	1.41

Moisture content test

Table 2 shows that the average moisture contents for the fine aggregates and the coarse aggregates used were 2.08% and 1.74% respectively.

Tab. 2 - Moisture content test for the aggregates

S/N	MATERIAL	MOISTURE CONTENT 1 (%)	MOISTURE CONTENT 2 (%)	MOISTURE CONTENT 3 (%)	AVERAGE MOISTURE CONTENT (%)
1	Fine Aggregates	1.97	2.18	2.10	2.08
2	Coarse Aggregates	1.74	1.73	1.76	1.74

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Aggregate Impact value (AIV) test

The Aggregate impact value is a measure of the resistance of coarse aggregates to impact load (sudden load). Table 3 shows that the average aggregate impact value of the coarse aggregates is 22.91%.

Tab. 3 - Results of Aggregate Impact value (AIV) test.

S/N	AIV 1	AIV 2	AIV 3	AVERAGE AIV
1	22.91%%	23.00%	22.83%	22.91%

Aggregate crushing value (ACV) test

Granular base layers and surfacing are subjected to repeated loadings from truck tires and the stress at the contact points of aggregate particles can be quite high. Crushing tests can reveal aggregate properties subject to mechanical degradation of this form. The aggregate crushing value gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. The average aggregate crushing value of the sample was obtained as 13.47% as shown in Table 4.

Tab. 4 - Results of Aggregate crushing value (ACV) test.

S/N	ACV 1	ACV 2	ACV 3	AVERAGE ACV
1	13.21%	13.50%	13.70%	13.47%

Specific gravity

The specific gravity of the ground tire, filler, fine aggregate and coarse aggregate were 2.75, 2.76, 2.74 and 2.65 respectively.

Particle size distribution test for the fine aggregate

Figure 6 shows the particle size distribution chart for the fine aggregate used. It can be observed that the soil is composed of silt and sand.

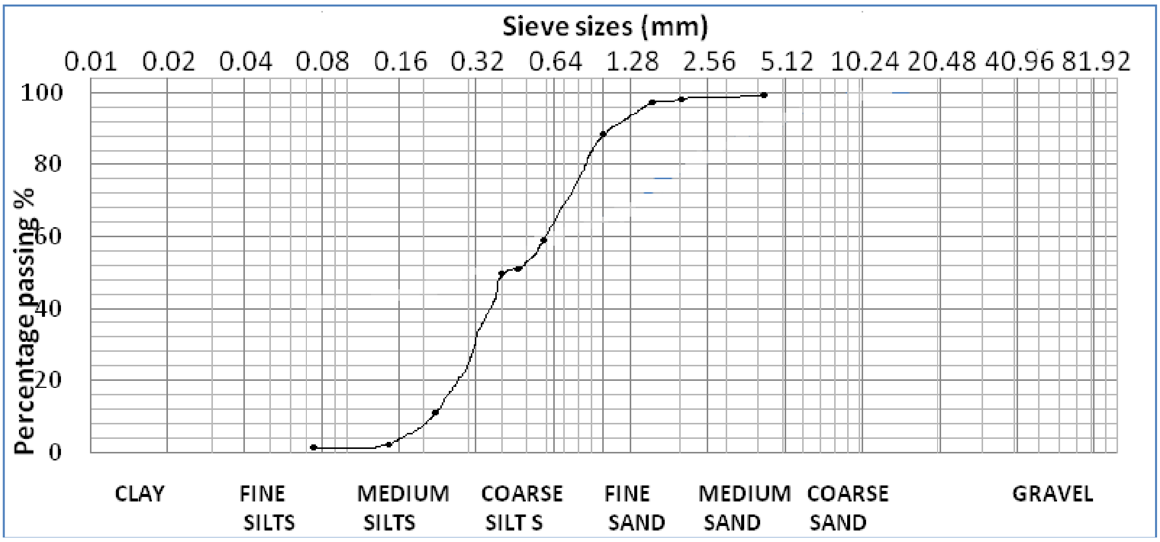

Fig. 6 - Particle size distribution chart for the fine aggregate.

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Water in Bitumen test (Dean and Stark method)

Table 5 shows the results for the water in bitumen test (i.e. moisture content). The moisture content of the bitumen and modified bitumen (0%, 2%, 4%, 6%, 8%, and 10%) from the table above are 2.35, 3.01, 3.32, 3.47, 3.37, and 3.88 (%) respectively. The moisture content increased with respect to the percentage of modified bitumen. The control bitumen moisture contest was 2.35%, but when the bitumen was modified with 2% ground tire the moisture content increased to 3.01%. Also when the bitumen was modified with 4% ground tire, the moisture content increased to 3.32%. There was also an increase in the moisture content (3.47%) up to 6% addition of ground tire after which there was a drop at 8% ground tire addition. The highest moisture content of 3.88% occurred when the bitumen was modified with 10% ground tire.

Tab. 5 - Water in Bitumen test.

S/N	% ADDITION OF GROUND TIRE	MOISTURE CONTENT (%)
1	0	2.35
2	2	3.01
3	4	3.32
4	6	3.47
5	8	3.37
6	10	3.88

Penetration test

Penetration is a measure of the consistency or hardness of bitumen and is the most common control test for penetration grade bitumen. Figure 7 shows the variation of penetration value against the corresponding percentages of tire added to the bitumen. The penetration value of the bitumen modified with ground tire decreases in relation to the control (bitumen without ground tire). The control's average penetration value was 70mm. When it was modified with 2% ground tire, the average penetration value decreased to 56mm. With 4% modified bitumen the penetration value further decrease to 47mm. However, at 6% modified bitumen the penetration value rises to 53mm, but starts to reduce again at 8% and 10% modified bitumen respectively.

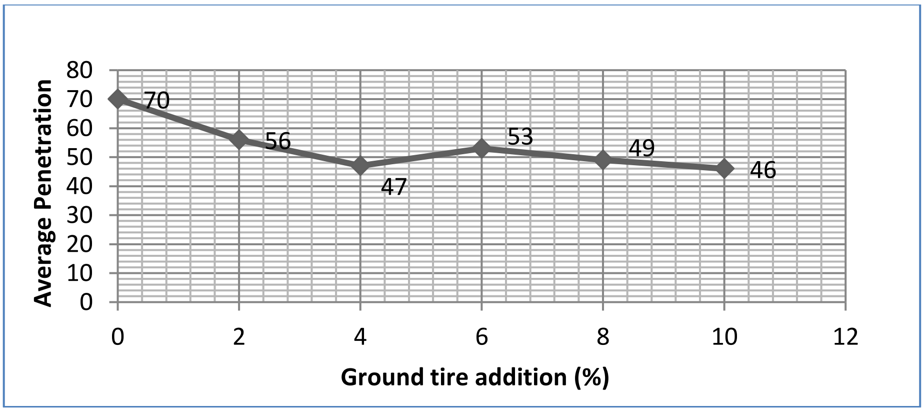

Fig. 7 - Graph of Average penetration against percent addition of ground tire.

Softening point test

The softening point is a measure of the temperature at which bitumen begins to show fluidity. It is also defined as the temperature at which a bitumen sample can no longer support the weight of a 3.5g steel ball. The softening point increases with increasing ground tire content as shown in figure 8. The control bitumen's softening point was 54ºC, but when the bitumen is modified with 2% shredded tire the softening point increases to 60ºC. With 4%, 6%, 8% and 10% modifications with ground tire the softening point increases to 66 ºC, 73 ºC, 78 ºC, and 83 ºC respectively.

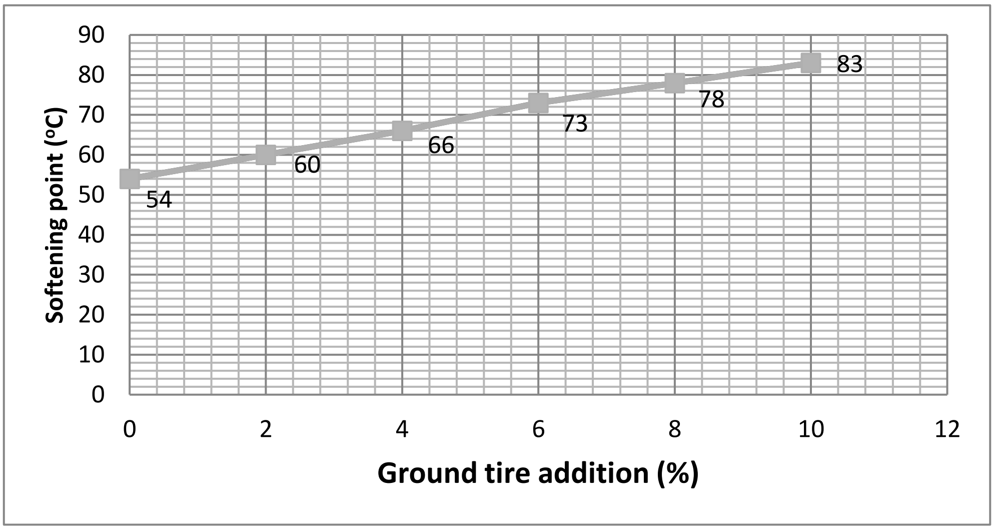

Fig. 8 - Graph of softening point against percentage addition of ground tire.

Flash and fire point test

Bitumen volatilizes (gives up vapor) when heated and at very high temperatures, bitumen can release enough vapor to increase the volatile concentration immediately above the bitumen to a point where it will ignite (flash) when exposed to a spark or open flame. This is called the flashpoint. For safety reasons, the flash point of bitumen is tested and controlled. The fire point, which occurs after the flash, is the temperature at which the material (not just the vapors) will support combustion. Figure 9 shows the graph of flash and fire point against the percentages of ground tire addition. It clearly shows that the addition of the ground tire reduces the flash and fire point. This test should be carried out to know the heat to be applied on the bitumen before it flashes and burns for 2-5 seconds. This will determine the amount of heat the bitumen can withstand on the site before it becomes viscous.

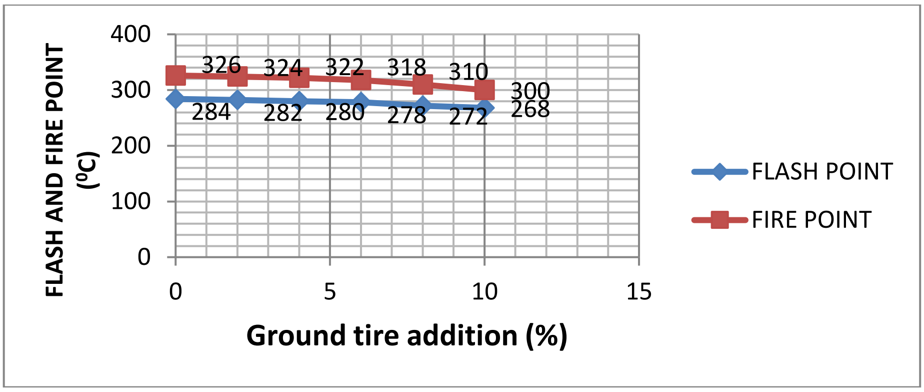

Fig. 9 - Graph of flash and fire point against percentage addition of ground tire.

Ductility test

Ductility is a measure of the breaking resistance or cracking resistance of bitumen during summer, a higher value of ductility shows a higher tensile strength of bitumen. Figure 10 shows that the ductility of the control bitumen was 93.11 cm, but when the bitumen was modified with 2 % ground tire the ductility increased to 99.98 cm. Thereafter, the ductility decreased up to 10% ground tire addition.

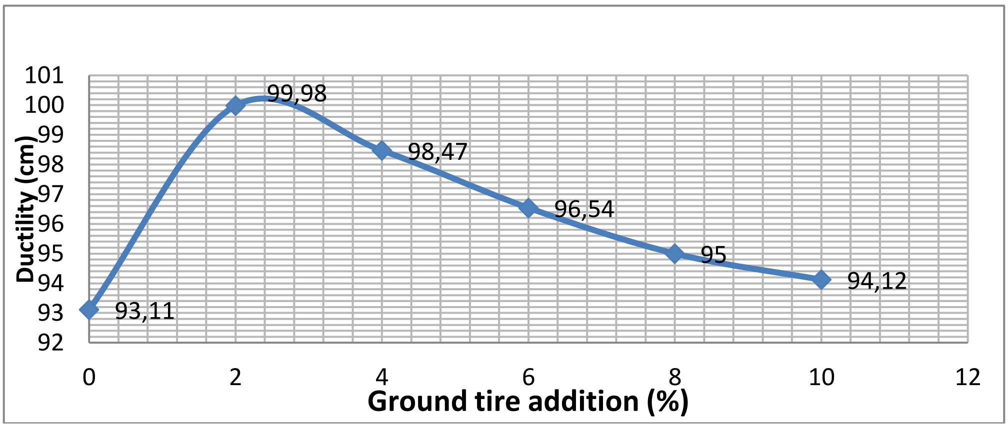

Fig. 10 - Graph of Ductility test against percentage addition of ground tire.

Discussion

The water in bitumen test on all the variations of bitumen resulted in moisture contents that were still within the specified standard of 0 to 5%. Under the penetration test, the results show that the penetration value of modified bitumen is affected by the presence of rubber particles mixed in the control bitumen. The penetration values for the modified binders decreases as the rubber binder mix increases as compared to the original bitumen. Lower penetration grades are preferred in temperate regions so as to prevent softening whereas higher penetration grades such as 180/200 are used in colder regions to prevent the occurrence of excessive brittleness. Lower penetration bitumen has better adhesion, and water-resistant properties.

The softening point test clearly shows that the addition of ground rubber to bitumen increases the softening point value, and as the ground rubber content increases the softening point also increases. This phenomenon indicates that the resistance of the binder with increasing heat

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reduces its tendency to soften in hot weather. Thus, with the addition of ground tire, the modified binder will be less susceptible to temperature changes. The specified standard for flash and fire point are 280 to 300 ºC and 300 to 320 ºC respectively [9]. The flash and fire point values obtained in this study all lie within these specifications. In the case of the ductility test, the highest value was obtained at 2 % ground tire addition to the bitumen. Thereafter, the ductility decreases up to 10% addition of ground tire.

CONCLUSION

Based on the laboratory test results, the mixture containing ground tire resulted in higher resistance to deformation. It appears that the ground tire causes a decrease in the consistency and an increase in the resistance of the material to temperature changes (this is based on the result of the penetration, ductility test, flash and fire point test and softening point test) while the resistance to flow also increases. It may be inferred that bitumen modified with used tire provided better resistance against deformations due to its higher softening point when compared to the control.

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