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Effect of Portland Cement and Waste Animal Bone on Asphalt Binder

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Abstract

Bituminous binder modification has been one of the methods to improve asphalt pavement quality. In this research the analysis of the effect of Portland cement and waste animal bone (PCWAB) additive on some properties of asphalt binder using conventional test and dynamic rheometer testing methods. Including the control specimen four binders were obtained by mixing the asphalt binder with three different percentages (2, 5, and 8%) by weight of asphalt binder, were added to the control 80/100 pen grade asphalt binder. The result show that addition of both modifiers had a significant influence on the binder properties. A reduction of penetration, increases of softening point and flash point were observed with increases in additive content, this implies improvement in stiffness and rutting resistance. As well as Dynamic Shear Rheometer test (DSR) such as Amplitude Sweep Test (AST), Frequency Sweep Test (FST) and Multiple-Stress Creep and Recovery test (MSCR) was conducted. Finally, the master curve shows that more percent addition of PCWAB on asphalt binder increases the stiffening property of asphalt binder at high temperatures and low loading frequencies. On the other hand, from the test result obtained from MSCR test the smallest total strain value obtained to be 8% followed by the 5% and 2%. Rheological analysis shows that addition of PCWAB improves the viscoelastic properties of the modified binders at high temperature. It is important as environmental preservation by minimizing solid waste products.

Keywords: Asphalt Binder; Rheology; Cement; Bone; Modification; Conventional Test; Dynamic Shear Rheome

Introduction

Service life of pavements and road infrastructures have a huge contribution for one country economic growth by facilitating transportation systems for easy movement of material and peoples from place to place. Currently in Ethiopia, the government stands for improving transportation systems throughout the nation because of the demand for transportation become increasing starting from the last decades [1].

In road construction engineers must Consider the primary user requirements of safety, economy and it is essential to construct asphalt pavement that remains with acceptable used for long lifetime. In order to achieve highway construction requirements pavement designer should be consider take into account environmental factors, traffic flow and asphalt concrete mixtures materials. The common problems in type of flexible pavements are pavement distresses which usually need continuous effort to tackle them. According to expressed Federal Highway Administration (FHA) There are different types of distresses appear in asphalt flexible pavement such as permanent deformation, fatigue cracking, shoving and low temperature cracking and etc. permanent deformation in asphalt pavements is one of the most cause significant types of deterioration which usually consists of longitudinal depressions in the wheel paths. The aim of this study is to investigate the effect and the performance of bitumen modified with Portland cement and waste animal bone at high temperature for rutting resistance.

Rutting (permanent deformation) of pavements layers occur due to the accumulation of strains over time under the action of repetitive traffic loading on pavement [2–5] and rutting in asphalt binder pavements leads to a serious problem that reduction in both structural and also reduce service life of the asphalt pavement. as well as Pavement performance is greatly affected by the bitumen properties. Therefore, there are different method to improve performance of bitumen concrete pavement. Some of the methods are improving the pavements material mix design, improving the construction methods, enhancing maintenance techniques and producing a new binder. These motivate and invited us to produce new binder with improved physical and chemical properties using modifiers. Hence, to minimize the damaging effect of asphalt layer rutting and improve its durability of the additive and polymers has an effective engineering solution. Modifiers have great contribution to improve the basic properties of bitumen such as elasticity, rigidity and durability [6–8]. Chemical composition of waste animal bone (WAB) mineral is complex which is made up of calcium, phosphate as well as hydroxyl ions, but which might furthermore hold a small or little amount of cationic, magnesium in addition to strontium replacing calcium which in addition to bicarbonate, replacing hydroxyl anions. Cattle bone has ultimate compressive strength of more than 140MPa and ultimate shear strength of more than 85 Mpa and also it is a visco-elastic material with a density of 1810 kg/m^3. Bone has a melting point of 1670°C [9]. asphalt binder's compaction and mixing temperatures of HMA and viscosity. The results showed that bone glue modification improved complex shear modulus. A Modified binders with bone glue showed great improvements on shear fatigue, creep compliance, and complex shear modulus than control asphalt [10, 11]. Bone Glue modification decreased the initial cost and will enhance the long-term serves period performance characteristics of pavement. Other modifiers have been also study as replacement or modification of bitumen binder to improve pavement performance and also Such as, the findings from the study of Nano silica modified asphalt binders and polymer-modified Nano clay modifier increased the rutting and fatigue cracking performance of asphalt mixtures and the addition of fibers and Nano charcoal coconut-shell ash on bitumen improves the rheological properties of bitumen, reduced the penetration, increased softening point and viscosity of bitumen which implies improved rutting resistance of asphalt mixtures and also it improved fatigue performance [12] and also, with the addition of crumb rubbers, the high temperature grade of asphalt has been increased (from PG64 to PG76). From the master curve permanent deformation (using the $|G^*|/\sin(\delta)$) of crump rubber asphalt shows a significance improvement in rutting resistant at each testing temperature and loading frequency as well as the addition of 0.75% soybean- derived biomaterial by weight of bitumen on neat bitumen binder and also polymer modified bitumen showed a significant effect on fatigue properties.

The addition of cement on asphalt binder also showed improvement on rutting parameter, $G^*/\sin(\delta)$ value and Super pave high PG temperature with increasing of cement-to- asphalt ratios. Furthermore, studies which have been conducted on partial replacement of cement with animal bone in concrete. For instance, a maximum of 10% bone powder ash was incorporated into cement [13,14] the results showed that the replacement of cement with 10% bone powder ash showed an increase in the compressive strength of concrete. Up to 5% bone powder replacement of cement increases both compressive and tensile strengths of concrete [15]. This is because bone powder is acting as nucleation agent which increases the hydration ability of cement. Mortars mixes' mechanical properties also showed higher performance.

As well as the use of Portland cement in asphalt mixture is not a new concept. Portland cement was used primarily as filler in bitumen binder or in warm-mixed with bituminous mixtures which to prevent or protect stripping of the bitumen binder from previously dried aggregate. It was used to enhance the coating of wet aggregate with bitumen or tar [16–18]. this indicated water resistance and with some aggregates a large increase in the dry resilient modulus (Mr) of the hot mixes, which imparted by adding the cement and lime as a slurry to the aggregate 24 h before the hot mix was made. The raw material which used in the manufacture or production of Portland cement (PC) consist of lime, silica, iron oxide and aluminium. The ASTM (Americans society for testing and material) has designated five types of Portland cement, designated Types I-V depend on physically and chemically analysis, these cement types different in their material, content of C3a also in their fineness.

Experimental Design

This methodology and experimental design focus the effect of waste Animal bone and Portland cement conducted on unmodified and modified bitumen. Additionally, to evaluate the rheological characteristics. Understanding the properties of bitumen material is important to quantify its engineering performance. Materials such as bitumen which exhibit aspects of both elastic and viscous behavior, must be characterized with test methods and analytical techniques that account for the time (or rate) of loading and temperature. The effect of rheological behavior of bitumen improved by modification of bitumen with Portland cement and waste animal bone. As well as every test approach, equipment and conditioning machines used to investigate asphalt's both conventional and fundamental test. Conventional test method such as penetration, ductility, softening, flash, fire point and also RTFO test has conducted. Fundamental properties are assessed using MARVEL BOHILN Dynamic Shear Rheometer test. Generally, in this research a comprehensive literature review made to understand the previous efforts, which include the, academic journals, research papers and review of textbooks are conducted in this research.

Materials

Bitumen binder grade 80/00 penetration was used for the preparation of modified binders blend in this study. this bitumen obtaining from China road Construction Company and its physical properties penetration, softening point, ductility, conditioning test, flash point and fire point [19–23] were studied to qualify the bitumen before modification. Two different filler additives namely waste Animal bone and Portland cement was used for the binder modification. The waste Animal Bone and Portland cement both obtained from local source. According to express on Ethiopian pavement design Manual [24] three different penetration grades of bitumen 40/50, 60/70 and 80/100. Bitumen grade 80/100 was used for this study because soft and less stiff bitumen.

Methods

Sample Preparation in laboratory for modifiers

The first step to clean the Bone samples, can, sun-dried and oven dried to reduce its oil content before crushing bone and screening into the desired sizes. As well as Portland cement is used in this study. The required size of both modifiers to prepared bituminous modifier is (<75μm). Fig 1

Figure 1: Sample preparation for Portland cement and Waste Animal Bone powder

These tests conducted on asphalt binder blend or mixed in different percentage of Portland cement and waste animal bone, varying between 2%-8% by weight of the bitumen, for mixing original bitumen was heated to a temperature of 140-160°C then the necessary amount of waste animal bone and Portland cement was added to asphalt binder by contentiously electrical stirring with revolution of 600 rpm the mixture for 60 minutes at a constant temperature to ensure good homogeneity.

Figure 2: Mixing by electrical stirrer

Conventional Test Method

Different tests were performed on the prepared samples according to established Standards to characterize the properties of asphalt binder mixed with different percentages of Portland cement and Waste animal bone by weight of the asphalt binder. These tests include penetration at 25°C, softening point, ductility test, flash point and fire point.

Penetration

Penetration test was conducted based on ASTM specification and determines the hardness of Bitumen by measuring the depth (in tenths of a mm) to which asphalt binder sample is heated to an appropriate temperature and poured in to a test container of 40 mm deep penetration tin. After 1 hour cooling on environmental atmospheric temperature, the sample is set to the standard test temperature of 25°C ± 0.1 in a temperature-controlled water bath. The sample container is then placed in the penetrometer equipment. A needle of 2.5 g weight is attached to the penetrometer and suspend direct over the sample. A 50-gram weight is attached to the needle's loading platform so that the total weight used for loading is 100 grams (50 g weight and 50 g needle holder). The penetrometer is lower until the needle tip keeps the surface place of the sample. The load is then released, allowing the weighted needle to penetrate the asphalt binder for duration of 5 seconds. The distance that needle penetrates in to the asphalt sample is reported the penetration result. Two samples with each three measurements are collected and reported the average.

Softening point

Softening point (Ring and ball) test was conducted based on ASTM D 36 or AASHTO T 53 specification. Softening point test characterize and evaluates the temperature at which asphalt binder sample begin to show fluidity. Softening point helps to classify bitumen, check uniformity and signify its tendency to flow at elevated temperature. Higher softening point indicates the lower temperature susceptibility and preferred in warm climates. Asphalt cement is heated and poured to 2-rings. Asphalt sample is to cool at atmospheric air temperature for more than 30 minutes. Then assembling the ring-holder, rings, thermometer and balls are conducted at 5°C water and allowed to equilibrate for 15 minutes. A steel ball of 3.5 g is put on a sample of asphalt contained in a brass ring which is suspend in a water. Remind that water is used for softening point of 80°C and below. Immediately transfer the container onto the heating unit. The bath temperature is raised at 5°C per minute, the binder gradually softens and eventually deforms slowly as the ball falls through the ring. The moment the asphalt and steel ball touch a base plate 25 mm below the ring, the temperature of the water is recorded. Average temperature of the two rings is reported.

Flash point and Fire point

The lowest temperature at which the application of test flame causes the vapors from the bitumen to momentarily catch fire in the form of a flash as well as the lowest temperature at which the application of test flame causes the bitumen to fire and burn at least for 5 second.

Basic procedure of RTFO Ageing Test

The Rolling Thin-Film Oven test was performed both on unmodified and modified bitumen in accordance as per AASHTO T 240, which analysis the "Effect of Heat, Air and investigate the loss of volatiles in spite of various other factors that contribute to asphalt binder aging. The asphalt's viscosity is increased due to the loss of volatiles from the asphalt binder which mainly occurs during the processes of manufacturing and placement. These aging procedures were developed to subject an asphalt binder sample to hardening condition that approximately simulate the condition that occur in normal, hot mix facility operation. Most importantly physical and rheological changes will be evaluated by performing appropriate tests on the asphalt before and after moving film oven. To address the issue of volatilization, the procedure incorporates a mass change determination. The change in mass is calculated based on the weight of the sample before and after aging.

The RTFO procedure is performed by pouring 35 g of heated asphalt binder into a glass bottle. If mass change is required measure the bottle first then measure with original asphalt binder. After aging measure the sample and report the result as a percentage (%).

Mass change = (Mass before aging - mass after aging)/ (mass before aging)*100

To start the test, the sample bottles are placed in a vertically rotating carriage in an oven operating at 163^{o}C and air pipe is connected with a compressor. The bottle carriage rotates at 15 rpm for a total time of 85 minutes. During rotation, a jet of air flow at the rate of 4 l/min blows into each bottle as it passes the bottom position in the carriage. After 85 minutes, any sample bottles being used for determining mass change are cooled to normal temperature before the final weight is determined. The remaining bottles are then poured and scrape in to a single sample container for additional testing.

Dynamic shear rheometer test

DSR test-used to characterize the rheological behavior of bitumen and rutting resistance at high, intermediate and low Temperature. This was done by measuring the viscous and elastic characteristics of asphalt cement with Standard test for determined the viscoelastic characteristics of asphalt cement using DSR test is described in AASHTO T315-10. DSR test utilized to measure different properties of bitumen before modification and after using modification. Test results at low, intermediate and high temperatures, which used to predict rutting resistance in asphalt pavements. The test can be done when the bitumen's sample is sandwiched between two parallel metal plate. The bottom (surface) plate is fixed (constant) and the upper plate oscillate forth and back across the sample to create a shearing action. Depending upon the type of bitumen being tested the test temperature, specimen size and plate diameter varies. Test temperatures greater than 46°C use a sample 0.04 inches (1 mm) thick and 1 inch (25 mm) in diameter), Test temperatures between 4°C and 40°C use a sample 0.08 inches (2mm) thick and 0.315 (8mm) in diameter . DSR tests are conducted on BRTFO (Before Rolling Thin Film Oven) and ARTFO (After Rolling Thin Film Oven) aged asphalt binder samples and then the rheological parameter is recorded such as complex shear modulus (G*), dynamic viscosity, frequency, phase angle (δ) and Accumulated strain, etc.

The complex modulus is a determined the resistance of asphalt cement to rutting (deformation) when exposed to a sinusoidal shear stress load and consists both visco- elastics when elastic (recoverable) and viscous (non-recoverable) component of material. The shear complex modulus (G*) measure of two components: one is loss modulus, G" (G''=G*sinδ) and the other is the storage modulus (G'= G*cosδ). The G' is the elastic (recoverable) component and it represents the amount or ability of energy that found (stored) in the sample during at each loading cycle. While the G" is the non-recoverable (viscous) component, represents the amount of power (energy) lost during at each loading cycle.

Phase angle (δ) is an indicator or represent of relative amounts of viscous and elastic components as well as the lag (difference) between the applied (load) shear stress and the resulting get shear strain. The values of complex modules G* and the value of phase angle (δ) for asphalt binder are dependent on the frequency of loading and test temperature. At high temperature asphalt cement behave change to like viscous fluids. At low temperature bitumen

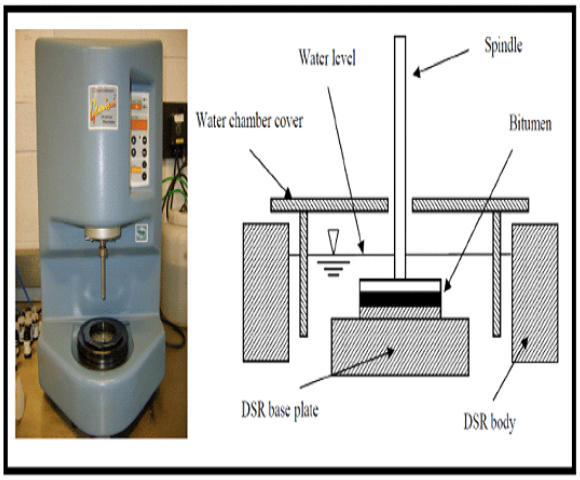

Figure 3: Schematic of dynamic shear rheometer testing configuration [33]

behave change to like elastic solids. The larger phase angle (δ), expressed more viscous material. so important to determine both the complex modulus(G*) as well as the phase angle(δ) within the visco-elastic range of response to characterize for aged and neat asphalt binders [25–32].

Performance grade determination (PG)

Performance grade test (PG-test)- This test was conducted at high temperature to categorize the tested bitumen binder sample in different temperatures, ± 6°C increments: For the purpose of this study from the above indicated high temperatures 52°C, 58°C, 64°C, 70°C and 76°C are used for performance grade determination (e.g PG70 No rutting until 70°C). A constant frequency 10 rad/sec is used; representing 80 km/hr to 100 km/hr speed on the highways. It was believed that the permanent deformation parameter G*/sinδ is a good indication for rutting on the pavement. To conduct this test, the DSR equipment is first initialized to operate with proper parallel plate geometry and gap. The plate is 25-mm and the gap is 1-mm. After conditioning the specimen for 10 minute the test begins with 10 rad/sec frequency and 10% (aged binder) or 12% (original binder) strain as an input.

Multiple stress creep and recovery (MSCR) Test

MSCR- is the latest indicate improvement on Super pave Performance Graded bitumen Binder specifications and addresses or measure at high temperature rutting (permanent deformation) both for unmodified and modified binders. This new test and specification provide accurately indicates the rutting performance of the binder and Recovery measurement can Identify and quantify how the polymer is working in the binder. A major benefit of the new MSCR test is that it eradicates the need to run tests like as elastic recovery and also phase angle procedures designing in specific to indicate or measure polymers modification of bitumen binder. The test protocol (AASHTO T350) requires that a 25-mm diameter and 1-mm thick asphalt specimen is subjected to 10 cycles of one second creep loading followed by 9 seconds rest period at stress levels of 100 Pa and 3200 Pa at the high PG temperature using a DSR. In this way 20 cycles at the 0.1-kPa stress level followed by 10 cycles at the 3.2-kPa stress level for a total of 30 cycles has been done. The first sample 10 cycle at 0.1 kPa was used for conditioning the specimen.

Result and Discussion

Elementary Analysis of Portland cement and waste Animal bone (PCWAB)

The result was conducted in Ethiopian central geological survey laboratory. Chemical component of Portland cement and waste Animal bone varies depend on type of cement and bone. The raw materials found in the manufacture of Pc consist mainly of lime, silica, alumina and iron oxide (CaO, SiO_2, Al_2O_3, Fe_2O_3).

Table 1: Chemical analysis of Portland cement and animal bone

Chemical %	Animal bone	Cement
Sio_2	5.28	43.62
Al_2O_3	0.01	3.92
Fe_2O_3	0.40	2.92
Cao	42.92	43.80
Mgo	0.94	1.00
Na_2o	1.34	0.32
K_2O	0.30	0.20
Mno	0.02	0.12
P_2O_5	26.94	0.14
TiO_2	0.01	0.25
H_2O	2.24	0.80
LOI	18.80	3.212

Conventional test method result

Penetration grade 80/100 neat bitumen selected for modification since it is softer. Indicating that asphalt binders became more viscous at lower temperature was checked for its conformity by conducting conventional tests. And the test results are represented as follows.

The Effect of Portland cement and waste animal bone on Penetration

Figure 4 presents the penetration test result of Portland cement and waste animal bone modified binders. As can be seen, the percent proportion of Portland cement and waste animal bone increase the penetration of binder mix become decreases. The modified binders have lower penetration values as compared to the control binder; this indicates that both additives have significant

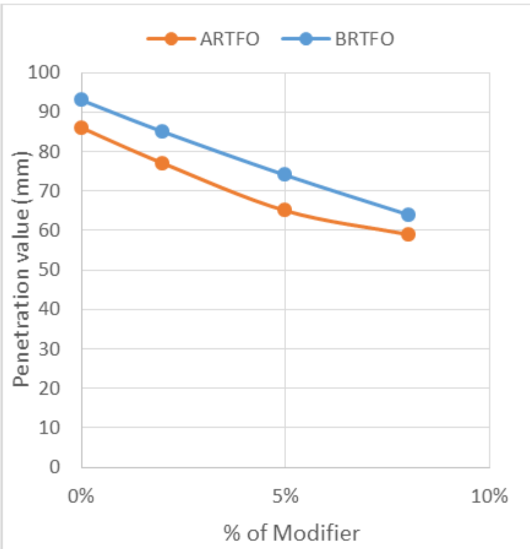

Figure 4: Penetration Grade

effect on decreasing the penetration values of the modified binders. The reason of the reduction of penetration may be free asphalt transforms to fixed asphalt (absorbed asphalt) which in turn stiffen the binder mix and the hardening of the bitumen can be beneficial as it increases the stiffness of the material, thus the load spreading capabilities of the structure. As well as the significant decrease in penetration values improving the modified binders' resistance against effects of temperature.

The Effect of Portland cement and waste animal bone on softening point

From Figure 5 shows below, it can be observed that addition of Portland cement and waste animal bone improve the softening point of binder mix. Modified binders have higher softening point temperature as compared to control unmodified binder. This indicates that addition of Portland cement and waste animal bone significantly increases the stiffness of the modified binders. The decrease in softening point shows negative effect on the property of asphalt binder. the increases in the softening point reflect in better rutting resistance at higher temperature. This will make the binders to be more resistant against rutting deformation.

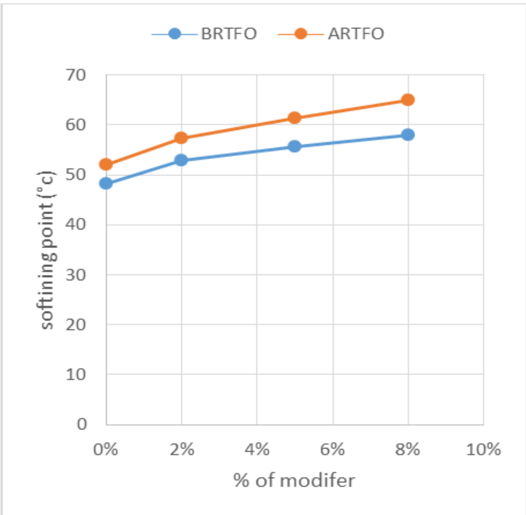

Figure 5: Softening point test result

The Effect of Portland cement and waste animal bone on ductility

The result of ductility test shows below in figure 6 decrease in ductility values up on increasing percentage of Portland cement and waste animal bone. The decrease in ductility value implies the breaking of the binder rapidly under a standard testing condition. And it is generally considered that a binder with a very low ductility will have poor adhesive properties.

The Effect of Portland cement and waste animal bone on flash point

As a petroleum product, an asphalt binder will release

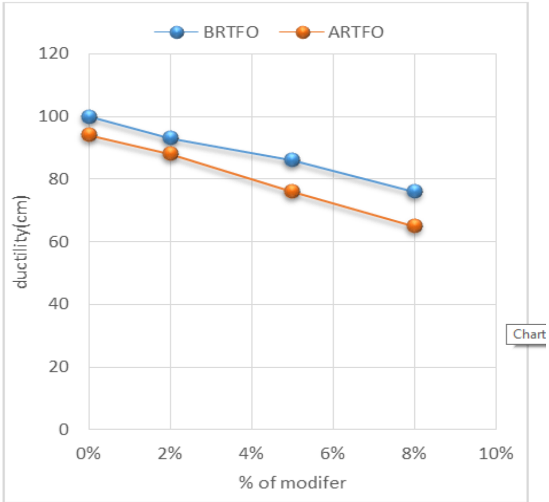

Figure 6: Ductility test result

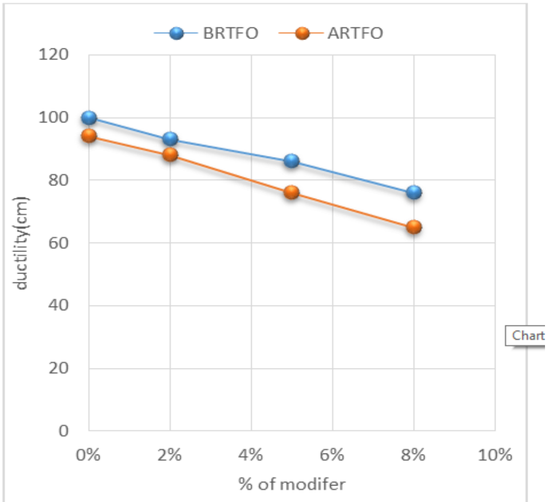

Figure 7: Flash point test result

combustible fumes when heated to sufficiently high temperature. The flashing point is an indication of the temperature at which a heated asphalt binder sample will instantaneously flash in the presence of an open flame. Therefore, addition of Portland cement and waste animal bone indicates increases flash point.

The Effect of Portland cement and waste animal bone on fire point

When temperature is usually well below the temperature at which the material will support combustion, which is fire point. after flash point the bitumen changed to fire so when addition of content of modifier the bitumen less fire point.

Dynamic shear rheometer test Result

DSR test was used to characterize the rheological behavior of bitumen and rutting resistance at high, intermediate and low

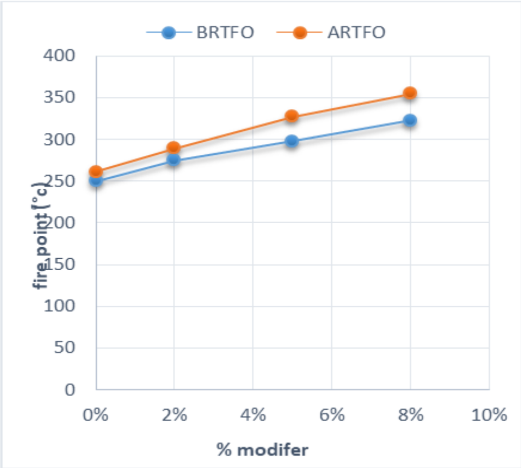

Figure 8: Fire point test result

Temperature. This was done by measuring the viscous and elastic characteristics of asphalt cement with Standard test for determining the viscoelastic characteristics of asphalt cement using DSR test and is described in AASHTO T315-10. DSR test was utilized to measure different properties of bitumen before modification and after using modification. Test results at low, intermediate and high temperatures, were used to predict rutting resistance in asphalt pavements.

The effect of Portland cement and waste animal bone on Amplitude sweep test

The linear viscoelastic range (LVR) is illustrated by the relationship between the complex shear modulus G* versus with shear strain. In SHRP study it is reported the linear viscoelastic range (LVR) was defined as the point where complex modulus decrease to 95% of its initial value. Therefore, AST provide LVE-range by limiting the strain value so that asphalt binder for which

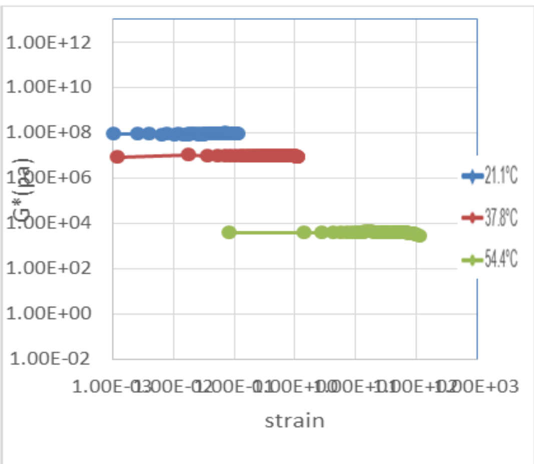

Figure 9: Linear Visco Elastic Range for 5% Modified Binder ARTFO

the stress-strain behavior is linear and independent of rate of loading and temperature. Figure 9 Shows that AST result as the complex modulus is aligned to Y-axis and strain (%) in X-axis. As an example, figure 9 below shows the amplitude sweep test result for 5% PCWAB modified binder.

As shown on above figure 9 the test result represented graphically the limiting strain values were analyzed considering the plateau strain values of each sample. Stiffness of asphalt binder and testing temperature had a significant effect on linear viscoelastic range. The stiffness of asphalt binder increases with addition of Portland cement and waste animal bone. As well as the LVE-range become small when addition of PCWAB and at high temperature modifier become too viscous and at low temperature modifier result elastic. The plateau modulus values are almost A constant value of G* is observed for different values of shear stress and shear strain before the graph declines and LVE strain limit can be calculated as the point beyond which the measured value of G* decreased to 95% of its Zero-strain as shown on above figure 9. Finally, for each and every curve of amplitude sweep result, a horizontal line along 0.95G* has been constructed to intersect the curve at a point. Then the corresponding strain value of that intersection point considered to be the limiting stain value (γL).

The effect of Portland cement and waste animal bone on Frequency Sweep Test

This can be described as an equation or curve on the graph used to compare different visco-elastic function at different loading time at a constant temperature [G] (or δ) as in terms function of frequency at which constant temperature are isothermal. It can be serves or used to study that time dependency of material. However, the rheological characteristics of bitumen cannot be presented over an extremely wide range of loading time or frequency because DSR testing usually only undertaken over limited frequency range.

As show that by simply looking at the isothermal graphs considering temperature, complex shear modulus, frequency, ageing and content of modifiers. As the temperature increases the shear stiffness decreases for all the binders. The increase in complex modulus values is observed to be more significant with increase in both additives content. This shows that the additives have significant effect on improvement of the complex modulus and also Aging improves shear stiffness (complex modulus). The increase in complex modulus observed in the modified binders indicates that the viscoelastic properties of the control binder were improved due to addition of Portland cement and waste animal bone.

The effect of Portland cement and waste Animal bone on performance grade test

PG determination test is conducted at high temperature with a 6oC temperature increment. If the sample passes the first selected

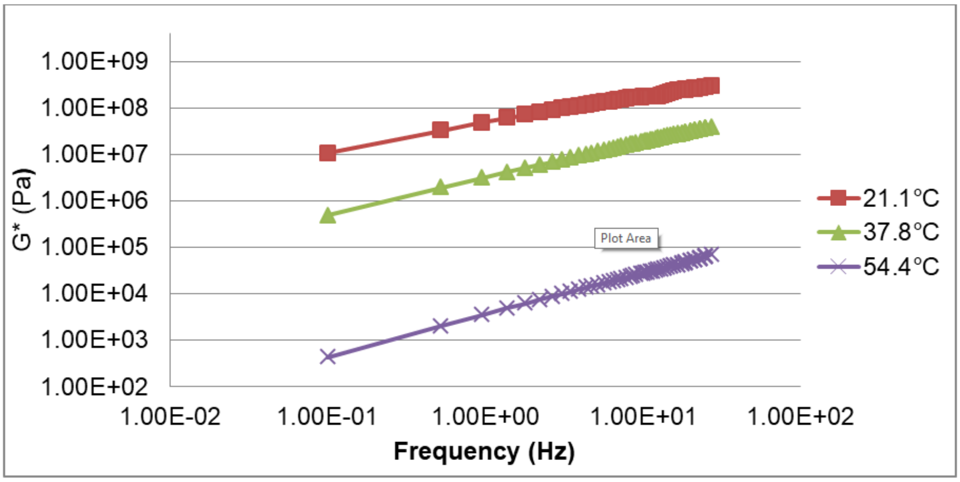

Figure 10: Frequency Sweep Test Result 5% PCWAB After RTFO

temperature, then it will continue to test for the next adjusted temperature. The final rheological parameter G*/sinδ, was believed to indicate the resistance of asphalt binder for permanent deformation at high environmental temperature before MSCR test was discovered. This study uses the parameter G*/sinδ and the increase in complex modulus values is observed to be more significant with increase in both additives content, this shows that Portland cement and waste animal bone have significant effect on improvement of the complex modulus, to identify the maximum temperature that the asphalt binder could meet the minimum criteria of AASHTO M-320.

Table 2: Performance grade determination of binder mixes typically at 5% RTFO aged

Temperature	Frequency	Phase Angle	Complex Modulus	Elastic Modulus	Viscous Modulus	G*/ sinδ >2.2	Remark
(°C)	(Hz)	(°)	(Pa)	(Pa)	(Pa)	(kpa)	
58.01	1.60E+00	74.22	1.62E+04	3.48E+03	1.61E+04	16.2>2.2	pass
64.04	1.60E+00	77.82	8.46E+03	2.36E+03	8.32E+03	8.46>2.2	pass
70.05	1.60E+00	80.91	6.4E+03	2.28E+03	2.42E+03	6.4>2.2	pass
76.05	1.60E+00	82.91	1.77E+03	2.18E+03	1.73E+03	1.77<2.2	fail
Pass/fail tem	75.4						
Grade	70						

As shown on table, performance grade determination of binder mixes typically at 5% RTFO aged binder mix. Thus, the value of G*/sinδ at 760C test temperature was 1.77 kpa which is below the minimum criteria of AASHTO M-320 for RTFO aged binder (2.2 kpa). The performance grade becomes one 6oC lower than the failed temperature (PG64-YY). The increment in PG clearly shows that modifying bitumen with Portland cement and Waste animal bone increases the stiffness of the asphalt binder.

Complex modulus Master curve

The construction of master curves is a powerful tool to understand the rheological properties of asphalt binder, also at high temperatures the modified bitumen binder has high complex shear modulus which is taken as indicate stiffness that helps for resisting rutting.

For all binders in almost similar pattern shear stiffness decreases as temperature increases. At low frequency and high temperature, the modulus increases appreciably as modifier increases. addition of PCWAB has a positive effect on asphalt binder thereby increasing its stiffness.

Multiple Stress Creep Recovery (MCSR) Test

This MSCR test was conducted after the determination of the performance grade. MCSR Test is performed using DSR by applying a controlled shear stress (100 and 3200 Pa) using a load for 1 second followed with 9-second rest period. During each cycle time the bitumen binder reaches a maximum or peak strain and also recovers before the next cycle stress is also applied again. The permanent strain is then accumulated for 10 cycle's total of 100 seconds. This implies it is good information regarding the rheological characteristic of asphalt binder.

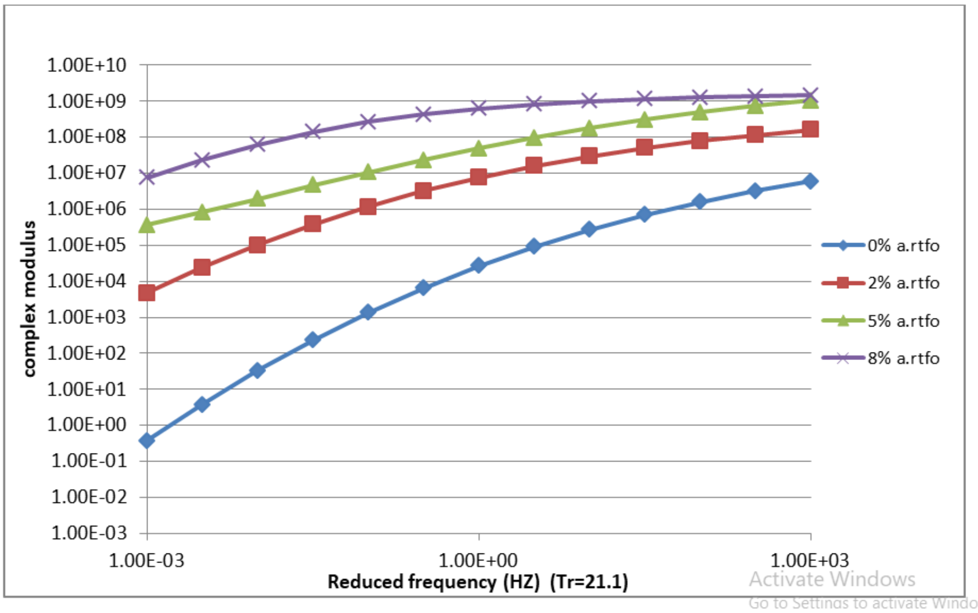

Figure 11: Complex Modulus master curve

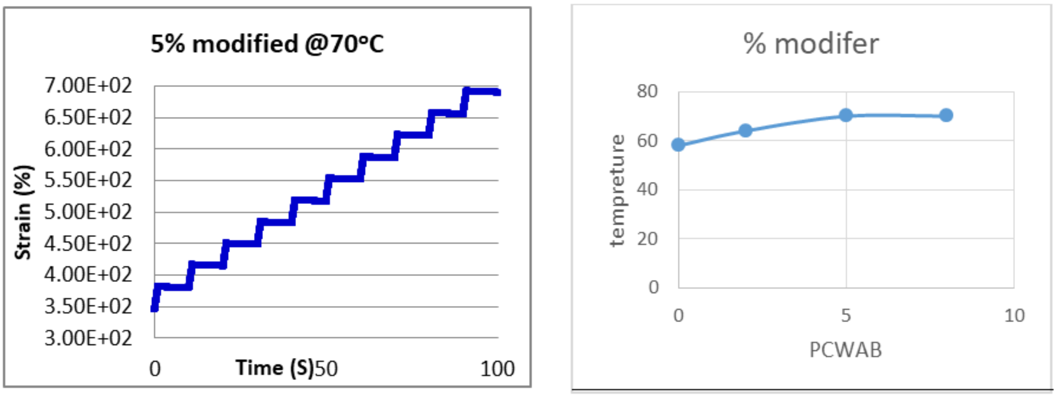

Figure 12: Addition of Portland cement and waste animal bone improves Rutting resistance at high temperature

Table 3: Multiple stress creep and recovery (MSCR) test and specification

Percent of Modified	0%	2%	5%	8%
Temperature (°C)	58	64	70	70
percent Recovery at 0.1kPa	5.23	22.42	17.82	9.92
percent Recovery at 3.2kPa	0.87	3.38	2.92	1.69
Percent Recovery difference (%)	83.3	84.92	83.6	82.9
Jnr at 0.1kPa	3.61	3.13	2.11	2.02
Jnr at 3.2kPa	3.98	3.92	2.44	2.13
Jnr Difference (%)	10.24	25.3	15.64	5.45

Traffic Designation	Traffic level (ESALs)	Load Rate	Jnr $_{3.2}$, Max kPa^{-1}
Standard Traffic "S"	<10 million	>70 km/h	4.5
Heavy Traffic "H"	10 to 30 million	20 to 70 km/h	2
Very Heavy Traffic "V"	>30 million	<20 km/h	1
[a] Extremely Heavy Traffic "E"	>30 million	<20 km/h	0.5

Based on above result it is possible to evaluate all the binders by contrasting the calculated basic MSCR parameters. The 5% modified binder with test temperatures 58, 64 & 70°C can be used. for simply heavy traffic at 64 and for standard traffic at 70oC. Jnr 8% -very good Jnr result used for Heavy traffic at 70oC and used for very heavy traffic at 64°C, this binder shows a significant improvement than the previous two binders in rutting resistance.

Conclusion

Based on the results in this study, the following conclusions can be drawn. Conventional test result indicates that, the modified binders show a reduction in penetration and increase in softening point temperature as well as improve flash point and fire point. This indicates improvement in hardness and resistance to temperature effects in the modified binders. Dynamic shear rheometer test rheological analysis shows that addition of Portland cement and waste animal bone improves the viscoelastic rheological properties of the modified binders at high temperature. Estimations of aging and rutting deformation indicates that, the Portland cement and waste animal bone will have significantly higher resistant to deformation. The complex modulus master curves show that at high temperature and low frequency the shear stiffens increases as percent modifier increases. For all binders in almost similar pattern shear stiffness decreases as temperature increases. Modification of asphalt binder with Portland cement and waste Animal Bone to improve the rheological characteristics of asphalt binder, it is important as environmental preservation by minimizing solid waste products.

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