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EFFECT OF BLENDING SPEED AND BLADE LEVEL ON THE PROPERTIES OF RECLAIMED RUBBER MODIFIED BITUMEN

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ABSTRACT

The modification of asphalt binder using crumb rubber has been verified to be extremely successful. Due to the increasing utilization of crumb rubber modifier in asphalt mixtures, there's more attitude to investigate their rheological and physical properties comprehensively. Generally the performance of rubberized asphalt binder are affected by the crumb rubber content and blending conditions. In this research, the examination was done in the laboratory on crumb rubber modified bitumen characteristics after changing three mixing speeds (250,750, and 1250 RPM) and three blade levels (low, mid, and high) using one rubber content (10% by weight of the base bitumen). The rubberizedbitumen was characterized in terms of viscosity and resistance for rutting at high service temperatures. The outcomes show that the blade level had no considerable impact on the properties of the modified binder, while the shearing rate was of great effect.

Keywords: crumb rubber, blending conditions, blending speed, blade level, viscosity, rheological properties.

INTRODUCTION

The objectives of decreasing the consumption of some valuable resources with the attempt to maximize the reusing of those natural resources for the sake of sustainable development have concerned in asphalt pavement works and have led road technicians to think about many methods for recycling of road pavement materials and structural layers [9]. Waste materials, like recycled scrap tire crumb, are utilized to create crumb rubber modified (CRM) bitumen. These modified materials have a great advantage for the environment through recycling waste tires that might somewhat be stockpiled or landfilled [3].

The utilization of elementary polymers to enhance the physical and rheological performance of asphalt binder has been followed for several years in order to mitigate the problems in asphalt pavement such as rutting and thermal cracking [17, 20]. However, the replacement of normal elementary material by using recycled polymers has been followed, so as to decrease modification costs and procure environmental advantage. Thus, a huge number of research works were dedicated to the investigation of asphalt binder enhanced by tire crumb rubber [7, 10, 20].

The introduction of recycled crumb rubber in asphalt binder modification is taken into account as a sustainable methodology that converts wasted rubber into a new beneficial material. It has been proven through field studies that crumb rubber can enhance the properties of bitumen pavement [8, 4].

The application of recycled crumb rubber in asphalt pavement road is outdated back to Nineteen Sixties once Charles MacDonald, throughout some maintenance project in town areas, knowledgeable about benefits of utilizing recycled rubber a modifier in bitumen to repaire potholes. MacDonald, actually, accurately discovered combination of the recycled rubber with the asphalt binder by giving the blend an adequate reaction time, and ongoing the investigational section work that preceded to the description of a method that's identified as Wet Process where rubber and asphalt binder are blended mutually at elevated temperatures, in order that the blend achieved is appropriate for producing asphalt mixtures [6, 9].

Meanwhile, two Swedish companies produced a wearing bituminous mixture using a small amount of ground rubber from recycled tires as a replacement for a part of the mineral aggregate, so as to get bituminous mixture with enhanced endurance to snow chains and studded tires, throughout a method called Dry Process where crumb rubber is mixed with the mineral aggregate prior to mixing with bitumen [9].

Recycled rubber gotten from waste tires has been used in an advantageous way in asphalt paving as elastic binder additive. Though, crumb tire rubber modified bitumen can provide enhanced mechanical performance, reduce reflective cracking, increase durability of pavement and fatigue resistance [20].

Some researchers have conducted studies on the influence of Crumb Rubber Modifier on the rheological performance of aged asphalt binder. The outcomes illustrated that crumb rubber has led to enhance the mechanical properties significantly [1,4,19].

All in all, blending crumb rubber with asphalt binder may enhance binder performance, and this may be shown by: lowering fatigue cracking [14]; lowering the temperature sensitivity of the asphalt binder, enhancing bitumen resistance to rutting[13, 11, 23, 22];saving natural resources and energy through using waste materials; improving durability and lowering pavement maintenance costs [16, 18].

The impact of crumb rubber on the rheological performance of asphalt binder at intermediate and low temperatures by varying shear rate had been conducted by Aflaki and Memarzadeh. The outcomes of this work illustrated the influence of high speed of rotation during

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mixing was higher than low shear rate on enhancing the low temperature properties [2, 4].

Another research has been done by Billiter *et al.* to work out the impact of curing process conditions on the asphalt binder properties modified by crumb rubber. Curing temperature, curing time, and shear rate of the blending process were the foremost effective curing conditions. It is shown that quantity of rubber dissolution into the binder throughout the curing process was increased with rising blending temperature, curing time, and speed of rotation rate of blending. This in return may enhance the intermediate- and low-temperature rheological performance of bitumen [7]. Actually, it is well proved that rubber can devulcanize and depolymerize amid blending with asphalt binder at high rotational speed and elevated temperature. Therefore, so as to produce a homogeneous rubberized asphalt mixture, variables like curing temperature, curing time, shearing rate have to be well controlled [7].

Generally, the properties of crumb rubber modified asphalt binder relies on interior factors like rubber particle size, quantity, and the composition of the base asphalt binder, and external factors like the mixing temperature, time, and shear rate, as well as the modification methodology followed. All these elements may control the swelling procedure of crumb rubber particles into the skeleton of asphalt binder leading to the increase of overall viscosity of the asphalt binder [12].

According to Aflaki 2011, the shear rate can influence the performance of CRMB. With high shear rate blending may lead to improve the low temperature performance, whereas medium and high temperature performance can be improved with low blending shear rate [2]. Rotational viscosity, on the other hand, is not influenced by shear rate of blending [15]. For better results of penetration and softening point values, Li *et al*. suggested a curing temperature of 180°C and blending time of 40 min with shear rate of 7000 RPM. The high shear speed may lead to reducing the size of the coarse particles of rubber, and this in return may increase the interaction process between the rubber and the asphalt binder [15]. Celauro *et al*., on the side, had shown that low shear rate of blending may give the best performance [9].

The core objective of this research is to analyze the implementation of crumb rubber modified bitumen as a function of mixing speed and blade level, keeping the other factors constant, through chosen binder tests. One asphalt binder (80/100 penetration grade bitumen) was utilized to be the base bitumen. The softening point, rotational viscosity and ruttingfactor (G*/sin δ)are accustomed to assess the properties of the resultant crumb rubber modified bitumen.

MATERIALS AND METHODS

Asphalt binder

The 80/100 penetration grade asphalt binder was utilized as the control bitumen in this research. Table-1 shows the physical properties of this base binder used.

Table-1. Properties of base asphalt binder used.

Type of test	Standard used	Test results
Penetration @ 25 °C	ASTM D5	85.3
Softening point, °C	ASTM D36	45
Flash point, °C	ASTM D92	280
Fire point, °C	ASTM D92	310
Specific Gravity	ASTM D70	1.036
Viscosity @ 135 °C (cpoise)	ASTM D4402	332
Viscosity @ 165 °C (cpoise)	ASTM D4402	111

Crumb rubber modifier

The recycled crumb rubber was generated by shredding scrap tire at ambient temperature into sequentially smaller particles to remove wire and fabric reinforcement to reach to the end product of crumb rubber. Only one batch of the used rubber was obtained to confirm that the consistency of the CRM was maintained during the study.

The premium and super-fine grade (40 meshes) tire crumb rubber manufactured from the selected tire material as illustrated in Figure-1. This material is compliance to the ROHS requirement. As a result of unique process and stringent quality control, T-MESH 40 offers a high passing rate and free of foreign contaminants in its properties. The chemical Compositions of the tire crumb rubber (T-MESH 40) used are shown in Table-2while Table-3 shows the Physical Composition of the used Crumb Rubber.

Figure-1. Tire crumb rubber used.

Table-2. Chemical composition of tire crumb rubber.

Properties	Standard used	Results
Acetone Extract%	JIS K 6350	10±5
Ash Content %	TGA	5±3
Carbon Black %	TGA	32±5
Rubber Hydrocarbon %	TGA	52±8

Table-3. Physical composition of tire crumb rubber.

Properties	Standard used	Results
Passing %	ASTM D 5644	> 90
Heat Loss %	ASTM D 1509	< 1
Metal Content %	ASTM D 5603	≤ 0.1
Fiber Content %	ASTM D 5603	≤ 0.3

Production of crumb rubber modified binder

The introduction of recycled crumb rubber from scrap tires in asphalt binder is in two forms; either a dry or wet process. The wet process is the method used in is study, where CRM binders were produced when finely ground crumb rubber was blended with asphalt binder high temperatures before mixing with aggregate. The modification in this method is due to both physical and chemical composition changes, and this process is called the interaction (reaction) between the recycled crumb rubber and bitumen. Where the recycled crumb rubber fine particles may swell in the binder because of the absorption of the lighter fractions (aromatic oils) of the asphalt binder, forming a viscous gel with relatively high viscosity because of the stiffening of the residual part of the binder [6, 3, 21, 12, 18].

The crumb rubber modified asphalt binder was prepared in the laboratory utilizing an open medium-shear batch blender, IKA RW20 (Germany), furnished with four blade impeller, at three blade levels (low, mid, and high) using three blending speeds (250, 750, and 1250) rpm with one blending time of 60 min., and mixing temperature of (180°C) as recommended by many researcher in literature.

Crumb rubber modified binder tests

The influence of blade level and shear mixing speed throughout blending on rubberized asphalt was investigated utilizing laboratory tests particularly, softening point test (ASTM D36), rotational viscosity test (ASTM D D4402), and dynamic shear rheometer test DSR (AASHTO TP5, and ASTM D6373). The DSR test procedure was utilized to estimate the rutting factor (G*/ sin δ) at a range of temperatures (40-82°C) with 6°C step.

RESULTS AND ANALYSIS

Softening point test

For the purpose of estimating the consistency of the produced CRM binders, softening test was conducted. This test was according to ASTM D 36 (ASTM D 36, 2000) to determine the softening point of asphalt binder utilizing the ring and ball equipment as a part of consistency measurements. The softening point results of three different blade levels and various blending speeds are illustrated in Figure-2.

It is clear from this figure that the softening point values is increased by adding CRM to the base asphalt binder and regardless of the shearing rate or blade level used. However, it is noticed that the softening point was decreasing with the increasing rotational speed of the blending blade. Likewise, the lowest softening point values were when setting the blade near to the bottom of the container.

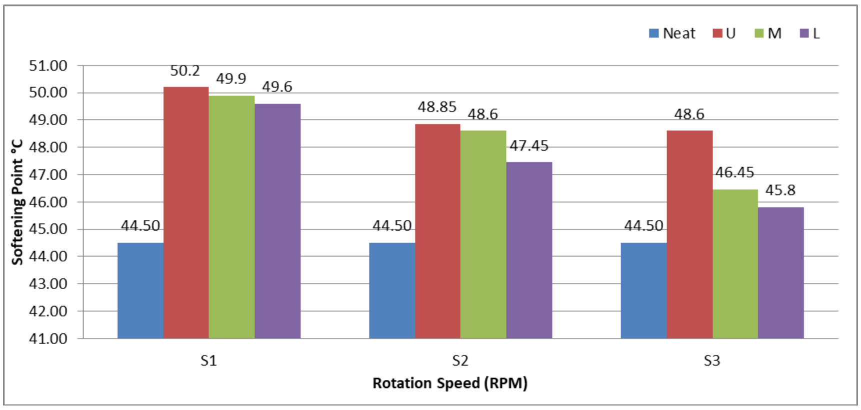

Figure-2. Softening point results at different rotation speeds and blade levels.

Rotational viscosity results

Brookfield rotational viscosity (RV) apparatus was utilized according to ASTM 4402 (ASTM 2011) procedure. The rotational viscosity test was used to measure the variation in consistency of asphalt binders before and after blending the rubber. A Brookfield viscometer was utilized to test the asphalt binders at 135, and 165°C.

According to the results shown in Figures-3at temperature of 135°C and Figure-4 at temperature of 165°C, CRM binders display higher viscosity values than the base bitumen, regardless of rotation speed and blade

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level.At a constant rotation speed, viscosity values for the high and mid blade levels are more than that of the low blade level. At the same blade level, viscosity values at higher rotational speed (1250 RPM) are lower, more reliable and less variable than that of the slower speeds (250 and 750 RPM).

Using a higher rotating speed of blending enhanced the interaction of the rubber particles with the bitumen. The decrease in consistency may be explained by the conclusion that more rubber particles introduced into the solution at the higher blending speed, at the same time, the molecular weight of the dissolved rubber was decreased. This implies that the devulcanization and depolymerization of recycled crumb rubber particles amid the blending process is actually a process of mass transfer. With the increasing blending speed, the dispersion of rubber increased allowing improved the light components of bitumen swelling by the rubber and this in return enhanced the interaction between the bitumen and crumb rubber particles.

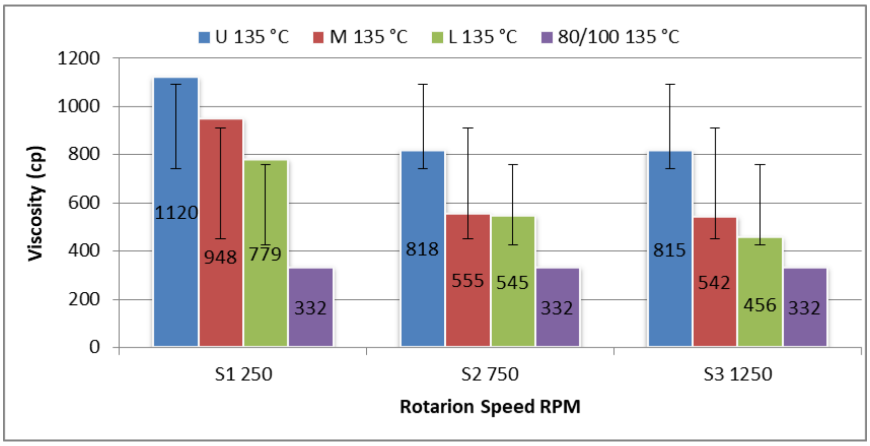

Figure-3. Effect of rotation speed and blade level on the viscosity measured at 135°C.

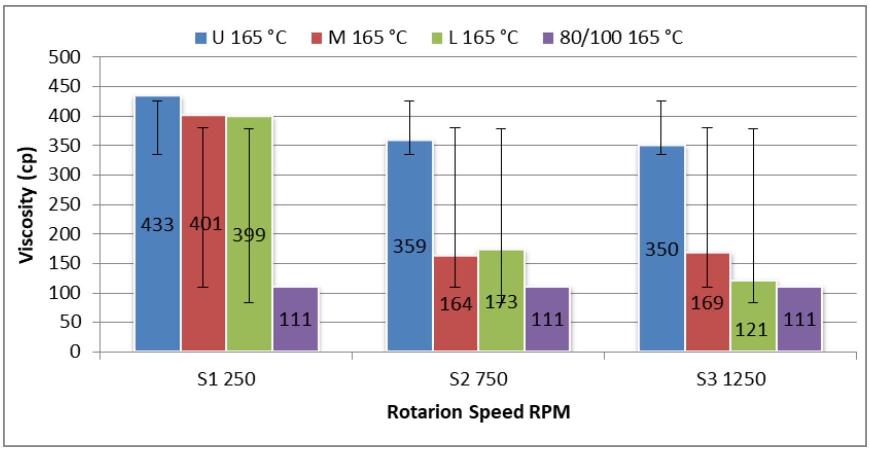

Figure-4. Effect of rotation speed and blade level on the viscosity measured at 165°C.

Dynamic shear rheometer results

The rheological testing plan was assigned to evaluate the rheological properties of Crumb Rubber Modified asphalt binder. The testing procedure were done following ASTM 7552 (ASTM 2010) or AASHTO T315 (AASHTO 2010). For this reason, HAAKE, Rheo Stress RS1, Phoenix, Dynamic Shear Rheometer was employed.

In this research, a plate of 1mm thick and 25mm diameter at 10 rad/sec frequency using stress controlled mode of loading at stress level of 0.12 kPa for unaged asphalt binders were used following the Strategic Highway Research Program for bitumen specifications (SHRP). The rutting factor (G*/sinδ) was utilized to indicate the relative stiffness and bitumen's resistance to permanent deformation. The minimum limit of rutting factor (G*/sin δ) is 1kPa for unaged asphalt binder. A DSR Temperature sweep test was conducted at high service temperatures that ranged from 40 to 82°C with a 6°C step to measure the effect of CRM on bitumen's performance as a function of temperature.

Figures (5-7) demonstrates the results of DSR testing in terms of rutting factor at a range of 40 to 82°C for the three blade levels and three blending speeds.

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However there is a decrease of consistency with the increase in rotational speed and lowering the blade level according to the physical tests, there is no significant effect of the two factors on the rutting factor (G*/sin δ) according to the temperature sweep test in DSR testing. As with earlier results, the introduction of crumb rubber into the asphalt binder may improve the high temperature rheological performance by increasing rutting factor of the asphalt binder. Figures (5-7) show the much more rapid increase in stiffness represented by complex modulus G* after adding crumb rubber to the base asphalt binder. However, with increasing blending speed to 1250 rpm there is a decrease in stiffness. This might be because of the increased interaction between the crumb rubber and the asphalt binder causing better mass transmission between the bitumen and crumb rubber. Though, the greater part of the improved interaction is almost because of the rubber-bitumen reaction. The rubber-bitumen reaction is the process of devulcanization and depolymerization in which destroying of the cross-linking system and shortening of the central chains takes place.

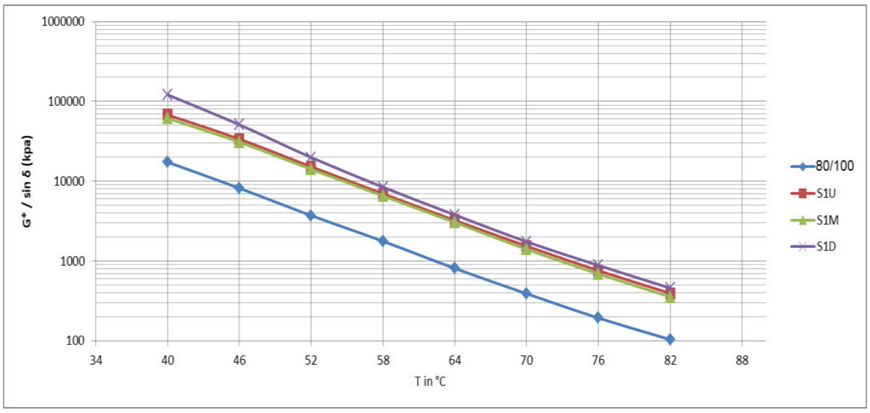

Figure-5. Effect of blade level on the rutting factor at 250 RPM shear rate.

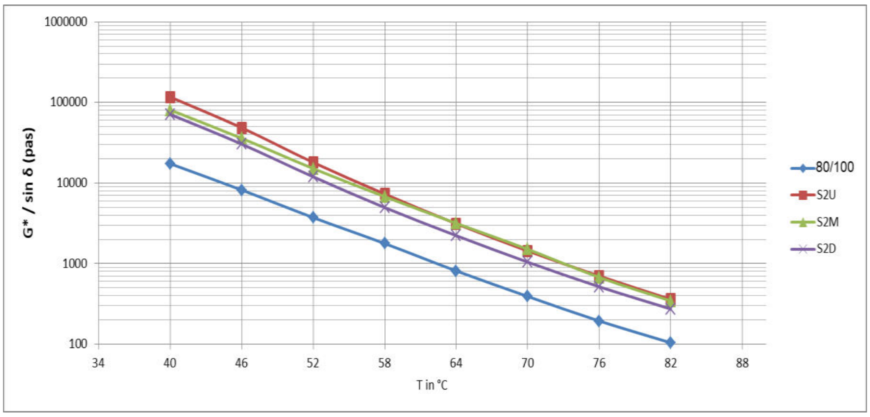

Figure-6. Effect of blade level on the rutting factor at 750 RPM shear rate.

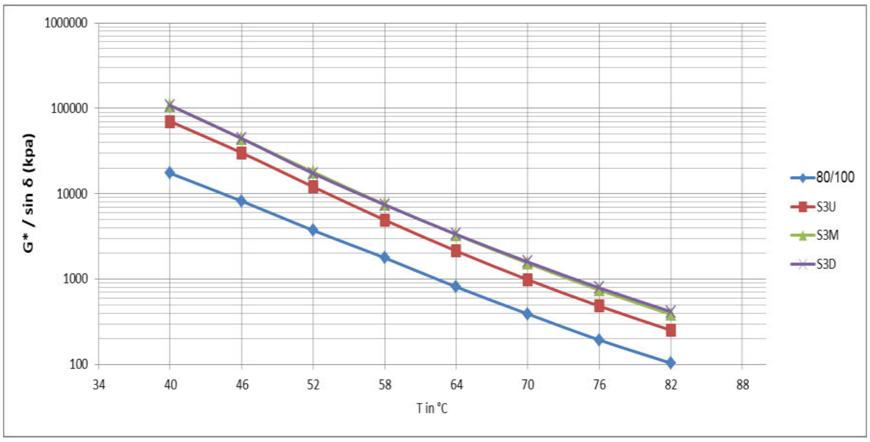

Figure-7. Effect of blade level on the rutting factor at 1250 RPM shear rate.

CONCLUSIONS

This research investigates the possibility of producing a more stable performance blending of CRM-asphalt binder appropriate for utilization throughout a wet method. This study follows a conception of fine particles of recycled crumb rubber dispersed in the bitumen. The followed methodology balances the improvement of consistency and viscosity properties as well as performance related properties.

The study confirms that the blade level and shearing rate control the interaction mechanism between crumb rubber and asphalt binder. The shearing rate was determined to enhance stability, and to increase the dispersion of the crumb rubber particles in the asphalt binder.

Increasing the shearing rate of blending has led to increase the quantity of rubber dispersed in the bitumen amid the blending process. The increased crumb rubber dispersion was found to enhance the high-temperature rheological performance of the bitumen. Additionally, after the initial improve in the viscosity with the adding of crumb rubber, the viscosity values started to decrease with the increasing incrumb rubber dispersion.

These outcomes are a dominant indicator that the 1 hour blending time at 180°Cand level of blade are not significantly effective on the consistency of the resultant binder. Nevertheless, the outcomes of this research intensely infer that increasing rotational speed during blending process can decrease the mixing time to a satisfactory level by increasing the devulcanization and depolymerization in the bitumen to provide an bitumen-rubber blend that is both truly elastic and homogeneous. This might be achieved with no decrease in asphalt binder properties.

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