International Journal of Materials Science and Applications
2017; 6(2-1): 1-6
http://www.sciencepublishinggroup.com/j/ijmsa
doi: 10.11648/j.ijmsa.s.2017060201.11
ISSN: 2327-2635 (Print); ISSN: 2327-2643 (Online)

Effect of Crumb Rubber Modifiers (CRM) on Characteristics of Asphalt Binders in Sudan

Magdi Mohamed Eltayeb Zumrawi

Department of Civil Engineering, University of Khartoum, Khartoum, Sudan

Email address:
magdi.zumrawi@yahoo.com

To cite this article:
Magdi Mohamed Eltayeb Zumrawi. Effect of Crumb Rubber Modifiers (CRM) on Characteristics of Asphalt Binders in Sudan. *International Journal of Materials Science and Applications.* Special Issue: 2D Materials and Van Der Waals Heterostructures.
Vol. 6, No. 2-1, 2017, pp. 1-6. doi: 10.11648/j.ijmsa.s.2017060201.11

Received: January 6, 2017; **Accepted**: January 20, 2017; **Published**: February 14, 2017

Abstract: The use of Crumb Rubber Modifiers (CRM) in flexible pavements to improve characteristics of asphalt binders has become a technique of great potential in recent years. In this regard an experimental program was undertaken to study the influence of CRM on the physical properties of asphalt binder. Asphalt cement modified with varying percentages of CRM, 0, 5, 10, 15, 20, and 30 percent were studied. Penetration, ductility, viscosity, softening point, flash and fire points, and specific gravity tests were performed on base and modified asphalts. The tests results show that addition of CRM to base asphalt has significant influence on its properties. Comparing the tests results, the viscosity, softening point, flash and fire points of the modified asphalts increased significantly, coupled with reduction in penetration and ductility as the CRM content increased. Addition of 15% CRM resulted in 200% and 15% increment in viscosity and softening point of base asphalt respectively, while the reduction in ductility and penetration were almost 75% and 25% respectively. It could be concluded that modification of asphalt binders by crumb rubber is successful and more beneficial technique.

Keywords: Base Asphalt, CRM, Modified Asphalt, Properties

1. Introduction

Recently, millions scrap tires are generated in Sudan and other countries have been disposed in landfills which pose two major problems: waste of valuable material and environmental pollution. Therefore, the use of crumb rubber as asphalt modifying agent may contribute in solving the waste disposal problem and improving the quality of road pavement. Crumb rubber has been added to asphalt concrete mixtures by various processes. The most established method uses the crumb rubber as a polymer modifier of asphalt cement (i.e. wet process) [1]. Using the crumb robber as an aggregate substitute (i.e. dry process) added during mixing is more economical but existing patents and unreliable results have hindered its use [2].

Crumb rubber types are various, their sources are broad and the components of them are different, so their modified effect on the asphalt binder will not be the same. Crumb rubber used in modification of asphalt binder improves its rutting resistant properties through increasing the stiffness and elasticity of asphalt at high service temperatures [3].

CRM extends the asphalt's fatigue life through thickening of asphalt film around aggregates and accordingly decreasing the asphalt's aging rate. Moreover, CRM reduces the stiffness of asphalt at very low service temperatures which is in favor of its low service temperature performance [3, 4]. Because of these advantages, there is an increasing interest in using CRM asphalt binders in flexible pavements in many countries [5, 6].

Magdi M. E. Zumrawi: Effect of Crumb Rubber Modifiers (CRM) on Characteristics of Asphalt Binders in Sudan.

Many previous investigations have shown promising results for improvement of asphalt binder after modification with crumb rubber. In this regard an attempt is made to study modification of asphalt with CRM in order to evaluate its influence on the physical properties of asphalt binder.

2. Previous Investigations

Modification of asphalt with Crumb Rubber Modifier (CRM) has been introduced as an environmental friendly method of scrap tires, while improving the asphalt's physical properties.

A great deal of researches on characteristics and applications of CRM asphalt binder have been done. Crumb rubber modifications of asphalt have been proven to improve characteristics of asphalt binder such as the viscosity, softening point, loss modulus, and storage modulus. This subsequently improves the rutting resistance due to higher viscosity, better resilience due to higher softening point, and improving fatigue cracking resistance of asphaltic mixes [7-10].

The advantages of using CRM asphalt binder in flexible pavements were reported by many investigators. Some of these advantages are improved resistance to surface initiated, retarded fatigue and reflection cracking, reduced temperature susceptibility, decreased traffic noise, improved durability and lower pavement maintenance costs, decreased pollution, improve environmental quality, saving in energy and natural resource by using waste products etc. [11-15].

The improvement degree of the base asphalt performance depends on many factors which were investigated by many researchers. These factors include the crumb rubber particle size, surface characteristics of the rubber particles, blending conditions, the manner in which crumb rubber devulcanizes, the chemical and physical properties of the base asphalt, as well as its source [3, 16, 17]. Some researches findings are reviewed below as examples. According to the study by Bahia et al. [18], the amount of crumb rubber in the modified asphalt binder does significantly increase in the rutting resistance of the asphalt.

Paulo and Jorge [19] reported that the blending time appear to have much effect on the rutting resistance, at least between the case of 30 and 60 min. In addition, the blending time of 30 min might not be enough to allow complete reaction between the crumb rubber and asphalt binder. Longer blending time, however, has better results on performance properties of modified asphalt binder.

Since asphalt is a visco-elastic material, its rheological properties are very sensitive to temperature as well as rate of loading. However, the properties of CRM asphalt binder at a wide range of temperature largely depend on the chemistry of the asphalt binder, the crumb rubber modifier percentage, particle size and texture; blending interaction temperature and blending time. In other research, Abdelrahman et al. [20] found that CRM dissolution in asphalt under an intermediate interaction temperature (i.e.190°C) and a high mixing speed (i.e.50Hz) produces a more homogenous CRM asphalt binder with enhanced high service temperature properties. However, its effect on other performance related properties like storage stability, aging susceptibility and low temperature performance of the asphalt needs to be further investigated.

The improvement of the properties of CRM asphalt likely depends on the interaction between crumb rubber and asphalt binder where crumb rubber modifier particles swell in the binder to form a viscous gel, resulting in an increase in the viscosity of the CRM binders [3, 21, 22]. It was found that swelling of the rubber particles is due to the absorption of the light fractions of the asphalt and stiffening of the residual binder phase are the main mechanism of the interaction [22, 23]. we are applied poly (ethylene terephthalate) as granular form, and the density is 1.68 gm per ml at 25°C was supplied from Sigma-Aldrich Company. UK. Multiwalled Carbon Nanotubes(MWCNTs) materials, Purity 99%, length (5μm) and diameter (15nm) were provided from Ad-Nano Technologies Private Limited, India.

3. Materials and Methods

As the objective and purpose of the research are to evaluate the efficiency of CRM in modification of asphalt binder, an intensive laboratory testing program was conducted. The tests were carried out determine the characteristics properties of natural asphalt binder and CRM asphalt binder and evaluate them in accordance with the standard specifications.

3.1. Materials Used

The materials used in testing include asphalt cement and CRM. The asphalt used in preparing all specimens of penetration grade 60-70. This type of asphalt cement is commonly used in Sudan. The asphalt was obtained from asphalt plants belong to road contractors at Toria hill in Omdurman town.

The crumb rubber was obtained from truck scrap tires. Tire rubber consists of three main components: approximately 22% by weight synthetic fiber, 18% by weight steel wire, and more than 60% by weight rubber mixtures. The crumb rubber was produced as powder by grinding process (see Figure 1). To ensure that the consistency of the CRM was maintained throughout the study, only one batch of crumb rubber was used.

Figure 1. *The sample of crumb rubber used in the study.*

The results of the blending for modified asphalt are presented in Table 3. Comparing the results, it can be observed that modified asphalt provide better properties and high values of viscosity and softening point density, which resist rutting and fatigue/reflection cracking and better resilience.

3.2. Preparation and Testing

The crumb rubber sample was subjected to grinding process and screening into fine sizes passing sieve no. 4 (4.75mm). Laboratory tests were carried out to determine the quality of base asphalt used and the constituents of crumb rubber.

For the evaluation of using CRM in asphalt binder, specimen of modified asphalt were prepared at CRM content 5, 10, 15, 20, and 30% by weight of asphalt. For all specimens, base asphalt and CRM were heated at temperature 180°C for 60 minutes. All specimens were prepared and tested in accordance with ASTM standard. A series of standard laboratory tests namely, penetration, ductility, softening point (ring and ball), kinematic viscosity, flash and fire points tests were performed on prepared specimens.

4. Results and Discussion

The results of the experiments conducted by measuring the physical properties of asphalt cement are listed in Table 1. The constituents of CRM are measured and presented in Table 2.

Table 1. *Physical properties of base asphalt used.*

Test	Method	Result yield (%)
Penetration at 25°C (0.1mm)	ASTM D5	67
Ductility at 25°C (cm)	ASTM D113	105
Kinematic Viscosity at 135°C (CST)	ASTM D2170	410
Softening point at 25°C (°C)	ASTM D36	45
Flash point (°C)	ASTM D92	266
Fire point (°C)	ASTM D92	280
Specific gravity	ASTM D70	1.01

Table 2. *The constituents of crumb rubber used.*

Component	Content (%)
Acetone extract	8.2
Rubber hydrocarbon	37.6
Carbon black content	24.3
Natural rubber content	25.4
Ash content	4.5

Table 3. *Physical properties of CRM asphalt tested.*

Test	CRM (%)					
	0	5	10	15	20	30
	67	65	61	50	47	43
	105	35	31	28	20	13
	410	565	860	1280	1555	2000
Penetration at 25°C (0.1mm)	51	54	55	58	60	78
	276	283	296	307	317	326
	290	296	305	314	336	349
	1.010	1.012	1.015	1.018	1.021	1.027
Ductility at 25°C (cm)	0	5	10	15	20	30
	67	65	61	50	47	43
	105	35	31	28	20	13
Kinematic Viscosity at 135°C (CST)	410	565	860	1280	1555	2000
	51	54	55	58	60	78
	276	283	296	307	317	326
	290	296	305	314	336	349
	1.010	1.012	1.015	1.018	1.021	1.027
Softening point at 25°C (°C)	0	5	10	15	20	30
	67	65	61	50	47	43
	105	35	31	28	20	13
	410	565	860	1280	1555	2000
Flash point (°C)	51	54	55	58	60	78
	276	283	296	307	317	326
	290	296	305	314	336	349
	1.010	1.012	1.015	1.018	1.021	1.027
Fire point (°C)	0	5	10	15	20	30
	67	65	61	50	47	43
	105	35	31	28	20	13
	410	565	860	1280	1555	2000
Specific gravity	51	54	55	58	60	78
	276	283	296	307	317	326
	290	296	305	314	336	349
	1.010	1.012	1.015	1.018	1.021	1.027

4.1. Effect of CRM on Penetration

The results of the penetration test for the base asphalt and CRM-asphalt are shown in Table 3 and Figure 2. It can be observed that the addition of CRM to the base asphalt reduces its penetration steadily. In the plot of Figure 2, a significant reduction in penetration property can be observed as the percent of CRM increases. The asphalt classification changed from grade 60/70 to 40/50 grade with the addition of 15% CRM. Thus, the consistency of the base asphalt changes and becomes harder. This fact indicates that the use of less costly crumb rubber can increase the hardness of asphalt binder.

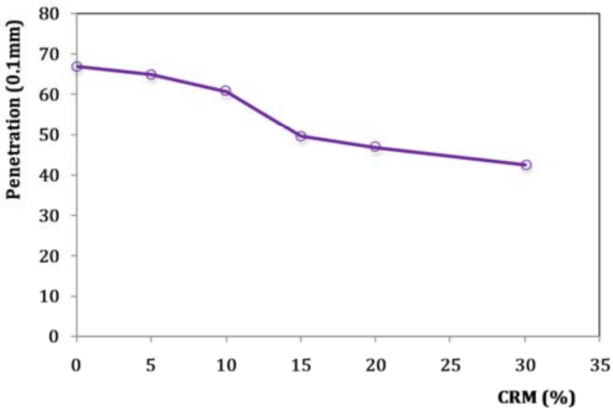

Figure 2. *Penetration variation with Crumb Rubber Modifier (CRM).*

4.2. Effect of CRM on Ductility

Ductility test provides a measure of tensile properties of bituminous materials. The ductility is measured by the distance in centimetres to which standard specimen will elongate before breaking. The ductility tests results at 25°C of different crumb rubber contents are illustrated in Figure 3. It is seen that base asphalt ductility appears to dramatically decrease as the crumb rubber content increases. The ductility value of base asphalt is 105 cm, which reduced to 35 cm by the addition of 5% CRM. This reduction is almost 70% of base asphalt value. This significant reduction in the ductility property indicates a great loss in the flexibility of the base asphalt occurred by addition of small percent of crumb rubber.

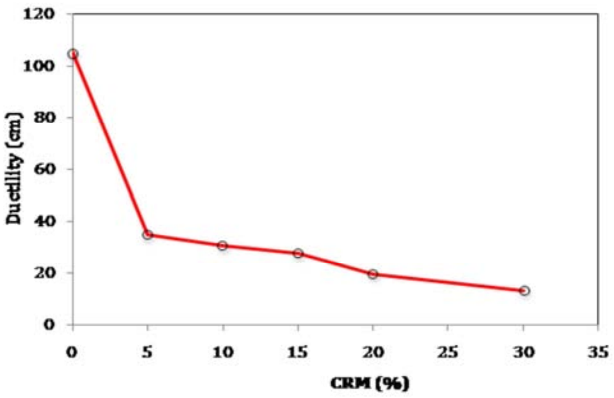

Figure 3. *Effect of crumb rubber content on ductility of asphalt binder.*

4.3. Effect of CRM on Kinematic Viscosity

The influence of CRM asphalt on kinematic viscosity property is shown in Figure 4. The addition of CRM led to increased kinematic viscosity. The plot in Figure 4 clearly demonstrated that kinematic viscosity increases from 410 CTS (base asphalt) to 1280 CTS with addition of 15% CRM. The increment in viscosity is almost two times the base asphalt value. This result indicates that the use of CRM is considered to be extremely effective to improve the viscosity property of asphalt binder. In fact higher viscosity is needed to improve rutting resistance and fatigue/reflection cracking resistance in flexible pavements.

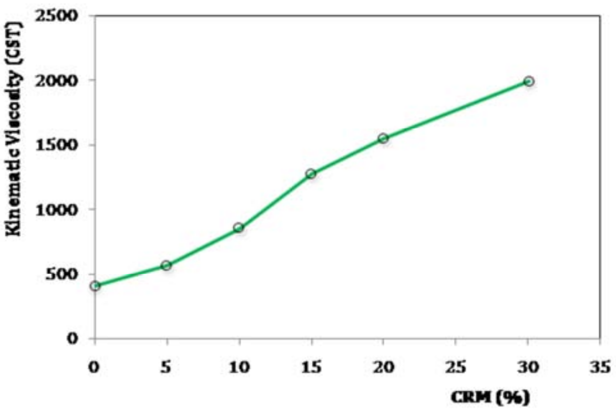

Figure 4. *Effect of crumb rubber content on viscosity of asphalt binder.*

4.4. Effect of CRM on Softening Point

The softening point measured by ring and ball method of the specimens prepared with the addition of 0%, 5%, 10%, 15%, 20%, and 30% of CRM to the base asphalt are presented in Figure 5. It is observed that the softening point property of the modified asphalt is increasing with increase in percentage of CRM values added to the base asphalt. The increase in softening point values of modified asphalt with addition of 30% CRM is almost 50% of virgin asphalt. As mentioned before in the literature, higher softening point is required for better resilience of asphalt pavements.

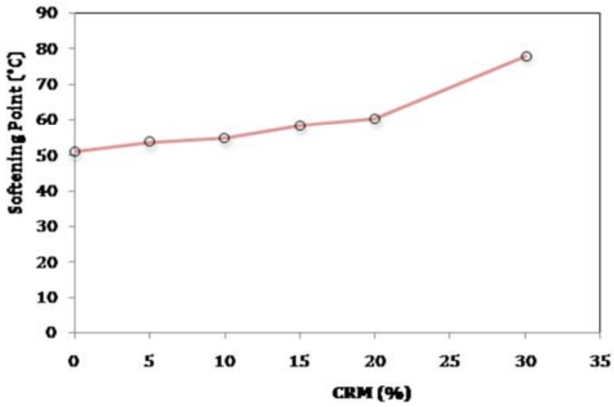

Figure 5. *Effect of crumb rubber content on Softening point of asphalt binder.*

4.5. The Effect on Flash and Fire Points

The variation of flash and fire points values with different percentages of CRM added to base asphalt is presented in Figure 6. Significant change in both flash and fire points are observed with addition of CRM to base asphalt. The increment in both flash and fire points values of modified asphalt with addition of 15% CRM is from 276°C and 290°C to 307°C and 349°C respectively, compared with the base asphalt. The increment in both flash and fire points is around 20% with addition of 30% CRM.

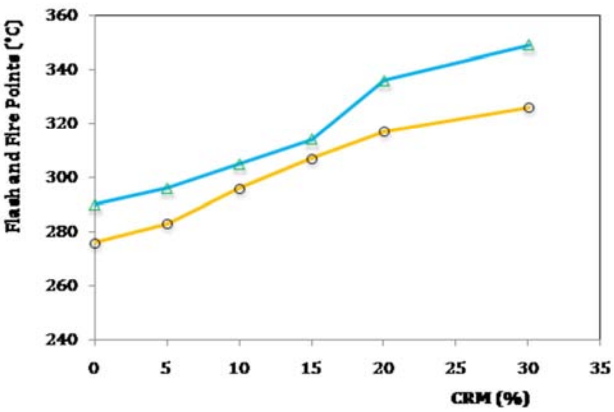

Figure 6. *Effect of crumb rubber content on flash and fire points of asphalt binder.*

Finally, from the above discussions, it is clear that there is improvement in the physical properties of asphalt binder modified with CRM. It is evident that the addition of CRM to the base asphalt showed an improvement in consistency and safety characteristics. This result made the use of CRM in modification of asphalt binder is reliable and beneficial technique.

5. Conclusion

In this research, the asphalt binder was modified with CRM, which is a waste material derived from scraped tires. The effectiveness of modifying asphalt binder by CRM was judged by the improvement in the physical properties of the tested samples. The following conclusions can be drawn:

- In this study, the base asphalt was modified by five CRM contents (5%, 10%, 15%, 20%, and 30% by weight of asphalt) to investigate their influence on physical properties namely, penetration, ductility, viscosity, softening point, flash and fire points of modified asphalt.
- Addition of CRM has major effect on physical properties of asphalt binder. A significant decrease in penetration and ductility of modified asphalt with increasing percentage of CRM. The reduction in penetration and ductility properties with addition of 15% CRM were found to be 25% and 75% respectively.
- Also, there is a considerable increase is observed in viscosity, softening point, flash and fire points by addition of CRM. The increment in viscosity with addition of 15% CRM is almost two times the base asphalt value, while the other properties (i.e. softening, flash and fire points) increment is around 10% to 20%.
- Asphalt modification by crumb rubber provides benefit through improving rutting resistance and reducing fatigue/reflection cracking due to higher viscosity and softening point. Thus, improve the service life of pavement and lower pavement maintenance costs.
- From the economic point of view, utilization of Crumb Rubber as asphalt modifier may reduce the cost of surface layer construction and maintenance in flexible pavements. The waste treatment industry may also reduce their cost of treating and disposing the huge number of scrap tires.
- Further research is still needed to obtain new specifications for the use of CRM in different fields of application to conserve Sudan natural resources and preserve the environment.

Acknowledgments

Thedepartment of civil engineering, faculty of engineering, university of Khartoum has supported this work, and I'd like to acknowledge the technicians of asphalt laboratory for supporting this research during the testing program.

References

[1] McDonald C. H., A New Patching Material for Pavement Failures, HRB, Highway Research Record 146, pp. 1-16. Construction Record 1t71 (1966), pp. 113-120.

[2] Takallou H. B., and Hicks R. G., Development of Improved Mix and Construction Guidelines for Rubber-Modified Asphalt Pavements, TRB, Transportation Research Record 1t71 (1988), pp. 113-120.

[3] Bahia H. U., Effect of Crumb Rubber Modifiers (CRM) on performance related properties of Asphalt Binders. Journal of Association of Asphalt Paving Technologists. Vol. 63, 1994, pp. 414-449.

[4] Billiter et al., Production of Asphalt-Rubber Binders by High-Cure Conditions. In Transportation Research Record: Journal of the Transportation Research Board, No. 1586, Transportation Research Board of the National Academies, Washington, D. C., 1997, pp. 50-56.

[5] Airey G., Singleton T. M., and Collop A., Properties of polymer modified bitumen after rubber-bitumen interaction. Journal of Materials in Civil Engineering, ASCE, Vol. 14, No. 4, (2002), pp. 344-354.

[6] Bahia H. U., Davies R., Effect of crumb rubber modifiers (CRM) on performance- related properties of asphalt binders. J. Assoc. Asphalt Paving Technol., 63: (1994), pp. 414-441.

[7] Katman H. Y., Ibrahim M. R., Karim M. R., Abdelaziz M., Resistance to disintegration of rubberised porous asphalt. Proc. Eastern Asia Soc. Trans. Stud., 7: (2009), pp. 286-297.

[8] Abdelaziz M., Karim M. R., Rheological evaluation of ageing properties of rubber crumb modified bitumen. J. Eastern Asia Soc. Trans. Stud., 5: 820-833. October 2003, ISSN 1341-8521.

[9] Fontes L., Triches G., Pais J. C., Pereira P., Evaluating permanent deformation in asphalt rubber mixtures. Constr. Build. Mater., 24: (2010), pp. 1193-1200.

[10] Wong C. C., Wong W. G., Effect of crumb rubber modifiers on high temperature susceptibility wearing course mixtures. Constr Build. Mater., 21: (2007), pp. 1741–1745.

[11] Thodesen C., Shatanawi K., Amirkhanian S., Effect of crumb rubber characteristics on crumb rubber modified (CRM) binder visc. Constr. Build. Mater., 23: (2009), pp. 295–303.

[12] Liu S., Cao W., Fang J., Shang S., Variance analysis and performance evaluation of different crumb rubber modified (CRM) asphalt. Constr. Build. Mater., 23: (2009), pp. 2701-2708.

[13] Lee S. J., Amirkhanian S., and Shatanawi K., Effects of crumb rubber on aging of asphalt binders Asphalt Rubber 2006, Vol. 3, pp.779-795, Palm Springs, California.

[14] Liang R. Y., and Lee S., Short-term and long-term aging behavior of rubber modified asphalt paving mixtures. Transportation Research Record: Journal of the Transportation Research Board, No. 1530, (1996), pp.11-17.

[15] Ruth B. E., and Roque R., Crumb Rubber Modifier (CRM) in asphalt pavements. Proceedings of the Transportation Congress, (1995). pp. 768-785.

[16] Yetkin Y., Polymer modified asphalt binders. Constr Build Mater; 21: (2007), pp. 66–72.

[17] Cao R., Chen R., Laboratory study on process parameters of asphalt rubber and their effects on performance. J Southeast Univ (Nat SciEdn); 38: (2008), pp. 269–273.

[18] Bahia H. U., Hislop W. P., Zhai H., Rangel A., Classification of asphalt binder into simple and complex binder. J. Assoc. Asphalt Paving Technol., 67: (1998), pp. 1-41.

[19] Paulo A. P., Jorge C. P., Laboratory optimization of continuous blend asphalt rubber. Proc. 3rd Eur. Pav. Asset. Manage., EPAM 3. Coimbra, 2008.

[20] Abdelrahman M., Ghavibazoo A., Ragab M., Mechanism of Crumb Rubber Modifier Dissolution into Asphalt Matrix and Its Effect on Final Physical Properties. Transportation Research Record Journal of the Transportation Research Board, (2013), Paper No. 13-4259

[21] Jeong K. D., Lee S. J., Amirkhanian S. N., Kim K. W., Interaction of crumb rubber modified asphalt binder. Const. Build. Mater., 24: (2010), pp. 824-831.

[22] Airey G. D., Rahman M. M., Collop A. C., Absorption of bitumen into crumb rubber using the basket drainage method. Int. J. Pav. Eng., 4(2): (2003), pp. 105-119.

[23] Shen J., Amirkhanian S. N., The influence of crumb rubber modifier (CRM) microst on the high temp. properties CRM binder. Int. J. Pav. Eng., 6(4): (2005), pp. 265-271.