Green Energy, Environment and Sustainable Development
C. Wang et al. (Eds.)

doi:10.3233/ATDE230376

Study on Properties of Modified Asphalt with Large Amount of Rubber Particle

Lu ZHANG[a], Yanzhao DU[a], Yijia ZHU[a], Jia WANG[b,c,1], Huabao MA[b,c] and Bin CAI[b,c]
[a] *China Construction Infrastructure Corp., Ltd., Beijing 100029, China*
[b] *Research and Development Center of Transport Industry of Technologies, Materials and Equipment of Highway Construction and Maintenance, Shijiazhuang 050091, Hebei, China*
[c] *Hebei Provincial Communications Planning, Design and Research Institute CO., Ltd., Shijiazhuang 050091, Hebei, China*

Abstract. With the continuous application and popularization of rubber asphalt material, its excellent performance has been proved by many projects, but the technology of rubber asphalt is influenced by existing conditions, the dosage of rubber particle can only reach 20%. The research group successfully prepared modified asphalt with different dosages of rubber particle (within 30%-40%) by chemical activation technology, and analyzed the property of asphalt with large amount of rubber particle. The modification mechanism was also discussed. The results show that the viscosity of the asphalt with high dosage of rubber particle is equivalent to that of the asphalt with conventional dosage of rubber particle, and its low temperature cracking resistance and compatibility are better than the conventional rubber asphalt. The rutting resistance of high temperature modified asphalt with high dosage of rubber particle decreases slightly, but its fatigue limit temperature is lower than the of conventional high dosage rubber asphalt, and it has a lower glass transition temperature and can be used in cold climate.

Keywords. Rubber-modified asphalt, high content, performance, dynamic thermodynamic analysis, super pave PG grading

1. Introduction

With the increasing demand for highway transportation, there are higher requirements for pavement performance, and the demand for road asphalt is also increasing day by day. All kinds of modified asphalt products are widely used. The result display that the rubber asphalt has excellent performance and reduces the production cost [1-4]. The waste automobile tire is also recycled, which has good environmental benefits. However, the existing content of particle rubber asphalt is low, which can only replace asphalt in a small amount. Rubber asphalt also has problems in stability, and its performance still has great room for improvement [5, 6].

Various studies show that the degree of activation of rubber particle will affect the comprehensive properties of particle rubber asphalt. Under high-speed shear and high temperature conditions, the rubber particle polymer began to depolymerize and dissolve

[1] Corresponding Author, Jia WANG, Research and Development Center of Transport Industry of Technologies, Materials and Equipment of Highway Construction and Maintenance, Shijiazhuang 050091, Hebei, China; Email: 782164963@qq.com.

into the asphalt. However, when the amount of glue particle is very large, it is difficult to disperse evenly in asphalt [7, 8]. So, it is necessary to improve the content of rubber particle in the production of rubber asphalt. In this study, high temperature chemical activation technology was adopted to rapidly degrade part of rubber particle in a short time, and the rubber particle in the asphalt system was degraded to improve the increment of rubber particle, so as to replace more asphalt. On the basis of preserving the elastic core of rubber dosage, by reducing the rubber particle's particle diameter particle in asphalt and degrading part of rubber particle, the problem of excessive viscosity of rubber asphalt was effectively solved, and its comprehensive performance was improved [9, 10].

2. Materials and Experimental Methods

2.1. Materials

70# asphalt in this project was supplied by Shell Oil Company. The penetration range is 60-80(0.1 mm). The properties of asphalt are listed in Table 1.

Table 1. Physical and mechanical properties of $70^{\#}$ asphalt.

Test	Values	Test methods
Penetration (100 g, 5s, 25°C)/0.1 mm	70	ASTM D5
Softening Point (R&B)/°C	48.5	ASTM D36
Ductility (15°C, 5 cm/min), cm	＞100	ASTM D113
Penetration index (PI)	-0.6	ASTM D5
Density (15°C)/(g/cm^3)	1.032	ASTM D70

A rubber particle commonly used in the market is used in this investigation, in which the size of rubber particle is controlled from 24 to 32 mesh.

2.2. Preparation of Large Amount of Rubber Particle

In this study, through high-speed shear, under the conditions of different temperatures and different concentrations of activators, 30% and 40% of the content of particle rubber asphalt was prepared.

First, we heated the base asphalt to the specified temperature, added the activator, and then added the rubber particle of different concentrations (20%, 30% and 40%). After the rubber particle was completely added, the mixture of rubber particle and asphalt expanded at a certain temperature for a period of time, and then the mixture was cut at a certain rate for a period of time. Then we added the stabilizer to the asphalt, and sheared again.

3. Physical Tests

Table 2 indicates that as the rubber particle content increased, the viscosity of the modified asphalt improved, but the increament is not large, which shown that the scheme of the research group is feasible to decrease the viscosity of the high dosage rubber asphalt. Compared with the conventional 20% rubber asphalt, the high dosage rubberized asphalt binder is softer (better penetration), which is caused by a large amount of degradation of the rubber particle. When the penetration of the high dosage rubberized asphalt binder increased, the softening point remained basically the same, which indicated that high dosage rubberized asphalt retained a certain amount of rubber particle core while the rubber particle was degraded. The excess rubber particle is decomposed into natural rubber, which makes the proportion of natural rubber in modified asphalt gradually increase. Natural rubber has good ductility, so the low temperature ductility of the modified asphalt is improved. and the degraded natural rubber is similar to the colloidal component in the asphalt and could be dissolved in the asphalt, which inevitably make the consistency of rubber particle and asphalt greatly increased particle, so the separation softening difference is gradually decreased. With the increment of rubber particle content particle, the elastic recovery index gradually decreases, this is owing to the degradation of the rubber particle, which causes the rubber particle to alter from a three-dimensional netlike structure to a chain structure and from a hard elastic body to a plastic elastic body. The mass loss of modified asphalt after aging is reduced, which may be related to the absorption of small molecules and light components in asphalt. More rubber particle absorbs more light components and leads to lower quality loss after aging. In summary, from the above physical properties of high dosage rubberized asphalt binder, the research group proposed a theory to preserve a certain amount of rubber particle elastic core, and degrade too much rubber particle to prepare high dosage rubberized asphalt binder and the idea of improving its performance is feasible.

Table 2. Physical and mechanical properties of high dosage rubberized asphalt binder used in this study.

Test	Values 20%	Values 30%	Values 40%	Test methods
Viscosity (180°C)	2.4	2.8	3.2	
Penetration (100G, 5s, 25°C) /0.1 mm	48	64	69	ASTM D5
Softening point (r&b)/°C	72.5	72.0	71.0	ASTM D36
Ductility (5°C, 5 cm/min), cm	12	16	18	ASTM D113
Flexible recovery (%)	89	84	81	
Segregation softening point difference (°C)	3.0	2.0	0.5	
Film heating test (163°C, 5h)	-0.35	-0.3	-0.3	ASTM D1754

4. Superpave PG Grading Test

Table 3 shown that as the rubber particle dosages increase, the high temperature grade of the rubber asphalt does not change, the low temperature grade decreases, the rutting factor decreases, the fatigue limit temperature gradually decreases, the creep stiffness of -24°C gradually decreases, and the value of *m* gradually increases. This proved the high dosage of rubber asphalt obviously improves the low-temperature performance and fatigue resistance of the modified asphalt under the condition of a slight decrease in high-temperature property, which is basically the same as the conclusions rubber asphalt' properties.

Table 3. PG of modified asphalt with different content of the rubber particle.

Dosages of the particle rubber particle (%)	PG	G*/sinδ (kPa) 88℃	G*/sinδ (kPa) RTFOT 88℃	G*sinδ< 5000 temperature (℃)	Creep stiffness (MPa)-24℃	m-24℃
20	88-28	1806.7	3017.8	16	329.5418	0.2897
30	88-34	1683.8	3429.5	13	201.9205	0.3054
40	88-34	1421.6	2767.2	10	166.9801	0.3147

5. Dynamic Thermodynamic Analysis (DMA) Test

The research group conducted dynamic mechanical analysis experiments on rubber asphalt with different dosages and matrix asphalt, which evaluated the cryogenic property of different modified asphalts. Figure 1 shown that the glass transition temperature of the matrix asphalt is -0.5℃, and the glass transition temperatures of the modified asphalts respectively being added with 20%, 30%, and 40% of the rubber particle are -8.4℃, -12.6℃, and -14.8℃, indicating that the adding of rubber particle can significantly reduce the glass transition temperature of asphalt and broaden the low temperature range of asphalt, of which 40% rubber asphalt has the lowest glass transition temperature. This is consistent with the conventional performance index of the asphalt and the result of the PG classification: the high dosage rubberized asphalt binder has more excellent low-temperature properties.

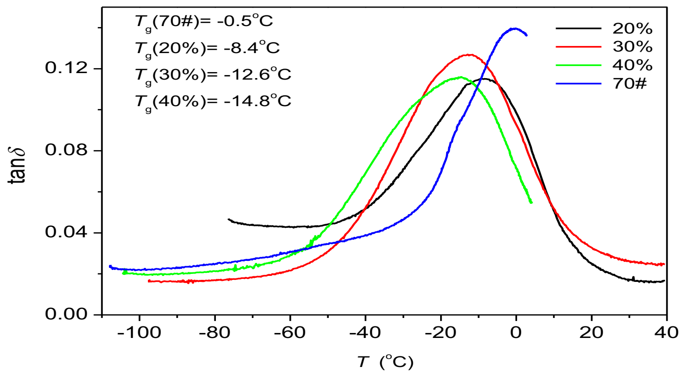

Figure 1. Dynamic mechanical spectrum of modified asphalt.

In addition, the tanδ of each material (i.e., the proportion of loss modulus to storage modulus) can be known from Figure 1. The tanδ represents the internal friction of the material at a certain temperature. The larger the tanδ, the greater the internal friction of the material, the better the damping performance, the better the damping effect, and the material is less likely to fracture under low temperature load.

When the temperature is higher than T_g temperature, there is no data of pure asphalt soon in the tanδ curve, while there is still data of rubber asphalt. This is because the temperature is higher than the T_g, the materials will change from the glass state into a viscous flow state, spline becomes very soft and does not produce the function of force response, so the curve has no data after vitrification temperature, but the rubber asphalt contains a lot of elastic rubber particle and carbon black, still can have a response to force. Therefore, the curve is not suitable for analyzing the viscoelasticity of asphalt and modified asphalt above vitrification temperature.

The tanδ value of the material below the glass transition temperature can be read from Figure 1, which can be compared with its damping performance. At -20℃, the tanδ value of the basis asphalt, 20% rubber asphalt, 30% rubber asphalt, and 40% rubber asphalt particle was 0.0695, 0.0952, 0.1189, 0.1126 respectively. It shows that the shock absorption performance of rubber asphalt is better than the pure asphalt, and the shock absorption performance of high dosage rubber asphalt is the best. At -30℃, the tanδ value of the basis asphalt, 20% rubber asphalt, 30% rubber asphalt, and 40% rubber asphalt was particle was 0.046, 0.071, 0.087, 0.097 respectively. The results proved that the 40% rubber asphalt particle has the best shock absorption performance.

6. Conclusions

(1) On the basis of preserving the elastic core of rubber particle, the particle size of rubber particle is decreased and part of rubber particle is degraded, so as to ensure the viscosity of the asphalt with ultra-high rubber content particle increases less.

(2) The storage persistence, cryogenic property and fatigue of the modified asphalt with ultra-high content rubber particle are significantly improved when the high temperature performance is slightly reduced.

(3) With the increment of rubber particle, the glass transition temperature of ultra-high dosage of rubber asphalt gradually decreases, and its cryogenic property and shock absorption performance are better than those of conventional content of rubber asphalt.

References

[1] Mashaan NS, Ali AH, Karim MR, Mahrez A. A review on using crumb rubber in reinforcement of asphalt pavement. Sci. World J. 2014;2014(21):214-222.

[2] Li P, Ding Z, Zhou P, Sun A. Analysis of physicochemical properties for crumb rubber in process of asphalt modification. Constr. Build. Mater. 2017;138:418-426.

[3] Tang N, Huang W, Xiao F. Chemical and rheological investigation of high-cured crumb rubber-modified asphalt. Const. Build Mater. 2016;123:847-854.

[4] Huang W, Lin P, Tang N, Hu J, Xiao F. Effect of crumb rubber degradation on components distribution and rheological properties of terminal Blend rubberized asphalt binder. Const. Build Mater. 2017;151:897-906.

[5] Saberi FK, Fakhri M, Azami A. Evaluation of warm mix asphalt mixtures containing reclaimed asphalt pavement and crumb rubber. Journal of Cleaner Production. 2017;165:1125-1132.

[6] Shen J, Li B, Xie Z. Interaction between crumb rubber modifier (CRM) and asphalt binder. Const. Build Mater. 2017;149:202-206.

[7] Wen Y, Wang Y, Zhao K, Sumalee A. The use of natural rubber latex as a renewable and sustainable modifier of asphalt binder. International Journal of Pavement Engineering. 2017;18:547-559.

[8] Xie Z, Shen J. Effect of cross-linking agent on the properties of asphalt rubber. Constr. Build. Mater. 2014;67:234-238.

[9] Singh D, Ashish P, Jagadeesh A. Influence of particle and interaction effects of different sizes of crumb rubber on rheological performance parameters of binders. J. Mater. Civil Eng. 2018;30(5):878-892.

[10] Ibrahim MR, Katman HY, Karim MR, et al. A review on the effect of crumb rubber addition to the rheology of crumb rubber modified bitumen. Adv. Mater. Sci. Eng. 2013;2013(3):24-33.