Technical Paper

ISSN 1997-1400 Int. J. Pavement Res. Technol. 2(5):211-217

The Application of Semi-Flexible Pavement on Heavy Traffic Roads

Tian-Qing Ling[1+], Zhi-Jie Zhao[2], Chu-Hua Xiong[3], Ying-Ying Dong[4], Yan-Yan Liu[5], and Qiang Dong[5]

Abstract: The focus of this paper is on the performance of a semi-flexible pavement mixture and AC-16 asphalt concrete. Semi-flexible mixtures were prepared using aggregates meeting the lower limit, middle value, and upper limit of the gradation curves of the mother mixture. The indirect tensile test and the low temperature bending test were used to investigate the low temperature performance of both mixtures. Brittle point temperatures and strain energy density indexes were determined. The results showed that the semi-flexible pavement mixture had excellent low temperature crack resistance compared with the AC-16 styrene-butadiene-styrene (SBS) modified asphalt concrete. Also, the high temperature stability, low temperature crack resistance, and water stability of the crumb rubber modified semi-flexible pavement were studied in the laboratory and compared with the AR-AC-16 asphalt concrete with asphalt-rubber. Finally, a test pavement was constructed. Both laboratory tests and the test pavement showed that the semi-flexible pavements with asphalt-rubber give excellent performance. Such pavements have good prospects for application, especially for service as a surface course on pavements with heavy traffic.

Key words*: Brittle point; Crumb rubber modified asphalt; Dynamic stability; Heavy traffic; Highway engineering; Low temperature cracking; Semi-flexible pavement; Strain energy density; Water stability.*

Introduction

Semi-flexible pavement is defined as a porous asphalt-aggregate paving mixture with air voids up to 20-28% and Marshall Stability no less than 3*kN*, which incorporate with a special cement-based slurry within the voids. Semi-flexible pavements are more flexible than cement concrete, but more rigid than asphalt concrete. Rutting levels are low for a semi-flexible pavement, even with high load levels. Moreover, the low-temperature crack resistance, anti-fatigue performance, and anti-skid performance of semi-flexible pavements are superior to those of ordinary asphalt concrete pavements. The thickness needed for semi-flexible pavement structures is almost the same as typical asphalt pavements, which leads to lower costs [1, 2]. In addition, semi-flexible pavement is acid and oil resistant, and it is nearly white in color, which improves brightness or visibility when used as a tunnel pavement or for the small radius of bus stations. Because of the lack of comprehensive studies and applications of semi-flexible pavements in China at present, it was necessary to conduct correlative research work. For semi-flexible pavements, high viscosity modified asphalt is used in the porous pavement mixture to increase the thickness of asphalt film and the durability of pavement. Crumb rubber modified asphalt is good choice for this use, because it also provides a good way to utilize waste tires [3-5]. The application of crumb rubber modified asphalt in China is becoming more and more popular.

The focus of this paper is on the performance of a semi-flexible pavement mixture and an AC-16 modified asphalt concrete. Semi-flexible mixtures were prepared using the lower limit, middle value, and upper limit of the mixture gradation curves. Indirect tensile tests and low temperature bending tests were conducted to investigate the low temperature performance of both mixtures. Brittle point temperature and strain energy density indexes were also determined. The high temperature performance, low temperature crack resistance, and water stability of semi-flexible pavement with asphalt-rubber were studied in the laboratory and compared to those of asphalt concrete prepared using an AR-AC-16 asphalt containing rubber. The purpose of this study was to develop a new kind of pavement material with a structure suitable for heavy traffic conditions such as vehicles with rear axle loads of more than 130*kN*, buses and trucks greater than medium size, and traffic of more than 3000 vehicles per day in each lane.

Raw Materials and Mix Design

Properties of Crumb Rubber and Asphalt-Rubber

The crumb rubber used was from natural sources and ground at room temperature. The gradation of the rubber is shown in Table 1. The asphalt used in the AC-16 mixture was AH-70 from Zhong-hai company. The asphalt-rubber was prepared using the AH-70 virgin asphalt, and its properties are shown in Table 2.

Table 1. Gradation of Crumb Rubber.

Size of Sieve (*mm*)	2.36	1.18	0.6	0.3	0.15	0.075
Passing Rate (%)	100.0	97.3	61.4	20.6	6.5	2.7

[1] Subdecanal, Institute of Civil and Architecture, Chongqing Jiao-tong University, Chongqing City 400074, China.
[2] Senior Engineer, Highway Research Institute of M.O.C., Beijing 100088, China.
[3] Associate professor, Institute of Civil and Architecture, Chongqing Jiao-tong University, Chongqing City 400074, China.
[4] Assistant Engineer, Institute of Civil and Architecture, Chongqing Jiao-tong University, Chongqing City 400074, China.
[5] Lecturer, Institute of Civil and Architecture, Chongqing Jiao-tong University, Chongqing City 400074, China.
[+] Corresponding Author: E-mail Lingtq@163.com
Note: Submitted September 21, 2008; Revised February 10, 2009; Accepted March 20, 2009.

Table 2. Properties of Asphalt-Rubber.

Test Items	Design Requirements	Asphalt-Rubber
Content	–	19%
Penetration (25℃, 0.1*mm*)	35-55	40
Soft Point (℃)	>60	69.4
Elastic Recovery at 25℃ (%)	>70	85
Rotary Viscosity (Pa·s, 180℃, 20r/min.)	1.5-5.0	3.9

Mix Design of Pavement Mixture

The gradation of the mother mixture in which the special cement mortar slurry was introduced, was determined based on the prior literature [1] and test results and is listed in Table 3. The design requirements of the mother mixture are listed in Table 4. The coarse aggregate, fine aggregate, and filler were all crushed from a typical limestone, and the properties of all materials met the requirements of the standard construction technology specification for highway asphalt pavements (JTG F40-2004 [6]).

As shown in Table 4, the optimum asphalt-aggregate ratio was determined using the Marshall procedure, the scattering loss test, and the leak loss test. The optimum binder content of the asphalt-rubber mixture was 3.6% and the AH-70 mixture was 3.2%.

Cement Used and Mix Design of the Cement Mortar

Ordinary Portland cement, P.O 42.5R, from La-fa-ji company in Chongqing, grade II fly ash from Xin-rong company, and Yangtze River super-fine sand from Chongqing were used in the study. The polymer used was a styrene-butadiene emulsion, SD622S, from the BASF company in Shanghai. The SD622S emulsion contained 47% solids; its viscosity was 0.03Pa·S, and it had a pH value of 9.5.

Two types of cement mortar were used. One was ordinary cement mortar; the other was polymer modified cement mortar. Their mixture proportions are listed in Table 5.

Low Temperature Splitting Property of Semi-Flexible Pavement Mixture

Ordinary cement mortar and polymer modified cement mortar were incorporated in the mother mixture in which three aggregate gradations of the upper, middle, and lower limits of the gradation curves were used. The tensile splitting properties of all of the mixtures were determined at six different temperatures, 10, 0, -5, -10, -15, and -20℃. All samples were prepared using Marshall size specimens. The width of the loading band was 12.7*mm*, and the loading rate was 1*mm*/min. The splitting test was conducted in accordance with specifications [7], and the splitting index was calculated. Based on the results, curves of failure strength, failure strain, and failure stiffness modulus as a function of temperature were plotted to evaluate the low temperature performance of the semi-flexible mixtures. These plots for mixtures prepared with both ordinary cement mortar and polymer modified cement mortar are shown in Figs. 1 to 3.

Table 3. Composite Gradation of Mineral Aggregates of the Mother Asphalt Mixture.

Size of Aggregates	Mix Proportion (%)	Size of Sieve (*mm*) 26.2	19	13.2	4.75	2.36	0.6	0.3	0.075
10-20*mm*	58.0	100.0	89.5	12.7	5.8	1.4	0.0	0.0	0.0
5-10*mm*	28.0	100.0	100.0	82.7	10.7	4.5	4.1	1.8	2.1
Chip	10.0	100.0	100.0	100.0	78.7	47.0	16.9	12.4	2.31
Mineral Powder	4.0	100.0	100.0	100.0	100.0	100.0	99.8	92.4	74.4
Composite Gradation		100.0	93.9	44.5	18.2	10.8	6.8	5.4	3.8
Upper Limit of Gradation [1]		100.0	100.0	70.0	30.0	20.0	15.0	12.0	10.0
Lower Limit of Gradation [1]		100.0	93.0	35.0	7.0	5.0	4.0	3.0	1.0

Table 4. Design Requirements of the Mother Asphalt Mixture.

Item	Density (g/cm^3)	Void Ratio (%)	Compaction Number (times)	Asphalt Content (%)	Stability (*kN*)	Flow Value (0.1*mm*)
Desired Value [1]	≥ 1.9	20-28	50 Each at Double Sides	3.0-5.0	≥ 3.0	20-40

Table 5. Mix Proportions of Ordinary and Polymer Modified Cement Mortar.

Types	Water/Cement Ratio	Polymer/Cement Ratio (%)	Sand (%)	Mineral Powder (%)	Fly Ash (%)	Fluidity (s)	7 days Strength (*MPa*) Flexural Strength	Compressive Strength
Ordinary Cement Mortar	0.65	–	14	10	6	11.4	4.4	17.2
Polymer Modified Cement Mortar	0.65	10	20	10	–	11.1	5.9	12.6
Desired Value [1]						10-14	> 2	10-30

Table 6. Comparison of Brittle Point Temperatures of Semi-Flexible Mixtures.

Gradation	Upper Limit		Middle Value		Lower Limit		AC-16 SBS Modified Asphalt Concrete
	Ordinary	Polymer	Ordinary	Polymer	Ordinary	Polymer	
Peak Temperature in R_T-T curve (ºC)	-9.0	-11.5	-8.5	-11.0	-7.5	-10.5	-8.0
Inflection Point Temperature in ε_T-T curve (ºC)	-10.0	-12.0	-9.5	-11.5	-8.0	-11.5	-9.0
Slope Changing Point Temperature in S_T-T curve (ºC)	-10.5	-13.5	-10.0	-13.5	-9.5	-12.5	-10.0
Comprehensive Brittle Point Temperature (ºC)	-9.8	-12.3	-9.3	-12.0	-8.3	-11.5	-9.0

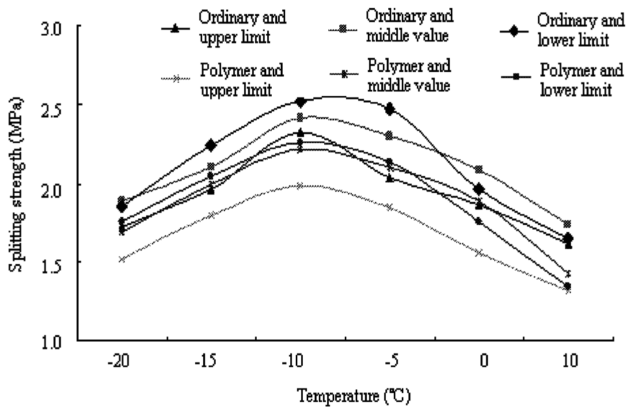

Fig. 1. Failure Strength Curves of Semi-Flexible Mixtures.

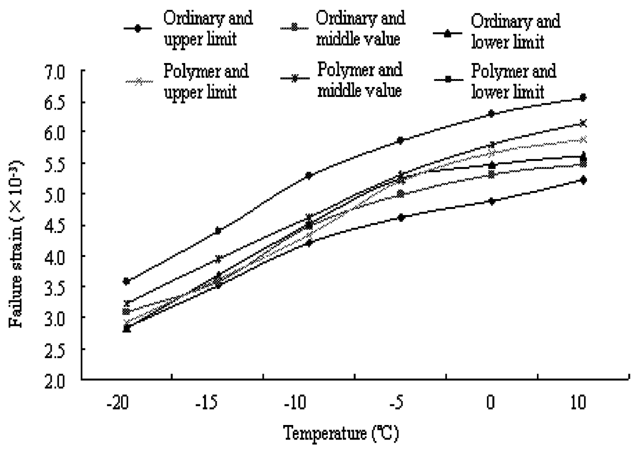

Fig. 2. Failure Strain Curves of Semi-Flexible Mixtures.

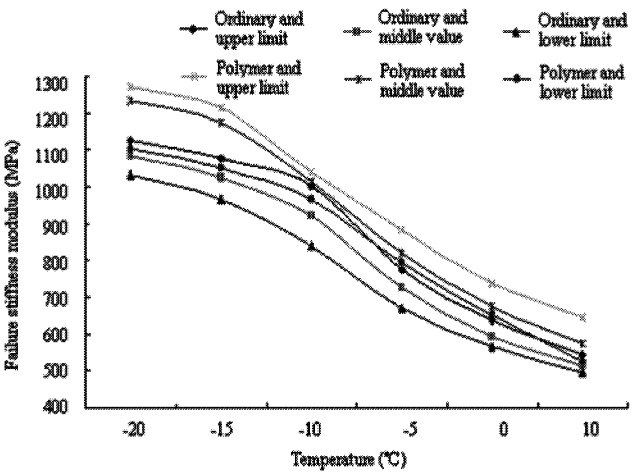

Fig. 3. Failure Stiffness Modulus Curves of Semi-Flexible Mixtures.

1. The effect of temperature on the failure strength of the semi-flexible mixtures was significant. When test temperature decreased, the semi-flexible mixtures became gradually harder, and their strength increased. The ultimate strength of the mixtures reached a maximum when the test temperature was about -10ºC. If the test temperature continued to decrease, the ultimate strength of the mixtures decreased rapidly. This, then, produced an obvious peak value in the curves.
2. From Fig. 2, it is seen that the failure strain of the semi-flexible mixtures decreased gradually when the test temperature was decreased. The failure strain was of the order of gradation upper limit > middle value > lower limit, which shows that the order of low temperature property of the semi-flexible mixture was upper limit > middle value > lower limit. The failure strength of the mixture was of the same order.
3. The stiffness modulus is a comprehensive index reflecting the stress and strain of asphalt mixture at low temperatures. Stiffness modulus test results indicate that the stiffness modulus at low of mixture temperatures is related to pavement cracking. From Fig. 3, the stiffness modulus of the semi-flexible mixtures decreased when the test temperature increased. Once the brittle point temperature was exceeded, the stiffness modulus decreased rapidly. When the test temperature was lower than the brittle point, the stiffness modulus curve became flat and reached a certain value.

The brittle point temperature is an important characteristic of an asphalt mixture and is an indication of the transformation of the mixture from a plastic to a brittle state. The lower the brittle temperature, the greater is the resistance of the mixture to low temperature cracking. Therefore, the brittle point is important together with the failure strain and stiffness modulus indexes. The brittle point temperature was obtained by completely analyzing different curves of R_T-T, ε_T-T, and S_T-T. The results are shown in Table 6.

As seen from Table 6, the order of the brittle point temperatures of the semi-flexible mixtures prepared with ordinary cement mortar were upper limit < middle value < AC-16 < lower limit. This shows the effect of the air voids of the asphalt mixtures on their low temperature properties. The low temperature properties become poorer when the air voids are increased. Compared with the AC-16 SBS modified asphalt concrete (middle value), the semi-flexible mixture with ordinary cement mortar (middle value) had a similar brittle point.

In addition, the brittle point temperature of the semi-flexible mixture with polymer cement mortar was smaller to that of the

Table 7. Low Temperature Bending Test Results.

Test Condition	Gradation Types	Flexural Tensile Strength (*MPa*)	Maximum of Flexure Tensile Strain ($\mu\varepsilon$)	Bending Stiffness Modulus (*MPa*)	Strain Energy Density (J/m^3)
-10℃ Temperature and 50*mm*/min. Loading Rate	Upper Limit	6.73	1,943	3,467	3,549
	Middle Value	6.95	1,838	3,780.6	3,387
	Lower Limit	7.57	1,523	4,970.3	2,931
	AC-16 SBS Modified Asphalt Concrete	8.29	1,265	6,582.4	2,753

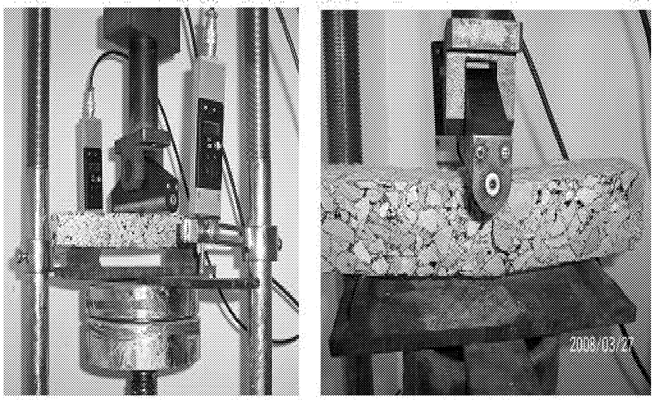

Fig. 4. Low Temperature Bending Test.

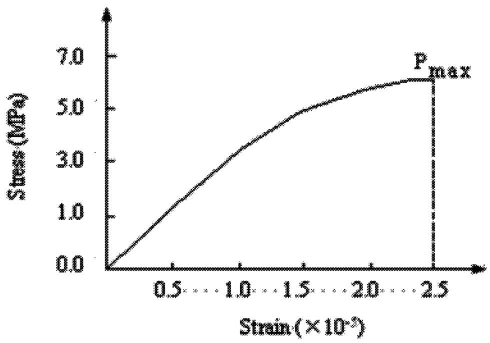

Fig. 5. Typical Stress-Strain Curve.

mixture with ordinary cement mortar. Also, it was found that during the test, the failure of mixtures with ordinary cement mortar was sudden and accompanied with a crisp noise. However, a few flaws emerged with gentle noise, but no failures in the samples, when the failure stress was reached with the polymer-modified cement mortar. This shows that incorporating polymer into the cement mortar enables semi-flexible pavement material to be more flexible. Thus, the low temperature properties of mixture are greatly improved. Therefore, incorporating polymer in cement mortar becomes an effective way to improve the low temperature properties of semi-flexible mixtures on heavy traffic roads and in lower temperature climates.

Low Temperature Bending Test of Semi-Flexible Pavement Mixtures

The 30 × 35 × 250*mm* beam for the bending test was prepared by cutting the rut samples of a semi-flexible mixture in accordance with the specifications [7]. The bending test was conducted at -10℃,

Table 8. Results of the Rutting Test.

Types	1min	45min	60min	Dynamic Stability (times/*mm*)
Semi-Flexible Pavement Mixture with Asphalt-Rubber	0.262	0.802	0.842	15750
AR-AC-16	0.635	1.972	2.243	2325

using a pavement material tester (Fig. 4) at a loading rate of 5*mm*/min. Four beam samples were used as a group and would be thermally stabilized at least six hours before testing.

The strength and deformation are important technical parameters of a pavement structure. However, it is insufficient to only consider the strength and deformation when the performance of a semi-flexible pavement mixture is being evaluated. In this paper, strain energy density at failure was calculated from the stress-strain curve, and the energy method was applied to evaluate this low temperature property of a semi-flexible mixture. Based on the bending test results, the stress-strain curve was constructed and is shown in Fig. 5.

Quadratic, cubic, and quadratic polynomial regression was conducted using the bending test results. It was found that the multiple correlation coefficients were all higher than 0.99 and met the precision requirement of the cubic polynomial regression of the stress-strain curve for semi-flexible pavement material. The stress-strain curve is determined as follows:

$$P(\delta) = A\delta^3 + B\delta^2 + C\delta + D \tag{1}$$

where, A, B, C, and D are all regression coefficients. The dashed line in Fig. 5 shows the failure (P_{max}). The strain energy density, E, at failure is determined by the integral of the area enclosed by the dashed line and stress-strain curve. The strain energy density, E, is calculated using the following formula:

$$E = \int_0^\delta P(\delta)d\delta = \int_0^\delta (A\delta^3 + B\delta^2 + C\delta + D)d\delta \tag{2}$$

The low temperature bending test results are listed in Table 7. From Table 7, it is evident that the air voids of the asphalt mixtures have some influence on the low temperature properties of semi-flexible mixtures. When the air voids are increased, the low temperature properties become poorer. Compared with the AC-16 SBS modified asphalt concrete, semi-flexible pavement with even ordinary cement mortar has a greater strain energy density at failure under low temperature. Therefore, the low temperature crack resistance

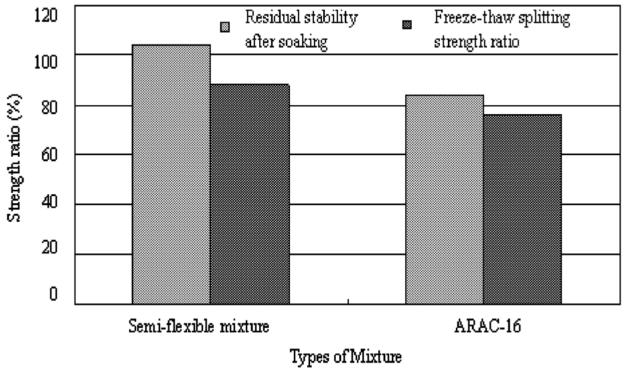

Fig. 6. Comparison of Water Stability Test Results.

of the semi-flexible mixture is better than that of the ordinary AC-16 asphalt concrete. Strain energy density at low temperatures is a good index to evaluate the low temperature crack resistance of the pavement material.

Study on the Performance of Semi-Flexible Mixture with Asphalt-Rubber

High Temperature Stability

The rutting test results of semi-flexible pavement mixtures with asphalt-rubber are shown in Table 8. From Table 8, the dynamic stability (DS) of the AR-AC-16 mixture was about 2,000times/*mm*, whereas that of semi-flexible pavement mixture with asphalt-rubber was up to 15,000times/*mm*. It is obvious that semi-flexible pavement mixtures designed in this study have better high temperature rutting resistance.

Water Stability

As shown in Fig. 6, when compared with the AR-AC-16 asphalt mixture, the residual stability of the semi-flexible mixture exceeded the freeze-thaw splitting strength ratio by 21.2% compared with 11.7% for the asphalt-rubber mixture. This shows that water stability of the semi-flexible mixture with asphalt-rubber was better.

It can be noticed that both the stability and residual stability of the semi-flexible mixtures with asphalt-rubber were up to about 20*kN*. It is thought that incorporating the cement obviously improved the rigidity of the asphalt mixtures. Also, the stability of the asphalt mixtures after 48hrs of soaking was larger than that of mixtures without soaking. This is because the strength of incorporated cement slurry had not been reached but increased gradually with time. When ambient temperature and humidity are increased, hydration of the cement is greatly enhanced, and growth in strength is correspondingly increased. The result is a greater residual stability of the mixtures after 48hrs soaking than for mixtures without soaking. In other words, after curing with soaking, the asphalt mixture has good water stability.

Low Temperature Crack Resistance

The indirect tensile test was used to investigate the low temperature crack resistance of the semi-flexible mixture with asphalt-rubber. Test results are listed in Table 9. Compared with AR-AC-16 asphalt concrete with asphalt-rubber, the semi-flexible pavement mixture with asphalt-rubber had a smaller splitting tensile strength, larger failure tensile strain, and smaller stiffness modulus, which showed that its low temperature crack resistance is better.

A Survey of the Practical Engineering Construction

A cement concrete pavement reconstruction project at the Xiao nan-hai cement plant in Chongqing was conducted in this study. This project was a plant pavement, which carried heavy traffic (rear axle load, 260*kN*), had a steep longitudinal slope (largest one up to 14.3%), and poor horizontal alignment. Thus, pavement damage occurred quickly during its service period and with the soaking of rainwater. Though sections were repaired several times, the overall service quality of the pavement gradually decreased, and parts of some sections even became unsafe. To restore its service quality, a design scheme was proposed to use a thin (1*cm*) stress-absorbing maintenance layer with asphalt-rubber (AR-SAMI) on the surface of the cement pavement followed by a 4-cm semi-flexible pavement layer with asphalt-rubber applied on the top of it. The total size of this project was 7,200m^2 with 800*m* mileage and 9*m* width.

1. Construction of AR-SAMI

Stress absorbing maintenance layer is defined as a layer, which is located between semi-rigid base or cement pavement and asphalt pavement, that is prepared using modified asphalt, which has good flexibility. This can result in stress relief over cracks and avoid the formation of reflection cracking in the finished asphalt pavement. The construction process includes primarily: (1) a complete cleaning of the surface of the base, (2) a determination of rubber powder dosage and preparation of the asphalt-rubber, (3) spraying with asphalt-rubber at the recommended amount of 2.0-2.6kg/m^2 and that of the aggregate at 16 ± 2kg/m^2, and (4) a compaction with a 25-ton rubber-wheeled roller clean of loose aggregate.

2. Paving of the mother mixture with asphalt-rubber

A semi-flexible pavement with asphalt-rubber is a pavement structure prepared by the incorporation of a cement mortar into the pores of a mother asphalt mixture. Therefore, it is necessary to accurately control porosities of the mother mixtures during the construction of the mother asphalt pavement. The paving parameters are listed in Table 10.

3. Preparation of cement mortar

The cement mortar was usually prepared on site using a mixer or

Table 9. Results of Low Temperature Crack Test.

Test Condition	Type of Mixture	Splitting Tensile Strength (*MPa*)	Failure Tensile Strain ($\mu\varepsilon$)	Failure Stiffness Modulus (*MPa*)
-10ºC Temperature and 1*mm*/min Loading Speed	Semi-Flexible Mixture	2.18	5,136	873.52
	ARAC-16	3.83	3,460	1,318.74

Table 10. Construction Parameters of Mother Mixture with Asphalt-Rubber.

Preparation of Asphalt-Rubber	Temperature	Virgin Asphalt	170℃
		Asphalt-Rubber	180-190℃
	Reaction Time	Mixing 300r/min.	45-60 min.
Mixing	Temperature	Asphalt-Rubber	170-190℃
		Mixture	180℃
	Time	Total Mixing Time	40s
Transportation	Temperature	Discharging Temperature	190-200℃
		Mixture Temperature on Site	175-200℃
Paving	Paving Speed	1-3*m*/min.	
	Loose Paving Coefficient	1.16-1.18	
	Paving Temperature	No Less Than 160℃ and Discarded Once Lower Than 140℃.	
Compaction	Combination of Compaction	Double Compaction Three Times by Heavy Double-Drum Roller in the Way of Both High Frequency and Low Frequency, Final Compaction One Time by Double-Drum Roller in the Way of Static Pressure.	

manually. The raw materials were added in the following order: mineral powder, cement, fly ash, fine sand, early strength agent, and water. The dry materials should be mixed thoroughly to be completely uniform before adding the water. Mixing with water is then continued for about two or three minutes or until uniform. To provide cement mortars of the same color, toners with a specific composition may need to be added to the asphalt-rubber mixtures in order to obtain a good landscape effect.

4. Filling of cement mortar

First, the void content of the mother mixture was determined by taking core samples and then calculating the required amount of cement mortar needed to fill the voids. Then, the fluidity of cement mortar was adjusted to ensure a complete filling of the voids. A rubber harrow was repeatedly used in paving the cement mortar to naturally fill in the voids in the construction process, and a small vibratory roller or vibrating plate was used to enhance the filling of the voids with the cement mortar. Thus, the cement mortar completely and uniformly filled the voids of the mother mixture. When there was a longitudinal slope in the pavement, the cement mortar needed to be paved starting from the bottom of the slope and working to the top so as to avoid poor void filling due to quick flow.

5. Treatment for good appearance

It is essential that the residual cement mortar on the road surface be cleaned with a harrow to make bare the irregular surface of the mother pavement mixture. A retarder was sprayed on the road surface to obtain a good pavement structure, which could be affected due to the incorporation of the cement mortar in the mother mixture. Then, when the final setting of cement mortar within the mother mixture was complete, the cement mortar on the road surface was washed off before its final setting to ensure enough strength of the internal cement mortar and to provide a good appearance.

6. Curing

Curing time changes with changes in the properties of cement mortar. The road is usually opened to traffic after two or three days, or even in a day provided the early strength of the cement or agent in the cement mortar is sufficient.

This 1000*m* test pavement using the ARSF20 showed excellent performance during service in low temperature of the South in the year 2007 and in the Chongqing's high temperature (up to 40℃) in year 2008. However, a weak failure emerged in the 6000*m* ARC-16 pavement bend. Therefore, semi-flexible pavement with asphalt-rubber is more suitable for the pavement structure with heavy traffic.

Conclusions

1. The low temperature properties of a semi-flexible pavement mixture decrease gradually with an increase of air voids of the mother asphalt mixture.
2. Compared with an AC-16 SBS modified asphalt concrete, a semi-flexible pavement mixture has a lower brittle point temperature, higher strain energy density, which properties are good to reduce low temperature cracking.
3. Incorporation of a polymer in the cement mortar is useful to improve the low temperature crack resistance of semi-flexible pavement mixtures.
4. Brittle point temperature and strain energy density are good ways to evaluate the low temperature properties of semi-flexible pavement mixtures.
5. Semi-flexible pavement material has the advantages of economy, technique, and performance. It is important to study and apply this material, which helps enhance highway construction skills, increase pavement service life, and reduce costs.

References

1. Japan Association of Roads, (1992). *Explain for General Code of Asphalt Pavement Engineering [M]*, Maruzen Co., Ltd., Tokyo, Japan.
2. Hao, P.W., Cheng, L., and Lin, L., (2003). Pavement Performance of Semi-Flexible Pavement in Laboratory, *Journal of Chang'an University (Natural Science Edition)*, 23(2), pp. 1-6.
3. Yang, Z.F., Li, M.J., and Wang, X.D., (2005). The History and Status Quo of Rubber Powder Used in Road Building, *Journal of Highway and Transportation Research and Development*, 22(7), pp. 19-22.
4. Rubber Pavement Association, (2000). How to Sell Asphalt-Rubber, *Rubber Pavement Association, Marketing*

Workshop, Paradise Valley, Arizona, USA.
5. Huang, P., Lu, W.M., Zhang, F.Q., and Wei, X.J., (2001). Research on Performance and Technology of the Rubber Powder Modified Asphalt Mixture, *China Journal of Highway and Transport*, 14(z1), pp. 4-7.
6. China Communications Press, (2004). *S JTG F40-2004, Technical Specification for Construction of Highway Asphalt Pavement*, China Communications Press, Beijing, China.
7. China Communications Press, (2005). *JTJ 052-2000, Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering*, China Communications Press, Beijing, China.