

Study of asphalt performance impact with ultraviolet aging

Min Luo^{1,2}

1 China Airport Construction Group Corporation of CACC,R&D Center, Beijing 100101, China

2Beijing Super-Creative Technology Co.,LTD. Beijing 100621,China

Abstract. To solve the problem of strong ultraviolet radiation on the road asphalt aging, ultraviolet aging environment box analog wild aging condition to be used to experiment, Through dynamic shear rheometer respectively to study the effect of SBS modified asphalt and asphalt matrix high temperature, low temperature and fatigue performance with the aging time to change. The results show that SBS modified asphalt can produce serious aging under strong ultraviolet light, the Main aspects is fatigue performance and low temperature performance greatly reduced, high temperature performance is further improved, They have a closer relationship with aging time; At the same time, along with the test temperature, aging time on the influence of $G^*/\sin\delta$, $G^*\sin\delta$ of amplitude decreases. That ultraviolet on SBS modified asphalt aging has temperature sensitivity. The research conclusion can choose the light aging resistance of airport pavement asphalt to provide good technical support.

1. Introductions

At present about road asphalt aging research mainly focused on thermal aging, and caused by ultraviolet light aging research is less. China's Tibet, xinjiang, yunnan, etc. of western region is located in the plateau, thin air strong uv radiation; Because of the characteristics of the region geological conditions are complicated and diversified so much use asphalt pavement; Intense ultraviolet radiation to the rapid aging of asphalt pavement, asphalt becomes dry, rigid, cracking, water damage, the aggregate surface easily happened asphalt layer falls off, pumping slurry, loose, threshing and other diseases. Therefore, strong ultraviolet effect is one of the main natural factors of asphalt pavement damage, it is necessary for asphalt ultraviolet aging characteristics in-depth study.

2. The raw materials and preparation

According to the specification of the SBS modified asphalt and the matrix asphalt performance indicators for a file with the SBS modified asphalt and PanJin matrix asphalt associated test (table 1). For fully simulate field conditions, sample for after short-term aging for ultraviolet aging asphalt, the asphalt in the appropriate preparation method first melt temperature (160 °C, 130 °C matrix asphalt modified asphalt), will be specified in a stainless steel pan and ensure tar membrane is 1.5 mm, cool place at room temperature.

Table 1. asphalt performance test results

Test items	SBS modified asphalt		PanJin matrix asphalt	
	measured	standard	measured	standard
penetration (25°C, 100g, 5s)(0.1mm)	51.6	>40	60.0	>40
Softening point (ring and ball method) (°C)	107.5	>60	45.8	>60
Flash point (COC)(°C)	352	>250	282	>250



ductility (5cm/min, 15°C)(cm)		-	-	>200	≥150
Equivalent softening point T ₈₀₀ (°C)		54.8	>50	-	-
Equivalent brittle point T _{1.2} (°C)		-16	<-8	-	-
Film heating test (TFOT) 163°C/5h	Quality loss	-0.015	<1.0	0.14	<1.0
	Penetration than	73.6	≥65	57.8	≥50
	ductility (10°C)(cm)	62.6	>30	>200	≥100

3. Strong ultraviolet light aging test of asphalt

Indoor accelerated ultraviolet aging test chamber, the upper install six ultraviolet light tube, distance of 70 mm, using meter measuring radiation intensity and ultraviolet irradiation intensity distribution, determine the sample from the tubes 10 cm distance is relatively appropriate, test the temperature control for 60 °C.

Ray radiation intensity and aging time are the main factors affecting ultraviolet aging. As a result, the length of the ultraviolet aging time directly affect the test results, this paper, based on the natural conditions of the region, assuming that eight hours of sunlight a day, using the aging condition of equivalent accelerated rate method to calculate the outdoor and indoor uv irradiation time conversion to accelerate the rate of $A_u = 11.32$, at the same time, considering the reduction of uv lamps and lanterns is 1.125, outdoor uv irradiation time and indoor uv irradiation time conversion are shown in table 2.

Table 2. outdoor uv irradiation time and indoor conversion relation

Outdoor uv irradiation time: months	Indoor uv irradiation time: hours
1	21.2
3	63.6
5	106.1
7	148.4
9	190.8
12	254.4

4. The surface distribution state of the asphalt

According to the indoor accelerated ultraviolet aging test for asphalt samples in different aging time test, according to the samples after the different ageing time found on the surface of the SBS modified asphalt is apparent state extended along with the aging time has obvious changes, after 254.4 h aging of the surface of the sample form a thick layer of hardcover, accompanied by fresh asphalt (figure 1).

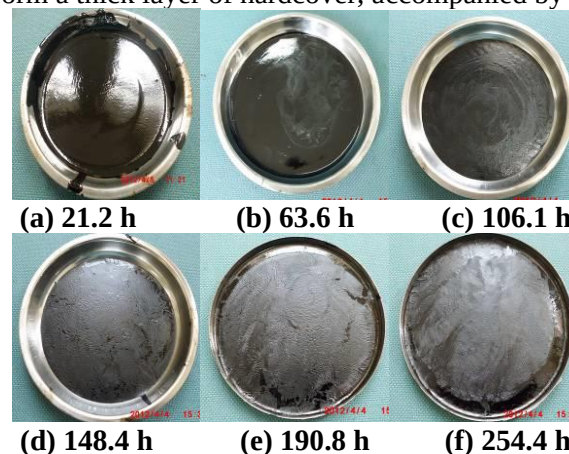


Figure 1 indoor accelerated aging of asphalt surface under different time distribution state

According to existing literature studies have shown that the SBS modified asphalt after aging, forming a layer of bright smooth surface film, to slow down the ageing process of the further. Through indoor accelerated aging test, the light of the SBS modified asphalt after TFOT aging 21.2 h, began to carbide surface, forming a thick layer of hard leather, light aging 106.1 h, a crusty layer was formed on

the surface of the SBS modified asphalt, started to crack, and with the extension of aging time, the crack begins to increase and extend. Early days of the sample surface micro cracks resulting from local contraction, as the aging degree of deepening, shrinkage and cracks, reveal the internal fresh asphalt, to ongoing light oxidation reaction, eventually lead to deep is gradually aging asphalt (figure 1).

5. The influence of the rutting resistance factor $G^*/\sin\delta$

At the high temperature of asphalt performance evaluation method and evaluation index more mature, SHRP research programs in the dynamic shear rheometer DSR measuring asphalt cement rheological properties under certain temperature and load frequency. Through the $G^*/\sin\delta$ as evaluation index of asphalt high temperature performance. In this paper, according to the standard of SHRP controlled by strain mode strain (1%, 8 mm test board, angular velocity 10 rad/s), asphalt specimen at different aging time temperature scanning (58 °C ~ 82 °C), and then against rutting factor $G^*/\sin\delta$, phase Angle of the delta , and comparing the composite shear modulus G^* (figure 2, figure 3 and figure 4).

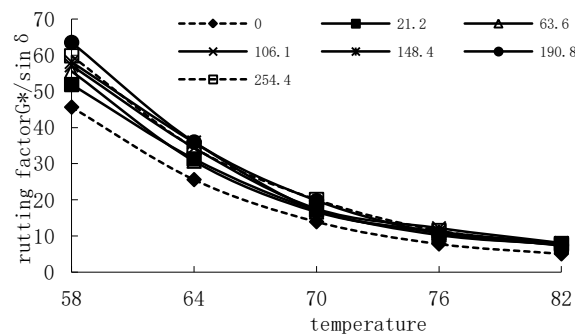


Figure 2 different aging time $G^*/\sin\delta$ change trend

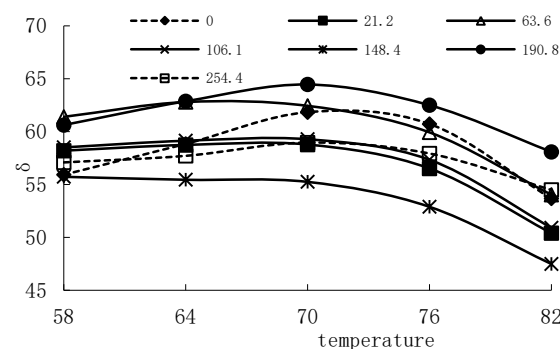


Figure 3 different aging time δ change trend

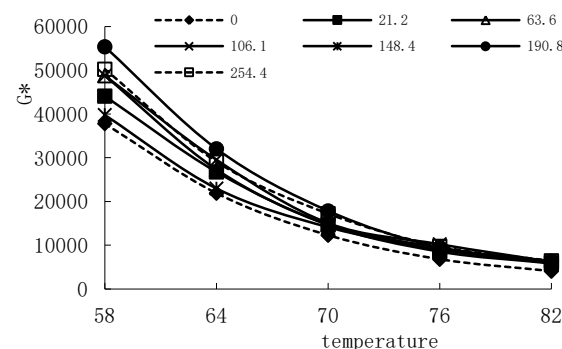


Figure 4 different aging time G^* change trend

According to figure 2 ~ 4:

(1) with the extension of light aging time, the SBS modified asphalt increase rutting resistance factor $G^*/\sin\delta$, but the overall change rule, main show is the $G^*/\sin\delta$ under different aging time distinguish bad sex, suggests that along with the increase of aging time of light, anti-rutting performance enhancements of the SBS modified asphalt, this may be because ultraviolet aging led to a part of the aromatics and asphaltene colloid into polarity, asphaltene content increased.

(2) with the increase of test temperature, SBS modified asphalt $G^*/\sin\delta$ decreases, and that the temperature rise, $G^*/\sin\delta$ light aging sensitivity decreases, namely different aging time of $G^*/\sin\delta$ almost consistent between 76 °C ~ 82 °C.

(3) ultraviolet aging time on the composite shear modulus G^* have great influence and phase Angle. Among them, for the phase Angle, the overall aging to reduce, but is distinguish between different aging time on the chaos, and instructions for the SBS modified asphalt ultraviolet aging is not sensitive to impact. At the same time, along with the test temperature, phase Angle decreases, the turning point in the 70 °C, a sharp fall in between 76 °C ~ 82 °C, instructions for SBS modified asphalt at 70 °C, ultraviolet light to start affected.

(4) compared with the phase Angle, with the extension of light aging time, the same temperature of G^* increase, with the increase of test temperature, G^* is less, but the trend is not obvious regularity, especially under 148.4 h, 190.8 h and 254.4 h change trend. Can be seen that different ultraviolet aging time asphalt G^* is different, on the whole, is in the same aging temperature and the longer the greater the composite modulus of asphalt, that under the condition of same temperature, the strength of the asphalt after aging improved, less deformation, are more likely to happen brittle failure.

According to test data, the different temperature of $G^*/\sin\delta$ change with aging time linear regression (table 3).

Table 3. $G^* / \sin\delta$ under different temperature and aging time correlation

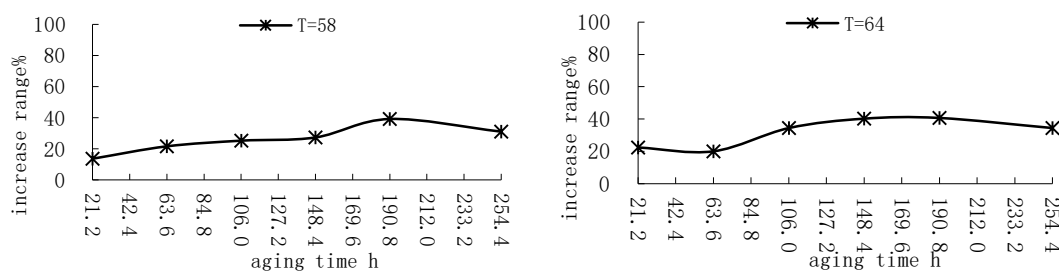
temperature °C	Linear regression equation	correlation coefficient
58	$y=0.0543x+49.895$	$R^2=0.7440$
64	$y=0.0319x+29.045$	$R^2=0.6240$
70	$y=0.0198x+15.252$	$R^2=0.7832$
76	$y=0.0094x+9.6054$	$R^2=0.3791$
82	$y=0.0067x+6.5918$	$R^2=0.3514$

According to table 3:

(1) resistance to rutting factor $G^*/\sin\delta$ and the relationship between light aging time influenced by temperature, as the temperature increases, the correlation coefficient R^2 decreases. Between 58 °C ~ 70 °C, the average correlation coefficient is 0.720, good correlation, anti-rutting factor $G^*/\sin\delta$ and light aging time contact between them is larger, can use $G^*/\sin\delta$ to characterization of ultraviolet light influence degree, high temperature performance of SBS modified asphalt in ultraviolet effect on airport pavement in outdoor environment.

(2) between 70 °C ~ 82 °C, $G^*/\sin\delta$ with aging time correlation is small, light, lower the overall by about 50%, the minimum is 0.3514, shows that ultraviolet effect on high temperature performance of SBS modified asphalt in continues to decline, this may be due to SBS modifier when high temperature affected by ultraviolet light produced change.

For further study of ultraviolet aging time of $G^*/\sin\delta$ affect the amplitude change trend, respectively under different temperature and light aging samples were analyzed (figure 5).



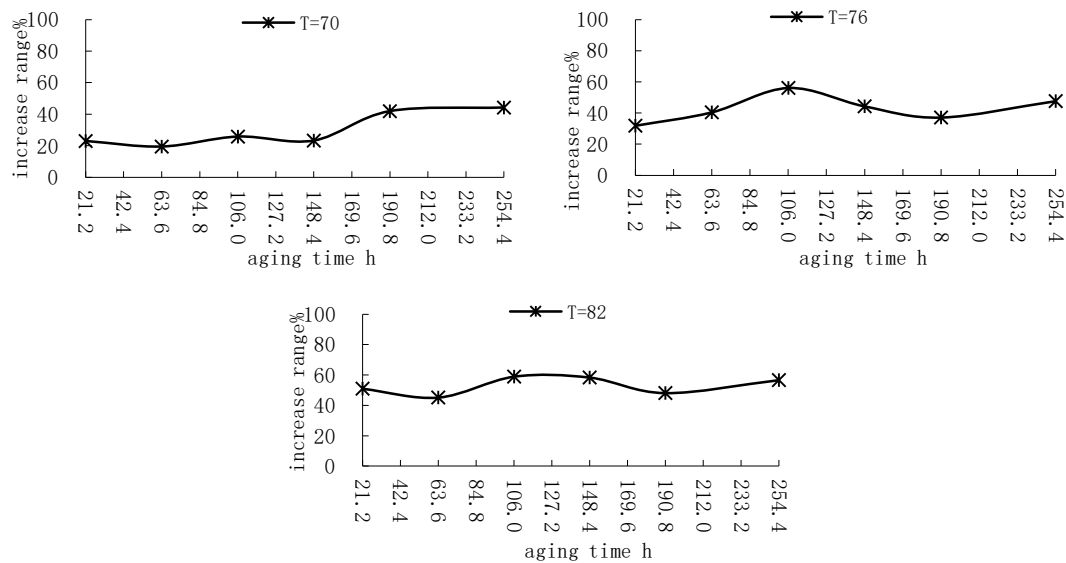


Figure 5 $G^*/\sin\delta$ changes compared with the same amplitude

Figure 5 different temperature describes the asphalt $G^*/\sin\delta$ range along with the change of light aging time, we can find that:

(1) $G^*/\sin\delta$ variation as the light aging time increases, the maximum after aging 254.4 h; $G^*/\sin\delta$ change gradually increases with temperature rise, and the biggest at 82 °C, the average is 53.5%, shows that as the temperature ultraviolet aging to further improve the SBS modified asphalt anti-rutting performance.

(2) different aging time rutting resistance factor $G^*/\sin\delta$ the overall trend is poor, poor regularity, 58 °C, main show is 148.4 h ~ 190.8 h, 190.8 h ~ 190.8 h $G^*/\sin\delta$ between appear larger degree change; 64 °C, large variation between 63.6 h ~ 160.0 h, then gradually smooth; And in 70 °C, 76 °C and 82 °C, the different period $G^*/\sin\delta$ change tendency is chaos.

6. The fatigue factor $G^* \sin\delta$

According to the SHRP research plan as a result, the composite shear modulus G^* multiplied by the phase Angle δ of sine value characterization of fatigue performance of asphalt binder ($G^* \sin\delta$), $G^* \sin\delta$ represented under the condition of strain is constant, the dissipation in a cycle of the wheel load induced fatigue crack in a viscoelastic material in energy. With 10 rad/s under loading frequency, $G^* \sin\delta$ reaches 5000 kpa, the fatigue resistance of the temperature characterization of this temperature is called the fatigue limit temperature, using FTT show, the lower the temperature of FTT, which indicates that the better the performance of material fatigue resistance. 22 °C ~ 34 °C temperature range, this paper USES the fatigue performance of different aging period asphalt specimen testing, the results are shown in figure 6, 7, and 8.

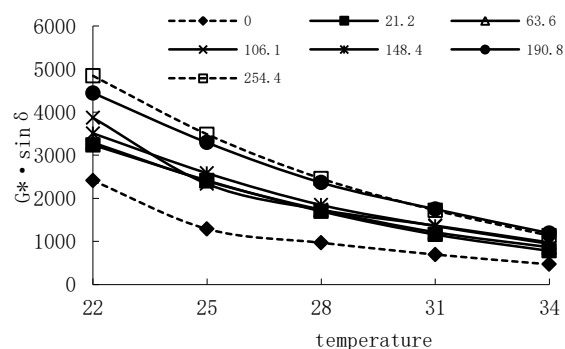


Figure 6 different aging time $G^*\sin\delta$ change trend

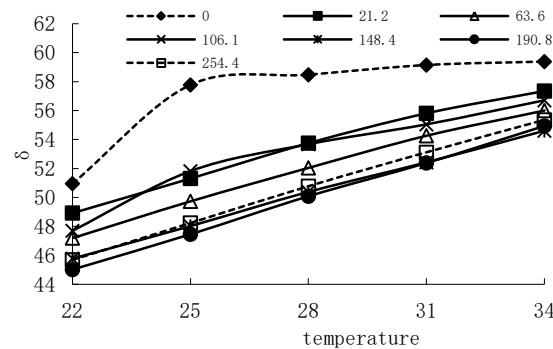


Figure 7 different aging time δ change trend

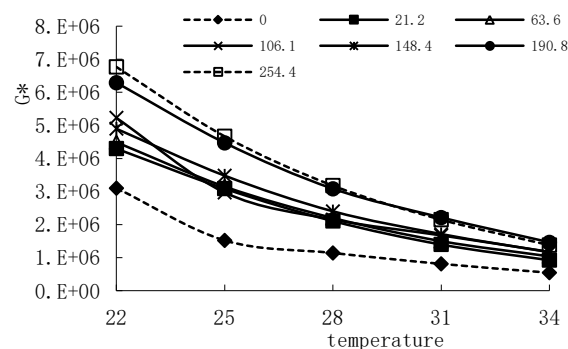


Figure 8 different aging time G^* change trend

According to figure 6 ~ 8:

(1) ultraviolet aging different extent influence on the fatigue test performance of the SBS modified asphalt, the fatigue factor $G^* \sin \delta$ are increased with the extension of aging time, the aging after 254.4 h $G^* \sin \delta$ the overall maximum, the maximum is 4843 Mpa, shows that with the extension of aging time, asphalt anti-fatigue performance serious decline. Among them, the ageing time on fatigue factor $G^* \sin \delta$ influence scope is mainly divided into three stages, from 0 to 21.2 h, 21.2 ~ 148.4 and 148.4 ~ 190.8 h, 0 h ~ 21.2 h, $G^* \sin \delta$ variation is obvious; 21.2 h ~ 148.4 h $G^* \sin \delta$ impact difference between small, shows that the ageing time has a certain influence on $G^* \sin \delta$ range, but even a short ultraviolet irradiation also can produce a degree of aging.

(2) fatigue factor $G^* \sin \delta$ decreases gradually with the temperature increasing of test, and between different aging time and with the temperature rise of $G^* \sin \delta$ amplitude decrease. That ultraviolet light is limited by the temperature influence on asphalt fatigue performance.

(3) the phase Angle δ As the change of the ageing time has changed significantly, the common law was gradually with the increase of aging time phase Angle smaller, that along with the aging time prolonging asphalt viscosity ratio is small, the low temperature deformation gradually become worse.

(4) composite shear modulus G^* is one of the important parameters, research can pitch viscoelasticity is the ratio of the stress and strain under dynamic load, low temperature condition, the G^* value, the greater the is its low temperature flow ability is poor, low temperature crack resistance, the worse. The figure 8 shows that at different levels and changes with aging time, G^* increased with the increase of aging time on the whole.

According to the data in the table above, each test temperature fatigue factor $G^* \sin \delta$ change with aging time linear regression (table 4).

Table 4. $G^* \sin \delta$ under different temperature and aging time correlation

temperature/°C	Linear regression equation	correlation coefficient
22	$y=8.2333x+2735.3$	$R^2=0.8729$
25	$y=6.968x+1762.4$	$R^2=0.7965$
28	$y=4.8223x+1288.7$	$R^2=0.8123$

31	$y=3.5657x+924.08$	$R^2=0.8358$
34	$y=2.3237x+647.89$	$R^2=0.7878$

According to table 4:

(1) the fatigue factor $G * \sin\delta$ and light aging time are linear relationship, the average correlation coefficient R^2 is 0.822, compared with the high temperature performance, is in a good correlation, explain with ultraviolet aging mainly affected the SBS modified asphalt anti fatigue performance, using $G * \sin\delta$ the aging of the SBS modified asphalt is more suitable to evaluate uv light.

(2) the fatigue factor $G * \sin\delta$ with the increase of test temperature phase relationship value is not a big change, this is the opposite of high temperature performance impact.

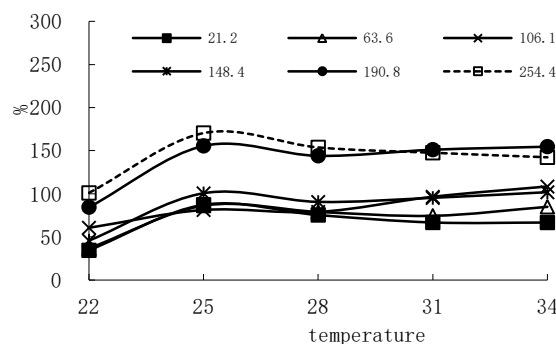


Figure 9 $G * \sin\delta$ change with aging time

Figure 9 depicts $G * \sin\delta$ under different temperature range along with the change of light aging time, we can find that:

(1) $G * \sin\delta$ change with the extension of light aging time increased, the overall increase the sharpest 254.4 h, $G * \sin\delta$ changes main component is in 21.2h ~190.8 h and 190.8 h~ 254.4h, between 21.2 h~190.8 h $G * \sin\delta$ smaller variations , almost can't distinguish the difference between time; In 190.8h ~254.4 h $G * \sin\delta$ variation is not obvious, the trend curve almost overlapping.

(2) $G * \sin\delta$ variation after first increases with temperature decrease. But different variations in temperature range, main show is 22 °C to 25 °C in the biggest change, the biggest (75.51%), and 25 °C~28 °C decreases, at 28 °C ~ 34 °C variation is more stable, shows a greater influence on the temperature on the fatigue test performance of the SBS modified asphalt.

7. Conclusion

(1) the SBS modified asphalt after ultraviolet aging its surface forming a layer of hard carbide films, and gradually thickening with aging time extended end covers the whole asphalt surface.

(2) ultraviolet aging can further improve the performance of SBS modified asphalt high temperature variations in the $G * \sin\delta$ increases with light aging time extending; Gradually increase with temperature, 82 °C average increase of around 53.5%, shows that as the temperature ultraviolet aging to further improve the SBS modified asphalt anti-rutting performance.

(3) the SBS modified asphalt after ultraviolet aging its anti-fatigue performance fell sharply, with the extension of the ageing time gradually serious, both have good contact, and the correlation coefficient R^2 values are not a larger with the increase of temperature of floating, the overall mean value of 0.822.

References

- [1] gong-yun liao, huang xiaoming, mulberry dunzhu. Asphalt anti-ultraviolet aging test to adapt to the Tibetan plateau environment research [J]. Journal of southeast university (English edition), 2008, 24 (4) : 503 ~ 507.
- [2] FengXiao Ye Fen, Huang Peng. Based on the analysis of asphalt aging ir carbonyl absorbance [J]. Journal of building materials, 2008, 11 (3) : 375 ~ 378.
- [3] TuJuan, yuan jun, flat package. Road asphalt and SBS modified asphalt ultraviolet aging research [J]. Journal of petroleum pitch, 2008, 22 (6) : 43 ~ 47.

- [4] Zhou Changlan, wang, hoyi. Inorganic nanoparticles affect the performance of ABS anti ultraviolet aging [J]. Journal of engineering plastics applications, 2005 (4) : 47 to 49.
- [5] yue-ling dai, dao-sheng liu, netsnake, etc. Road asphalt after aging of relations with the use of performance study [J]. Highway, 2002, 22 (2) : 9 ~ 13.
- [6] Liao G Y, Huang X M, Ba Sang D Z. Anti-ultraviolet aging tests of asphalts adapting to environment in Tibetan Plateau of China[J]. Journal of Southeast University (English Edition),2008,24(4): 503-507.