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Influence of Aging on Viscoelastic Response of Asphalt Mixture

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Key words: asphalt mixture; aging ; visco-elastic response; influencing factor

Abstract: Two gradations of asphalt mixtures were conducted to short term and long term aging tests. And then, static creep test was implemented on the samples of mixture. According to creep compliance curves from the stress-strain relations, Burgers viscoelastic model parameters were got to analyze the influences of aging effect on the viscoelastic response of asphalt mixture. The results and analysis indicated that aging is an important reason introducing viscoelasticity changes of asphalt mixture. For aged asphalt mixtures, the stiffness increases, the flexibility declines, the instantaneous elastic and the viscous compliance decrease. But short-term aging and long-term aging have different effects. And the viscoelastic parameters of the asphalt mixture with large voids vary more significantly, so aging process is much faster.

Introduction

Viscoelasticity of asphalt mixture has closely relationship with rutting, cracking, fatigue and other diseases of asphalt pavement. So researchers have paid more attention to viscoelastic responses of asphalt mixture[1]. Little[2] simulated asphalt mixture creep test using visco-elastic model. Chang[3] analyzed viscoelasticity of asphalt mixture with Maxwell, Kelvin, Burgers model individually, pointing out that Burgers model can simulate micro-view of mechanical properties of asphalt mixture better. Schwartz [4] carried out creep tests under the same load, 25 ºC to 45 ºC temperature to obtain viscoelastic parameters. Guan Hongxin[5] got fatigue damage model for visco-elastic which including temperature, load size and loading frequency. Zhou Zhigang[6] deduced visco-elastic parameters of asphalt mixture by dynamic creep tests, and discussed the relationship between the model parameters and rutting dynamic stability. Asphalt aging is an important influencing factor of viscoelastic response of asphalt mixture. In this paper, Burgers model parameters of asphalt mixture for different aging state were compared to analyze the influences of aging on the viscoelastic response of asphalt mixture. It can provide some reference for asphalt pavement design and failure analysis.

Aging method and creep test of asphalt mixture

Aging method. The rheological properties and performance of asphalt mixture will decay with asphalt aging[7]. According to specifications[8], short-term and long-term aging tests were conducted on AC-13 and AC-20 mixtures. The short-term aging test is to simulate the aging effect of construction by putting the loose mixture into the oven keeping 135 ºC for 2h. While long-term aging test is simulating the aging of asphalt pavement by the short-term aged specimens in the strong wind oven at 85 ± 1 ºC for 120 ± 0.5h. The basic properties of asphalt and gradation of aggregate for the mixtures in the experiment are shown in the table 1 and table 2.
Creep test. The two gradation mixtures (AC-13 and AC-20) samples were prepared with SBS modified asphalt. Uniaxial static creep tests were conducted under different temperatures and stress levels using MTS 810 testing machine, with the third group of parallel test for reducing the dispersion. Test conditions were 0.7 Mpa and 60 ºC. To reduce boundary effects tryout and

accelerated testing process, φ150mm × H110mm large specimen was formed by Troxler 4140 Rotary Compactor, and then get the size drill core specimens φ100mm × H110mm. Test process as follows: (1) 0.005 MPa, preloading 10 min; (2) apply to the required instantaneous load and hold set 60 min; (3) instantaneously unload to 0.005 MPa and maintain 30 min; (4) accurately measure deformation of specimen using LVDT.

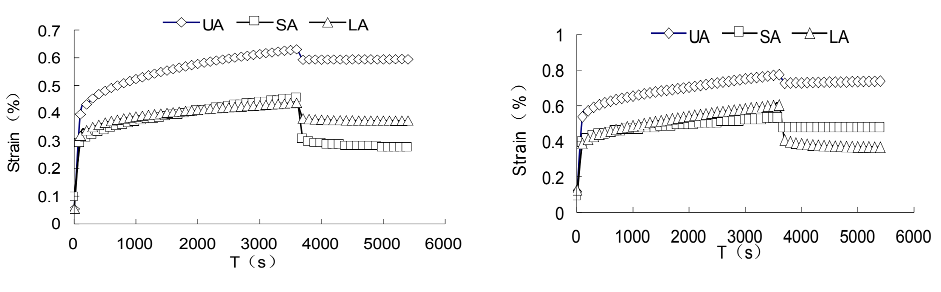
Table 1 Basic properties of asphalt

Test Indicators		Units	SK-SBS
Density (15ºC)		g/cm3	1.031
Penetration (25ºC,5s,100g)		1/10mm	69
softening point(R&B)		ºC	75
Ductility (5ºC,5cm/min)		cm	42
flash point		ºC	298
penetration index		-	-0.032
Film heating test (163ºC,5h)	Mass loss	%	0.08
	Penetration ratio	%	65
	Residual ductility(5ºC,5cm/min)	cm	23

Table 2 Gradation of aggregate

gradation	Sieve passing rate (%)											
	26.5 mm	19 mm	16 mm	13.2 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm
AC-13			100	95	76.5	53	37	26.5	19	13.5	10	6
AC-20	100	95	85	71	61	41	30	22.5	16	11	8.5	5

The creep tests were implemented on the three mixtures (unaged, short-term and long-term aged) under the condition of 60 °C and 0.7MPa. The creep deformation curves for different aging state are shown in the fig.1. According to the stress-strain relationship from the test, creep compliance can be obtained.



(a)AC-13 (b)AC-20

Fig.1 Creep strain curves for different aging states

Burgers Viscoelastic model parameters

Burgers model can describe the creep and relaxation characteristics of viscoelastic materials, which is used to express viscoelastic constitutive model of asphalt mixtures[9-10]. Studies[1,4,6] show that permanent deformation of asphalt pavement has a strong relationship with creep characteristics of mixture. Burgers model creep equation of asphalt mixture is,

$$\mathbf{J}(t) = \frac{1}{E_1} + \frac{t}{\eta_1} + \frac{1}{E_2}(1 - e^{-\frac{E_2}{\eta_2}t}) \tag{1}$$

In the equation, creep compliance J(t) of asphalt mixture is composed of three parts: instantaneous elastic compliance J_e under the load, time-related viscous compliance t/η_1 and viscoelastic compliance $J_{ve} \cdot (1 - \exp(-E_2 t/\eta_2))$. J_e reflects the resistance to deformation of asphalt mixture under high load, which is inversely proportional to the value of the elastic element E1. The parameter η1 is a viscosity coefficient reflecting residual deformation, which has relationship with the cumulative deformation of asphalt mixture under the repeated load. The two parameters E2 and η2 are viscoelastic indices reflecting the slow-developing and not-immediately-resume deformation under a long time load and usual temperature conditions. The numerical processing software was used to fit creep compliance curves by Burgers model, and the viscoelastic parameters of the three mixtures under different aging states are presented in Table 3.

Tab.3Changes of Burgers model parameters of asphalt mixture at different aging state

Gradation	Aging state	Burgers model parameters(Pa)				R2
		E1	η 1	E2	η 2	
AC-13	Not aging(UA)	2.44E+08	1.82E+12	4.48E+08	1.05E+11	0.9823
	Short-term aging(SA)	3.15E+08	3.58E+12	5.96E+08	2.37E+11	0.9782
	Long term aging(LA)	3.38E+08	3.34E+12	6.10E+08	1.95E+11	0.9841
AC-20	Not aging(UA)	1.87E+08	1.56E+12	4.05E+08	4.91E+10	0.9834
	Short-term aging(SA)	2.54E+08	3.15E+12	5.63E+08	7.56E+10	0.9769
	Long term aging(LA)	3.79E+08	2.17E+12	4.63E+08	5.42E+10	0.9815

Influence of Aging on the viscoelastic response of asphalt mixtures

For the two mixtures, four parameters E1, η1, E2, η2 of asphalt mixtures after short-term aging significantly increase. So stiffness increases, flexibility weakens, instantaneous elastic and viscous compliance decrease, and resistance to deformation under load is enhanced. After long-term aging based on short-term aging, E1 values of the two mixtures increase again, but E2 values vary not the same, with that of AC-13 increasing a little and that of AC-13 decreasing a lot. At the same time, η1 and η2 of the two mixtures decrease by different extents. It is analyzed that short-term aging test was conducted on the loose asphalt mixtures, so various property changes of asphalt in compacted mixture have relatively uniform distribution. Therefore overall performances of the resistance to deformation under load significantly increase. While for long-term aging test, compacted specimens were conducted and asphalt was aged uniformly, aged degree in the gap of mixture is serious. In actual fact, despite absolute stiffness of the asphalt increases, micro-crack damage on loads is more prone to occur. Therefore, for the long-term aged specimens, viscoelastic parameter changes are caused by asphalt properties change and cumulative damage, parameters are more complex.

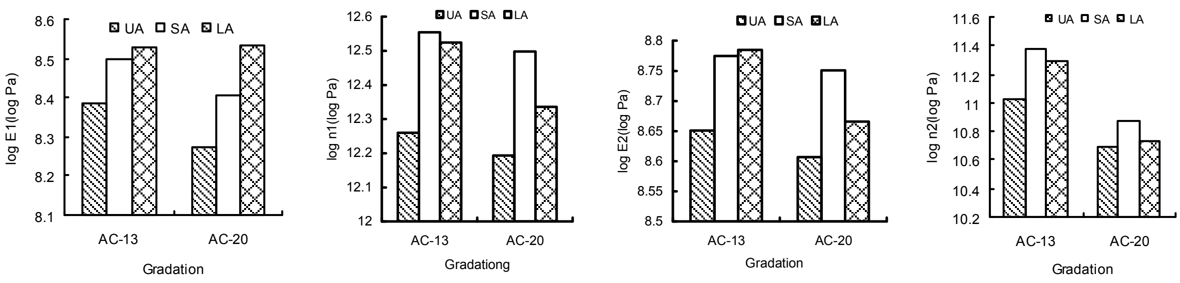


Fig.2 Efect of aging on Viscoelastic parameters

Compared with the AC-13 mixture, parameter changes of AC-20 mixture are more obvious. In general, porosity in the AC-20 mixture is greater than in the AC-13 mixture, so aging effect is much more significant because of more contact oxygen.

Summary

Burgers model parameters of aged asphalt mixtures have significant changes. For aged asphalt mixtures, the stiffness increases, the flexibility declines, the instantaneous elastic and the viscous compliance decrease. Therefore aging is a main factor causing viscoelastic properties decay for asphalt mixtures, but short-term aging and long-term aging have different effects. And the viscoelastic parameters of the asphalt mixture with large voids vary more significantly, so aging process is much faster.

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