

Viscoelastic Analysis of Asphalt Mixture Based on Creep Test

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Abstract: Two kinds of mineral fibers were added to AC-16C asphalt mixture. Trabecular bending creep experiments of asphalt mixtures were carried out at -10 and 20°C. The influence of mineral fibers on the low temperature viscoelasticity of asphalt mixtures were analyzed systemically. Furthermore, by using Origin, Burgers viscoelastic model was used to investigate the parameter regression for the creep test results at the different temperatures. The results show that the addition of mineral fibers can effectively improve the bending creep rate of asphalt mixtures, indicates the increase of crack resistance of asphalt mixtures. Good agreement between experimental data and Burgers model was found. The parameters of Burgers model at different temperatures can also provide data support for the viscoelastic design of asphalt pavements.

Keywords: Bending creep, mineral fiber asphalt mixture, numerical simulation, viscoelastic

INTRODUCTION

As a kind of inorganic fiber, mineral fiber is additive that characterized by good recycling property, tensile property, heat-resistance, acid-resistance, alkali-resistant and salt-resistant. Previous study showed that adding mineral fiber was efficient to improve the pavement performance (Shen, 2001; Zhao and Zhao, 2011; Chen *et al.*, 2005; Kim and Little, 2004). Asphalt mixture was a kind of typical viscoelastic fiber with completely obvious creep and relaxation properties. The researches on rheological properties and dynamic performance were carried out widely in the world. Further information about the relationship of material constitutive and mechanical behavior of asphalt mixture would facilitate the prediction of pavement performance of asphalt mixture (Si *et al.*, 2002; Luo, 2007; Zhao and Wang, 2010). We conducted a bending creep test using asphalt mixtures without fiber addition, with short cut mineral fiber addition and with mineral fiber addition, respectively at various temperature conditions. In addition, the viscoelastic behavior properties of the 3 kinds of asphalt mixture were also studied by exploring the same rheological model.

THE EXPERIMENT

The experiment use AC-16 C asphalt mixture, aggregate gradation Table 1. The experiment chooses two kinds of basalt mineral fiber, 1 is short cut mineral

fiber, and the other is cotton mineral fiber. Fiber contents of creep experiment selected 0.2%, experimental temperature, respectively is -10 and 20°C. The size of specimens is 40×40×250 mm, adopted midspan loading form; the loading schematic diagram is shown in Fig. 1.

The value of creep test load was decided by many experiments: For comparative analysis, 3 kinds of asphalt mixture in the same temperature condition used the common creep load; The initial load selected as 10% of the trabecular bending test load, considering the time factor, the transfer period of creep curves is controlled within 60 min, after many adjustment, finally determined that creep test load were -10°C for 164 N and 20°C for 16 N.

ANALYSIS OF EXPERIMENTAL RESULTS

The influence of mineral fiber to asphalt mixture creep properties: Creep rate is within the unit stress condition, strain's change value in the unit of time, in the low temperature, the more creep rate is, the better deformation capacity and toughness are, which show that the mixture has better stress relaxation ability in the same condition. In data processing, choose the stability period no less than 1/2 h to calculate the creep rate. The bending creep result was shown at Table 2 and Fig. 2.

From the result we could see that in the low temperature, the creep rate of mineral fiber asphalt mixture was greater than the ordinary asphalt mixture,

Table 1: The aggregate gradation of AC-16C asphalt mixtures

Screen hole size (mm)	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Through the percentage / %	95	82	68	48	34	20	15	11	8	4

Table 2: Results of asphalt mixture bending creep test

Testing temperature (°C)	Type of specimens	Creep flexural stress (σ_0 /MPa)	Bending creep rate ($\epsilon_{\delta} / \times 10^{-7}$ 1/s/MPa)
-10	No fiber	0.769	1.28
	Short-cut		1.68
	Cotton		1.65
20	No fiber	0.069	16.8
	Short-cut		17.9
	Cotton		17.9

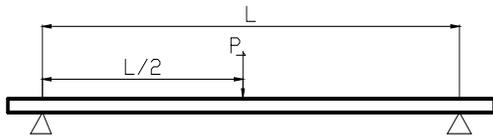


Fig. 1: Loading schematic of bending creep test

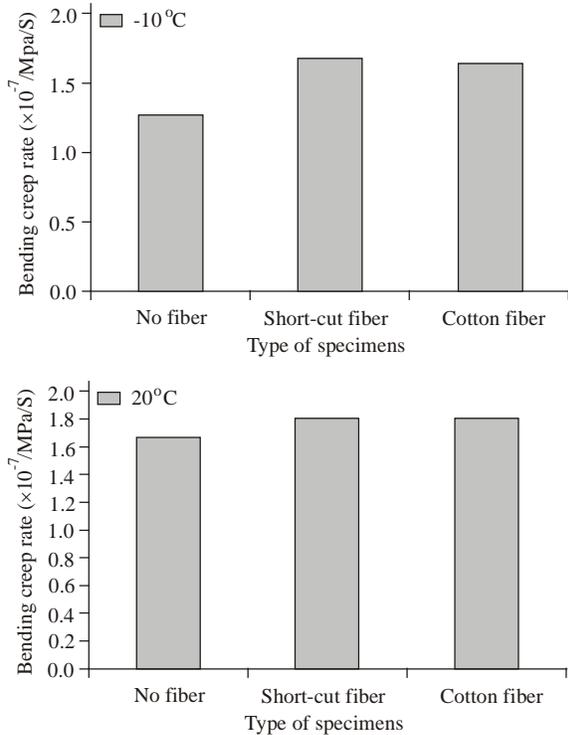


Fig. 2: Results of asphalt mixture bending creep test

which was shown that the mineral fiber asphalt mixture has good stress relaxation ability and better low temperature crack resistance property in the same condition and more suitable for cold area.

Rheological model of mineral fiber asphalt mixture: Viscoelastic mechanics model of mineral fiber asphalt mixture: The current asphalt pavement design

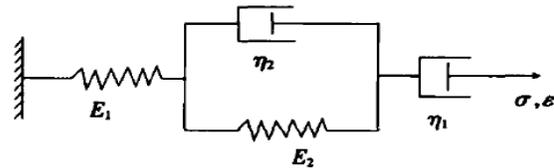


Fig. 3: Burgers mode

is based on the theory of elastic multi-layer system; use this method to design the structure often fall short of the expected service life. For technical economic consideration, proceed the asphalt pavement viscoelastic design becomes necessary. Viscoelastic of material can use proper mathematical model to describe, Burgers model (Fig. 3) can better reflect the asphalt mixture's creep and relaxation characteristics, especially in the loading process can more reflect the superiority of the model, so it is widely used in the road engineering (Zhang, 2005; Meng, 2005; Zheng *et al.*, 2008). Burgers model of the creep equation shown as type (1):

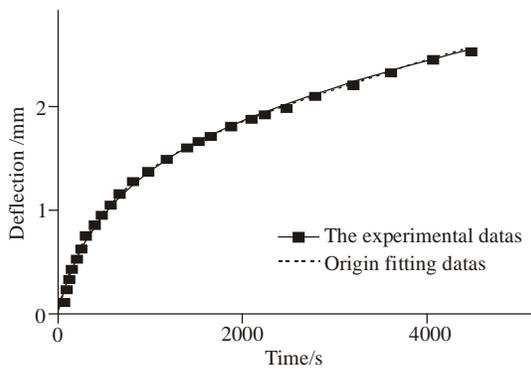
$$\epsilon(t) = \sigma_0 \left[\frac{1}{E_1} + \frac{1}{\eta_1} t + \frac{1}{E_2} \left(1 - e^{-\frac{E_2 t}{\eta_2}} \right) \right] \quad (1)$$

The first part of type (1) represents the transient elastic modulus that is produced by elastic elements 1; The 2nd part stands for the permanent deformation generated by stick pot 1, more less the η_1 is, more fast the deformation rate with time; The 3rd part of the model representatives viscoelastic deformation produced by the Maxwell model ; The ratio of E_2 and η_2 has a great impact on the curvature of the stress-strain curve, the less E_2/η_2 means viscoelastic deformation rate becomes faster in creep process.

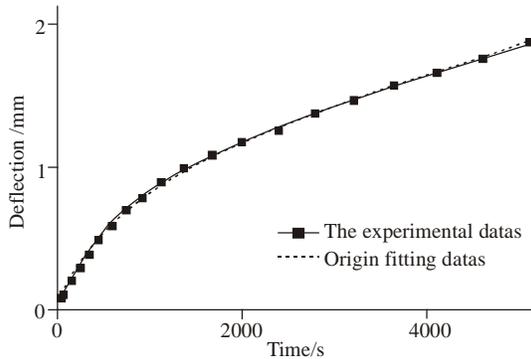
Determine the viscoelastixity parameter: It can be seen from the results of creep test; fiber asphalt mixture has been showed the similar creep property with common asphalt mixture, so Burgers model was

Table 3: Parameters of burgers mode for asphalt mixtures

Testing temperature (°C)	Type of specimens	E1(×10 ⁶ MPa)	η ₁ (×10 ⁵ MPa·s)	E ₂ (MPa)	η ₂ (×10 ⁴ MPa·s)	(E ₂ /η ₂)
-10	No fiber AC-16C	2.8	33.4	630.2	28.4	22.2
	Short-cut AC-16C	3.6	26.4	492.4	23.6	20.8
	Cotton AC-16C	3.6	32.3	530.3	26.3	20.2
20	No fiber AC-16C	2.5	2.90	108.3	4.20	25.7
	Short-cut AC-16C	2.7	1.90	68.70	2.80	24.3
	Cotton AC-16C	3.5	2.20	54.10	2.30	23.5



20°C no fiber AC-16C



(b) 20°C cotton AC-16C

Fig. 4: Fitting curve of asphalt mixture creep test in 20°C

selected for charactering the viscoelasticity of fiber asphalt mixture. Model parameter was determined through custom fitting the data of time-displacement by Origin mathematical analysis software; fitting results are shown in Table 3. Figure 4 reflected creep fitting curves about two different kinds of asphalt mixture in 20°C, fitting curves in -10°C was similar with the curves in Fig. 4.

Figure 4 predicted that creep curves from test was agree well with Burgers model curves through custom fitting by Origin software and the fitting correlation were all above 99% which fully indicated that Burgers

viscoelastic constitutive model provided a favorable way to reflect viscoelasticity of mineral fiber asphalt mixture in low temperature.

Table 3 showed that fiber addition had influenced on the parameters of Burgers model. The E₁ value increased after fiber addition, demonstrating the decrease of the elastic deformation at the same temperature and stress condition; the decrease of η₁ and E₂/η₂ represented that the elastic deformation of asphalt mixture increased, which was consistent with results of creep test.

CONCLUSION

The viscoelastic analysis was conducted on asphalt mixtures without fiber or with addition of kinds of basalt mineral fibers through bending creep test. Main conclusions were obtained as following:

- The increase of bending creep speed rate of the asphalt mixture with mineral fiber addition showed that adding mineral fiber effectively improved low temperature sticky toughness of asphalt mixture.
- The viscoelastic property of the mineral fiber asphalt mixture can be reflected by Burgers model. The result of fitting curve was consistent with the experiment result. Viscoelastic parameters of the fiber asphalt mixture were obtained from curve fitting. The parameters of Burgers model, η₁ and E₂/η₂ ratio decreased with the addition of fiber. This result predicted that the viscous yielding increased with fiber addition which was in line with the results from creep test.

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