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Analysis of viscoelastic properties of basalt fiber reinforced asphalt concrete

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Abstract. According to the time and displacement curves obtained by the static creep test of asphalt concrete with different length and different content of basalt fiber, the viscoelastic parameters of the modified Burgers model are identified. Analyze the change of viscoelastic properties with the effect of fiber length and fiber content as well as the sensitivity of viscoelastic parameters to temperature under different fiber content based on the identification results. The results show that: The addition of basalt fiber increases the instantaneous elastic deformation parameters and the time delay elastic deformation parameters. At the same viscous flow deformation parameters and viscoelastic deformation parameters are also increased. However, the increase amplitude of elastic deformation parameter is much smaller than that of viscous flow deformation parameter and viscoelastic deformation parameter. With the temperature increasing, the instantaneous elastic deformation parameters, viscous flow deformation parameters show a downward trend. However, the decline trend of asphalt concrete added basalt fiber is slow, that is, the addition of basalt fiber reduces the sensitivity of the asphalt concrete matrix to temperature.

Key words. Road engineering, basalt fiber, asphalt concrete, viscoelastic parameters Reference.

1. Introduction

The research of elasticity and viscosity of bituminous concrete was starting in 1960s. It was proved the ability can be analyzed with Burgers Model by Morusmith C. L. [1] by means of hydro-variety theory. Vlachovicova [2] and his teammates conducted a creep experiment of SBS bitumen, which manifests, the law of elasticity

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and viscosity can't show in polymer modified asphalt under high pressure. Szydlo [3] made a research about the rheological parameter of bitumenous mixture, which manifests that rutting depth is extremely influenced by delayed elasticity deformation parameter E_2 and viscose flow deformation parameter η_1. Shear elasticity calculated mode presentde by Abbas [4] and his teammates reform to experiment's result well. Lee [5] conduct calculations of bituminous mixture's micro-damage resulted by rheological parameters and damage factor in Schapery's constitutive model. Viscoplasticity conscious model put forward by Tashman [6], which can connect important micro-structural character with macroscopic conscious performance, describes permanent deformational behavior of bitumenous mixture under high temperature. Lu regarded bituminous as linear viscoelatic material, then build the corresponding visco elastic plastic constitutive model by using Persyna Theory [7]. In addition, scholars have introduced viscoelastic parameters into the evaluation from various performance models, for example, Zhang et [8] al first coupled the elasticity and viscoelasticity, then the intrinsic relation between deformation and viscoelastic parameters is determined on this basis; Lee [9] and other verified the validity of the viscoelastic vatigue damage model by experiments; Krishnan [10] et al. considered the viscoelastic effect of asphalt mixture in the study of pavement temperature dynamic coupling effect, besides the combination of analytical method and experimental method.

In China, a series of studies have been carried out on the viscoelastic properties of asphalt concrete. Zheng Jianlong has done a lot of experimental research in this field and a relatively comprehensive theoretical analysis. He first proposed the asphalt concrete fatigue process may be analyzed by Boggs model, moreover, the viscoelastic parameters in the Boggs model can be determined by dynamic tests [11]. Then through the research of delayed cracking on the performance of crack beam it showed that: in the asphalt concrete, the crack expansion has obvious viscoelastic plastic fracture characteristics, and simple thermo rheological constitutive model of materials for fracture parameters is still applicable [12]. At the same time, he studied the stress relaxation characteristics of asphalt concrete under different temperature and put forward Thermo viscoelastic constitutive model, which can describe the asphalt concrete under different temperature whose rationality was verified by tests [13]. He is also starting from the three-dimensional thermo viscoelastic theory, deduced the calculation formula of temperature stress of asphalt pavement under low temperature, and calculated the time temperature equivalent shift factor by stress relaxation tests at different temperatures, and got the viscoelastic parameters of the generalized Maxwell model, which explained that the cumulative dissipation energy is directly affected by viscoelastic parameters, etc [14]. Xu Zhihong, Peng Miaojuan and others have established a nonlinear visco elastic plastic constitutive model which can influence the rutting of pavement [15]. Shao Lageng and others took direct tension tests on asphalt mixture and studied its viscoelastic damage characteristics, got a model whick can reflects the strain rate effect and stress softening phenomenon; meanwhile, the tensile stress response of the continuous temperature zone was obtained by combining the Arrhenius shift factor [16]. Based on linear elastic theory, Feng Jiliang deduced the creep model of asphalt and dynamic model by using uniform stretching rate direct tensile tests and dynamic mechanical tests, and through BBR, DTT test verified that it is reasonable to characterize the viscoelastic constitutive relation of asphalt materials by Boggs model; at the same time, the method of determining viscoelastic parameters is introduced [17]. Based on the theory of thermo viscoelastic mechanics and the generalized Maxwell model, the viscoelasticity of asphalt mixture was simulated, and the incremental thermo viscoelastic constitutive relation was deduced. Based on the theory of thermo viscoelastic mechanics and the generalized Maxwell model, the viscoelasticity of asphalt mixture was simulated by Qian Guoping and others, and the incremental thermo viscoelastic constitutive relation was deduced [18]. Through creep tests, Zhou Jinchuan and Wang Suiyuan obtained that the Burgers model can simulate the creep compliance curve better [19]. Based on the stress relaxation test and the time temperature equivalence principle, Li Yiming obtained the modulus of relaxation stiffness modulus of asphalt concrete, which covered the temperature range and time zone required [20]. Huang Weidong et al. studied viscoelastic properties of asphalt mixture by means of micro film viscometer and uniaxial creep test, and discussed the relationship between viscoelastic parameters and dynamic stability [21]. Hou Jincheng et al. Regarded relaxation modulus as the research object, using the stress relaxation experiments, studied the fiber asphalt concrete of several common, which manifests the Poisson ratio increases while the relaxation modulus of the matrix decreases; and the addition of fiber can reduce the residual deflection and maximum deflection during loading [22]. Guo Naisheng and Ye Qunshan used the first viscous element model for the Burgers nonlinear correction of fiber asphalt concrete visco elastic properties research, the results show that the modified model can still reflect the viscoelastic properties of asphalt concrete after adding fiber better [23].

From the domestic and foreign research situation, the object of study is mainly asphalt mixture. As regards decrease of viscoelastic properties of asphalt caused by adding fiber concrete, the main method is putting forward the viscoelastic constitutive model, then the model is verified by experiments, at the same time the regression of viscoelastic parameters are gotten, according to the variation of the viscoelastic parameters qualitative analysis can be made. The ultimate purpose of viscoelastic research is to improve its macroscopic service performance by exploring characteristics of viscoelastic properties of asphalt concrete.

Therefore, viscoelastic parameters are introduced into the evaluation model of various performances, quantitative analysis is then performed, this will be an important research area in the future.

2. Test methods and test scheme

2.1. Experimental method

Analysis of viscoelastic properties are made by the static uniaxial creep test, with standard Marshall specimen of grade AC-13 chosen to make tests, and the compaction times of double sides is 75 times. The length of basalt fiber is chosen by 6mm and 9mm, in which the length of 6mm fiber is 0.12%, 0.15% and 0.17%, and the corresponding amount of 9mm long fiber is 0.05%, 0.07% and 0.1%, respectively. Test equipment is CRT-NU14 pneumatic servo test machine for asphalt material. The experimental stress level is 0.7MPa, and the loading time is 60min. Before the static uniaxial compression creep test, 4 hours in the environment is needed for specimen in isolation. In the test, the anti friction film is laid on the two round ends of the specimen.

2.2. Test scheme

Viscous properties of viscoelastic materials have outstanding performance in the condition of high temperature, and very strong dependence on time, so the test temperature were selected as 30 °C and 45 °C, 60 °C, then they chose 30 °C to simulate normal asphalt pavement temperature in the seasonal frozen region in spring and summer time, 45 °C to simulate the road surface temperature in seasonal frozen region in summer sunshine time, 60 °C to simulate road surface summer temperature in especially high temperature time in season frozen area.

3. Analysis of variation law of viscoelastic parameters

The mechanical properties of asphalt concrete are related not only to the length of the loading time, but also to the temperature. When the temperature is different, the viscoelastic parameter will change accordingly. At the same time, the addition of basalt fiber will also change the viscoelastic parameters of asphalt concrete. High and low temperature performance of asphalt concrete, will be reflected indirectly by the viscoelastic parameters, For asphalt pavement in large temperature changes in the environment, the sensitivity of the viscoelastic parameters on temperature, directly reflects the high and low temperature performance of asphalt concrete.

By means of the fitting values of the viscoelastic parameters at different temperatures, the variation curves of temperature and viscoelastic parameters are obtained, as shown in Figures 1, 2, 3, and 4.

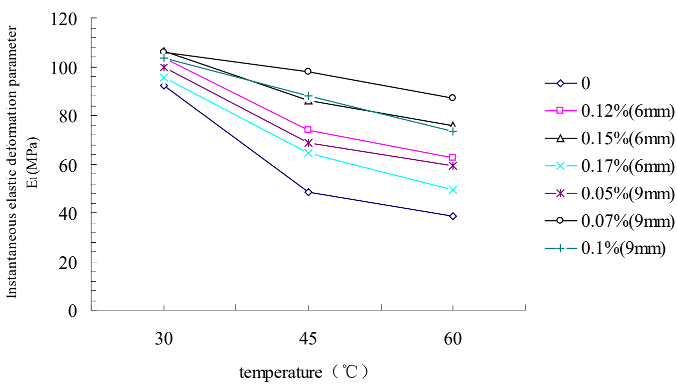

Fig. 1. Variation curves between temperature and E_1

As can be seen from Figure 1, the instantaneous elastic deformation parameters E_1 show a downward trend with the increase of temperature. But the decline trend of basalt fiber reinforced asphalt concrete's E_1 is relatively slower, and the rate of change is lower. The parameter E_1 of normal asphalt concrete decrease obviously, and the rate of change is higher. This indicates that the addition of basalt fiber can affect the sensitivity of the asphalt concrete matrix within a certain temperature range.

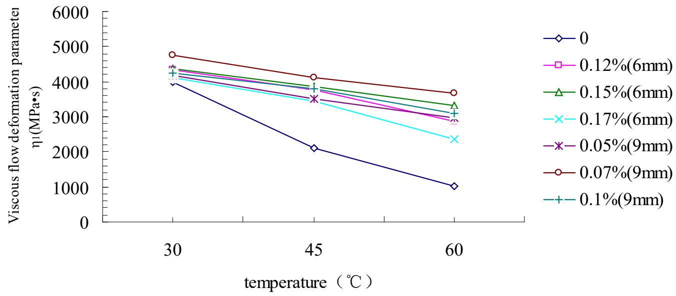

Fig. 2. Variation curves between temperature and η_1

As can be seen from Figure 2, the viscous flow deformation parameters show a downward trend with the increase of temperature, especially the trend of decline of ordinary asphalt concrete in relatively high temperature range. At the same temperature, the change rate of η_1 of basalt fiber reinforced asphalt concrete is still smaller than the decline rate of ordinary asphalt concrete. This indicates that the presence of fibers prevents the flow of asphalt mortar at high temperature, and at the same time the larger total surface area of the fiber increases the content of the structural bitumen. In the case of high temperature, the increase of structural bitumen is equivalent to the use of low grade asphalt.

According to the calculation formula of the viscous deformation characterization, at relatively high temperatures, the permanent deformation of asphalt concrete is greater than basalt fiber asphalt concrete, namely the traffic load under the same condition, the rutting depth shallower, which is very meaningfulthe for improving the high temperature performance.

As can be seen from Figure 3, the delay elastic deformation parameters E_2 all increase with the increase of temperature. In the 30 to 45 DEG C temperature zone, the delayed elastic deformation parameter value E_2 of the ordinary asphalt concrete is smaller than the basalt fiber asphalt concrete; in the 45 to 60 DEG C temperature zone, E_2 of ordinary asphalt concrete increased significantly, ; at close to 60 degrees Celsius temperature, E_2 of ordinary asphalt concrete is greater than those with basalt fiber. This indicates that adding basalt fiber can reduce the sensitivity of delayed elastic deformation parameters of asphalt concrete in higher temperature range, and make asphalt concrete maintain relative stability at high temperature.

It can be seen from Figure 4 that the viscoelastic deformation parameters η_2 all decrease with the increase of temperature. In the selected experimental temperature zone, the viscoelastic parameters η_2 of the asphalt concrete of the asphalt concrete

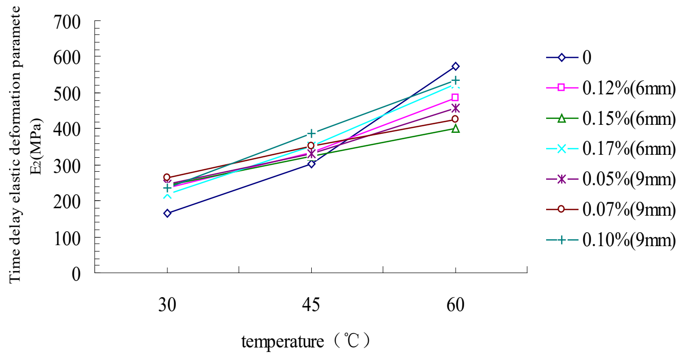

Fig. 3. Variation curves between temperature and E_2

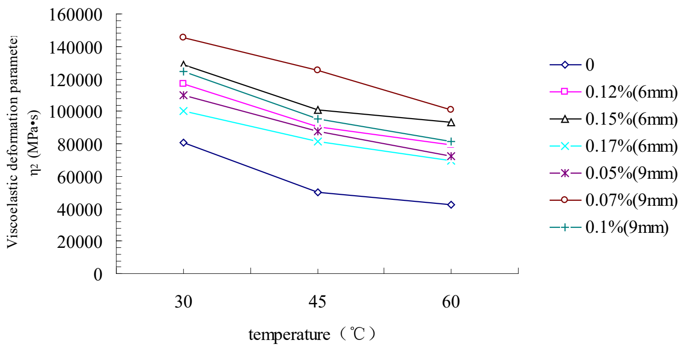

Fig. 4. Variation curves between temperature and η_2

are lower than that before and after adding basalt fiber. Combined with the analysis of the changes of figure 3.15, if the temperature suddenly increases, the basalt fiber asphalt concrete will have a deformation relatively stable performance, but the deformation performance of ordinary asphalt concrete will fluctuate, as the former is conducive to the recovery of the deformation, and the deformation recovery is not ideal.

4. Conclusion

1. The addition of basalt fiber makes the instantaneous elastic deformation parameters and delay elastic deformation parameters increase together, viscous deformation parameters and viscoelastic deformation parameters increasing as well, but the elastic parameters increase much more slowly than the viscous deformation parameters and viscoelastic deformation parameters.

2. The variation of the same viscoelastic parameters under different temperature analysis shows that with the increase of temperature, the instantaneous elastic deformation parameters, viscous flow deformation parameters showed a downward trend, but the trend of basalt fiber reinforced asphalt concrete is relatively slow,

which indicates that the basalt fiber can decrease the sensitivity of asphalt concrete to the temperature.

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