Creep Properties of Asphalt Binder, Asphalt Mastic and Asphalt Mixture

Johannes Büchner, Michael P. Wistuba, and Thilo Hilmer

Abstract For designing asphalt materials resistant to permanent deformation and rutting, a low creep deformation at high temperature is the crucial performance property. Usually, creep deformation is assessed through static or cyclic compression tests at elevated temperature, both for asphalt mixtures as well as for asphalt binders. For asphalt mixtures, static and cyclic compression tests are specified in the European Technical Standards. For asphalt binders, creep tests are usually performed by means of a Dynamic Shear Rheometer (DSR), such as Multiple Stress Creep and Recovery Test (MSCRT) developed for Polymer-modified asphalt binders. However, different author questioned the control parameters and significance of the MSCRT, especially for plain asphalt binders. In this paper, creep properties of asphalt binders and asphalt mastics (binder-filler-mixtures) are tested in the DSR using increased loading and recovery times to ensure steady-state flow conditions. These tests are performed on a set of 10 different asphalt binders and 18 corresponding asphalt mastics. The same material combinations are used in asphalt mixtures produced in the laboratory and then subjected to a cyclic compression test to assess the creep properties of the asphalt mixture. Finally, the creep properties resulting from asphalt binder tests, asphalt mastic tests, and asphalt mixture tests are correlated. The results show reasonable correlations over the different scales. It is concluded, that the asphalt binder has a significant impact on the creep behavior of the corresponding asphalt mixture.

Keywords Asphalt Mastic · Dynamic Shear Rheometer · DSR · Creep Test · Permanent Deformation · Asphalt Performance

1 Background and Objective

The predominant deterioration mode in asphalt pavements in the high temperature range is rutting due to permanent deformation. Such distress is related to the viscous

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creep properties of the corresponding asphalt binder. Different static and cyclic test procedures are known to assess the creep properties of asphalt materials.

For assessing creep properties of asphalt mixtures in the laboratory, generally a cyclic test is performed, where a periodical (usually sinusoidal) compressive load is applied to an asphalt mixture sample at a temperature higher than 50 °C. A typical example for a cyclic creep test performed on asphalt mixture is the triaxial compression test according to the European Standard EN 12697–25 [1]. During the test, the applied mode of loading transforms the material into a state of flow where the resulting plastic strains accumulate. Strain accumulation is usually presented in form of a creep curve, showing the strain increase in function of the number of load cycles (Fig. 1). The creep curve is generally divided into three phases. During the first phase a distinct increase of the strain rate is observed, while the second phase is represented by a quasi-stationary strain rate. Finally, a disproportional increase of the strain rate is observed in the third phase, and before the specimen fails [2]. The creep rate in phase II is usually considered as a time-independent rheological parameter characteristic for the material creep behaviour and its resistance to permanent deformation.

For studying creep properties of the asphalt binder, the Dynamic Shear Rheometer (DSR) has become a common test instrument, and the Multiple Stress Creep and Recovery Test (MSCRT) was introduced in the Technical Standards to determine creep behavior of asphalt binders. However, the MSCRT is only applicable for polymer modified binder but not for plain binders or asphalt mastic (binder-filler-mixture). Moreover, several researchers mentioned problems in regard to MSCRT, such as:

- The creep phase is too short to address constant flow; and recovery phase is too short to address asphalt binder recovery properties [4–6],
- Some rheometers showed problems when controlling the test due to instrument inertia [3, 7].
- Resulting parameters are of empirical type, and they do not characterize the material rheology in physically sound way [3, 8].
- The MSCRT methodology is neither suitable for plain binders nor for asphalt mastic [6, 8].

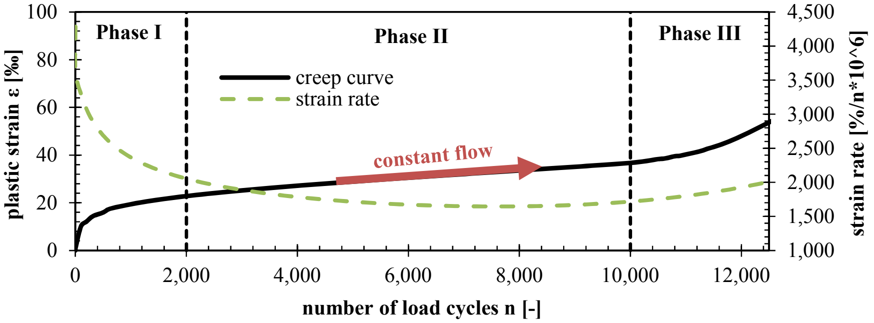

Fig. 1. Typical plot of a creep test, showing three typical phases (acc. to Wistuba [3])

As a solution to these concerns, significant research work is dedicated to alternative ways in assessing creep properties of asphalt binders. E.g. Santagata et al. [4, 8] developed a Single Stress Creep and Recovery Test (SSCRT), representing a creep test that includes one creep phase only, but also a subsequent recovery phase, both with increased creep and recovery times. The methodology appears to be applicable for both plain and polymer modified binders, and it allows distinct differentiation of the creep properties. The constant flow of the material in the second phase of the creep curve (cp. Fig. 1) can clearly be determined and used as a time-independent parameter to evaluate asphalt binder creep properties.

This paper presents latest work on assessing creep properties of asphalt binder and asphalt mastic based on a modified SSCRT concept. Moreover, the results obtained for binder and mastic are correlated with the creep properties of the asphalt mixture. The outcome of this work may provide deeper understanding of creep behaviour at various scales, by analysing the corresponding asphalt binder, asphalt mastic and asphalt mixture at the same time.

2 Methodology and Testing

In this study, 18 different asphalt mixture compositions are used, following the specifications of an asphalt concrete of the type AC 11, with a nominal maximum grain size of 11mm. Four different asphalt binders and three different types of aggregates are considered, as summarized in Table 1. From the asphalt mixtures the composition of the asphalt mastic in terms of binder content and filler composition (reclaimed and new filler) is derived. The asphalt binders and fillers (aggregates < 0.063 mm) are mixed together in laboratory to produce mastic samples that are used for subsequent DSR testing.

For asphalt mixture creep testing cycling compression tests are used (acc. to [9]). A cylindrical specimen with a diameter of 200 mm and a height of 40 mm is loaded uniaxially by a pressure stamp with a diameter of 80 mm. The test is run at a temperature of $T_{G*(binder)=15kPa}$ corresponding to a shear modulus of 15kPa of the asphalt binder, up to a number of 10.000 sinusoidal load cycles. During the test, the resulting creep strain is recorded and the accumulated creep curve is plotted. The gradient in phase II of the creep curve is considered as the characteristic parameter of the creep test.

For creep testing of asphalt binder and asphalt mastic, the DSR is used. A SCCRT according to Santagata et al. [4, 8] is used, but modified to adequately address the material creep properties. Table 2 summarizes the parameters of the DSR tests.

Different parameters are defined for asphalt binder and asphalt mastic testing such, that the second phase of the creep curve can be observed and to allow almost full recovery of the material. In Fig. 2, the evolution of deformation in the creep and the recovery phase is displayed exemplarily. The quasi-stationary phase (constant flow) of the creep curve is used to determine the time-independent creep compliance rate of the materials, according to Santagata et al. [4].

Table 1 18 different variants of asphalt concrete AC 11 by variation of asphalt binder type and aggregate type

Asphalt mixture AC 11 variants	Asphalt binder type (plain and polymer modified)		Aggregate type (gabbro, porphyry, silicate)
1	50/70	Manufacturer A	Coarse aggregate: gabbro Added filler: limestone Provenience: Germany
2		Manufacturer B	
3		Manufacturer C	
4		Manufacturer D	
5	25/55–55	Manufacturer A	
6		Manufacturer B	
7		Manufacturer C	
8		Manufacturer D	
9	70/100	Manufacturer B	
10	45/80–65		
11	50/70		Coarse aggregate: porphyry Added filler: limestone Provenience: Austria
12	25/55–55		
13	70/100		
14	45/80–65		
15	50/70		Coarse aggregate: silicate Added filler: limestone Provenience: Switzerland
16	25/55–55		
17	70/100		
18	45/80–65		

Table 2. Test parameters for DSR creep tests performed in this study

	Asphalt binder	Asphalt mastic
Plate size / gap	25 mm / 1 mm	25 mm / 1 mm
Test temperature	$T_{G^*(binder)=15kPa}$	$T_{G^*(binder)=15kPa}$
Creep phase duration	1 min	60 min
Recovery phase duration	14 min	60 min
Shear stress during creep phase	0,1 kPa	0,5 kPa

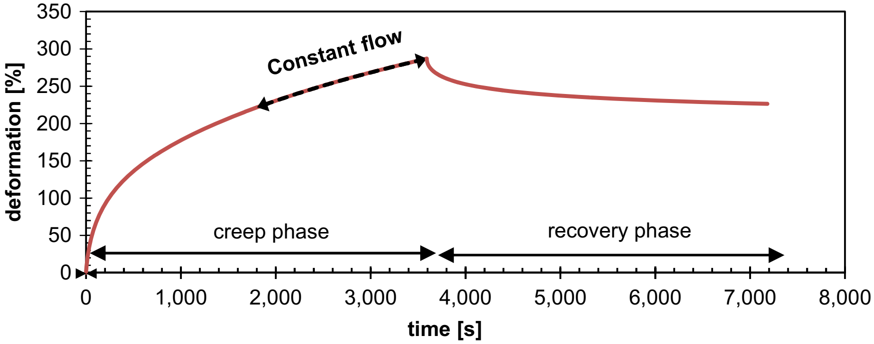

Fig. 2 SSCRT test results for asphalt mastic tested in DSR.

3 Results

The creep properties of asphalt mixture, asphalt mastic and asphalt binders are obtained in terms of creep rate in the second phase of the creep curve. The results are illustrated in Fig. 3.

Figure 3a shows the correlation of the creep rates of the asphalt binders and the corresponding asphalt mixtures. From a total number of 42 individual test results, a linear regression is drawn with a coefficient of determination of 0.90.

Figure 3b shows the correlation of creep rates of asphalt mastics and corresponding asphalt mixtures. The relationship is of logarithmic nature, as the horizontal x-axis is displayed in logarithmic scale. From a total number of 63 individual test results, a logarithmic regression is found with a degree of determination of 0.95.

4 Summary and Conclusions

Different creep tests were performed on a number of different asphalt binders as well as corresponding asphalt mastics and asphalt mixtures. For each of the materials, the creep rate in the quasi-linear phase of the creep curve was determined by using appropriate creep tests. The so-obtained creep curves were used to evaluate the creep rates of the asphalt binder, the asphalt mastic and the asphalt mixture. Finally, the creep properties at the different observation scales were correlated. From this study, the following conclusions can be drawn:

- The creep rate can serve as a universal time-independent material property to analyse creep properties of asphalt materials. It can be determined individually for asphalt binder, asphalt mastic and asphalt mixture from test procedures identified in this study.

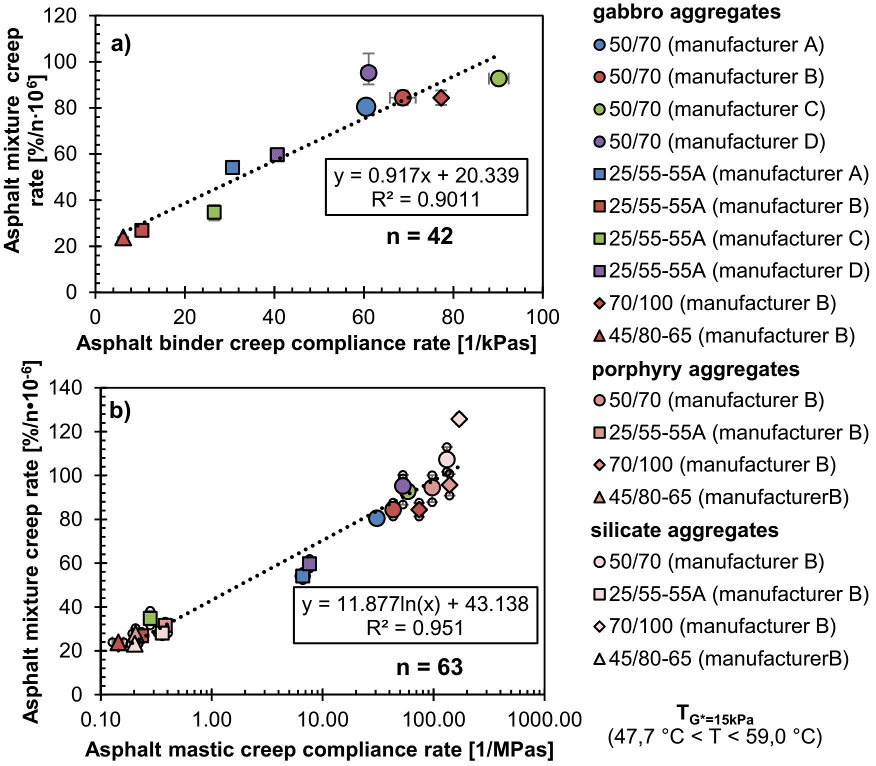

Fig. 3. Correlation of creep rates for **a** asphalt binder versus Asphalt mixture and **b** Asphalt mastic versus Asphalt mixture

- The presented methodology in the DSR can be used for assessing creep properties in the high temperature range of both unmodified and modified asphalt binders as well as for asphalt mastics.
- Sound correlations were found between the creep properties of asphalt binders and asphalt mixtures, as well as of asphalt mastics and asphalt mixtures.
- It appears that the creep behaviour of asphalt mixture is mainly driven by the creep properties of the corresponding asphalt binder.

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