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Data collection for the 2nd generation of European bitumen standards in the Czech Republic – round robin test experience

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Abstract

The second generation of European standards for bituminous binders will include, largely, those performance-related characteristics, which have been gradually implemented in practice. With respect to the regular use though, the characteristics have been recognized as a new requirement. Long-term experience with determination and interpretation is still missing. Due to the fact that polymer modified bituminous binders (PMB) in particular have become a standard product for all types of asphalt mixtures, it is necessary to stipulate the basic requirements for particular binders specified in the standard and based on their characteristics. Extensive data collection over all of Europe has gone on for several years. The main expectation is for laboratory data to provide sufficient information for the proposed initial set of the required parameters to be potentially included in the standards. The Czech Republic has started to gather experience and values based on round robin tests as well. The first stage of the project was launched in 2014 and 3 laboratories have tested two binders from different bitumen producers - virgin, short-term aged (RTFOT) and long-term aged (RTFOT + PAV). Traditional and performance analyses were employed. The second stage of the project followed in 2015; there were already six participating laboratories. Four binders were tested (one paving grade, three PMBs) in a similar framework as in 2014 with the addition of some conditions (e.g. testing temperature on DSR, BBR test etc.). The last stage in 2016 included six laboratories and four binders again (one paving grade, three PMBs). The last stage involved a further extension of test temperatures on DSR, and included a new addition of different temperatures and further stress level for the MSCR test (8 kPa). The evaluation of all results has led to the conclusion on a broader data collection for all polymer-modified binders in use in the Czech Republic. The data collection should be based on the draft requirements, which can be expected for EN 14023. The data will be collected from all producers/traders on the market anonymously. Then they will be evaluated by an expert team after 3-year collection. This evaluation will result in the determination of requirements for the standard PMB specifications. If the Czech Republic decides to use performance-related characteristics in specifications of paving grades, a similar approach to data collection could be applied.

Keywords: European standards; performance testing; conventional tests; polymer modified bitumen; round robin test; short term ageing; long term ageing; data collection; empirical parameters.

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1. Introduction

In many European countries, the significantly increasing traffic loads, particularly the increase of the heavy loaded vehicles share on the traffic flow, numerous changes in both vehicle and tire construction, gradual climate changes and the permanent lack of funds for pavement maintenance and rehabilitation have led to deteriorating road networks. The trend has been noticeably aggravated in the last twenty years. This is often attributed to poorer quality and durability of bituminous binders – the argument is heard often not only from the users but, unfortunately, also from the clients and administrators, or even from some professional associations. However, objectively speaking, the existing situation should not be viewed from this one angle alone; a multi-criteria evaluation is called for to allow describing the individual factors with more precision. What seems to be essential is a need to obtain a better understanding of the bituminous binder behavior in various stages of its work, and to search for correlations between the behavior of a bituminous binder and the asphalt mixture produced with such binder. That is the basic idea behind the introduction of functional testing of bituminous binders in the so-called second generation of specification standards.

Although, the original CEN plan has not been complied with to the fully extent (assuming the implementation of functional testing in both standards EN 12591 for Paving Grade Bitumen and EN 14023 for Polymer Modified Bitumen), a number of problems have been overcome and functional testing has been gradually implemented and used within the ongoing review of EN 14023. The fact that we do not have a sufficient set of data available to allow us to determine the relevant standardized threshold values for individual types of binders has proved to be a limitation. The results available for the individual functional tests often vary greatly, and remain beyond the usual values of repeatability and reproducibility. The essential need for an in-depth explanation not only of individual values but also of the basic test philosophy to a broader audience of specialists.

In the Czech Republic, the aforementioned circumstances inspired thoughts and discussions about the possible uses of functional bitumen testing. The fact that harmonized standards are not permitted to include normative national annexes (NA) and these must be incorporated in a different national regulation has prompted some decision-making. The Czech Republic undertook to compile the application standard, ČSN 65 7222-1 – Bitumen and Bituminous Binders – Modified Bitumen – Part 1: Polymer Modified Bitumen which refers to either EN 12591, or ČSN 65 7204 – Specifications for Paving Grade Bitumen and to EN 14023 in particular. Thanks to the understanding and cooperation of State Fund for Traffic Infrastructure (SFDI) and the Czech Motorways and Roads Administration (RSD CR), the principal client in road-related work, the “Technical Development of New Technologies” program has embraced the project of comparative testing of bituminous binders with funding granted by the aforementioned program. The project, its framework and professional content of which were prepared by the Road Contractors Association expert team. This project was launched with stage I in 2014. Once the Stage I output had been evaluated, the decision to continue work in stages II (2015) and III (2016) was adopted. Each stage was concluded with a separate final report and the summary result of all three stages is the collection of binder test data for polymer modified bituminous binders, which are actually utilized in the Czech Republic. The data collection, started in the second half of 2017, is provided by the relevant facility of the key public investor and administrator, RSD CR, authorized by the Ministry of Transportation, Czech Republic. Data collection is anonymous and the envisaged output to be delivered in 3 to 5 years is a database to be used to determine the standardized values for functional testing in ČSN 65 7222-1, which will come fully into effect after EN 14023 review completion and release.

2. Round robin tests of bituminous binders – stage I

2.1. Basic information

Project Stage I commenced in 2014 on the assumption of comparing the results of laboratory analyses of several bituminous binder types, both in respect of conventional and functional testing results. The project was based primarily on the initial proposals for including functional testing in the scheduled review of EN 14023. With respect to the minimum extent of experience with such testing and the absence of laboratory values, it was suggested to carry out the first extensive comparison within the Czech Republic outside development work of the Czech technical universities. The determination of the basic framework for the completion of this task involved contacting three laboratories with functional testing equipment and, naturally, with certain experience in the field of functional testing available. Subsequently, two individual types of bituminous binders supplied by various

manufacturers for the comparative tests were selected: (i) paving grade bitumen 50/70 (OMV, PKN Orlen, TOTAL), (ii) PMB 25/55-55 (Colas, Eurovia, OMV, PKN Orlen, TOTAL).

Each binder type was received from the predetermined source. Based on the agreement, the samples from each source were prepared depending on the number of laboratories, and distributed to the individual laboratories afterwards. Each participating laboratory divided the sample delivered in a manner facilitating an analysis of virgin sample as well as a sample subject to long-term ageing by the RTFOT + PAV method. The results were summarized by a final report. Based on the recommendations listed in this report, the decision to extend the bituminous binder comparison project was made in winter 2014 / 2015 in cooperation with SFDI and ŘSD ČR. The tests listed in Table 1 were included in the initial part of the second stage.

2.2. Stage I: results and output

The results of conventional tests (ring and ball method softening point, penetration @ 25 °C, dynamic viscosity at 135 °C) demonstrated no anomalies comparing the results from individual laboratories. The results are fully comparable and meet the requirements of reproducibility as stipulated by the standards. Certain variance was detected in the Fraass breaking point test in one of the participating laboratories. The discussion of the results revealed that this might be caused by different approach of sample preparation in the individual laboratories. The alternative preparation methods are permitted by the applicable standard. It has been demonstrated that the laboratory sample preparation must be paid careful attention and the marginal conditions for individual tests must be respected. In this context, it has been confirmed that some test conditions need to be declared more clearly to guarantee identical conditions and subsequent full-scale comparability (this applies e.g. to the long-term PAV simulated ageing process where the agreement stipulated proceeding solely with 2.1 MPa pressure for 20h ± 10 min. at 100 °C), (Valentin et al., 2014).

Table 1. Test program for the stage I of the project.

Test	Standard	Notes for testing
Virgin bitumen		
Softening point (ring and ball)	ČSN EN 1427	
Penetration @ 25°C	ČSN EN 1426	
Fraass breaking point	ČSN EN 12593	only for paving grade bitumen
Dynamic viscosity @ 135°C	ČSN EN 13302	
Complex shear modulus G^* and phase angle δ for frequency 1.59 Hz @ 60 °C	ČSN EN 14770	
MSCR Test ($R_{0.1}$, $R_{3.2}$ a $J_{nr0.1}$, $J_{nr3.2}$) @ 60 °C	ČSN EN 16659	
Long-term aged bitumen (RTFOT + PAV)		
Complex shear modulus G^* and phase angle δ for frequency 1.59 Hz @ 60 °C	ČSN EN 14770	
MSCR Test ($R_{0.1}$, $R_{3.2}$ a $J_{nr0.1}$, $J_{nr3.2}$) @ 60 °C	ČSN EN 16659	

The overall results presented several findings including practical recommendations summarized as follows:

- The Fraass breaking point test may utilise, in compliance with applicable standard, alternative approaches to sample preparation. However, if no comments on the processing method are provided, different values can be recorded and this should be taken into account e.g. in the national standards;
- The particular test conditions have to be unified within the framework of test sample preparation for RTFOT + PAV long-term ageing testing as well. A certain leeway in the applicable standard (temperatures of 90, 100 or 110 °C and the testing period varying accordingly under the fixed 2.1 MPa pressure) could result in certain deviations, particularly in the case of PMB binders. Therefore, it was recommended for the Czech regulations to use 2.1 MPa pressure, temperature of 100 °C and test duration of 20 h;
- A suitable complement to the tests required particularly for PMBs seems to be the softening point (ring and ball method) determination not only for the short-term ageing (RTFOT) but also for long-term ageing (PAV after RTFOT). At the same time, it was recommended to consider setting the penetration value for PMBs at 25 °C even after RTFOT;
- DSR measurements were taken under the standardised frequency of 1.59 Hz and at 60 °C. The results achieved suggested extending the scope of measurement by additional frequencies. The standardised 1.59 Hz frequency corresponds to traffic at approx. 90 km/h; using another 3 to 4 frequencies within the 0.1 Hz to 10 Hz range could facilitate a better assessment of bituminous binder behaviours;

- The DSR measurements taken under the standardised temperature also showed that the use of the temperature for paving grade bitumen is only suitable for harder grades. Softer grades should be tested at 50 °C. The boundary binder is the bitumen 50/70;
- The results of MSCR test demonstrated more variance; however, the fact that the results of individual laboratories tended to show identical trends was quite important. The results also indicated an urgent need for further comparative measurements, as well as the need to record the type of measurement equipment. Multi-functional Rheometer shows significantly larger variance than specialised one. Certain differences can also be assumed in the software provided by individual Dynamic Shear Rheometer (DSR) manufacturers. The factual need for very precise sample preparation, which requires a certain level of dexterity and experience of the laboratory technician, was also noticed. Other considerations were discussed in the field of test temperature, which was so far set to 60 °C. The question remains whether this only limit is representative and sufficient for the entire paving grade and modified bitumen portfolio.

A summary of results obtained for one of the binders tested, 50/70 or PMB 25/55-55 is given in Tables 2 and 3.

Table 2. Project result of stage I for paving grade bitumen 50/70.

Test	Unit	Standard	Testing laboratory		
			1	2	3
Virgin bitumen					
Penetration @ 25°C	0.1 mm	ČSN EN 1426	62	63	61
Softening point (ring and ball)	°C	ČSN EN 1427	48.8	48.2	47.6
Fraass breaking point	°C	ČSN EN 12593	-17	-12	-16
Dynamic viscosity @ 135°C	mPas	ČSN EN 13302	458	457	460
DSR testing at frequency 1.59 Hz and T=60 °C					
Complex shear modulus G*	Pa	ČSN EN 14770	2 314	3215	2 474
Phase angle δ	°	ČSN EN 14770	87.0	87.0	86.8
Long-term aged bitumen (RTFOT + PAV)					
DSR testing at frequency 1.59 Hz and T=60 °C					
Complex shear modulus G*	Pa	ČSN EN 14770	11 098	37 100	16 131
Phase angle δ	°	ČSN EN 14770	81.2	73.0	78.5

Table 3. Project result of stage I for PMB 25/55-55.

Test	Unit	Standard	Testing laboratory		
			1	2	3
Virgin bitumen					
Penetration @ 25°C	0,1 mm	ČSN EN 1426	49	45	47
Softening point (ring and ball)	°C	ČSN EN 1427	56.4	61.0	62.8
Force ductility @ 10 °C	J/cm²	ČSN EN 13589	1.5	2.4	2.2
Dynamic viscosity @ 135°C	mPas	ČSN EN 13703	743	1009	750
		ČSN EN 13302			
DSR testing at frequency 1.59 Hz and T=60 °C					
Complex shear modulus G*	Pa	ČSN EN 14770	5 867	10 145	5 825
Phase angle δ	°	ČSN EN 14770	76.7	70.0	74.4
MSCR Test at 60°C					
R _{3,2}	%	ČSN EN 16659	7.7	14.9	14.4
Jnr _{3,2}	kPa ⁻¹	ČSN EN 16659	0.817	0.696	1.082
Long-term aged bitumen (RTFOT + PAV)					
DSR testing at frequency 1.59 Hz and T=60 °C					
Complex shear modulus G*	Pa	ČSN EN 14770	33 272	70 600	46 965
Phase angle δ	°	ČSN EN 14770	64.5	59.0	61.3
MSCR Test at 60°C					
R _{3,2}	%	ČSN EN 16659	53.1	77.4	54.2
Jnr _{3,2}	kPa ⁻¹	ČSN EN 16659	0.041	0.009	0.049

3. Round robin tests of bituminous binders – stage II

3.1. Basic information

In 2015, project stage II continued based on the results reported above. The settings of the basic framework for this stage took into account conclusions and experience from the project stage I. It involved six laboratories, which analyzed the following three types of bituminous binders under identical conditions: (i) paving grade bitumen 50/70, (ii) PMB 25/55-60 and (iii) PMB 40/100-65.

Each bitumen was taken from a predetermined source. Subsequently, each type was divided at a predetermined laboratory to test specimens of virgin binder and binder for short-term ageing (RTFOT) or long-term ageing (RTFOT + PAV) for the individual laboratories involved. The binder samples were aged centrally, in the stipulated laboratory, and then distributed to the remaining laboratories. This ruled out any possibility of increased, or inconsistent thermal stress, which might subsequently affect the values measured. The PMB 40/100-65 ageing process was an exception: in this case, the ageing process was left up to the individual laboratories. A uniform time period was set for the testing of each binder as such. Extreme attention was paid to maximum precision of the preparation in order to affect the reproducibility of the functional tests as little as possible. Within the framework of the preparation, the decision to measure with DSR in stress mode was adopted. A uniform approach was agreed and one laboratory determined the stress level for the individual binders, and the stipulated values were then used by all laboratories involved. This procedure ensured measurement within linear viscoelastic range for each bitumen. In this stage, the total test scope was accompanied by testing selected properties after 3x RTFOT. Although it is not established within the framework of European standards, it was agreed to implement the method to provide the possibility of comparing the values for individual binder types with respect to the expert discussion on the effects of RTFOT + PAV vs. 3 x RTFOT and on the options of using this method within the Czech Republic. Table 4 lists the tests taken with the aforementioned bituminous binders.

Table 4. Test program for the stage II of the project.

Test	Standard	Notes for testing
Virgin bitumen		
Penetration @ 25°C	ČSN EN 1426	
Softening point (ring and ball)	ČSN EN 1427	
Dynamic viscosity @ 135°C	ČSN EN 13302	
Force ductility @ 10 °C	ČSN EN 13859	temperature according to PMB type
	ČSN EN 13703	
Complex shear modulus G* and phase angle δ	ČSN EN 14770	T=50 °C (paving grades); 60 °C (PMBs) Frequency 0.1; 1.59; 6; 10 Hz
Bending beam rheometer testing @ -16 °C	ČSN EN 14771	stiffness S and m-value
MSCR Test (R _{0.1} , R _{3.2} a Jnr _{0.1} , Jnr _{3.2}) @ 60 °C	ČSN EN 16659	
Short-term aged bitumen (RTFOT)		
Softening point (ring and ball)	ČSN EN 1427	
Force ductility @ 10 °C	ČSN EN 13859	temperature according to PMB type
	ČSN EN 13703	
Complex shear modulus G* and phase angle δ	ČSN EN 14770	T=50 °C (paving grades); 60 °C (PMBs) Frequency 0.1; 1.59; 6; 10 Hz
Bending beam rheometer testing @ -16 °C	ČSN EN 14771	stiffness S and m-value
MSCR Test (R _{0.1} , R _{3.2} a Jnr _{0.1} , Jnr _{3.2}) @ 60 °C	ČSN EN 16659	
Long-term aged bitumen (RTFOT + PAV)		
Softening point (ring and ball)	ČSN EN 1427	
Force ductility @ 10 °C	ČSN EN 13859	temperature according to PMB type
	ČSN EN 13703	
Complex shear modulus G* and phase angle δ	ČSN EN 14770	T=50 °C (paving grades); 60 °C (PMBs) Frequency 0.1; 1.59; 6; 10 Hz
Bending beam rheometer testing @ -16 °C	ČSN EN 14771	stiffness S and m-value
MSCR Test (R _{0.1} , R _{3.2} a Jnr _{0.1} , Jnr _{3.2}) @ 60 °C	ČSN EN 16659	
Long-term aged bitumen (3x RTFOT)		
Softening point (ring and ball)	ČSN EN 1427	
Force ductility @ 10 °C	ČSN EN 13859	temperature according to PMB type

	ČSN EN 13703	
Complex shear modulus G^* and phase angle δ	ČSN EN 14770	T=50 °C (paving grades); 60 °C (PMBs) Frequency 0.1; 1.59; 6; 10 Hz
Bending beam rheometer testing @ -16 °C	ČSN EN 14771	stiffness S and m-value
MSCR Test ($R_{0.1}$, $R_{3.2}$ a $J_{nr0.1}$, $J_{nr3.2}$) @ 60 °C	ČSN EN 16659	

3.2. Stage II: results and output

The results of conventional tests (ring and ball softening point, penetration @ 25 °C, force ductility, dynamic viscosity at 135 °C) demonstrated no anomalies when comparing the individual laboratories. The results are fully comparable and meet the requirement of reproducibility as implemented by the standards. It was demonstrated that the preparation of laboratory samples must be paid careful attention and the stipulated boundary conditions for individual tests must be respected. In this context, it was reaffirmed that some test conditions must be declared with higher precision to make sure the tests are taken under identical conditions to make them fully comparable. This applies e.g. to the PAV long-term simulated ageing process where the project earlier involved an agreement to work with 2.1 MPa for 20h \pm 10 min. at 100 °C.

The functional test results delivered several findings to which the final report (Valentin et al., 2015) elaborated additional recommendations. The extensive underlying material including the summary tables with individual results of participating laboratories for the tested binders in each test stage shows the following facts:

- DSR measurements were taken both under standard frequency 1.59 Hz and under three more frequencies (0.1; 6.0; 10 Hz). It was confirmed that a more consistent indication of bitumen behaviour would benefit from at least optional measurements using another two or three values.
Another point in the DSR measurements is the standardised geometry of the PP8 (plate – plate system, 8 mm diameter), and PP25 (plate – plate system, 25 mm diameter) respectively. According to the findings, sample preparation was difficult with some binders due to their properties (e.g. high stiffness, higher softening point) which ultimately results in values, which are not fully comparable. Therefore, it would be appropriate to initiate an expert debate to discuss whether the stipulated geometries cover the entire range of various bituminous binder types with respect to the test temperatures, binder stiffness or viscosity.
A fundamental prerequisite for working with DSR is to take the measurements within a stabilised oscillation range in the linear viscoelastic area, which puts higher demands on time.
- Bending beam Rheometer (BBR) testing demonstrated the determination of threshold values method by measurements at multiple temperatures (at least 4-5) as more advantageous. This range allows an improved fit of the curve of flexural creep stiffness dependence on temperature, which in turn gives a more precise final value of flexural creep stiffness modulus S, or the m-value in the form of a tangent to the curve.
- The MSCR test confirmed the experience available so far as well as information received from other countries. The test relies, to an extreme degree, on perfect sample preparation, on binder type and even on the type of test equipment, where variance is demonstrated based on the software used. This might result in certain differences in the way the individual values are determined. The testing and subsequent comparison of the results obtained has highlighted the fact that, if binders with a higher softening point located above the standardised temperature for MSCR testing are assessed, the values measured are extremely low and usually right upon the measuring capacity of the test apparatus, particularly with lower stress levels of 0.1 kPa. Therefore, stipulating the upper critical temperature (UCT) for the bitumen in question and the subsequent reduction thereof by e.g. 5 °C appears to be a more effective method of setting the measurement temperature. Even with the MSCR test, there is the question of standardised measurement geometry of PP8 and PP25 along with the set gap (bitumen sample thickness).

The final report (Valentin et al., 2015) presented also other results and conclusions where the project team proposed options for the next steps, aiming particularly to use the results measured to determine the threshold values for the relevant bituminous binder standards. The prerequisites for such procedure include specification of some framework conditions for the testing, and a broader database including real production and real market data to be collected over time from existing production and market.

4. Round robin tests of bituminous binders – stage II

4.1. Basic information

Stage III of the round robin testing of bituminous binders reflected the outputs from both preceding stages. The last stage involved six laboratories in total and focused particularly on functional testing. The binders were selected in connection to the parallel project of asphalt mix comparative testing aiming to intensely search for correlation between the bituminous binder properties and the behaviour of asphalt mixtures produced with these binders. Based on those aspects the round robin tests involved following binders: (i) paving grade bitumen 50/70 (sampled at PKB a.s. mixing plant), (ii) PMB 25/55-60 (sampled at the Herink mixing plant of EUROVIA CS a.s.), (iii) PMB 25/55-80 (sampled at the Herink mixing plant of EUROVIA CS a.s.) and (iv) PMB 45/80-65 (sampled at the Běchovice mixing plant of PORR a.s.).

All bituminous binders were simultaneously used to prepare asphalt mixtures subsequently analysed in the asphalt mix round robin testing running in parallel. Similarly to Stage II, the individual binders were divided into the particular laboratories to determine the fresh binder characteristics and into partial samples to be centrally short-term aged (RTFOT) and long-term aged (RTFOT + PAV). The essential condition was again to minimise thermal stress on the samples, and to unify the basic input for laboratory testing. When the samples were distributed to the individual laboratories, a time interval was determined for the scheduled tests. The individual types of bituminous binders were tested in sequence over approx. 4 weeks for each relevant bituminous binder type. Identically to the preceding stages, the summary results achieved were discussed in the project team and the outputs were included in the final report (Valentin et al., 2016). The laboratories carried out the tests according to Table 5.

Table 5. Test program for the stage III of the project.

Test	Standard	Notes for testing
Virgin bitumen		
Penetration @ 25°C	ČSN EN 1426	
Softening point (ring and ball)	ČSN EN 1427	
Dynamic viscosity @ 135°C	ČSN EN 13302	
Storage stability (PMB) – softening point difference	ČSN EN 13399	
Complex shear modulus G^* and phase angle δ at frequency 1.59 Hz	ČSN EN 14770	temperatures 30, 40, 50, 60 °C (paving grade) and 40,50, 60, 70 °C (PMB)
MSCR Test ($R_{0.1}$, $R_{3.2}$, $R_{8.0}$ a $J_{nr0.1}$, $J_{nr3.2}$, $J_{nr8.0}$)	ČSN EN 16659	temperature 50 °C and 60 °C (paving grade); 60 °C and 70 °C (PMB)
Short-term aged bitumen (RTFOT)		
Softening point (ring and ball)	ČSN EN 1427	
Complex shear modulus G^* and phase angle δ at frequency 1.59 Hz	ČSN EN 14770	temperatures 30, 40, 50, 60 °C (paving grade) and 40,50, 60, 70 °C (PMB)
MSCR Test ($R_{0.1}$, $R_{3.2}$, $R_{8.0}$ a $J_{nr0.1}$, $J_{nr3.2}$, $J_{nr8.0}$)	ČSN EN 16659	temperatures 50 °C and 60 °C (paving grade); 60 °C and 70 °C (PMB)
Long-term aged bitumen (RTFOT + PAV)		
Complex shear modulus G^* and phase angle δ at frequency 1.59 Hz	ČSN EN 14770	temperatures 40, 35, 30, 25, 20 °C (paving grade) and 30, 25, 20, 15, 10 °C (PMB)
MSCR Test ($R_{0.1}$, $R_{3.2}$, $R_{8.0}$ a $J_{nr0.1}$, $J_{nr3.2}$, $J_{nr8.0}$)	ČSN EN 16659	temperature 50 °C and 60 °C (paving grade); 60 °C and 70 °C (PMB)

4.2. Stage III: results and output

In this stage conventional tests were used solely to facilitate easy attribution to a specific bitumen type and to provide a quick comparison of the input parameters. Due to that, all laboratories determined the softening point and penetration @ 25 °C. Softening point was measured for binders subjected to short-term ageing (RTFOT) as well. The storage stability tests of PMBs and dynamic viscosity tests were divided so that three laboratories determined storage stability and three other laboratories the viscosity. In the field of conventional tests, the results achieved supported the conclusion that this type of testing, performed as a routine while adhering to the relevant standards, demonstrates no anomalies. It was recommended based on the dynamic viscosity test results to specify the requirements for a suitable spindle more precisely, depending on the individual bituminous binder types.

DSR functional testing (complex shear modulus G^* and phase angle, irreversible shear compliance J_{nr} and elastic recovery R) was completed over a broader range of test temperatures, with a 5 °C step, or at two temperatures in the case of MSCR test. At the same time, Stage III chose controlled strain mode for the oscillation test method to determine the complex shear modulus. The strain value was defined uniformly at max. 12 % of the gap between the measuring plates. The results and values obtained supported the following conclusions:

- In some cases, the complex shear modulus G^* and phase angle values obtained by the individual laboratories demonstrated a certain distribution; however, the graphic output shows that the trends achieved within the tests have similar tendencies with satisfactory reproducibility. Figures 1, 2, 3 and 4 use four types of bituminous binders: 50/70, PMB 45/80-65, PMB 25/55-60 and PMB 25/55-80, to show the summary results and trends of the six laboratories involved in the project.
- In the case of some binder types, certain problems were detected, resulting from the stipulated controlled strain mode value. The chosen value of 12 % seems to be too high and contributes towards increased fluctuation of the results achieved. Due to that, it was recommended reducing it to a maximum of 4-6 % of the gap between the plates. Even such controlled strain values are recommended to be further specified, particularly with respect to various types of polymer modified binders and boundary conditions, especially the test temperature.
- The testing repetitively proved – similarly to the preceding stages – the extreme demands on sample preparation, particularly in the case of the PP8 test geometry with 2 mm gap.
- The results clearly show that a true assessment of the spectral area of bituminous binder behaviour requires an optimised number of frequencies and set temperatures; working with the master curves of individual binders including the application of the time and temperature superposition principles constitutes an advantage. However, this method is rather time demanding and not feasible in common operation testing. In any case, testing must be taken both under controlled stress and controlled strain in the linear viscoelastic region of each individual binder. The comparison of Stage II and Stage III results concluded that controlled stress and controlled strain modes correlate with each other.
- The MSCR test repeatedly demonstrated the fact that the values which are defined at low stress (0.1 MPa), particularly in stiffer bituminous binder types, are extremely low and often are located near the limits of rheometer measuring capacity. This inspired the recommendation that in case $J_{nr} < 0.1 \text{ kPa}^{-1}$, the testing should be taken again at a higher temperature (5-10 °C higher).
- It was also recommended to start discussion on the temperatures for this test. Although the stipulated test temperature of 60 °C set by the draft of reviewed EN 14023 corresponds with the temperatures the wearing courses are exposed to during summer, very low values are measured in the case of several types of modified bituminous binders and binders with a higher softening point. This in particular contributed to misrepresentation or even misinterpretation of the results achieved. Again, the assumption that values with a higher information value can be obtained if the high critical temperature (HCT) is reduced e.g. by 5 °C, were confirmed. The issue of temperatures at which the binders should be tested applies to both paving grade and PMB binders.
- Based on a study of the sources available, Stage III also included MSCR testing taken at 8 kPa. The results obtained demonstrate a rather broad distribution of values when compared to lower stress values. In this case, further research might be needed to see whether this stress level is applicable, or sensible from the point of view of interpreting the results achieved.
- The final project stage involved repetitive doubts on the suitability of the measuring geometry settings for plate – plate systems in relation to the individual bituminous binder types, or in relation to the individual stages of the binder where the values are determined

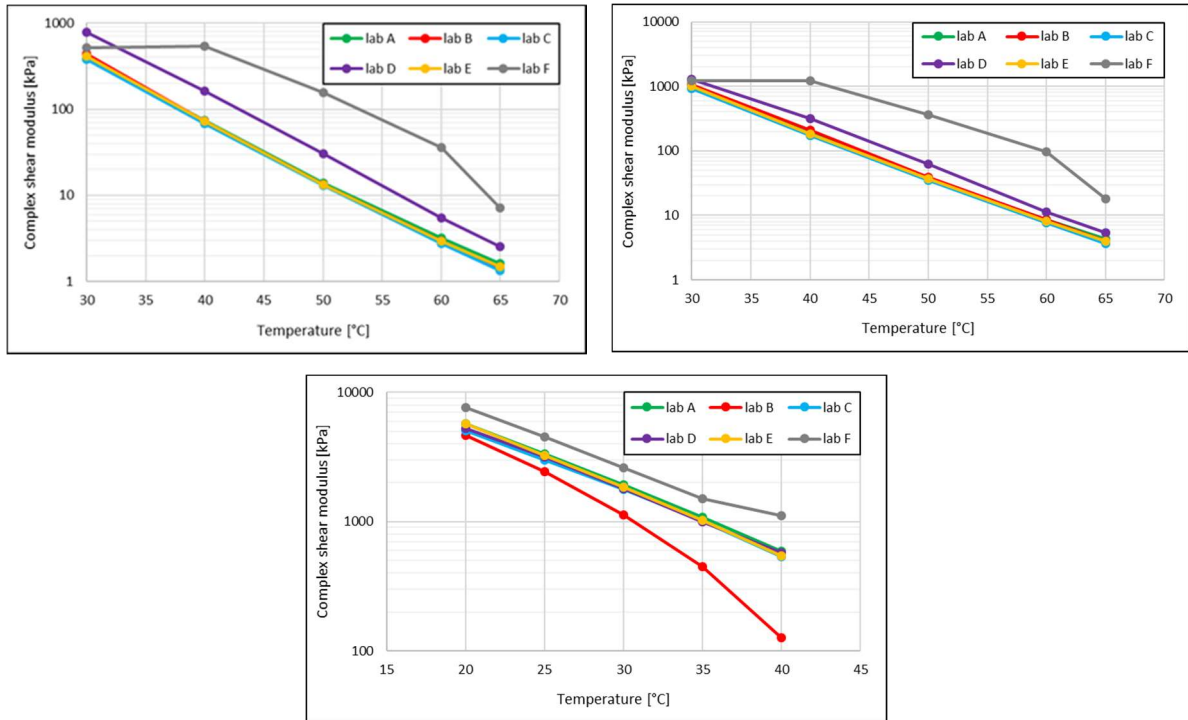


Fig. 1 Complex shear modulus G^* of the paving grade bitumen 50/70 (virgin binder; RTFOT aged; RTFOT+PAV aged)

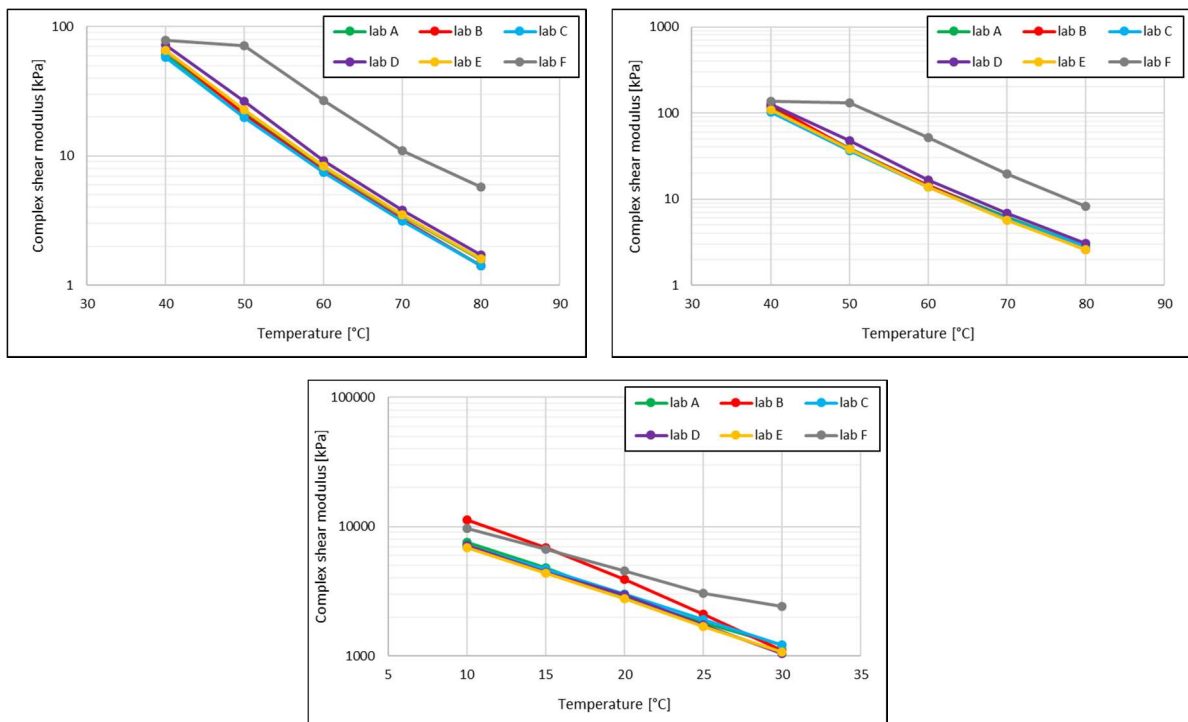


Fig. 2 Complex shear modulus G^* of the PMB 45/80-65 (virgin binder; RTFOT aged; RTFOT+PAV aged)

The final report (Valentin et al., 2016) of the round robin testing of bituminous binders stressed that the framework conditions for some tests were specified in more detail. Gained experience may be applied for the sake of later data collection which could allow authentically realistic values to be set for the individual functional tests in compliance with the requirements of the reviewed standard EN 14023, or with the requirements of ČSN 65 7222-1. Analogously, the procedure could be subsequently applied to the envisaged review of EN 12591, or the national standard ČSN 65 7204. This recommendation for a data collection is one of the project's major conclusions. The

recommendation also considered the option of compiling specifications for certain groups of related products. Nevertheless, the option must be further evaluated within the framework of subsequent expert debate. At the same time, the recommendations summarized in this report confirmed that not only the results achieved herein but also the results to be achieved in the future suggest that more attention will have to be paid to the search for correlation between bitumen properties and the performance-based behavior of asphalt mixes prepared using the binders.

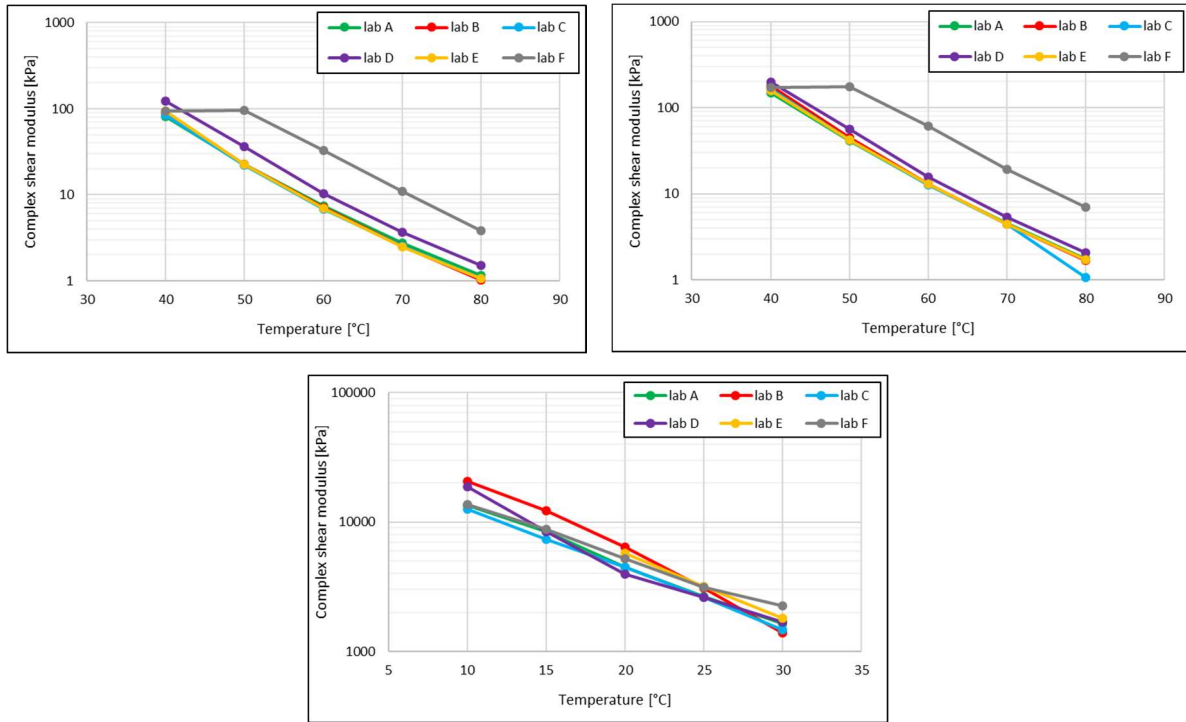


Fig. 3 Complex shear modulus G^* of the PMB 25/55-60 (virgin binder; RTFOT aged; RTFOT+PAV aged)

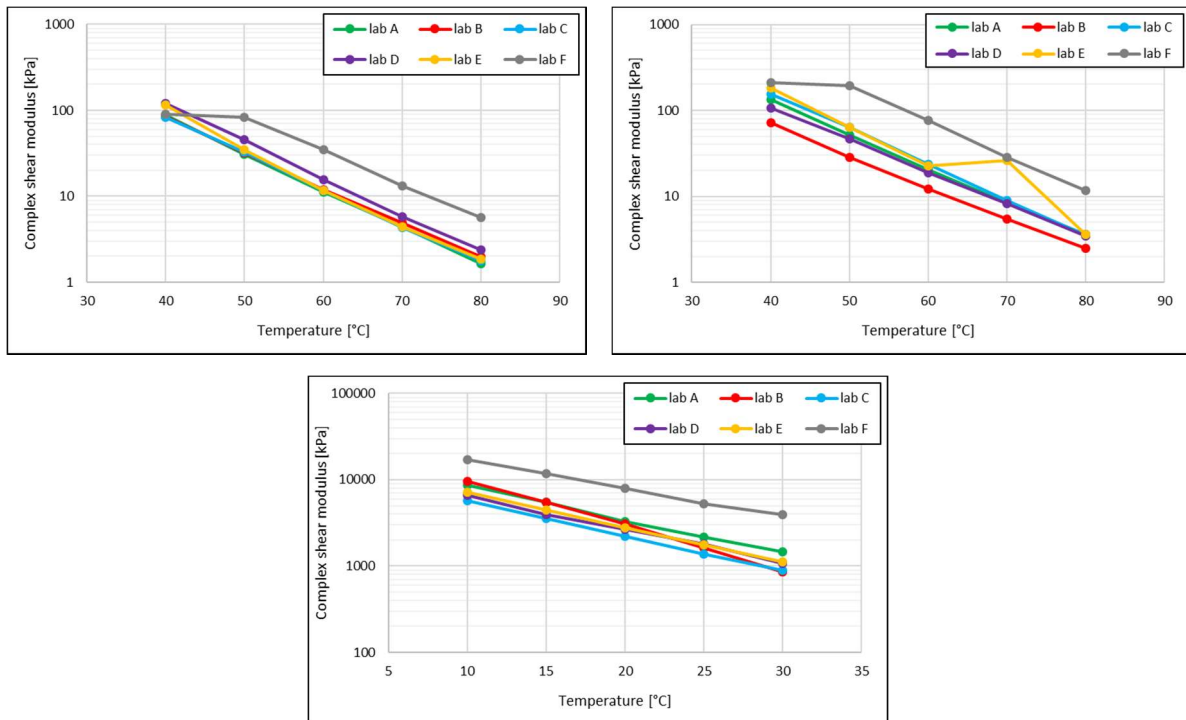


Fig. 4 Complex shear modulus G^* of the PMB 25/55-80 (virgin binder; RTFOT aged; RTFOT+PAV aged)

5. Data Collection for parameters determination in national standard ČSN 65 7222-1

Based on the conclusions and recommendations listed in the final reports (Valentin et al., 2014, 2015, 2016) of the individual stages of the round robin testing of bituminous binders, a proposal has been discussed for national-wide data collection for functional characteristics of polymer modified bituminous binders used in the Czech Republic. The data collection aims to ensure anonymous provision of test results for commonly applied binders in the long term. The data will subsequently allow determining the standard limits for the individual characteristics within the framework of the national specification standard, ČSN 65 7222-1. The data collection is based both on the individual functional tests proposed for the revised version of EN 14023, accompanied by selected standard properties (softening point, ring and ball method etc.).

In accordance to the European proposal and reflecting particular PMB types included in national standard ČSN 65 7222-1, proposal of data collection scheme was elaborated as shown in Table 6. The table further includes the precise conditions for the individual tests based on the recommendations of the round robin bituminous binders testing project.

In the first stage of the proposal for regular data collection, the framework requirement for test result distribution was discussed with all manufacturers and distributors/importers who supply bituminous binders to the Czech Republic market. The basic framework included information on the set of required characteristics (see Table 6) and the data collection duration (5-year term). The data shall be provided semi-annually by individual product types stipulated by ČSN 65 7222-1 on the assumption that the entity in question manufactures, or supplies within the reported period a quantity of the relevant product type exceeding 100 tones to the Czech market.

Table 6. Particular test selected for PMB data collection.

PMB binder:			
	Tested property	Unit	Value
	Penetration @ 25 °C	0,1 mm	
	Softening point (ring and ball)	°C	
Testing after short-term ageing (RTFOT)			
	Softening point (ring and ball)	°C	
	DSR at frequency 1.59 Hz and for a defined strain (strain mode)		
-	Temperature T ₁ , at which G* = 5 MPa (PP8 mm)	°C	
-	Phase angle δ @ T ₁	°	
-	Temperature T ₂ , at which G* = 50 kPa (PP25 mm)	°C	
-	Phase angle δ @ T ₂	°	
	MSCR Test @ 60 °C		
-	value of R _{3,2}	%	
-	value of Jnr _{3,2}	kPa ⁻¹	
Testing after long-term ageing (RTFOT + PAV)			
	DSR at frequency 1.59 Hz and for a defined strain (strain mode)		
-	Temperature T ₃ , at which G* = 5 MPa (PP8 mm)	°C	
-	Phase angle δ @ T ₃	°	
-	Temperature T ₄ , at which G* = 50 kPa (PP25 mm)	°C	
-	Phase angle δ @ T ₄	°	
	Bending Beam Rheometer Testing		
-	Temperature T, at which stiffness S = 300 MPa	°C	
-	m-value @ T		

An important factor was the issue of anonymity of the individual data providers, data management and subsequent data handling. Therefore, based on further discussions, it was approved to collect data under the auspices of the Ministry of Transportation of the Czech Republic using the www.pjpk.cz platform. The executive authority was entrusted to ŘSD ČR, Department of quality control. With the assistance of its IT specialists, ŘSD ČR prepared a data cloud for data from the individual providers based on the anonymized access rights. The data will be accessible to the individual participant anonymously and continuously evaluated in collaboration of the National Application Team 1, CTU in Prague and TU in Brno. When the envisaged data collection term is up, or when the reviewed EN 14023 has been released, the data will be used to determine the national standard threshold values for the individual tests within the framework of ČSN 65 7222-1.

Within the scope of its authority, ŘSD ČR considered introducing the provision of the aforementioned data for data collection as an additional contract requirement. At the same time, ŘSD ČR considered the option of conducting internal testing in the form of authorizing an accredited laboratory and, again, providing the data to the collection database.

6. Conclusions

The comparative testing of bituminous binders allowed carrying out a broad range of measurements with bituminous binders used in the Czech market. Thanks to the considerable support by SFDI and ŘSD ČR, as well as thanks to the enthusiasm and experience of the participating laboratories of CTU in Prague, TU in Brno, DuPont CZ s.r.o, EUROVIA CS a.s. – central laboratory, UniCRE a.s. Litvínov and VIAKONTROL, spol. s r.o., the three-year project managed to complete a number of tests and comparative measurements. The outputs could be later used in the compilation of the relevant standards and regulations in the field of asphalt mixtures, as well as in the organization of data collection scheme for functional testing of bituminous binders. The project has shown that some test conditions must be further specified, or the choice and setting thereof should be revisited by expert discussion and, possibly, laboratory verifications. At the same time, the project output has confirmed the relatively limited experience with new functional methods and interpretation of the results and outputs achieved so far. It can be assumed that the planned data collection will facilitate a deeper and more detailed insight and understanding of the context for the entire specialist public. The ultimate goal remains the effort to improve quality of asphalt pavement structures.

Acknowledgements

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7. References

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