Comparison of bitumen multiple-stress creep recovery test values from the viewpoint of different test parameters

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Abstract. Multiple Stress Creep and Recovery (MSCR) test is a suitable test for assessing the resistance of bituminous binders to permanent deformation. This is one of the most frequently used tests on Dynamic Shear Rheometer (DSR) in the world because it describes in a suitable way the nonlinear viscoelastic behaviour of the bituminous binder. The test is performed at higher temperatures and is particularly suitable for modified bituminous binders. The method is described in the European standard EN 16659, which is valid in the Czech Republic since October 2016. The principle of the test is based on multiple loading and recovering of a bitumen sample, which determines the percentage of elastic recovery and non-recoverable creep compliance $J_{nr}$ of the bituminous binder. The paper deals with the assessment of the influence of the different input parameters set on the DSR device - three selected stress levels, two test temperatures and a different geometry of the measuring device. The paper also compares different number of loading cycles applied during the test. Conclusions are made with respect to selecting appropriate test temperature and to consider most suitable test geometry. In case of additional stress level further laboratory assessments are needed.

1 Introduction
The durability of an asphalt mixture is largely dependent on the performance behaviour of the used bitumen. Basic empirical tests can characterize or classify bituminous binders, but in order to more accurately describe their behaviour, functional tests are needed, for example by using Dynamic Shear Rheometer (DSR).

In recent years there has been an increasing demand on road traffic in most parts of Europe, which lead to the necessity for developing bituminous binders with improved performance behaviour if compared to conventional paving grade bitumen. This causes the progress and use of a wide range of bitumen modifiers which improve the performance of the basic bitumen and thus the asphalt mixture [1, 2, 3, and 4]. The most widely used technical standards for bituminous binders in the Czech Republic as well as in many other countries in Europe are based on the behaviour of neat binders that cannot properly characterize potentials of modified binders.

One of the fundamental failures of asphalt pavements at higher operating temperatures are permanent deformations (rutting). Since the 90s’ rutting prediction of asphalt mixtures was based on
G*/sin δ bitumen criterion. This parameter works reliably for conventional speed and moderate traffic volume, but for pavements with slowly moving loads and/or high traffic volumes it has been shown that it does not correspond sufficiently to permanent deformations [4, 5, and 6]. Values of complex shear modulus (G*) and the shift factor (δ) are measured in the linear viscoelastic domain, but permanent deformations are not a linear viscoelastic phenomenon and therefore the characteristic G*/sin δ does not sufficiently correlate with permanent deformations [7]. From the perspective of permanent deformation of bituminous binders there is a need to pay attention on the area of nonlinear behaviour of bituminous binders, which include Jnr parameter obtained during the MSCR test. According to the authors [8, 9] parameter Jnr has a significantly better correlation with rutting measurements on asphalt mixtures than conventional oscillatory frequency sweep test.

However, since bituminous binders are complex viscoelastic materials determined parameters are very sensitive to boundary conditions and predefined test parameters. In case of dynamic tests which can be performed on DSR these parameters are related to selected test temperature(s), used test geometry including the thickness of tested bitumen sample, level of applied stress, number of cycles as well as range of gathered data which are considered for final calculations.

2 Multiple stress creep recovery test (MSCR)

Multiple Stress Creep and Recovery test is a test of repeated loading and relaxation/recovery, using a device called Dynamic Shear Rheometer (DSR). The test is used for measuring the accumulated strain in the bitumen within the prescribed stress level. The MSCR test uses a constant stress creep of 1 second duration followed by a zero stress recovery of 9 seconds duration. This cycle is according to technical standards in Europe or the U.S. repeated 10 times for each stress level. Figure 1 presents the typical creep and recovery cycle in the test.

![Figure 1. Typical creep and recovery cycle](image)

Two most important parameters of bituminous binder calculated from the measured strain at individual stress levels are non-recoverable creep compliance (Jnr) and percent recovery (R). Jnr is a measure of the amount of residual strain left in the specimen after repeated creep and recovery, relative to the amount of stress applied. Parameter Jnr is currently perceived as the best rheological parameter for the assessment of the susceptibility of bituminous binder to resist permanent deformation in asphalt mixture. The lower the Jnr is, the greater proportion of the stress the bitumen is able to absorb and the less susceptible to plastic deformation it is. Nevertheless, there are no threshold values neither in the Czech technical standard nor in the European standard. Besides the mentioned characteristics, stress sensitivity parameters Rdiff and Jnr,diff are calculated. Golalipour [10] indicated that determine the stress level is not a simple task and no one level can be clearly defined as most appropriate of what a binder is exposed to in a real mixture. Therefore it seems most reliable to use the sensitivity parameter (Jnr,diff). The Jnr,diff is important mainly when pavement is exposed to unexpected traffic loads or extremely high
temperatures. In case the $J_{nr,diff}$ value is greater than 75%, the bituminous binder is classified as a very stress sensitive material, which is not recommended for use in the construction of a pavement structure, [11].

MSCR is a test that has received a lot of attention and holds great promise for predicting rutting resistance of asphalt mixtures, but there are still many problems in its implementation, evaluation and interpretation of results. Some of these concerns are related to the number of cycles, the value of stress level or the temperature of testing. Conventional test set is based on the standard EN 16659 [12] and indicates the stress levels (0.1 and 3.2 kPa), number of loading/unloading cycles at each stress level (10) and the geometry of the device (25 mm parallel plate with a 1 mm gap). The test temperature is not exactly defined, which remains still a questionable task for the future.

Some research works showed [8, 13, and 14] that in order to study the bitumen behaviour in the nonlinear domain, it is necessary to apply a higher stress level than 3.2 kPa, depending on the bitumen type. Moreover, according to studies [13, 14] the higher stress level is used, the better correlation coefficient for resistance to permanent deformation of mixtures (French rutting test) is received.

3. Used testing procedures

This paper compares different groups of bituminous binders due to the widest possible coverage of the different behavior of bituminous binders. Some variants are conventional paving grade bituminous binders, but in most cases modified binders (crumb rubber – labeled CR, polymer modified binders – PMB or low viscosity additives) are tested and analyzed. Attention has been given to assessing the impact on the selection of the applied stress level and temperature of testing. Furthermore, two different testing geometries were used on DSR device and finally calculations were compared using the average of 10 cycles with values calculated from the last 5 cycles.

3.1 Effect of test temperature and applied stress level

The attention in this part is paid to the use of different test temperatures and stress levels. In the technical standard EN 16659 [12] test temperature is not prescribed, but should be selected suitably in the range 50-80 °C. The exact prescription of one temperature is even not planned for the revised EN 14023 standard for PMB binders. Different polymer modified binders (PMB) and one neat bitumen were compared. PMB are used in highly loaded pavement structures and for this reason test was measured at normal test temperature (60 °C) and elevated test temperature (70 °C). On the contrary neat bitumen 50/70 was measured at normal test temperature (60 °C) and at a reduced test temperature (50 °C). Another parameter that can be determined during the MSCR test is using different stress levels. The standard EN 16659 prescribes stress level of 0.1 kPa and 3.2 kPa. But as mentioned above, values obtained at higher stress level correlate better with permanent deformations. In addition, the application of a higher stress can cause significant increase of $J_{nr}$. For this reason, the standard stress levels were completed with 8.0 kPa stress.

The following Table 1 presents the calculated values of elastic recovery $R$, non-recoverable creep compliance $J_{nr}$ and stress sensitivity characteristics $R_{diff}$ and $J_{nr,diff}$.

As seen in Table 1 it is obvious that the PMB binders have high value of elastic recovery and very low non-recoverable creep compliance. As the temperature increases the shear strain increases and that is associated with an increase of $J_{nr}$ value. Increased susceptibility to permanent deformation is logically at higher temperature (higher $J_{nr}$ value). This is connected with the reduction of elastic recovery, but surprisingly, slight increase of $R$ was observed for two PMB binders at a stress level of 0.1 kPa. This increase is probably caused due to the variability of the measured values (detailed in section 3.3).
Table 1. Values of elastic recovery, non-recoverable creep compliance and sensitivity parameters

| Binder type          | 0.1 kPa  | 3.2 kPa  | 8.0 kPa  | 0.1-3.2 kPa | 3.2-8.0 kPa | 0.1-8.0 kPa |
|----------------------|---------|---------|---------|-------------|-------------|-------------|
|                      | R [\%] | J_{nr} [kPa^{-1}] | R [\%] | J_{nr} [kPa^{-1}] | R [\%] | J_{nr, diff} [\%] | R_{diff} [\%] | R_{diff} [\%] | R_{diff} [\%] | R_{diff} [\%] | R_{diff} [\%] | R_{diff} [\%] |
| 50/70_50 °C          | 2.5     | 1.59    | 1.2     | 1.09        | 0.5         | 1.08        | 53.7        | -31.2        | 60.1         | -0.9         | 81.5         | -31.8        |
| 50/70_60 °C          | 0.5     | 4.93    | 0.1     | 4.41        | 0.0         | 4.57        | 87.3        | -10.7        | 60.3         | 3.7          | 95           | -7.4         |
| 45/80-65_60 °C       | 83.1    | 0.12    | 85.5    | 0.09        | 87.2        | 0.07        | -2.9        | -23.3        | -2.0         | -17.1        | -5           | -36.4        |
| 45/80-65_70 °C       | 89.8    | 0.19    | 85.6    | 0.20        | 57.4        | 0.64        | 0.1         | -15.8        | 32.9         | 213.3        | 33           | 163.8        |
| 25/55-80_60 °C       | 69.4    | 0.15    | 66.6    | 0.16        | 66.4        | 0.17        | 4.1         | 3.8          | 0.3          | 5.1          | 4.3          | 9.1         |
| 25/55-80_70 °C       | 70.4    | 0.42    | 58.9    | 0.52        | 52.8        | 0.63        | 16.3        | 25.4         | 10.4         | 20.9         | 25           | 51.7        |
| 25/55-60_60 °C       | 76.8    | 0.13    | 38.5    | 0.49        | 29.7        | 0.57        | 49.9        | 267.0        | 22.9         | 14.7         | 61.4         | 320.8       |
| 25/55-60_70 °C       | 55.1    | 1.06    | 24.7    | 1.85        | 13.5        | 2.38        | 55.2        | 73.6         | 45.3         | 28.8         | 75.5         | 123.6       |

The paving grade bitumen 50/70 has high stress sensitivity \( R_{\text{diff}} \) (Figure 2), which is caused by very low elastic recovery values (Table 1.). This neat bitumen also experienced the most pronounced reduction in elastic recovery at a higher test temperature. The most significant change in \( J_{nr} \) value between test temperatures in case of PMBs was found for 25/55-60. This binder seems no longer to be in the linear viscoelastic range at 70 °C. Figure 2 presents that this binder has a high sensitivity \( R_{\text{diff}} \) at both temperatures and Figure 3 shows an extremely high sensitivity \( J_{nr, \text{diff}} \) at 60 °C. An extreme increase is due to the fact that at stress 3.2 kPa, there was a significant increase of \( J_{nr} \) (compared with a stress 0.1 kPa), which leads to a high parameter \( J_{nr, \text{diff}} \). This binder is the only one that has failed the US condition \( J_{nr, \text{diff}} < 75 \% \) for stress levels 0.1 kPa and 3.2 kPa. The same binder has a lower \( J_{nr, \text{diff}} \) (0.1-3.2 kPa) at temperature of 70 °C because it has a relatively high \( J_{nr} \) value at stress 0.1 kPa, (the binder is in nonlinear domain at higher temperature).

In contrary PMB 45/80-65 changed the determined values significantly between stress levels 3.2 kPa and 8.0 kPa at 70 °C (Figure 2.). Other binders can be described as very low stress sensitive. Generally, the increasing temperature increases deformation, reduces elastic recovery and increases non-recoverable creep compliance. Difference is more pronounced with higher stress level.

Additionally it shall be noted why the selected temperatures for the paving grade bitumen 50/70 and for the selected polymer modified binders are not the same. The determining factor in this case is the softening point. For the paving grade bitumen it was expected and proven by the ring & ball test that the softening point range around 50 °C, whereas polymer modified binders were expected to have softening point values \( \geq 60°C \). If all binders were tested for MSCR test at 50°C polymer modified binders would show very low values at the outline of measurability. On the contrary testing paving grade bitumen at 70°C would lead to uncertain results due to low viscosity the bitumen would have at this temperature. Therefore the temperatures used for paving grade and for modified binders differ.
Figure 3. Stress sensitivity parameter $J_{nr,diff}$

Higher stress level 8.0 kPa was conducted also for the second group of binders containing variants with the basic paving grade bitumen 20/30. This binder was modified by selected low-viscosity waxes in an amount of 2-4 M% or by combination of crumb rubber CR (15 M %) with low viscosity waxes. Higher stress level was determined only for selected variants.

Table 2. Values of elastic recovery, non-recoverable creep compliance and sensitivity parameters

| Binder type | 0.1 kPa | 3.2 kPa | 8.0 kPa | 0.1-3.2 kPa | 3.2-8.0 kPa | 0.1-8.0 kPa |
|-------------|---------|---------|---------|-------------|-------------|-------------|
| R [%] | $J_{nr}$ [kPa$^{-1}$] | R [%] | $J_{nr}$ [kPa$^{-1}$] | R [%] | $J_{nr,diff}$ | R [%] | $J_{nr,diff}$ | R [%] | $J_{nr,diff}$ | R [%] | $J_{nr,diff}$ |
| 20/30 | 9.4 | 0.425 | 6.7 | 0.402 | - | - | 28.6 | -5.3 | - | - | - |
| 2% CM | 15.4 | 0.209 | 8.9 | 0.296 | 4.0 | 0.385 | 42.6 | 41.7 | 55.4 | 29.9 | 74.4 | 84.0 |
| 3% CM | 18.1 | 0.222 | 14.1 | 0.236 | - | - | 22.0 | 6.4 | - | - | - |
| 3% BM | 11.1 | 0.656 | 5.4 | 0.644 | - | - | 51.2 | -1.7 | - | - | - |
| 4% BM | 14.6 | 0.462 | 7.3 | 0.495 | 2.3 | 0.590 | 50.0 | 7.0 | 68.4 | 19.2 | 84.2 | 27.5 |
| 15% CR | 73.5 | 0.015 | 67.9 | 0.018 | - | - | 7.6 | 20.9 | - | - | - |
| 15% CR+2% CM | 81.7 | 0.006 | 74.6 | 0.008 | 73.3 | 0.009 | 8.7 | 31.8 | 1.8 | 6.3 | 10.3 | 40.2 |
| 15% CR+2% BM | 78.6 | 0.007 | 75.7 | 0.008 | 73.3 | 0.009 | 3.7 | 12.5 | 3.2 | 11.4 | 6.8 | 25.3 |
| 15% CR+2% E10 | 72.7 | 0.011 | 70.6 | 0.012 | 67.6 | 0.013 | 2.9 | 1.8 | 4.2 | 9.1 | 7.0 | 11.1 |

Table 2 shows the fundamental values calculated from MSCR test. Crumb rubber (CR) modification resulted in a significant increase in the elastic recovery and decrease in $J_{nr}$ in comparison with referential 20/30 bitumen. High $J_{nr}$ values are expected to mean low resistance to permanent deformation. Application of low-viscosity additives (CM, BM and E10 synthetic waxes) does not significantly influence R or $J_{nr}$ values. R values are very low and $J_{nr}$ relatively high, when low-viscosity waxes are used with the bitumen 20/30. This leads logically to higher values of stress sensitivity characteristics $R_{diff}$. On contrary, CR binders have high elastic recovery, which helps to have lower values of $R_{diff}$ (below 10 %) for all stress levels. This indicates good elastic properties even at a stress level of 8.0 kPa. When comparing the stress sensitivity parameter $J_{nr,diff}$, it is obvious that the US limit for stress level 0.1 kPa and 3.2 kPa ($J_{nr,diff} < 75 \%$) would be fulfilled by all tested binders. But it is clear that a binder that has 2% CM is the most stress sensitive and especially $J_{nr,diff}$ is in this case high if comparing low (0.1 kPa) and high (8.0 kPa) stress level.
3.2 Effect of selected testing geometry used for DSR
In general, for more than two decades two testing geometries are used with the DSR for bitumen testing, namely 8 mm diameter plate-plate with a 2 mm gap (labelled PP08) or 25 mm diameter plate-plate and 1 mm gap (PP25). Geometry used for the testing device is based on the operating conditions. Geometry PP08 is generally used at low and medium temperatures (-5 to 30 °C) or for aged binders (frequency sweep test). Geometry PP25 is preferred for measurements at high temperatures (30 to 90 °C) and is therefore selected as a base for performing MSCR test. Different geometries were compared for PMBs and neat 50/70 after ageing, and in addition for bitumen modified by crumb rubber (CR).

Table 3. Values of elastic recovery, non-recoverable creep compliance and sensitivity parameters

| Binder type          | PP25          | PP08          |
|----------------------|---------------|---------------|
|                      | 0.1 kPa       | 3.2 kPa       | 0.1 kPa       | 3.2 kPa       |
|                      | R [%] Jnr [1/kPa] | R [%] Jnr [1/kPa] | R [%] Jnr [1/kPa] | R [%] Jnr [1/kPa] |
| 50/70+10% CR         | 35.5          | 0.50          | 7.8           | 0.81          | 33.7          | 0.42          | 7.5           | 0.70          |
| 50/70_R              | 5.6           | 1.59          | 1.1           | 1.57          | 8.1           | 0.54          | 5.1           | 0.58          |
| 25/55-60_R           | 73.9          | 0.16          | 73.2          | 0.15          | 73.9          | 0.07          | 74.8          | 0.06          |
| 25/55-60_R+P         | 84.8          | 0.09          | 88.9          | 0.04          | 84.8          | 0.03          | 89.2          | 0.02          |
| 50/70_R+P            | 17.0          | 0.28          | 14.0          | 0.23          | 25.2          | 0.06          | 23.9          | 0.06          |
| 25/55-60_R+P         | 64.5          | 0.07          | 64.2          | 0.06          | 69.0          | 0.02          | 65.1          | 0.03          |
| 40/100-65_R+P        | 88.6          | 0.02          | 88.2          | 0.02          | 91.7          | 0.01          | 90.1          | 0.01          |
| 50/70_3R             | 16.9          | 0.32          | 13.0          | 0.28          | 21.5          | 0.11          | 22.2          | 0.08          |
| 25/55-60_3R          | 70.0          | 0.07          | 65.6          | 0.09          | 67.0          | 0.05          | 66.9          | 0.04          |
| 40/100-65_3R         | 92.1          | 0.02          | 91.8          | 0.02          | 82.7          | 0.02          | 90.4          | 0.01          |

Table 3 presents quite low difference of the percent recovery between the two geometries. The relative difference is up to 10 % with the exception of all variants of 50/70 bitumen, which have very low values of R and for this reason the percentage change is significant. The relative difference between the two geometries of Jnr value is shown in Figure 4. The Jnr value is always lower in the case of PP08 and even more than about half in most variants (with the exception of variant with CR). Overall, this implies that the selected testing geometry has a major influence on the Jnr values.

3.3 Effect of number of cycles for calculating characteristics of the MSCR test
Taking the average of the 10 cycles to calculate characteristics, as required in the MSCR standard procedure, could be misleading because the response is significantly changing with number of cycles. The following figures show the percentage difference for the calculation from the last 5 cycles compared to the calculation from all 10 cycles for each group earlier.
Figure 5 presents the percent change of percent recovery between the values calculated from all 10 cycles, and only the last 5 cycles. The calculated differences are not significantly high at all stress levels (less than 7%). Figure 6 shows the percentage difference of $J_{nr}$ between two methods of calculating. The maximum difference is about 20% at stress level of 0.1 kPa, which is quite significant change that may be a source of variability of the results. This change is lower at higher stress and it is about 5% when the stress level is 8.0 kPa, which can be considered negligible. Higher difference of $J_{nr}$ is evident for binders with CR.

Figures 7 and 8 show that applying higher stress level leads to reduction of result variability in the test. The dotted lines in the figures show the average values calculated from all 10 cycles. Individual values have larger fluctuations at a low stress level, while a higher stress level contributes to a better reproducibility of results. Modification with low-viscosity waxes (Figure 7a-b) have only a first calculated value significantly different from other values at the stress level 0.1 kPa. Conversely in case of modification with CR (Figure 8a-b), there is not only the first value significantly different for all stress levels. For these binders (modified by CR with max. 15 M% content) would be therefore certainly appropriate to increase the number of cycles to obtain steady values (especially at lower stress level). This might by as hypothesis valid only for crumb rubber modified bituminous binders (CRmB) where the content of used crumb rubber would not exceed 15 M% and the maximum particle size would not exceed 1.0 mm.
Figures 9 and 10 present the difference of the values calculated as the average of all 10 cycles in comparison with the average of last 5 cycles. The difference in elastic recovery ranges up to 12 %, but for certain binders are differences in the calculation of $J_{nr}$ considerably higher. All PMB binders have similar trend which is seen in Figure 12 and 13, wherein the R values in the first 3-4 cycles gradually increase ($J_{nr}$ values decrease) and in the following cycles are stabilized. This pattern is evident among stress levels 0.1 kPa and 3.2 kPa. Increase of relative change looks like a very low because of the relatively high values of R. Conversely, the variants that have very low $J_{nr}$ have percent change significant between values calculated of 10 cycles and 5 cycles. Important change occurred in PMB
45/80-65 at 70 °C (Fig. 14), Jnr value is increasing in each cycle at stress 8.0 kPa, which is the opposite trend than at other stress levels. This likely indicates the fatigue of the material which occurs in the nonlinear viscoelastic region. The closest values of all cycles are evident for neat binders (represented by Fig. 11), only for the lowest stress level 0.1 kPa are apparent differences, but very low.

Figure 9. Relative change of two methods of calculating elastic recovery R

Figure 10. Relative change of two methods of calculating creep compliance Jnr

Figure 11. Elastic recovery values at each test cycle

Figure 12. Elastic recovery values at each test cycle
Figure 13. Non-recoverable creep compliance values at each test cycle

Figure 14. Non-recoverable creep compliance values at each test cycle

Figure 15. Percent change between two methods of calculating J_{nr} at stress level 3.2 kPa

Figure 15 shows the last group of bituminous binders with different geometry of the test device. Variants with geometry PP08 are labeled (2). While the change in the calculation of R, considering the last 5 cycles, is less than 10 % for all variants of this group (excluding 50/70 + 10% CR variant, which has a 15 % difference), the change of J_{nr} value is around 30 % for most PMBs, which generally corresponds to the previous group with PMB binders. Unmodified binders have the smallest difference of J_{nr}, but this is again mainly related to high J_{nr} value thanks to which, the percentage difference is very small between the J_{nr} value calculated from all 10 cycles and the last 5 cycles.

4. Conclusions

Currently, the MSCR test is promoted as the most appropriate method for assessing the resistance of bituminous binders to permanent deformation. The advantage of MSCR test compared to Frequency Sweep test is applying a larger load and deformation which reflects better the real situation in the pavement. Parameter G */\sin \delta characterizes bitumen in its linear domain (lower stress/strain) but permanent deformation occurs in nonlinear domain and it is necessary to describe the behavior in such domain by different parameters, e.g. J_{nr}.
This paper presented results of MSCR test comparing the influence of temperature, stress level, type of testing geometry and number of cycles for calculation individual values.

Performed measurements indicate that the method of averaging the response for 10 cycles at each stress level can lead to misleading values due to the changes during the cycles. Since the most significant differences are during the initial cycles. It would be therefore appropriate to calculate non-recoverable creep compliance and elastic recovery from the second half of the cycles at each stress level.

Research study showed that it would be preferable (especially for PMB) to increase the number of cycles since the 10 cycles for most of PMBs is according to presented findings not sufficient to achieve a stable secondary creep. An alternative option is to select a higher stress level, which leads to faster stabilization of test results.

In case the strain is very small (on the limit of the measuring device range) it is not possible to calculate sufficiently the accuracy of determined values. This problem occurs especially at lower test temperatures or at low stress level (0.1 kPa) when the divergence between cycles is high. Additionally, correlation with asphalt mixtures (resistance to permanent deformation) is lower when the stress level is 0.1 kPa [15]. For these reasons, it is preferable to use a higher stress level, e.g. 8.0 kPa.

Selected testing geometry primarily affects the $J_{in}$ value. Classical geometry PP25 is simpler for handling in DSR, as well as sample preparation (pouring) is easier. But in case of modification by crumb rubber with particle size of 1 mm or larger, it is necessary to use different geometry with a larger gap (PP08) or to analyze the possibility to use the standard geometry PP25 with a larger gap. Results show that the use of different geometry produces varying results and it is therefore necessary to specify the type of used testing geometry.

Performing the test at a higher temperature leads to a higher strain, thereby reducing the risk of inaccurate measurements due to the limits a DSR device has. Temperature of 60 °C would be an appropriate temperature for conducting MSCR test for many binders assuming that the test resistance to permanent deformation for asphalt mixtures would be performed at the same temperature (currently, the test is carried out at 50 °C), in order to better compare the measured values.

In general it is recommended to run the test always with the geometry plate-plate 25 mm (PP25) and consider proper test temperature in relation to softening point a bitumen has. It might be more difficult to test crumb rubber modified binders especially if the rubber particles are >1 mm. In such case the used test gap (bitumen sample thickness needs to be increased. Adding a higher stress level seems to be an interesting approach but this needs to be validated by additional test. In overall MSCR test confirms to be a suitable bitumen test which can help to indicate rutting resistance of the asphalt mixture.

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