Jnr DIFFERENCE AND QUALITY OF POLYMER MODIFIED BITUMENS

June 2023

Road performance is much more than Jnr Diff

INTRODUCTION

The Performance Grading (PG) system of grading bitumen (asphalt binders) was introduced in the Mid 1990's to solve challenges with quality of bitumen used for road paving application. The system was standardized as American Association of State Highway and Transportation Officials (AASHTO) M320 (also as ASTM D6373). The system relies on testing bitumen at small stress or strain to characterize the bitumen behavior within the Linear Visco-Elastic range (LVE). In early 2000's a project by the National Cooperative Highway Research Program (NCHRP) was completed to investigate the application of the PG system to polymer modified Bitumens (PmBs). The findings of this project, which is summarized in the NCHRP Report 459[1] indicated that a revision of the concept of using the parameters of complex modulus (G*) and phase angle (δ) is needed for modified bitumens, and a more effective test for evaluating the contribution of bitumens to rutting resistance of asphalt mixtures is the Creep and Recovery Test. The findings also indicated that modified bitumens show non-linear behavior that depends on the stress applied and the total strain the bitumen is tested at. The findings showed that for PmBs, the non-recoverable strain is the most important parameter for qualifying the contribution of bitumen to rutting resistance of asphalt pavements. Many research studies followed the NCHRP project and the majority confirmed the need to replace the oscillatory test measuring the G* and δ with a repeated creep and recovery test. In 2012, Federal Highway Administration (FHWA) researchers introduced the Multiple Stress Creep Recovery (MSCR) test as the latest improvement to the Superpave Performance Grading (PG) asphalt binder specification. This new test and specification – listed now as AASHTO T350 and AASHTO M332 – includes the use of a repeated creep and recovery test and a new high temperature binder specification that more accurately indicates the rutting performance of the asphalt binder and is blind to modification[2]. A major benefit of the new MSCR test is that it eliminates the need to run tests such as elastic recovery, toughness and tenacity, and force ductility, procedures designed specifically to indicate elastomeric polymer modification of asphalt binders. A single MSCR test can provide information on both performance and formulation of the asphalt binder[2].

The new AASHTO M332 includes 3 parameters measured with the MSCR procedure:

- Non-recoverable Creep Compliance (Jnr) at two stress levels: 0.1 and 3.2 kPa
- Percent recovery (% R) at same stress levels
- Percent difference of Non-recoverable Creep Compliance (Jnr Diff)

While most studies conducted in many countries confirm the benefits of the MSCR test and the AASHTO M332 specifications for PmBs qualifications, many research studies in USA, Australia, and Europe report problems with the usefulness of the Jnr Diff parameter. Due to challenges with this parameter, the implementation of the AASHTO M332 is not uniform in the USA and other countries. Many governmental agencies in the USA and other countries are waiving the Jnr Diff requirement. In July 2019 the AASHTO Subcommittee on Materials voted to change the specifications and remove the Jnr Diff parameter for the E grade bitumen.

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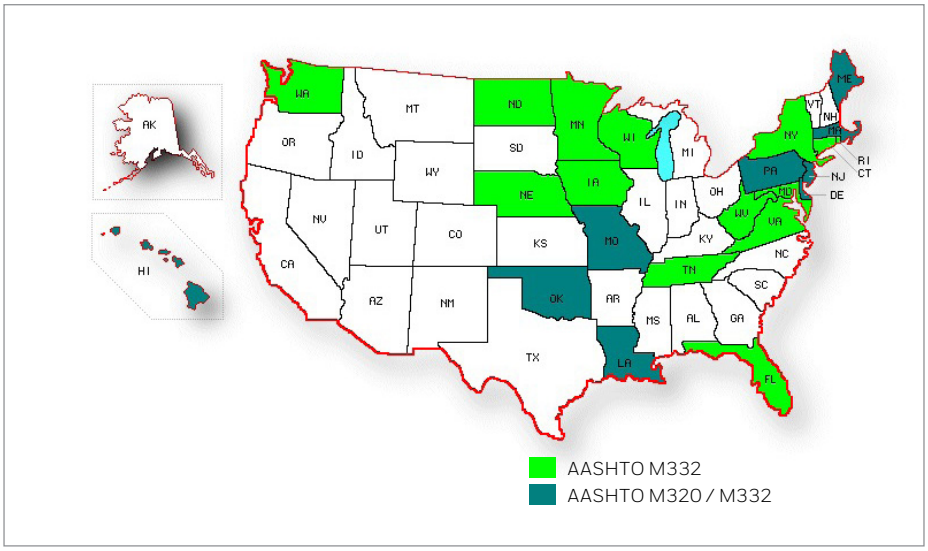

Figure 1. US State DOT AASHTO Specification *Source: diymaps.net (c)*

This technical bulletin is written to show that using the Jnr Diff parameter for defining the quality of PmBs could be misleading and could exclude high quality functional polymers that provide significant benefits to bitumen and asphalt mixture performance.

Jnr DIFF IS NOT NECESSARILY A MEASURE OF BETTER PERFORMANCE

Although the MSCR test has been part of the AASHTO standards since 2011, when it was given provisional status in the TP70 procedure, the implementation of the test remains incomplete in the US. The map in Figure 1 shows the status of its implementation at the end of 4th quarter, 2022. More than twenty five states continue to use the original PG system for the AASHTO M320 grading with no use of the MSCR, and only 16 states have switched to the AASHTO M332 with the use of MSCR. Many of the reasons behind the lack of acceptance of MSCR concerns the details of the test and some of the parameters being proposed.

The Federal Highway Administration (FHWA) and the Asphalt Institute (AI) have issued several statements to address the confusion surrounding the usefulness of the MSCR (Jnr) versus the existing AASHTO M320 high temperature dynamic shear rheometer (DSR) parameters (G* and δ). These statements[1,2] explained the objectives of each of the parameters measured by MSCR (Jnr, %R, and Jnr Diff).

Significant studies in the US and other countries have attempted to evaluate the effectiveness of each of these parameters in relation to performance of asphalt mixtures. The MSCR's new high temperature rutting parameter, Non-recoverable Creep Compliance (Jnr), has been shown to more accurately predict the rutting performance of the asphalt binder – both in the field and in test strips – than the current parameter of G*/sinδ used in the AASHTO M320. However, a large number of agencies are reluctant to adopt the MSCR and the AASHTO M332 because of the uncertainty about the Jnr Diff parameter.

Many research studies have identified critical gaps in measuring this parameter and in using it in practice. The parameter is calculated as the change in Jnr value measured at 0.1 kPa and 3.2 kPa as a percentage of the former (Jnr at 0.1 kPa). In the current AASHTO M332 specification, all binders need to show a change of less than 75% of the Jnr at 0.1 kPa. It is unknown what led to the selection of the stress selection of 0.1 kPa and what performance data were used to place the limit at 75%. This lack of justification for the lower stress level of 0.1 kPa for testing and the 75% change limit continue to raise concerns and delay implementation of the MSCR concept.

The following list includes examples of studies raising concerns about the Jnr Diff:

- Researchers from Asphalt Institute (AI) and FHWA found significant variability in Jnr values with highly modified bitumens[3] and called for waiving Jnr Diff when Jnr @ 3.2 kPa is less than 0.25 kPa^{-1}.
- Researchers from the University of Wisconsin - Madison concluded it is unclear what Jnr Diff is intended to measure (stress sensitivity, polymer network/quality, polymer type?). They also stated that its relationship to performance is unknown, so if a universal limit on Jnr Diff (75%) is enforced, many good quality bitumens may be rejected[4].
- Researchers from Australia conducted an extensive study on the topic and reported that most polymer modified bitumens failed to meet the Jnr Diff limit of 75% required in AASHTO M332[5].
- European researchers studying MSCR also concluded the Jnr Diff should be reconsidered. In a study published in 2017 it was reported that there is both poor test accuracy at the low stress level (0.1 kPa) which is used to calculated Jnr Diff in the current AASHTO M332 specification, and poor correlation to asphalt mixture performance (rutting resistance) at the 0.1 kPa stress level[6].
- The FHWA technical staff, in a presentation to the Expert Task Group (ETG) in May 2018 reported that the d2s % of multi-lab is 61.2% for this parameter, which means that the 75% limit for Jnr Diff can be 75% +/- 61.2% as tolerance range. The acceptance range is too large: 13.8% - 136.2%[7].
- In 2016, the MSCR/Jnr Task force reported at the PCCAS conference that the group was concerned about the large variability in the Jnr test results. As a "purchase spec" it puts the supplier/contractor at risk[9].

The analysis of results from the Mini Round robin (Table 1) indicate that one lab (#1) shows that all binders meet the Jnr Diff limit of maximum 75% while all other 3 labs reported results that vary significantly and range between 45% and 2139%. The Coefficient of Variation (CoV) varied between 21% and 110% for the various binders and temperatures. The conclusion by the author was that Jnr Diff seems not to be a useful specification requirement.

Table 1. Overview of Jnr Diff Variability reported by the Asphalt Institute based on a 2017 Mini Round Robin for Polymer Modified Asphalts

BINDER	A (ELASTOMER)		B (NON-ELASTOMER)		C (NON-ELASTOMER)		D (ELASTOMER)	
Temperature	76 °C	64 °C	76 °C	64 °C	76 °C	64 °C	76 °C	64 °C
Lab #1	69	2	60	16	39	6	20	5
	50	1	60	18	28	3	25	6
Lab #2	456	594	105	57	196	119	121	89
	680	2139	100	54	173	125	106	89
Lab #3	715	453	87	46	174	87	101	61
	643	387	91	46	178	120	85	74
Lab #4	1875	1678	74	45	189	119	82	92
	795	160	63	48	159	134	112	92
Average	**660.4**	**676.8**	**80.0**	**41.3**	**142.0**	**89.1**	**81.5**	**63.5**
COV	**81%**	**110%**	**21%**	**35%**	**45%**	**57%**	**44%**	**55%**

- One of the managers of the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program for asphalt binders testing reported during the Asphalt Binders Expert Task Group Meeting in Salt Lake City in 2017 that due to the high variability of the percent difference in Non-recoverable Creep Compliance (Jnr Diff), a recommendation was made to the Administrative Task Group (ATG) that the Jnr Diff not be used for laboratory accreditation purposes due the challenges in getting repeatable values[8]. The following statement is taken from the referenced presentation.

"Looking ahead: while we continue to solicit for test data for all reporting parameters in the MSCR (AASHTO T350/ASTM D7405), Administrative Task Group(ATG) has been informed of the situation: AASHTO Accreditation Program (AAP) proposal to ATG is to not evaluate percent difference in recovery and percent difference in Non-recoverable Creep Compliance (Jnr) for accreditation Purposes."

Jnr DIFF IMPLEMENTATION IN THE UNITED STATES

The following list shows the current (2022) status of the use of the Jnr Diff in various states in the US. This list shows that while many states are using the M332 specifications, they are not yet ready to use this parameter due to the challenges faced with measuring it and possibly the relationship to performance.

- **Alaska:** no requirement
- **Georgia**: no requirement
- **Louisiana:** no requirement
- **Nevada:** report only
- **South Carolina:** no requirement
- **Nebraska:** waived for all grades
- **West Virginia:** waived for all "E" grades
- **Iowa:** waived for all grades
- **Minnesota:** waived for all "E" grades
- **Wisconsin:** waived for all grades
- **Delaware:** no requirement
- **Tennessee:** waived for "V" and "E" grades
- **Washington:** report only

In a recent study by Arizona DOT, a significant effort was directed at correlating the Jnr Diff to increase in rut depth. The researchers concluded that results "confirm Jnr Diff does not show a strong relationship with performance"[10].

Jnr DIFF IMPLEMENTATION IN OTHER COUNTRIES

Many countries, such as South Africa, Qatar, and Australia, which are considering the use of the MSCR test and AASHTO M332, are not considering the Jnr Diff limits.

- South Africa recently published their new PG grading of bitumen and they have adopted the use of the MSCR. However only Jnr @ 3.2kPa is used (thus no Jnr Diff)[12].
- Australia has considered using the MSCR but the studies conducted on modified bitumens meeting the Australian requirements showed that most highly modified binders fail the Jnr Diff limit[5].
- Qatar is one of the first countries to implement the AASHTO M332, but early in the implementation an Interim Advisory Note (IAN 100) was published in 2015 that required only reporting Jnr Diff[14].

Therefore, blind implementation of AASHTO M332 (with using the Jnr Diff) is not advisable.

SUMMARY

- AASHTO M332 is considered a step forward in relating bitumen properties to mixture performance. However there continues to be significant debate and concerns about using the limits of Jnr Diff in the specifications;
- The Jnr at 0.1 kPa lacks repeatability, in particular for heavily modified bitumens with Jnr values lower than 0.5 kPa^{-1};
- The Jnr Diff could not be correlated to performance in many detailed studies worldwide;
- Using the 75% limit could result in formulations that are very difficult to handle in production as PmB producers continue to try to cross link and/or increase polymer content;
- Stress dependency is important but should be measured properly. Therefore, a study should be authorized by State Government Agencies to determine a better way of measuring the stress dependency and derive limits accurately related to performance;
- Honeywell will be happy to support such studies.

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12. Combined State Binder Group; Method of Acceptance for Asphalt Binders; January 2017, P. ii

13. South Africa Bituminous Association (SABITA) Asphalt News, Issue 3, 2015, P.16

14. Qatar Public Work Authorities, ASHGHAL, Interim Advisory Note (IAN) 100, August 2015

For more information
https://industrial.honeywell.com/us/en/applications/specialty-additives/polymers-for-asphalt-modification

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