ELASTIC RECOVERY AND QUALITY OF POLYMER MODIFIED BITUMENS

June 2023

Road performance is much more than elastic recovery (ER)

INTRODUCTION

One of the most widely used methods for bitumen modification is the use of organic polymers. Although other types of additives have been used or are currently being used for modification, the use of polymers is more widespread and ubiquitous than other additives. Because of the good experience with polymers, many agency specifications include a method to verify that elastomeric polymers are used for the modification rather than other additives. The challenge faced by the industry today is that there are many other types of polymers that can used. These polymers can give better properties and/or can be incorporated into the bitumen in much simpler and more effective methods than elastomers, but do not pass the agency's elasticity requirement for the modified bitumen.

In general, for bitumen modification, the two main types that have seen wide acceptance are the Thermoplastic Elastomers and Thermoplastic Polymers (also called Plastomers). While both types of polymers have been used successfully to improve pavement life cycle cost, the method of detection of the polymer could be different and challenging. For elastomers, it was discovered very early that they increase the elastic behavior of bitumen and thus an elastic recovery test is quite commonly used in the bitumen/asphalt industry worldwide to detect the presence of elastomers and quantify the approximate amount used. For Plastomers, since they do not increase the elasticity of a bitumen, using the elastic recovery is not useful. Because of the simplicity of the elastic recovery test, it became the de facto method for determining polymer modification, and many agencies included the test as a bitumen specification as a requirement. Although the elastic recovery test is successful in detecting the elastomeric modifier, it has been shown not to correlate to performance of bitumen or the asphalt mixture performance. In addition, the use of the test for polymer modified bitumen resulted in excluding the use of plastomers, which are known to provide good performance comparable to elastomers.

In recent years, the Multiple Stress Creep Recovery (MSCR) test has been proposed as a better method than Performance Grade PG or PG+ to detect the effect of additives on rutting resistance performance of bitumen and asphalt mixtures. The test calculates a parameter, Jnr, correlated to rutting resistance and also includes a measure of elastic recovery, called Percent Recovery (%R).

Unfortunately, many agencies are now attempting to complement the rutting criteria with elastic recovery to qualify modified binders. While the recent effort to implement the MSCR Test is a step in the right direction, the persistence on using the %R as a as a surrogate for elastic recovery requirement has the same problems with respect to limiting the possibility of better performance using simpler and possibly more effective polymer modifiers.

This technical bulletin is written to show that using elastic recovery test or the percent recovery of the MSCR test to define quality of polymer modified bitumen (PmB) could be misleading and could exclude other functional polymers that provide significant benefits to bitumen and asphalt mixture performance.

ELASTIC RECOVERY IS NOT NECESSARILY A MEASURE OF BETTER PERFORMANCE

While some users of PmBs consider elastic recovery a necessary measure of modification of binders, many technical institutions and federal government agencies have tried to clarify the role of elastic recovery in defining the quality of polymer modification.

Honeywell

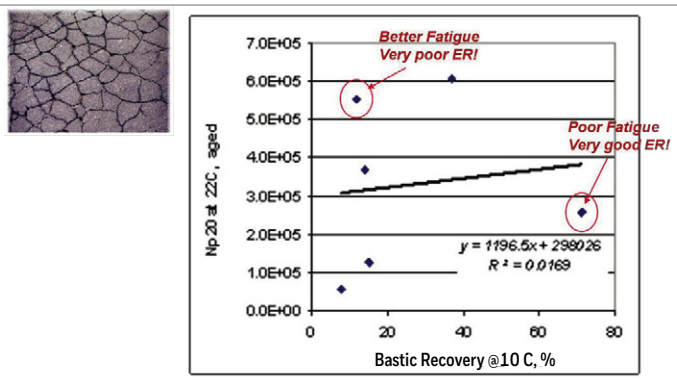
As a start, any scientist or engineer knowledgeable about polymers recognizes that not all polymers are elastomers, and there are in the asphalt industry business many examples of very useful polymers used in modification that are not elastomers. In fact, one of the most advanced bitumen specifications introduced in the 1990s in the USA and being adopted around the world (called Performance-Graded Asphalt Binder- AASHTO M320) did not include the elastic recovery test. Over time, agencies introduced tests elastic recovery, Force Ductility, Toughness and Tenacity and Phase Angle measurements) to roughly quantify the amount of elastic polymers (elastomers) used to modify bitumen. These tests became known as PG+ tests.

The Asphalt Institute (AI) and Federal Highway Administration (FHWA), to avoid confusion and provide guidance, have issued several statements regarding the usefulness of the Multiple Stress Creep Recovery (MSCR) test to replace the existing AASHTO M320 high temperature Dynamic Shear Rheometer (DSR) test after short term aging.[1,2] 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 test. It has been integrated into a new specification for grading of binder called the AASHTO M332 and is being adopted by many agencies.

The MSCR test standard (AASHTO T350) protocol also allows calculating a value referred to as percent recovery (%R). As explained in the AI statement[1], %R is introduced to enable specifying agencies to confirm the presence of an elastic polymer in the asphalt and would replace elastic recovery, force ductility, toughness and tenacity and phase angle measurements. It would in essence replace the panoply of current PG+ tests. The current levels of %R recommended, however, are expected to require the presence of high loadings of cross-linked elastomers. Other polymers such as elastomers that are not cross-linked, plastomers, Polyphosphoric Acid (PPA) and Ground Tire Rubber (GTR), which can produce modified binders with very good Jnr values – and therefore should perform well in the field – would "fail" the minimum %R associated with a given Jnr that is currently in AASHTO TP70. Thus, %R cannot be considered "blind to modification" but in fact is limited to detecting specific elastomeric polymers.

If specifying agencies implement %R as a specification requirement, it will limit the adoption of other polymers and/or technologies.

This is especially troubling since %R has not been shown to correlate with any performance in the field and SBS shortages have occurred recently and the future supply of Butadiene – a component of SBS – is uncertain. In fact, studies have shown there is no correlation between elastic recovery or %R to rutting or fatigue cracking. In 1988 a comprehensive paper on asphalt rheology reported the lack of relationship between elasticity and performance.[3] More recently, in 2004, a paper presented at CTAA showed no correlation ($R^2 = 0.125$) between Gv, a binder rutting parameter equal to 1/Jnr, and elastic recovery. The same paper[4] also demonstrated that binder fatigue (as measured by Np20 at 22°C) did not correlate with elastic recovery ($R^2 = 0.0169$). *Figure 1* is taken from that paper.

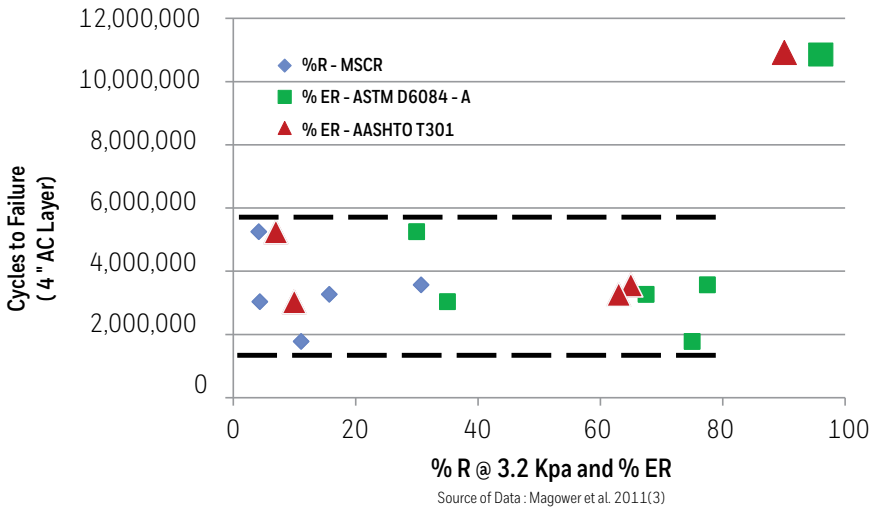


Elastic Recovery does not relate to fatigue

Figure 1 Source: CTAA 2004 paper4

More recently, another group of researchers comparing fatigue performance of asphalt mixes to bitumen elastic recovery showed that there was no correlation ($R^2 = 0.285$) between %R (@ 3.2 Kpa) with cycles to failure of a four-inch AC layer.[5] *Figure 2* is taken from that study. The results show that for values of %R ranging from 5.0% up to 80%, which is much higher than the recommended range in the MSCR- %R, the fatigue of mixtures had no relationship to the increase in elastic response measured by %R at 3.2 kPa.

In the last 5 years a new test for measuring the Fatigue Resistance of asphalt mixtures has been introduced and is being considered for implementation by many agencies. The test is used to measure the fracture potential of asphalt mixtures using the Flexibility Index Test (FIT). It has been standardized by AASHTO under the TP 124 procedure.



Source of Data : Magower et al. 2011(3)

Figure 2

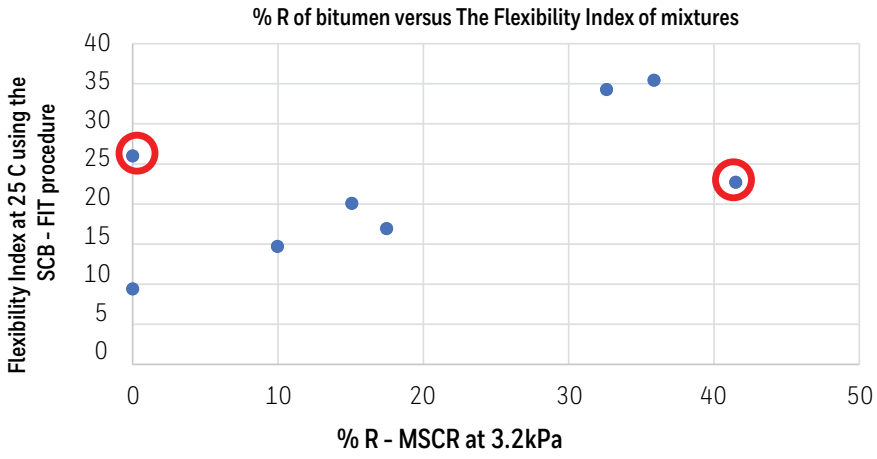


Figure 3

Source of Data: WHRP Report 17 04, 2019[6]

The test was used in an extensive study by the Wisconsin Highway Research Program (WHRP) in 2018 to evaluate the effect of oil and polymer modification on Fracture Resistance. The results shown in the *figure 3* confirms the lack of relationship between the % R measured by the MSCR and the fracture resistance potential. As shown in the plot one of the mixtures with a binder of 0.0 %R gave a better Flexibility Index Value (better fracture resistance) than the mixture produced with an elastomeric modifier with 40% percent recovery.

SUMMARY

In summary, the use of elastic recovery or %R as a predictor of performance in the field is not warranted. The current use of elastic recovery, and the suggested use of the MSCR %R, will effectively ban certain polymers and eliminate useful technologies from PmA supplier's toolbox. Such polymers or technologies could have a more stable supply chain, be more economically competitive or have other intrinsic advantages when used in modified asphalts.

It is recommended that AASHTO M332 and the non-recoverable creep compliance (Jnr) measured in the MSCR test be utilized by agencies to specify asphalt binders for best road performance, irrespective of elastic recovery or %R.

These measures give a false impression that binders with higher %R will ensure better performance than other binders with similar Jnr but lower %R or lower elastic recovery.

There is a concern that using %R or elastic recovery will just add another test and that specifying agencies will not be able to agree on required limits because there is no basis to relate to acceptable performance. It is estimated there currently are more than 10 different elastic recovery test methods and criteria for the same reason, which is lack of correlation of these tests to performance.

Since this recommendation of not using elastic recovery or %R is against long standing practice and many agencies would hesitate to accept it, it is recommended that trials waiving elastic recovery (and %R from MSCR) be encouraged to validate (or repudiate) the lack of relationship between elastic behavior and asphalt pavement performance.

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5. Mogawer, W., A. Austerman , M. Emin Kutay & F. Zhou, "Evaluation of Binder elastic recovery on HMA Fatigue Cracking using Continuum Damage and Overlay Test Based Analyses," Road Materials and Pavement Design, Volume 12, 2011 - Issue 2- pages 345- 376
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https://industrial.honeywell.com/us/en/products/performance-additives/asphalt

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