Use of RAP with Modified Asphalts

Executive Summary, 2023

Overview

The optimum use of modified asphalt binder in mixtures containing Reclaimed Asphalt Pavement (RAP) has been debated and researched since modified asphalt binder began to be more widely used in the late 1990's. This topic has become even more important to understand with the comparatively higher percentages of RAP being used today, the increasing cost of procuring virgin raw materials (i.e. aggregate, asphalt binder, and polymer), increasing traffic loads, and the most recent worldwide drive for Sustainability – the latter in an effort to reduce Greenhouse Gas (GHG) emissions, to slow Global Warming.

Problem

The majority of paving projects in the United States are awarded based on a "Lowest Bid" type of procurement, rather than a "Best Value" type of procurement.

Additionally, there has long been a nationwide desire to use higher and higher RAP percentages in asphalt mixes (due to the economic and environmental benefits of doing so), and an industry-wide assumption that all of the RAP's binder content is "*available*"[1] for mix design purposes. Therefore, most agencies allow assigning 100% credit for the oxidized binder in the RAP as a 1-to-1 replacement for what would otherwise need to be virgin binder being added to the mix.

The above two facts, combined with reducing the addition of virgin binder based solely on volumetric considerations, can often lead to asphalt mixes/pavements that may be under asphalted, so less crack resistant and less durable than they could be, thus shortening their life cycle.

Further compounding the issue above is that the current Life Cycle Assessment (LCA) process for asphalt mixes to create Environmental Product Declarations (EPD's), does not include the "Use Phase" of the asphalt mix or resultant pavement. Rather, the current LCA/EPD process is based only on "Cradle to Gate", which further rewards increased RAP contents and reducing the virgin binder contents of the mixes, without considering the impacts on the resultant mixture's performance or long-term pavement performance.

While there are a handful of ways to attempt to reduce an asphalt mix's environmental impact, such as covering RAP and aggregate stockpiles to minimize their moisture content (as higher moisture contents in RAP and aggregate stockpiles drives higher fuel consumption for drying), the quickest and least expensive way for mix producers to lower their EPD's GWP (Global Warming Potential) is typically to reduce the amount of virgin materials being used in the asphalt mixes, by using more RAP. However, as outlined above, increasing RAP, especially if also reducing the addition of virgin binder, can have a negative impact on the mixture's performance, and resultant pavement life, if doing so in the absence of assessing whether adequate mixture performance (i.e. crack resistance and durability) is being maintained at the higher RAP percentages and/or with the reduced virgin binder contents.

Solution

Over the past seven (7) years, the Balanced Mix Design (BMD) concept has been evolving after initially being established by the former Federal Highway Administration (FHWA) Expert Task Group (ETG) Balanced Mix Design Task Force in 2015. The reason BMD is gaining acceptance is likely due to the fact that "*concerns with durability and cracking issues of asphalt pavements along with the growing awareness of the shortcomings of volumetric mix design systems have driven many SHAs and the asphalt pavement industry to explore the use of BMD as a new approach to asphalt mix design and production acceptance*".[2]

BMD is an asphalt mix design process that uses "*mixture performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure, per AASHTO PP 105-20*".[2]

In general, asphalt mixes tend to either be rut resistant or crack resistant, and often (especially when produced with unmodified asphalt binders), these two asphalt mix characteristics can counteract one another. The "Balanced" part of the BMD name primarily means "balancing" these two asphalt mix characteristics, so that the mix has both adequate rut resistance and crack resistance.

It has long been established that using SBS (Styrene-Butadiene-Styrene) polymer to modified asphalt binder improves both the high-temperature rutting resistance of the mix (Isacsson and Zeng, 1997; Zhang et al. 2018), and enhances the fatigue performance [crack resistance] (Behnood and Olek, 2017; Attoh-Okine et al. 2016).

While the addition of elastomer, such as Styrene-Butadiene-Styrene (SBS), or Reactive Terpolymer (RET) has become a common method of modifying asphalt binders today, the use of other asphalt binder modifiers like Ground Tire Rubber (GTR) have been evolving since the 1960's, Polyphosphoric Acid (PPA) since 1973, as well as other chemical modifiers, extenders, hydrocarbons and anti-stripping additives and more recently, isocyanate-based modifiers, and even recycled plastics have been used – all in an attempt to improve the performance of asphalt binders.

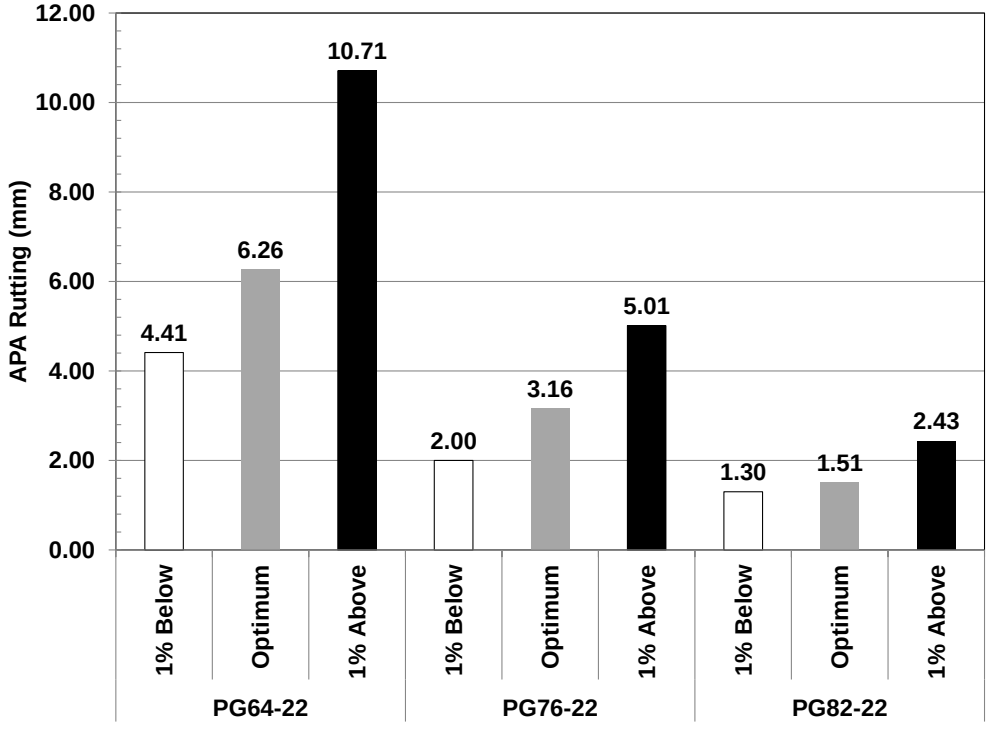
Therefore, mixture performance testing as part of the BMD process is how the asphalt pavement industry can demonstrate that modified asphalt binders can increase an asphalt mixture's rut resistance and crack resistance, allowing it to achieve a longer service life, thus greatly increasing the resultant asphalt pavement's Sustainability.

The BMD process can also demonstrate that using an insufficient effective binder content can have a negative impact on mixture performance, therefore a negative impact on the long-term performance of the asphalt mixture, thus reducing the resultant asphalt pavement's Sustainability.

Data

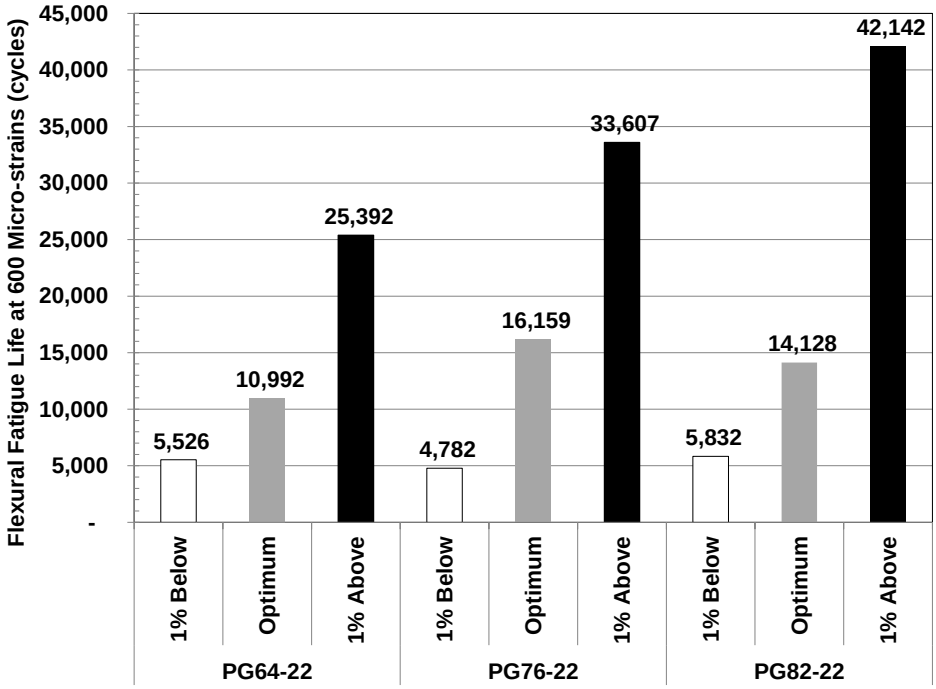
To increase a mixture's crack resistance and long term durability, increased effective binder contents are needed. However, with unmodified binder, increasing the binder contents greatly increases the mixture's rut susceptibility. Modified asphalt allows for increased binder contents with minimal increases in rut susceptibility.

As an example, it has been shown that the higher the SBS modification of asphalt binder, the greater the ability to increase binder content of the asphalt mixture without increasing the mix's rut susceptibility.

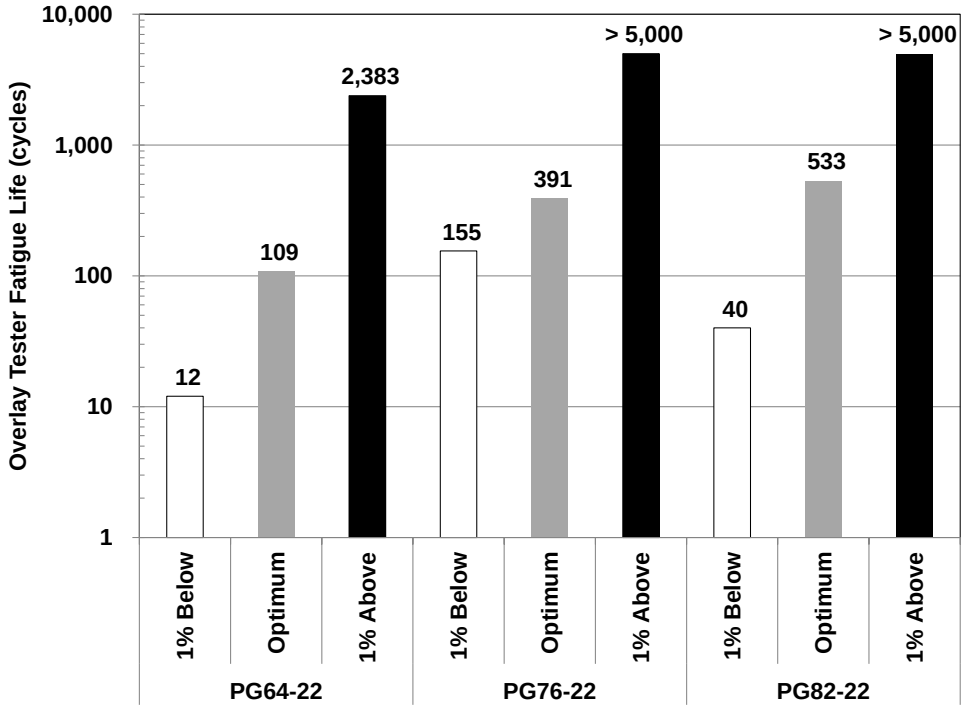


Tom Bennert, Rutgers University (2012)

At the same time, with a 1% increase in binder content, a mixture's Flexural Fatigue Life can be increased by 2 to 10 times, with either unmodified or modified binder. However, modification of the asphalt binder (SBS modification in the two examples below), is necessary for doing this without increasing the mixture's rut susceptibility.



Tom Bennert, Rutgers University (2012)



Tom Bennert, Rutgers University (2012)

Summary

Ultimately, what needs to be better understood, is that extending the service life of our pavements to create Long-Life Pavements is the surest way of creating Long-Term Sustainability for the asphalt pavement industry.

Achieving this industry goal will take continued collaboration, and for the "Use Phase" aspect of the LCA (Life Cycle Assessment) process to be taken into consideration, when establishing sustainability standards and goals for asphalt binders, asphalt mixes, and asphalt construction. Current shorter term "Cradle to Gate" assessments do not take the comparative service life of pavements into consideration, which could result in the need for additional maintenance and rehabilitation activities, and shorter pavement life – having a negative impact on sustainability.

If the shorter term goal of only using individual material components with lower GWP's or using mix design methods that are solely focused on increasing RAP or reducing the use of virgin binder in an effort to lower the asphalt mixture's GWP and initial cost, is not balanced with the resultant mixture's performance, and ultimately the service life of the resultant pavement life – Long-Term Sustainability of pavements will likely not be achieved.

Resources

[1]Transportation Research Board Record: Journal of the Transportation Research Board
A Method to Quantify Reclaimed Asphalt Pavement Binder Availability (Effective RAP Binder) in Recycled Asphalt Mixes (Kaseer, Arámbula-Mercado, Martin, January 8, 2019)

[2]NAPA Balanced Mix Design Resource Guide
https://www.asphaltpavement.org/expertise/engineering/resources/bmd-resource-guide

Dr. Amma Wakefield, Ph.D., P.Eng.
Improving the sustainability of asphalt pavements
Asphalt Magazine – Fall 2022

NCAT – Balanced Mix Design Resources
https://eng.auburn.edu/research/centers/ncat/education/bmd

Cathy Frye
Superpave Comes of Age
Date: September/October 2002
Issue No: Vol. 66 No. 2
U.S. Department of Transportation/FHWA
https://highways.dot.gov/public-roads/septemberoctober-2002/superpave-comes-age