Chemical Warm Mix Additives: Compaction without Plasticization

What are "Chemical Warm Mix Additives"?

Warm mix additives (WMA) have been in use through multiple forms and processes since the early use in Europe in the 1990s (1). Additives have commonly played a role in warm mix asphalt in later years, often broadly categorized as "organic additives" and "chemical additives". Common examples of organic additives are Fischer-Tropsch and Fatty Amid waxes (2; 3). These materials have melting points that are lower than typical hot mix asphalt compaction temperatures, acting as bitumen plasticizers (viscosity reducers) when above their melting temperatures, and as bitumen stiffeners when below their melting point. The plasticization process has been observed to help with compaction, however its significant impact on bitumen standard grades has required the industry to adopt suitable specifications around the impact of such additives.

Chemical warm mix additives have been used successfully for years across the world. Their use has become especially prevalent in North America and parts of Europe due to the ease of implementation and lack of impact on standard bitumen grade. Such additives are believed to perform through improving the ability of the bitumen to coat the aggregates, rather than reduction of viscosity (2). Some research on this topic has suggested modification of bitumen surface free energy (4) and the internal friction (2) as driving forces of improving mixture densification, without significant change in bitumen rheological properties and standard grade.

How do chemical WMAs impact bitumen rheology?

Chemical WMAs do not have a significant impact on bitumen rheology when used at the prescribed dosages. As oils with lower viscosity than bitumen, some minor impact is to be expected when blended with bitumen, however, this impact is usually not nearly large enough to result in a change of grade.

The following examples show the impact of Cargill's Anova® WMA on bitumen properties. It can be seen that the impact on the performance grades are often in the order of 1°C or less. For reference, to change a full performance grade a change of nearly 6°C may be necessary.

Example 1: Binder from a terminal in Northeastern United States was sampled and tested with and without treatment with Anova WMA to verify conformance with PG64S-22 grade in accordance to AASHTO M320 requirements. The results presented in Table 1 show that the addition of the Anova WMA did not change the binder grade. The bitumen was used successfully to produce high performing warm mix asphalt pavements, without reliance on bitumen plasticizing or major rheological change.

Example 2: North American bitumen testing was conducted by the order of the AASHTO National Transportation Pavement Evaluation Program (NTPEP) in the United States to confirm that addition of the Anova® chemical warm mix additive does not change the bitumen performance grade. The Table 2 results indicate that no change in the standard bitumen performance grade occurred. Furthermore, the results show that the impact on viscosity is also minor, further highlighting that chemical WMAs do not operate as a plasticizer.

Table 1 Minor impact of Cargill Anova WMA on Northeast USA bitumen performance grade

Bitumen Description	High Temperature PG	Low Temperature PG (Stiffness)	Low Temperature PG (Relaxation)	Final Standard Performance Grade
Neat Bitumen	67.3°C	-23.2°C	-25.5°C	PG64S-22
+ 0.6% Cargill Anova WMA	66.6°C	-24.7°C	-25.3°C	PG64S-22

Table 2 Minor impact of Cargill Anova WMA on AASHTO NTPEP bitumen viscosity and performance grade

Bitumen Description	Viscosity at 135°C (AASHTO T316)	High Temp. PG	Low Temp. PG	Final Standard Performance Grade
Neat Bitumen	0.55 Pa.s	69.8°C	-22.4°C	PG67S-22
+ 0.5% Cargill Anova WMA	0.52 Pa.s	67.9°C	-24.9°C	PG67S-22

Example 3: Bitumen from a Brazilian source was tested by an independent laboratory in Brazil following typical local specifications. The results show that the bitumen rheological properties were only minorly impacted by the addition of the Anova WMA, as shown in Table 3. The resulting warm mix bitumen performs very well in production of asphalt at reduced temperatures. This can be clearly observed in Figure 1, at which the relatively small impact of reduced compaction temperatures on the WMA compactability is clearly evident in comparison to Hot Mix Asphalt (HMA).

Table 3 Minor impact of Cargill Anova WMA on bitumen viscosity, softening point, and penetration grade properties

Bitumen Properties	Pen50/70 Original	Pen50/70 + 0.4% Cargill Anova WMA
Softening Point (R&B), °C	52°C	52.5°C
Penetration at 25°C, dmm	66 dmm	52.5 dmm
Brookfield Viscosity at 135°C	318 cP	325 cP
Brookfield Viscosity at 150°C	149 cP	150 cP
Brookfield Viscosity at 177°C	56 cP	62 cP
Ductility, cm	> 120 cm	> 120 cm

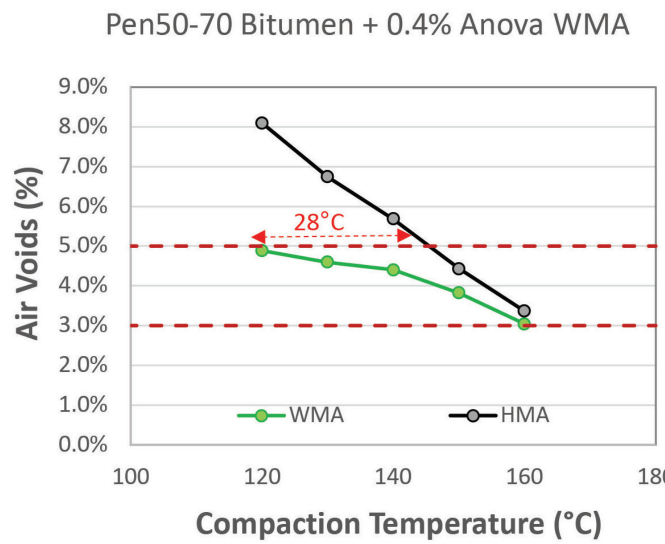

Figure 1 Impact of reduced compaction temperatures on achieved mixture air voids

How do chemical WMAs impact mix and field performance?

Chemical warm mix additives have many years of proven field performance. A good example of monitored use of chemical warm mix additives as compaction aids in pavements is that of the section constructed in 2018 at the National Center for Asphalt Technology (NCAT) facility in Auburn, AL, USA. The pavement section used 0.5% of Anova chemical warm mix additive and as of April 2021, it has been subjected to 10 million equivalent single axle loads (ESALs) applied by truck traffic. This level of traffic is beyond that experienced by most pavements and presents a robust assessment of the performance of such materials. The field performance, as shown in Figure 2, has shown no signs of early distress throughout the service life.

The plant produced material was subjected to thorough mixture performance testing in parallel to the continuous weekly pavement condition assessment. Comparing the results shown in Table 4 with the corresponding typical HMA performance thresholds confirms that mixes using chemical WMA can perform at the same level as that of a typical HMA.

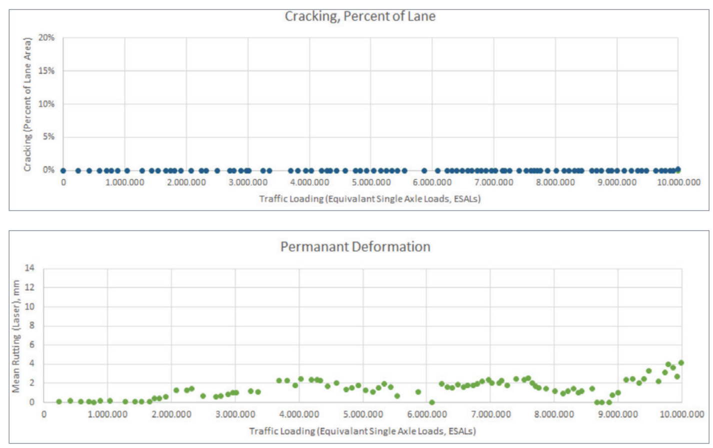

Figure 2 Field performance from monitored NCAT test section after 10 million ESALs of loading

Table 4 Mixture performance results from NCAT test section

Distress Type	Test Name and Method	Test Temperature	Unit	Cargill Anova WMA Test Result	Typical Threshold
Thermal Cracking	Disc Compact Tension (DCT) -12°C ASTM D7313 (MNDOT)	-12°C	J/m² Standard Deviation	**529** 59	450 (min)
Cracking	IDEAL-CT ASTM D8225	25°C	CTIndex (-) Standard Deviation	**102** 15	70 (min)
Cracking	Overlay Tester NJDOT B-10	25°C	Cycles to Failure Standard Deviation	**296** 70	200 (min)
Rutting	Hamburg Wheeltracking Test AASHTO T-324 Hamburg Wheeltracking Test AASHTO T-324	50°C 50°C	mm at 10K Cycles mm at 20K Cycles	**2.5** **3.2**	12.5 (Max) 12.5 (Max)
Rutting	Asphalt Pavement Analyzer AASHTO T-340	64°C	mm Standard Deviation	**2.97** 0.48	8 (max)

How are chemical WMAs typically specified?

Although the precise method of specifying warm mix additives varies from region to region, a general consensus on approach seems to have emerged over the last decade. The agency will generally approve an additive based on a combination of prior history of use, and laboratory data. This usually consists of the following steps:

A. The laboratory binder tests will typically consist of confirming that the standard performance grade (penetration / softening point grade) can be maintained at typical dosages. This does not mean that zero impact is observed, but only that the grade can be reliably maintained.

B. At the mixt scale, the rutting and/or moisture resistance performance is checked against typical requirements for a reference mix design and material. This is typically achieved by Indirect Tensile Strength Ratio (ITSR) testing, or the Hamburg wheeltracking test.

If both A and B are satisfied, either through testing by the agency itself or through review of credible data from other independent sources, the additive is placed on a list of approved products (sometimes called a Qualified Product List (QPL). Inclusion of an additive on such lists means that asphalt producers can use the additives per the manufacture's guidance to prepare mix designs for agency approvals, subject to the final mix designs meeting all relevant agency quality and performance measures.

Conclusions and recommendations

This paper briefly reviewed the typical impact, process, and specifying practice for use of chemical warm mix additives. Such additives have been shown to be robust and reliable methods of achieving pavement density at reduced temperatures or increased haul distances, without the complication of potential change in bitumen standard grade.

The typical specification process presented in the later sections of this paper may provide some good points of consideration for agencies looking to reliably and efficiently incorporate such technologies in their districts.

References

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