

Application of Warm Mix Asphalt on Non-Typical Paving Projects

September 9, 2011

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ABSTRACT
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In 2005, warm mix asphalt was largely an experimental paving technology applied in small trial sections in just seven states. By 2010, warm mix asphalt technologies had been used in mainstream projects to construct thousands of lane-miles of asphalt pavements in the United States and around the world. Yet while virtually every class of aggregate and binder has been used in widely varying climate conditions to construct warm mix pavements on everything from rural roads and car parks to airfields and interstates, the technology has been used most widely in the United States to construct dense-graded asphalt overlays.

This paper describes work to expand the scope of warm mix technology to include several specialty paving applications: 1) warm mix asphalt utilized in a spray-paver under cold weather conditions, 2) warm mix used to construct an ultra-thin bonded wearing course (Novachip), 3) warm mix construction using asphalt mixtures containing polymer modified asphalt and both Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS), and 4) warm mix paving in sub-zero conditions. Job materials and mix properties are described. Production details, construction operations, and pavement performance observations to date are also presented. Benefits realized during mix production and construction of these innovative warm mix asphalt pavements is also discussed.

PAPER
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INTRODUCTION

Compared to other technological changes in the asphalt industry, such as the use of polymer-modified asphalts or the implementation of Superpave design and testing protocols, the adoption of warm mix asphalt technology has been rapid. Within a mere five years, warm mix asphalt (WMA) production has grown from a few thousand tons produced and placed in 2005 to an estimated 46 MM tons in the U.S. alone in 2010 (1).

In the North America, this sweeping change has been driven only in part by the demonstrated environmental and human health benefits (2). The main reason for the rapid expansion of WMA technologies has been the achievement, by both agencies and asphalt contractors alike, of a number of long sought-after goals in mix production, pavement construction, and pavement performance. For example, transportation authorities have observed a range of benefits including higher density pavements (3), longer pavement service life resulting from both improved density and reduced fatigue cracking (4), and quicker pavement construction (5). Asphalt mix contractors have realized a number of mix plant process efficiency improvements, such as reduced fuel consumption, lower stack emissions, higher manufacturing throughput, and less heat-induced wear on mix plant equipment. Lastly, pavement construction contractors have achieved benefits ranging from lower fumes exposure for paving crews and less compactive effort, to thinner lift capabilities, longer hauls, late season paving and, in some states, bonuses for smoothness, in-place density, and moisture resistance.

Dense-Graded WMA Containing RAP and RAS Applied through a Spray-Paver

The use of warm mix asphalt is increasingly seen as a means of further enhancing pavement construction efficiencies brought about by recent equipment innovations. In a 2010 construction demonstration, warm mix asphalt containing reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS) was applied using a spray-paver. The choice of warm mix asphalt using Evotherm 3G was made because this project required milling down to concrete and overlaying the concrete with asphalt. In the past there were several projects that developed “joint bumps” when hot mix asphalt was placed over concrete due to the expansion of crack sealer in the joints. Warm mix asphalt has been effective in controlling these bumps since the lower mix temperature does not cause the moisture or the mastic in the cracks to expand. At the same time the spray paver and polymer modified tack coat was chosen to form the best bond between the warm mix asphalt layer and the concrete.

The job was a mill and inlay, and the jobsite was an off-ramp from Interstate 70 in St. Louis at the exit 249 interchange. Weather on the day of construction ranged from 45°F (7°C) in the morning to 60°F (15°C) in the afternoon with brisk winds ranging from about 15-20 mph (24-32 km/h). The bonding membrane was produced using a polymer-modified, cationic rapid-set (CRS) asphalt emulsion typical for this application in the U.S.

The WMA mixture was a 12.5mm Superpave surface mix containing limestone and traprock plus 17% RAP and 3% RAS. The virgin binder was a PG 64-22, and the total binder

content was 5.9% by weight of mix. The mix was a 100 gyrations design utilizing AASHTO T-312. Haul time for the WMA mix from the mix plant to the job site was roughly one hour. Use of the spray-paver enabled application of the gap-graded WMA mixture immediately after (CRS) emulsion membrane to maximize bonding. In typical applications, the hot mix asphalt surface mix with this JMF would be applied at roughly 320-350°F (160-177°C). The warm mix asphalt gap-graded mixture was applied at 270-280°F (132-138°C). Concerns over lowering the mix temperature any further were raised since it was unknown at the time if the polymer-modified, emulsified tack would set properly. No problems were experienced during placement and the mix is well bonded to this day.

Mix lift thickness was 1 ¾ inches (44 mm). A second 1 ¾ inch lift was placed on top of the first lift. The second lift was also placed using the spray paver and the polymer-modified, cationic rapid-set (CRS) asphalt emulsion.



FIGURE 1 Dense graded WMA bonded to concrete.

Cores were taken from jobsite for bond strength testing and to determine the roadway density. Densities averaged 94.3% of Gmm. The bond strength testing is ongoing and is being directed by Marvin Exline of Road Science, LLC. The preliminary testing shows a superior bond strength between the warm mix asphalt and concrete when compared to hot mix asphalt bonded with traditional tack coat on other projects. To date the warm mix asphalt has performed well in a demanding, heavily-trafficked interchange. The preliminary bond tests indicate that the concerns over the polymer-modified, cationic rapid-set asphalt emulsion not setting properly were not justified. The warm mix asphalt delivered in mitigating the potential joint bump problem, allowed for a longer haul, and achieved optimal density.

Warm Mix Asphalt Used to Construct an Ultra-Thin Bonded Wearing Course

WMA has been shown in hundreds of projects across the U.S. to be easily substituted for HMA. WMA can also be used in technically advanced construction applications. In an August 2010 project in St. Louis County, Missouri, WMA was used to construct an ultra-thin bonded wearing course using a Roadtec SP-200 spray paver. From a materials use and sustainability viewpoint, ultra-thin bonded wearing courses are an attractive alternative to conventional asphalt overlays because less aggregate materials are required to produce the thin lift. The incorporation of WMA further enhances the sustainability benefits of ultra-thin asphalt pavements.

This project was the first time that the St. Louis County Department of Highways and Traffic had used an Ultra-Thin Bonded Wearing Course (UBAWC). The contract required that during the mix design that the stripping potential of the oil from the aggregate be evaluated using AASHTO T-283 with 4 inch (100 mm) molds. The initial tensile strength ratio test indicated that the mix had a tensile strength ratio of 68%, less than the minimum 80% required by the contract. N.B. West Contracting proposed using Evotherm 3G M1 as an adhesion promoter and as a warm mix additive. The St. Louis County Department of Highways was very receptive and through well orchestrated partnering meetings an agreement was reached to switch the project to a warm mix Ultra-Thin Bonded Wearing Course. The mix tensile strength ratio was performed again, this time with the inclusion of the warm mix additive, and the result was a ratio of 91%.

The ½ inch (12.5 mm), open-graded mix was produced between 300-310°F (149-154°C). Mix was hauled approximately 45 minutes by tarped, end dump trucks and delivered between 290-300°F (143-149°C). Daily high temperatures reached 85°F (29°C). Relative humidity was 80-90%. Typically this mix without the warm mix additive would be produced at 330-350°F (160-177°C). The mixing temperature was moderated due to long haul distances, concerns over the set time of the bonding membrane, increased cooling rate of open-graded mixes and wanting to make sure the project was an overwhelming success for the taxpayers of St. Louis County. A Roadtec SB-2500 materials transfer vehicle was employed to meter mix into the Roadtec SP-200 spray paver. A polymer-modified, cationic rapid-set emulsion again was used to provide the impermeable bonding membrane. The 1/2 inch mix was placed in a ¾ inch (19 mm) lift with lay down temperatures 260-270°F (127-132°C) behind the screed. A Caterpillar CAT CB-534D steel roller was used to compact the mix using two passes in static mode. Figure 2 shows the finished mat. To date the pavement has performed excellently.

During a post job meeting to evaluate the lessons learned, all parties were pleased with the execution of the project. There was a significant increase in knowledge of the interaction of the warm mix additive and UBAWC. The warm mix additive provided protection against moisture induced damage, allowed for lower temperatures, reduced the time to re-open the road and minimized odors from the project in a largely residential area. Throughout the project neither N.B. West Contracting or St. Louis County Department of Highways and Traffic received any negative phone calls about the project. This project was awarded a 2010 Missouri Asphalt Pavement Association Quality Paving Award.



FIGURE 2 Warm Mix UBAWC St. Louis County, MO.

WMA Used in Dense-Graded, Polymer-Modified Mix Containing RAP and RAS

The National Asphalt Paving Association's strategic plan focuses squarely on sustainability issues facing the asphalt paving industry. Two key elements of NAPA's strategic plan involve increasing the use of WMA and increasing levels of RAP used in asphalt pavements. Much research is currently underway in universities and laboratories such as National Center for Asphalt Technology (NCAT) to understand the synergies enabled by the tandem use of WMA with RAP. Field work has shown that the use of WMA technologies enables higher RAP percentages to be used than in HMA mixtures. The results of a number of investigations have shown that, since WMA mixtures are produced at lower temperatures, less oxidation of the virgin binder occurs and so higher percentages of RAP may be included in the mixture. Additionally, work has shown that the stiffness of the finished binder (the combination of the WMA virgin binder and oxidized RAP binder) is lower than that in a comparable HMA formulation, resulting in higher resistance to thermal cracking and fatigue cracking. The combination of WMA technology and RAP with RAS incorporation takes this synergistic benefit to a higher level.

A number of successful projects in Missouri have utilized warm mix to enable the incorporation of both RAP and RAS in ways not possible with HMA. Table 1 gives details on a few of these projects. Figure 3 and 4 show photos from the first Route 50 Gasconade project WMA, RAP, and RAS project. Figures 5 and 6 show photos of the Interstate 44 and Interstate 70 projects.

TABLE 1
Projects Using WMA with RAP & RAS Mixtures

Site	Rte 50 (a)	Sullivan MO	I-44	I-70	Rte 47 (b)	Rte 63 (c)	Rte 63 (c)
NMAS	12.5	19	19	12.5	12.5	19	9.5
PG	64-22	70-22	76-22	64-22	70-22	70-22	70-22
%RAP	18	18	7.5	10	10	7.5	>10
%RAS	0	0	2.5	3	5	2.5	3
Haul (min)	60	5	30	60	60	50	50
T-lay down (°F / °C)	242 / 117	250/121	250/121	256/124	289/143	250/121	265/130
% Gmm	93.4	93.2	93.0 – 95.0	94.2	92.2	94.5 +/- 2.5	93.7
TSR Bonus	+3%	+3%	+3%	NA	+3%	+3%	+3%

- a. Gasconade County
- b. Franklin County
- c. Phelps County

Some of these projects included an HMA section. WMA sections routinely gave target densities, sometimes with less compactive effort than that used in the HMA sections, where density targets were not always achieved despite higher mix production temperatures. The Route 50 project was originally bid as hot mix asphalt with RAP and RAS. The project was stopped and converted to warm mix asphalt after the hot mix suffered from voids in the mineral aggregate (VMA) collapse contributed to the breakdown of the recycled asphalt shingles under high temperatures for a long haul time. Many of the WMA projects shown in Table 1 using RAP and RAS not only met density targets, but received density bonuses from the agency. (Missouri is one of 25 states that award bonuses for in-place density.)

The warm mix technology used in these projects was a chemical additive, which functions both as the warm mix additive for low-temperature coating, workability, and compactability, but also as an adhesion promoter. Liquid anti-stripping agents, used in the HMA mixtures, were removed from the WMA mixtures. Yet, in many of the WMA projects listed in Table 1, not only were moisture resistance properties at targeted levels, but TSR bonuses were awarded. The Missouri Department of Transportation specifications allow for a 3% bonus per 10,000 tons of Superpave asphaltic concrete plant produced mix placed on a project for achieving a tensile strength ratio greater than 90%. All projects that use Superpave asphaltic concrete are tested once per 10,000 tons using AASHTO T-283. Table 2 shows the adjustment to the contract unit price based on tensile strength ratio testing results.

Table 2

Missouri Department of Transportation TSR Contract Unit Price Adjustment

TSR	Percent of Contract Price
90% and above	103
75-89%	100
70-74%	98
65-69%	97
<65%	Remove

Under conventional hot mix asphalt operations, use of RAP and RAS in the mixtures discussed herein required very high mix temperatures (typically above 335°F (169°C)) for a number of reasons, one of which was to dry out the RAP and RAS. To reach such high temperatures, manufacturing throughput may have to be reduced when making HMA containing RAP and RAS. With the WMA technology used in these operations, coating can be achieved at lower temperatures, enabling production rates to be increased. Reduced production temperatures enable throughput to be increased. Also, reduced production temperatures leads to less wear on plant equipment. Figure 7 shows a crack in a trundle caused by the very high temperatures used to manufacture the HMA, RAP and RAS mixtures.



FIGURE 3 Route 50 Gasconade County 12.5-mm NMA S WMA RAP and RAS Pavement



FIGURE 4 Route 50 Gasconade County 12.5-mm NMA S WMA
RAP and RAS – Low Temperatures



FIGURE 5 Interstate 44 12.5-mm NMA S WMA
RAP polymer-modified asphalt pavement



FIGURE 6 Interstate 70 12.5-mm NMAS WMA RAP and RAS
Cold weather paving at 23° F (-5°C)



FIGURE 7 Heat-Stress Cracks in Trundle Caused by
High Mix Temperatures for HMA RAP and RAS Mixtures

COLD WEATHER PAVING

One of the touted benefits of warm mix asphalt is extending the paving season by allowing compaction to be achieved at lower temperatures. Several of the projects presented earlier were placed as late as December. The Interstate 70 project was an emergency repair placed when the temperature was 23° F (-5° C). Even though the mix contained RAP and RAS and had a sixty minute haul time the mix was still produced at 305° F (152° C). Granted this mix was not produced at typical warm mix temperatures, but there was still a significant reduction in temperature compared to hot mix asphalt. This reduction in temperature is important considering the stress placed on an asphalt plant superheating aggregate with below freezing air and aggregate temperatures. At the same time it was possible to achieve density on the roadway.

CONCLUSIONS

The unprecedented growth in WMA usage in the U.S. clearly has resulted from a broad, collaborative effort by members of all sectors of the asphalt industry. Programs sponsored and directed by our industry leadership, the Federal Highway Administration, National Asphalt Pavement Association, NCAT, and the Asphalt Institute, continue to promote integration of WMA technologies into the mainstream industry. Through innovative initiatives like “Everyday Counts,” it is expected that more than 40 state DOT’s and all U.S. Federal Lands Divisions will have specification language allowing WMA use by 2010 (6). A fertile environment has been created to enable contractors to expand WMA use beyond conventional dense-graded asphalt applications and into the bonded dense-graded, open-graded, and high RAP and RAS mixes utilizing polymer-modified asphalt cement. At one time some people thought that warm mix asphalt would spell the end of using RAS in asphalt since it “required” high mix temperatures to melt the shingles to release the asphalt cement. It has been shown that the smaller the grind size of the shingles the more asphalt cement is available for aggregate coating even at lower warm mix asphalt temperatures.

Experiences in Missouri have shown that WMA can be used in spray paving applications to capture all of the demonstrated benefits of this construction technology: better bonding between the wearing course and lower pavement layers, reduced construction times and thereby decreased traffic delays, and greater conservation of resources by applying durable thin lifts. The use of WMA gives additional benefits such as lower fuel consumption, less site fumes and odors, and increased use of RAP and RAS. Several projects conducted in 2010 demonstrated the combination of WMA with RAP and RAS can enable a number of additional synergistic benefits to be realized. Among these are smoothness, density and TSR bonuses, increased mix production rates, and removal of rollers at the construction site to name a few.

Moving forward new opportunities are arising in terms of utilizing warm mix asphalt in everyday applications. Millions of tons of warm mix asphalt have been placed by highly skilled and trained laborers, equipment operators, and truck drivers on our highways. What is needed is a transfer of this knowledge to the maintenance crews, county and city highway departments, and commercial asphalt contractors. Utilizing lower temperature asphalt mixtures will require the continuing research, training and development of new paving practices so that the stakeholders in every project receive the full benefits of warm mix asphalt.

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