Evaluation of Warm Mix Asphalt Technologies with Asphalt Rubber and Terminal Blends

CalRecycle
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Executive Summary

The California Pavement Preservation Center was contracted by CalRecycle from July 2010 through May 2012. The center evaluated warm mix technologies for asphalt rubber, terminal blend hot mix, and asphalt rubber spray applications. The purpose of this investigation was to determine the benefits of using asphalt rubber and terminal blend hot mix at lower application temperatures, as well as to establish the energy savings and emissions reduction of using chip seals and spray binders. The Center worked on this study with the assistance of Caltrans, local agencies, and industry to evaluate the environmental and energy benefits of using these warm mix technologies.

CalRecycle contracted the California Pavement Preservation Center to complete a variety of tasks encompassing the various aspects of warm mix technologies. Researchers completed the following tasks during the study:

- Literature review consisting of contacting warm mix technology industries to determine whether warm mix applications have been tried with asphalt rubber or terminal blends. After further review, it appeared that California is the primary state utilizing asphalt rubber and terminal blends.
- Development of a computerized database for all paving projects placed by Caltrans or local agencies. The database includes all projects monitored as part of this project. Information in the database includes, but is not limited to, the project location, mix design, construction information, initial performance, and multiple year surveys.
- Laboratory testing of warm mix performance related properties include testing for moisture sensitivity and rutting potential using the Hamburg device. The center also ran Dynamic Shear Rheometer and Bending Beam Rheometer tests on the binders. l
- Monitoring new and existing Caltrans paving projects as well as local agency projects.
- Disseminating the findings on warm mix technologies with asphalt rubber overlays and with chip seal utilizing technical memos, reports, and papers.
- Creating final reports summarizing the activities and findings, and presenting the results to the Department of Resources Recycling and Recovery (CalRecycle).

The California Pavement Preservation Center made several recommendations contained in this report. Some of the recommendations include further evaluation of warm mix technologies for asphalt rubber terminal blends and asphalt rubber spray binders, continued work with Caltrans, local agencies and industry to monitor long-term performance of warm mix asphalt rubber projects, and the documentation of the emission reduction and energy saving of using warm mix technologies.

Introduction

Background

The California Department of Resources Recycling and Recovery (CalRecycle) promotes the use of waste tires in various pavement strategies as part of its ongoing efforts to divert waste tires from landfills in California. In an effort to improve these strategies, CalRecycle wanted to quantify the potential energy and environmental benefits of using warm mix technologies for asphalt rubber and terminal blend rubberized asphalt overlays and chip seals. The potential savings in energy and reduction in emissions could be substantial. For overlays, warm mix technologies can also allow night paving with better compaction, extend the paving season, and enable an increased haul distance without detriment to the quality of construction. For asphalt rubber chip seals, by reducing the temperatures of application, environmental controls presently used may not be required. This will potentially increase the usage of asphalt rubber chip seals by making the product more cost-effective, environmental friendly, and also more accessible to areas of the state with colder climates.

At present, there are many technologies used throughout the United States, including several that are being used in California. They include forms of emulsion technology, addition of waxes, the addition of a clay substance, and a foaming process.

These additives allow the mixes to be placed at temperatures up to 100^{o} F below the normal compaction temperatures. Agencies in California have also begun to use the additives in spray applications using asphalt rubber and terminal blend asphalt binders. Use of the additives in asphalt rubber binder spray applications could result in savings in energy and reduce emissions because the additives allow the spray application at lower temperatures, eliminating the need for the current environmental controls.

Project Objectives

The objectives of this project are as follows:

- Evaluate the use of warm mix technologies for asphalt rubber and terminal blend hot mixes and quantify the benefits of conducting operations at lower temperatures without harming the performance of the mix.
- Evaluate the use of warm mix technologies for use in spray binders, especially asphalt rubber spray binders. This could result in significant energy savings and a reduction in the emissions. It would also be necessary to determine the effect on short-term and long-term performances.
- Work with Caltrans, local agencies, and industry to place additional trials or test sections of these products in California.

The expected benefits of this study could be significant savings in energy costs and emission reductions, as well as better performance through better compaction for the asphalt products.

Accomplishments

Task 1

Literature review

This task consisted of contacting warm mix technology industries to determine whether warm mix applications have been tried with asphalt rubber or terminal blends anywhere in the world. As of 2012, it appears that California is the primary state that uses warm mix technology with asphalt rubber and terminal blends. Lerose Lane participated in the International Conference on Warm mixes in October 2011. The papers developed by the California Pavement Preservation Center and by Caltrans were the primary ones that dealt with asphalt rubber and warm mixes. Ding Cheng participated in a FHWA/AASHTO conference in July 2012 to present findings on the use of warm mix additives in chip seal applications.

Several of the warm mix additive suppliers were contacted for this information related to this project. Table 1 provides contains the latest update the additives used in the United States.

Table 1. Warm Mix Technologies Used in the United States.

Manufacturer	Brand name	Type of Additive	Website
Maxam Equipment	AQUA Black Solutions	Foaming	www.maxamequipment.com
McConnaughay Technologies	Low Energy Asphalt	Foaming	www.lowenergyasphalt.com
MWV	Evotherm (ET)	Emulsion	www.meadwestvaco.com
MWV	Evotherm (DAT)	Chemical plus water	www.meadwestvaco.com
MWV	Evotherm 3G or (REVIX)	Chemical	www.meadwestvaco.com
PQ corporation	Advera(5)	Clay product (Zeolite)	www.pqcorp.com
Sasol Wax Americas Inc.	Sasobit (4)	Wax	www.sasolwax.com
Shell and Kolo-Veidekke	WAM-Foam	Foaming	http://www.shell.com/global/products-services/solutions-for-businesses/bitumen/products/shell-wam-foam.html
Suit-Kote	Low Emission asphalt	Emulsion	www.lowemissionasphalt.com

Manufacturer	Brand name	Type of Additive	Website
Terex Roadbuilding	Warm Mix Asphalt System	Foaming	http://www.terexrb.com/content.aspx?pgID=308
Engineered Additives	Astech PER (3)	Wax	www.engineeredadditives.com
Engineered Additives	Engineered Additive WRM (2)	Wax	www.engineeredadditives.com

New Products Listed by WMA Technologies (7)

Manufacturer	Brand name	Type of Additive	Web site
Herman Grant Company	HGrant Warm Mix System	Foaming (water injection)	http://www.hermangrant.com/warm-mix.htm
Iterchimica	Qualitherm	Foaming process	http://www.qprshopworx.com/products/asphalt-engineering/qpr%C2%AE-qualitherm/
Kumho Petrochemical and Korea Institute of Construction Technology	LEADCAP	Organic	http://leadcapwma.com/index.html
Shell	Shell Thiopave	Chemical (Sulphur)	Sulphur in Roads - Shell Global
Sonneborn Products	SonneWarmix	Wax	http://www.sonnewarmix.com/
Stansteel	Accu-Shear Dual Warm-Mix Additive System	Not an additive, it is a blending system to enhance mixing or foaming of an additive	http://www.stansteel.com/plantsolutions.asp

1. Rediset used by City of Stockton for PG76-22 terminal blend overlay projects
2. Engineered Additive WRM used by City of Roseville for asphalt rubber chip seal project
3. Astech PER from Engineered Additive used by Caltrans, District 6 for asphalt rubber chip seal project
4. Sasobit used by City of Stockton for PG76-22 terminal blend overlay project
5. Advera used in 2011 by Caltrans, District 3 for rubberized hot mix asphalt projects at various locations
6. Evotherm used in 2011 by Caltrans, District 1 and District 3 for rubberized hot mix asphalt projects at various locations
7. It is not known if these new technologies have been used in the U.S. at this time.

The research team worked closely with Caltrans and local agencies to document the construction and initial performance of their warm mix sections as well as determining the potential energy savings and emission reductions with using warm mix technologies. A number of projects were

monitored in the summers of 2010 and 2011 where both warm mixes with terminal blends and asphalt rubber were used

Task 2

Develop a database for all projects

The research team developed a computerized database for all innovation projects placed by Caltrans or local agencies. The database can be found on our website located at http://www.ecst.csuchico.edu/cp2c/software/pptdb/. All of the projects monitored as a part of this project were included in the database. The research team continues to work with Caltrans and others to track the performance of existing warm mix projects assuming the warm mix projects currently under review by CalRecycle are funded. Information contained within the database includes:

- Project location
- Mix design information
- Construction information including mix temperatures and energy consumption
- Initial performance including photos
- Multiple year surveys and more

Task 3

Laboratory testing for warm mix projects

This task consisted of purchasing equipment to expand CP2 Center's laboratory capabilities to include the testing of performance-related properties of terminal blends and for asphalt rubber. Binder equipment which has been purchased includes the following:

- Dynamic Shear Rheometer (DSR)
- Bending Beam Rheometer (BBR)
- Rolling thin film oven (RTFO)

Equipment obtained for testing binder content for both terminal blends and asphalt rubber also included an ignition oven (received from the U.S. Forest Service) which is housed off campus at a Knife River Facility. Our APA rut tester (which includes the Hamburg device) was used to test warm mix asphalt rubber from various projects for moisture sensitivity and rutting potential. Caltrans now requires all warm mix asphalt rubber projects to pass the Hamburg tests and we are testing these mixes to make sure that they meet the specifications.

Other laboratory equipment, which is still needed by CP2 Center to perform tests on binders and mixes for the development of performance curves, includes the Pressure Aging Vessel (PAV), portable coring equipment, and beam fatigue apparatus. There were insufficient funds to purchase

these items on this contract. Table 2 shows the status of equipment, including what has been obtained with the current contract which ends in May 2012.

Table 2. Equipment Purchased or on Order

Equipment	Status
1. DSR	Purchased
2. PAV	Delayed
3. RTFO	Purchased
4. Asphalt ignition oven	Donated
5. Asphalt rubber lab and field testing equipment*	Receiving bids
6. Force air ovens (2)	Donated
7. Ductility equipment	Donated
8. Pavement quality indicator	Purchased
9. Upgrade to APA rut tester	Purchased
10. Lab and field testing accessories and materials	Donated

Task 4

Monitor new and existing projects

As a part of the contract, the research team monitored the projects shown in Table 3. Project reports for these construction projects have been developed and are included in a CD which was furnished to CalRecycle along with this summary report.

Table 3. Projects Monitored to Date

Projects	Location	Comments
Caltrans	○ District 1, SR 1 ○ District 1, SR 101 ○ District 3, SR 99 & I-5 ○ District 3, SR 20 in Yuba City ○ District 6, I-5 ○ District 7, SR 150	○ RHMA-G ○ Terminal blend hot mix ○ RHMA-O and RHMA-G ○ RHMA-O ○ AR chip seal ○ AR chip seal
Local agencies	○ L.A. County ○ City of Stockton ○ City of Roseville ○ City of Fort Bragg	○ AR chip seal ○ Terminal blend hot mix ○ AR chip seals ○ AR cape seal

Information collected on each of the projects included:

- Construction information:
  - Mix temperatures during production, placement, and compaction using our infrared camera and temperature monitoring devices.
  - Emissions-visual. We are looking for equipment to support a future contract with an outside environmental contractor to measure and analyze emissions.
  - Energy consumption during production-We are working with the contractors to determine energy savings.
  - Asphalt rubber with warm mix, mix design.
  - QC/QA data – from the contractor and agency.
- Pavement condition surveys (ride, distress, and overall surface appearance) before and after construction.

In the winter 2011/spring of 2012, some of the projects constructed in 2010 and 2011 were revisited and evaluated for performance. It was not possible to visit all the projects because of a lack of travel funds and time constraints.

Researchers also identified a number of Caltrans projects that were constructed during the 2011 construction season. Table 4 provides a summary of these projects including contractor information and schedule. Some of these projects were monitored using the CalRecycle funding, while a few were monitored using Caltrans funding. The general finding was that warm mix with rubberized asphalt usage was increasing in California. This trend was expected to continue for the 2012 construction season.

Table 4. Warm Mix Rubberized Hot Mix Asphalt Projects Constructed in 2011

Contract No.	District/County Route	Description	Contractor	Warm Mix Cost, $ Millions	Completion Date
01-499504	01-MEN-01	RHMA-G	Granite Construction	1.821	Completed 10/26/2011*
01-3994U4	01-LAK-175 01-LAK 29 01-MEN-175	RHMA-G	Granite Construction	7.361	Ongoing 8/15/2012*
03-4M1404	03-PLA-49	RHMA-O	Granite Construction	0.721	Completed 1/21/2011
03-1F3704	03-SUT-99	RHMA-O	George Reed	1.470	Completed 8/26/2011

Contract No.	District/County Route	Description	Contractor	Warm Mix Cost, $ Millions	Completion Date
03-1E6704	03-SAC-99	RHMA-G	Teichert	0.750	Completed 4/10/2012 *
03-1F3604	03-PLA-80	RHMA-G	Knife River	3.997	Ongoing 5/21/2012 *
03-3C8904	03-COL-5	RHMA-G	George Reed	8.672	Completed 4/11/2012 *
03-1F4804	03-YOL-5	RHMA-G	Ghillotti Bros.	4.897	Completed 8/4/2011
03-0F5904	R03-SAC-5	RHMA-O RHMA-G	Granite Construction	12.794	Ongoing 1/04/2013*
03-1F4604	03-YUB-70	RHMA-O	Teichert	1.020	Completed 4/19/2012*

* Estimated completion date as shown in the State of California Department of Transportation's Statement of Ongoing Contracts dated March 2, 2012

Task 5

Disseminate the knowledge

This task consisted of writing papers, technical memos, and reports to disseminate the knowledge of using warm mix asphalt with asphalt rubber overlays and chip seals.

All of the project reports were updated, and can be found on our website at http://www.csuchico.edu/cp2c/index.shtml. Most projects were performing well with two exceptions. The L.A. County cape seal project exhibited some early cracking. The cause of this distress was determined to be the result of the extreme cold temperatures during the first winter, resulting in top down cracking in the microsurfacing. The other project which has experienced some early distress was the one placed in the City of Roseville. The project had some soft spots in the cul de sacs due to excess asphalt rubber binder being applied. The contractor has taken corrective measures by applying a slurry seal over the double chip seal. Articles on the "lessons learned" from both projects have been published in the California Pavement Preservation Center's newsletter (http://www.csuchico.edu/cp2c/newsletter.shtml). These projects will be reassessed next spring.

Task 6

Final reports

This task consisted of the preparation of a final report summarizing the activities and findings, and presenting the results to the Department of Resources Recycling and Recovery (CalRecycle). At present, the following deliverables were completed:

- A summary report covering all the tasks. This report includes information on the accomplishments and on the general findings from the study.
- Individual project reports which include information on the design, construction, and initial performance of all projects. These are available on our website and have also been included on a CD provided to CalRecycle.
- A report on the energy and emissions savings when using warm mix additives with asphalt rubber products, which was also included on the CD.

Recommendations

The following recommendations are warranted as a result of the findings from this study:

- Continue to evaluate the use of warm mix technologies for asphalt rubber, terminal blend hot mixes, and asphalt rubber spray binders and quantify the benefits of conducting operations at lower temperatures without harming the performance of the mix. This could result in significant energy savings and a reduction in the emissions. It would also be necessary to determine the effect on short-term and long-term performances.
- Continue to work with Caltrans, local agencies, and industry to place additional trials or test sections of asphalt rubber binder warm mix products in California.
- Continue to monitor long-term performance of warm mix asphalt rubber projects in the field to confirm asphalt rubber warm mix binder products' dependability.
- Continue to develop laboratory capabilities for research and development of asphalt rubber binder performance curves and asphalt rubber mix properties.
- Continue to develop field testing capabilities for research on energy and emission reduction by lower temperatures during plant production and construction with asphalt rubber binder warm mix products.
- Continue to be a conduit for disseminating information to Caltrans, local agencies, and industry regarding asphalt rubber warm mix binder products.
- Document and research on the detailed emission reduction and energy saving of using warm mix technology in asphalt rubber and terminal blend applications including overlay and spray applications.

Abbreviations and Acronyms

CP2C – California Pavement Preservation Center

AR – Asphalt Rubber

FHWA – Federal Highway Administration

AASHTO – American Association of State Highway and Transportation Officials

WMA – Warm Mix Asphalt

DSR – Dynamic Shear Rheometer

BBR – Bending Beam Rheometer

RTFO – Rolling Thin Film Oven

PAV – Pressure Aging Vessel

RHMA – Rubberized Hot Mix Asphalt

TB – Terminal Blends Rubberized Asphalt