

Thin overlay of warm mix asphalt containing terminal blend asphalt rubber and Evotherm warm mix additive is placed on Calif. 1, the Pacific Coast Highway, near Fort Bragg two hours after load out



Photo courtesy of Tom Kuennen

Rubber Expands

Asphalt containing rubber continues to stretch its way into more state Departments of Transportation.

After years of promotion, pavements using asphalt rubber, or rubberized asphalt (there's a difference), are spreading far and wide in the United States.

Formerly a Southwest and California phenomenon – its use is mandated by California law – and a handful of states elsewhere, asphalt pavements containing rubber currently are being used in a majority of states. And while all those states may not have actual specifications for pavements containing rubber, they at least are giving them a try.

Use of rubber in asphalt pavements likely will get a boost as the Federal Highway Administration (FHWA) updates its 1992 *State of the Practice: Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier* (Search for FHWA-SA-92-022 in Google).

In May 2013, representatives from the Rubber Manufactur-

ers Association, Tire Industry Association, Rubber Pavements Association, Rubberized Asphalt Foundation, National Asphalt Pavement Association and Liberty Tire Recycling met with FHWA's John Baxter, associate administrator for infrastructure.

Their purpose was to encourage FHWA to update that document to reflect innovations and changes that have occurred in the rubberized asphalt industry since it was published 22 years ago.

A new guide will be produced that will capture the best practices in design, construction, application, testing, storage and handling of rubberized asphalt materials in use today. The guide will help agencies and contractors that are exploring the implementation of rubberized asphalt technologies of various kinds by providing specifications and quality control procedures that have been successfully used around the globe.

Among these innovations are use of recycled tire rubber as a modifier in PG asphalt binders, sustainable polymer modification, quiet pavement designs, warm-mix technologies in combination with rubberized asphalt, binder stabilizers (fiber replacement) to prevent drain down in permeable, porous and open graded mixes, use of recycled tire rubber with reclaimed asphalt pavement and shingles, and reduced thickness designs for highly modified asphalt rubber mixes.

Rubberized Asphalt Foundation chairman George Way, P.E., and Rubber Pavements Association executive director Mark Belshe, P.E., are providing input to FHWA towards the new document.

What is asphalt rubber?

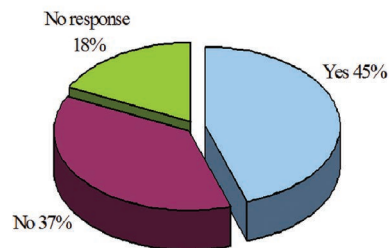
Asphalt pavements utilizing rubber have a number of permutations.

Asphalt rubber (AR) binder consists of a blend of asphalt cement, ground recycled tire rubber (crumb rubber), and other additives such as extender oil, natural rubber and polymers, as needed, says Paola Bandini, Ph.D., P.E., New Mexico State University, in his 2011 paper, *Rubberized Asphalt Concrete Pavements in New Mexico*. “The rubber content should be at least 15 percent (by weight) of the total blend to provide acceptable properties of the material, according to the *Standard Specification for Asphalt-Rubber Binder* (ASTM D6114/D 6114M-09). Higher rubber contents, between 18 and 22 percent by weight, are often used or specified.”

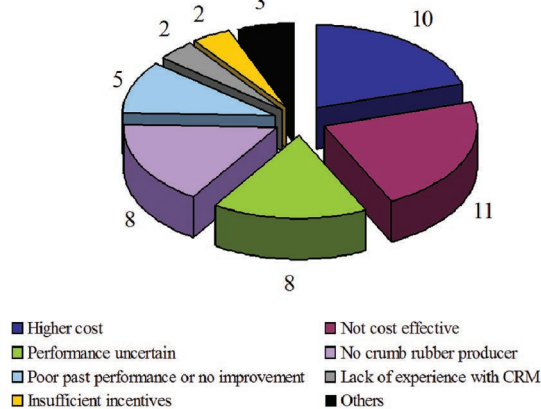
Bandini says the ground rubber should be blended sufficiently in the hot asphalt cement (347 degrees Fahrenheit) to cause swelling of the rubber particles and a considerable increase of the viscosity, which is strongly affected by the crumb rubber content and particle sizes. “Because the AR binder is mixed and blended at the job site, it is also called field-blend asphalt-rubber binder based on its manufacturing process.

Rubberized asphalt (RA) binder is also called **terminal-blend or field-blend** rubberized asphalt modified binder, depending on the manufacturing process, or just rubberized asphalt, Bandini says. “In practice, rubberized asphalt is mostly terminal blended [blended by the liquid asphalt supplier] and consists of asphalt cement with crumb rubber modifier or CRM binder (less than 15 percent by weight),” he says. “Rubberized asphalt binder is often referred to as PG 76-22TR (tire rubber) or PG 76-22PM (polymer-modified) binder because these are the only RA binder types currently approved for the specifications of Caltrans.”

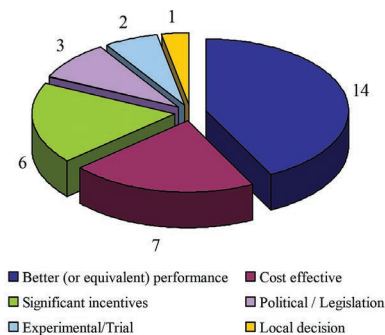
Used or Currently Use Crumb Rubber in Pavement Applications



Reasons For Not Using CRM in Pavement Applications



Reasons for Using CRM in Pavement Applications



Reasons for using crumb rubber in pavement applications by state DOTs, 42 of 51 agencies responding in 2011

Historically, rubberized asphalt has contained up to 10 percent of CRM, thus it does not meet the requirements of ASTM for asphalt rubber. “However, in recent years, greater rubber contents have been used in RA binders in some projects,” he says. “The RA binder is generally made with CRM smaller than

30 mesh and may contain 1 to 4 percent styrene-butadiene-styrene (SBS) polymer.”

Finally, there is the dry process as compared to the wet process. Crumb rubber recycled from waste tires in asphalt mixtures and pavement rehabilitation treatments can be achieved in two different ways, Bandini says.

“Crumb or ground rubber can be used either as fine aggregate in the mixture [dry process], or as processed rubber added to the asphalt binder [wet process],” he says. “The dry process is any method that adds granulated or crumb rubber modifier from scrap tires as a substitute for a percentage of the aggregate in the asphalt concrete mixture, not as part of the asphalt binder. The crumb rubber is mixed with the aggregate fraction before adding the asphalt cement. The resulting product is often called rubber-modified asphalt concrete mixture. Different gradations or sizes of granulated or CRM can be used.”

In this process, the asphalt cement is not modified significantly by the addition of the crumb rubber; however, the properties of the resulting HMA pavement are modified. The dry process can be used in dense-graded, open-graded and gap-graded mixtures to accommodate the rubber particles in the aggregate gradation, but cannot be used for cold mix, chip seals and surface treatments, Bandini says.

The wet process is the method of modifying the asphalt binder with CRM from scrap tires before the binder is added to form the asphalt concrete mixture. “The resulting product is called asphalt rubber or rubberized asphalt,” Bandini says. “The wet process requires thorough mixing of the CRM with the asphalt concrete and other components of the modified asphalt binder at temperatures between 375 to 435 degrees Fahrenheit, and requires maintaining the blend at temperatures between 375 to 425 degrees Fahrenheit for a certain specified minimum time, generally 45 minutes.”

In addition to the performance benefits of RA or AR, the processes yield environmental benefits as they reduce the population of scrap tires. “Application of crumb rubber modified asphalt has been identified as one of the possible solutions to address the scrap tire issue while benefiting pavement industry,” say Shahrzad Hosseinnazhad, Darius Holmes, and Ellie H. Fini, Ph.D., P.E., Department of Civil and Environmental Engineering, North Carolina A&T State University, in their 2014 Transportation Research Board paper, *Decoupling the Physical Filler Effect and the Time Dependent Dissolution Effect of Crumb Rubber on Asphalt Matrix Rheology*. “It is predicted that if just 10 percent of asphalt which is used during one year in the

U.S. contained 3 percent rubber, approximately all scrap tire would be consumed for that year.”

Yet crumb rubber modified asphalt is not used in large volumes consistently from coast-to-coast, they observe. “Due to lack of in-depth understanding of the various interaction mechanisms between CR and asphalt binders, CRM asphalt is not widely used,” they say. “Largely, such interactions depend on the physical and chemical properties of the asphalt binder and the CRM as well as the interaction environment including the rubber percentage, particle size and texture of the CRM as well as source of rubber and asphalt.”

Who uses asphalt rubber?

Arizona has been the leader in using rubberized asphalt, but California, Florida, Texas, South Carolina, Nevada, Georgia, Pennsylvania and New Mexico are very active as well. The penetration of asphalt rubber into the 50 states was explored in a 2012 survey sponsored by the Rubberized Asphalt Foundation.

That survey found that 70 percent of transportation agencies have previously used or currently use recycled tire rubber in asphalt. About half of the respondents indicate that they have a specification for using recycled tire rubber. The survey was conducted for RAF by the Highway Sustainability Research Center at the University of Massachusetts-Dartmouth.

Agencies have utilized recycled tire rubber routinely for crack sealing (30 percent), chip seals (26 percent), dense-graded hot mix asphalts (15 percent), joint sealants (15 percent), stress absorbing membrane interlayers (SAMIs, 11 percent), and open-graded friction courses (OGFCs, 11 percent), the survey found.

Other respondents reported the same uses for rubberized asphalt on an experimental basis. Another aspect of the survey notes the technologies being used by transportation agencies to incorporate recycled tire rubber into their pavements. These results show that terminal blending is the predominant method in use, chosen 59 percent of the time.

In his paper on rubber pavements for New Mexico, Dr. Bandini surveyed state DOTs to gauge use of the materials in the nation. He sent out 51 surveys (including D.C.) and received 42, an 82 percent response. Of the 42 agencies who responded, about 55 percent have used, or currently use crumb rubber in one or more pavement application, and the remaining agencies (45 percent) have not used crumb rubber in flexible pavements (Fig. 1).



Asphalt rubber pavements are created as granulated tire rubber reacts with hot liquid asphalt to modify asphalt performance, as here in Arizona

When the agencies who have not used or tried crumb rubber in pavements (19

agencies) were asked why not, 10 of them referred to the higher cost of CRM, 11 agencies indicated that it was not cost-effective for their agency, eight agencies said there was no crumb rubber producer in their state, and eight agencies did not use it because the performance of CRM asphalt was still uncertain (Fig. 2).

When the agencies who have used or tried crumb rubber in pavements were asked why they use it, 14 of them (61 percent in this group) indicated that these pavements perform either better than, or equal to conventional pavements without CRM, and seven agencies indicated that it is or may be cost-effective for their agency (Fig. 3).

CRM and other modifiers

Because of the prevalence of polymer modified asphalt in the age of Superpave's performance graded (PG) asphalt binders, researchers have worked to quantify the relationship between CRM and polymer modifiers in binders.

There are two classic polymer types, elastomers and plastomers. Elastomers increase modulus (stiffness) and also give the asphalt elasticity and the ability to stretch. Under load they can provide recovery under deflection. Plastomers are more limited in that they just stiffen the asphalt, so they don't provide the kind of recovery you get with an elastic material, but still may be best suited for a particular application.

A very common elastomer for asphalt modification is styrene-butadiene-styrene (SBS), in which the butadiene molecule actually is a kind of synthetic rubber. The November 2012 publication, *Performance Testing for Superpave and Structural Validation* (Google FHWA-HRT-11-045), says explicitly that "based on the full-scale performance and laboratory tests,

crumb rubber (recycled tires) modified asphalt (Arizona wet process) was shown to significantly slow or stop the growth of fatigue cracks in a composite asphalt pavement structure."

But what of rubber and polymer modifiers? "A hybrid technique to modify asphalt with a combination of crumb rubber and conventional polymers (terminally blended) exhibited good fatigue cracking resistance relative to the control binder," the report says.

That SBS-type polymer modifiers are "friendly" to CRM is borne out in recent Canadian research, which investigated performance-based asphalt cement (AC), AC modified with warm mix technology additives (warm AC), rubberized asphalt cement (RAC), and warm RAC.

The 2013 TRB paper, *Quality and Durability of Warm Rubberized Asphalt Cement in Ontario*, by Hattie Xu, Andrew McIntyre, Tham Adhikari and Simon A.M. Hesp, Queen's University, Kingston, Ontario, and Pamela Marks and Seyed Tabib, Bituminous Section, Ontario Ministry of Transportation, describes how control, warm, and rubberized asphalt cement (RAC) binders from Ontario construction contracts were investigated for compliance with conventional Superpave as well as additional specification criteria.

"One warm AC and two field-blended RAC samples showed high levels of physical hardening, which can lead to early cracking," they write. "In an effort to formulate warm RAC with improved properties, a number of compositions were prepared with soft Cold Lake AC and a small quantity of naphthenic oil. These binders showed little chemical and physical hardening and reasonable critical crack tip opening displacements. Strain tolerance was much improved by co-blending with a high vinyl type styrene-butadiene-styrene (SBS) polymer and a small amount of sulfur."

Replace SBS Completely?

A white paper issued recently by RAF concludes that recycled tire rubber binders can be used in place of polymer modified binders such as SBS and achieve the same performance-graded (PG) results. The white paper was authored for RAF by advisory board member Dr. John D'Angelo, P.E., principal of D'Angelo Consulting, LLC, and a long-time FHWA expert on asphalt.

"Polymer modified binders such as Superpave PG 76-22 have been used extensively on high volume highways to improve rutting and cracking performance," said RAF chair Way. "Given the current economics and higher costs for materials, highway agencies are looking for alternatives to the typical

polymer modified binder systems.”

Recycled Tire Rubber (RTR) binders have been extensively used to provide the same type of improved performance as SBS, RAF says. The issue with polymer modifiers is that they are subject to supply demands and chemical production variations that can lead to supply shortages and higher costs. Scrap tire rubber for RTR is in plentiful supply with a relatively stable cost that is attractive for use to produce improved binders.

“History has demonstrated recycled tire rubber binders will perform well in rutting and cracking,” D’Angelo says. “Using the new testing techniques, RTR binders can be compared directly to the polymer modified binders. This clearly demonstrates that RTR can be used in place of or in combination with polymer to provide a high quality performance graded, (PG) binder.” ❖