Research Report

KTC-93-2

DEVELOPMENT OF GUIDELINES AND PERFORMANCE FOR ASPHALT PAVEMENTS CONTAINING RUBBER -- REVIEW OF STATE-OF-THE-PRACTICE

Interim Report

by

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January 1993

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
KTC-93-2		

4. Title and Subtitle	5. Report Date
DEVELOPMENT OF GUIDELINES AND PERFORMANCE FOR ASPHALT PAVEMENTS CONTAINING RUBBER -- REVIEW OF STATE-OF-THE-PRACTICE	January 1993
	6. Performing Organization Code
7. Author(s) Kamyar Mahboub, and Donn Hancher	8. Performing Organization Report No. KTC-93-2
9. Performing Organization Name and Address Kentucky Transportation Center College of Engineering University of Kentucky Lexington, KY 40506-0043	10. Work Unit No. (TRAIS) 11. Contract or Grant No. KYHPR-93-150
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet State Office Building Frankfort, KY 40622	13. Type of Report and Period Covered Interim Report (1992) 14. Sponsoring Agency Code

15. Supplementary Notes

Publication of this report was sponsored by the Kentucky Transportation Cabinet with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

This interim report provides a summary of key points that are important to successful implementation of the asphalt rubber technology in Kentucky in accordance with ISTEA. Various asphalt rubber technologies are presented in this report along with their advantages and disadvantages. Issues related to structural design and construction are discussed. A variety of environmental issues such as: emissions, leachate and issues related to future recyclability are presented. Finally, criteria are recommended to be used for selection of future asphalt rubber projects in Kentucky.

17. Key Words	18. Distribution Statement
Asphalt rubber, asphalt additives, scrap tire rubber, crumb rubber modifier, dry process, wet process, rubber modified hot mix asphalt	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	15	

Form DOT 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

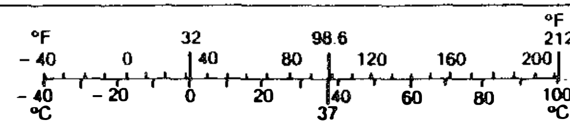
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in²	square inches	645.2	millimetres squared	mm²
ft²	square feet	0.093	metres squared	m²
yd²	square yards	0.836	metres squared	m²
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	kilometres squared	km²
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.028	metres cubed	m³
yd³	cubic yards	0.765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
ha	hectares	2.47	acres	ac
km²	kilometres squared	0.386	square miles	mi²
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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Scope of the Interim Report

Task 1 (Review of the State-of-the-Practice) of the work plan includes a survey of literature and submittal of an interim report. This interim report is intended to provide an overview of the literature on the subject. Recently, an FHWA report was released on the subject; this report provides an excellent source of information on the history, as well as the state-of-the-art of the asphalt rubber technology (Heitzman 1992). In the context of this interim report, the intention is to provide a summary of key points that are important to successful implementation of the asphalt rubber technology in Kentucky in accordance with ISTEA, while realizing that more details may be found in references listed at the end of this report. Various asphalt rubber technologies are presented in this report along with their advantages and disadvantages. Issues related to structural design and construction are discussed. A variety of environmental issues such as: emissions, leachate and issues related to future recyclability are presented. Finally, criteria are recommended to be used for selection of future asphalt rubber projects in Kentucky.

Terminology

Unfortunately, the misuse of asphalt rubber terms is common throughout the asphalt industry. This section is designed to establish a common ground for the asphalt rubber terminology in Kentucky. Terminology that is acceptable by ASTM, FHWA, and asphalt rubber producers is summarized and it is recommended for adoption by the Transportation Cabinet. The following summary of terminology and abbreviations was adopted from the report FHWA-SA-92-022 by Heitzman, 1992.

Asphalt Rubber (AR):

> Asphalt cement modified with crumb rubber. Note that ASTM D-8 defines it as: "a blend of asphalt cement, reclaimed tire rubber and certain additives in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles".

Buffing Waste:

> High quality scrap tire rubber which is a by-product from the conditioning of tire carcasses in preparation for retreading.

Crackermill:

> Process that tears apart scrap tire rubber by passing the material between rotating corrugated steel drums, reducing the size of the rubber to a crumb particle (generally 4.75 millimeter to 425 micron, No.4 to No. 40 sieve).

Crumb Rubber Modifier (CRM):

> A general term for scrap tire rubber that is reduced in size and is used as a modifier in asphalt paving materials.

Cryogenic:
: Process that freezes the scrap tire rubber and crushes the rubber to desired particle size.

Diluent:
: A lighter petroleum product (typically kerosene) added to asphalt rubber binder just before the binder is spray applied to the pavement surface.

Dry Process:
: Any method that mixes the crumb rubber modifier with the aggregate before the mixture is charged with asphalt binder. This process only applies to hot mix asphalt (HMA) production.

Extender Oil:
: An aromatic oil used to supplement the asphalt/crumb rubber modifier reaction.

Granulated CRM:
: Cubical, uniformly shaped, cut crumb rubber particles having a low surface area which are generally produced by a granulator.

Granulator:
: Process that shears apart the scrap tire rubber, cutting the rubber with revolving steel plates that pass at close tolerance, reducing the size of the rubber to a crumb particle (generally 9.5 millimeter to 2.0 millimeter, 3/8-inch to No. 10 sieve).

Ground CRM:
: Irregularly shaped torn crumb rubber particles having a large surface area which are generally produced by a crackermill.

Micro-mill:
: A process that further reduces a crumb rubber to a very fine ground particle, reducing the size of the crumb rubber below 425 micron (No. 40 sieve).

Reaction:
: The interaction between asphalt cement and crumb rubber modifier when blended together. The reaction, more appropriately defined as polymer swell, is not a "chemical reaction". It is the absorption of aromatic oils from the asphalt cement into the polymer chains of the crumb rubber.

Rubber Aggregate:
: Crumb rubber modifier added to HMA mixture using the dry process which retains its physical shape and rigidity.

Rubber Modified Hot Mix Asphalt (RUMAC):
Hot mix asphalt which incorporates crumb rubber modifier primarily as rubber aggregate.

Shredding:
Process that reduces scrap tires to pieces 0.15 meter (6 inches) square and smaller.

Stress Absorbing Membrane (SAM):
A surface treatment using an asphalt rubber spray and cover aggregate.

Stress Absorbing Membrane Interlayer (SAMI):
A membrane beneath an overlay designed to resist the stress/strain of reflective cracks and delay the propagation of the crack through the new overlay. The membrane is often a spray application of asphalt rubber and cover aggregate.

Wet Process:
Any method that blends crumb rubber modifier with the asphalt cement prior to incorporating the binder in the asphalt paving project.

NOTE:
According to the Asphalt-Rubber Producers Group (ARPG), the term Asphalt Rubber should be used when referring to the material derived from the wet process, while the term Rubberized Asphalt should be used for the material produced via the dry process (Roads and Bridges Magazine, December 1992).

Major Applications of the CRM Technology

Wet Process

This process is basically an asphalt binder modification process. The crumb rubber modifier (CRM) is added to the asphalt binder prior to its paving application. A reaction takes place between the asphalt and the CRM at high temperatures (350°F to 400°F) and after 45 minutes to 1 hour of mixing and agitation. This reaction, which is called polymer swell, is often enhanced by the addition of extender oils such as kerosene.

Advantages

1. Performance tends to be similar to polymer modified asphalts. That is, the crumb rubber modified asphalt produced via the wet process exhibits higher viscosity and less temperature susceptibility compared to the original unmodified asphalt.

2. Because the process deals with the binder alone, it lends itself to both hot mix and spray applications. It may also be produced in emulsion form (Terry Industries, 1992).

3. In hot mix applications, the material may be used in batch plants as well as drum plants without any operational complications.

4. Mix design may be accomplished with minor modifications to the conventional hot mix design practices. These modifications are almost identical to binder rich polymer modified mixes.

5. Experienced suppliers operate under the umbrella of the Asphalt-Rubber Producers Group (ARPG, sometimes referred to as the "Arizona Group"). These suppliers have the experience and the capability of engaging in a partnering relationship with the state DOTs and producing a custom made product.

Disadvantages

1. The crumb rubber modified binder produced via the wet process has a short shelf life; it must be used within hours of its production.

2. Special pumps and tanks (reaction tanks with a mechanical agitator system) are needed.

3. Frequent monitoring of the reaction is necessary.

4. Long-term performance characteristics are unknown.

Dry Process

The term "dry" refers to the addition of granulated crumb rubber to the heated aggregate in dry form prior to becoming "wet" by asphalt. Due to the particular nature of this process, there is only a slight reaction between the granulated rubber and asphalt cement during mixing.

Advantages

1. Application in the batch plant is simple. Bags of CRM may be delivered to the pugmill similar to certain polymers, fibers, etc.

2. Compared to the wet process, much larger quantities of scrap tire rubber may be disposed of in this manner.

3. The production cost of granulated rubber is less than the fine ground type. Additionally, the dry process HMA is less complicated and therfore, less expensive than the wet process. Hence, the overall cost of dry process is less than the wet process (dry process: 30% to 50% cost increase, compared to wet process: 60% to 100%, Roads and Bridges Magazine, December 1992; Rouse Rubber Industries, Information Brochures, 1992; Estakhri et al., 1992; Heitzman, 1992).

4. In response to a patented gap graded dry process, called PlusRide, most states have developed their own versions, called generic dry technology, information on which is available to the public.

Disadvantages

1. The dry process is only limited to HMA applications.

2. It is hypothesized that with time, the "unreacted" rubber particles in the asphalt pavement rob the asphalt from its lighter molecules and thereby induce premature aging and brittleness in the pavement.

3. Application in the drum plant involves introducing the CRM at a point away from the flame in order to prevent emissions associated with combustion of rubber (i.e. blue smoke). This requires a drum plant having an opening designed for this purpose (such as the recycled asphalt opening) or double barrel drum plant. However, this may not be a major concern since most drum plants in Kentucky are outfitted with a recycled material feed capability.

4. Depending upon the size of rubber particles used, alterations in the aggregate gradations and the job-mix formula may be necessary.

5. Long-term performance characteristics are unknown.

New Technologies

UltraFine™

Rouse Industries, of Vicksburg, Mississippi, developed a material which is very fine 180 micron (No. 80) - with a mean particle size of 74 micron (No. 200), Rouse Rubber Industries, Information Brochures, (1992). They have shown that by using their UltraFine™ material the "reaction time" may be significantly reduced (less than a minute instead of an hour). There have been a few test sections in place and data on long-term performance of this material are not available.

Advantages

1. Short reaction time.

2. Has potential to be produced at the terminal in a manner similar to conventional modified asphalt binders.

Disadvantages

1. The material producer has been primarily focusing on selling the UltraFine™ material and not necessarily the associated paving technologies.

2. Long-term performance characteristics are unknown.

Flexochape™

The French road contractor, Beugnet, developed a process by which the shelf-life of the asphalt rubber increases to eight days; the binder is marketed under the trade name Flexochape™. Conventional asphalt rubber binders, produced by the wet process, must be used within a few hours of production. The Flexochape™ may viewed as a major breakthrough in implementation of asphalt rubber technology. At this time, there are no performance data available for this material.

Advantages

1. Extended shelf-life (days instead of hours).

2. Has a long-term potential to be handled in a manner similar to conventional modified asphalts.

Disadvantages

1. It is expected to be very expensive.

2. It is not widely available in the U.S.

3. Long-term performance characteristics are unknown.

Chunk Rubber Asphalt Concrete

The Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Army Corps of Engineers was contracted by the Strategic Highway Research Program (SHRP) to study ice- debonding characteristics of paving materials. Initially, PlusRide was marketed as a very flexible asphalt having ice-debonding properties. As an extension of the PlusRide concept, CRREL developed a dense graded mix having a CRM gradation within 12.5 to 4.75 millimeter (1/2-inch to No. 4 Sieve). Unfortunately, studies on this material have been limited to laboratory only.

Other Applications

Surface Treatments

A surface treatment that involves a spray application of asphalt rubber followed by a layer of cover stone is called a stress absorbing membrane (SAM). Surface treatment is a very inexpensive means of providing a fresh pavement surface with good skid resistance. Sometimes the membrane is sandwiched between two layers of a pavement structure, in which case the membrane is called a stress absorbing membrane interlayer (SAMI). Perhaps the most widespread application of SAMI is as a reflective crack retarder in asphalt overlays on top of aged portland cement concrete pavements.

Asphalt rubber SAM or SAMI may be applied with minor modifications by use of conventional surface treatment equipment. However, these modifications are necessary to account for the harshness of the CRM asphalt binder and its excessive wear on the equipment and higher operating temperatures.

Finally, there other derivatives of surface treatments and spray applications which include: tack coat, fog seal, cape seal, microsurfacing, and many others.

Advantages

1. Ease of application.

2. Low cost.

Disadvantages

1. It adds no structural benefit to the pavement.

2. Heavy duty spray nozzles and pumps are required.

3. Relatively small amount of rubber is disposed in this fashion.

4. Long-term performance characteristics are unknown.

Joint and Crack Sealants

Perhaps the most unadvertised use of rubber in asphalt is in the form of products that are used for joint and crack sealing. The process for producing this materials is identical to the wet process for asphalt rubber with a typical rubber content of approximately 18%.

Advantages

1. Ease of application.

2. Low cost.

Disadvantage

1. Relatively small amount of rubber is disposed in this fashion.

2. Long-term performance characteristics are unknown.

Structural Design Issues

There is a tendency to assign a higher structural coefficient to crumb rubber modified asphalt primarily on the basis of its higher stiffness/modulus as compared to conventional hot mix asphalt. Based upon studies in California and Arizona, Van Kirk (1992) concluded that CRM asphalt overlays may be designed 30%-50% thinner than the conventional HMA overlays having the same performance. It must pointed out that Van Kirk's report reflects a limited database and the author cautions against unwarranted extrapolations.

As a result of lack of adequate information on structural behavior of CRM asphalt, state agencies are considering construction applications which would minimize exposure to traffic loads. This has led to applications in shoulders, base, and/or subbase courses. Base and subbase applications offer an added advantage of isolation from most environmental elements leading to a more durable pavement.

Construction Issues

Plant Type

The asphalt rubber technology lends itself to both spray and hot mix applications. At the same time, in the wet process and spray applications, the harsh and viscous nature of the CRM asphalt binder requires heavy duty pumps and nozzles. Both dry and wet processes may be accomplished with the currently available plant technology in Kentucky. The drum plant, however, must have an opening, away from the flame, for introduction of rubber particles. This may be easily accomplished through the opening for the recycled asphalt pavement (RAP) materials, which most drum plants in Kentucky presently have. Batch plants, on the other hand, offer a means for easier application and better quality control.

Compaction

Compaction of CRM hot mix asphalt (CRM-HMA) may be easily accomplished with conventional equipment. Some minor increase in the level of field compaction might be necessary due to the more viscus nature of CRM asphalt binder, which makes the mix somewhat harsh. Some rubber mixes containing coarse rubber particles have a tendency to exhibit "elastic rebound", which may make achieving the specified field densities more difficult.

Post Compaction Cooling Prior to Traffic

Rubber is known to increase the latent heat capacity of hot mix asphalt. Therefore, it might be necessary to provide a longer cooling time for the freshly laid asphalt pavement prior to exposure to traffic.

Environmental Issues

Although there are a number of issues raised relative to the environmental impact of the CRM technology, there is no definite and authoritative ruling on the matter. The environmental Protection Agency (EPA) has an ISTEA mandate to submit an environmental impact statement to FHWA by the mid-summer of 1993. At this point, there does not appear to be a well coordinated study underway to produce the necessary data mandated by the ISTEA; therfore, it appears that the jury will be out on this issue for some time.

There have been some limited studies in Canada (1992) and Texas (1992) on plant emissions. Generally, these studies have been inconclusive and further research is currently underway to better define the impact on plant emissions. Similarly, there are no data on the worker issue.

Potential for leachate of CRM asphalt pavements is another concern. One may hypothesize that local conditions such as soil conditions, surface runoff chemistry, and other factors which influence the pH of surface and ground water may influence the chemistry of the leachate. More data are expected to be generated by the EPA in this area.

There is a major concern for recycling potential of the asphalt pavements containing rubber. Currently, the Kentucky Transportation Cabinet does not use recycled asphalt pavement (RAP) in hot mix. Use of RAP materials by the Cabinet is almost exclusively limited to base and subbase construction. Local governmental agencies, however, use a significant amount of RAP in their hot mix projects. There is potential for state legislation to mandate more usage of RAP in a manner similar to California, where landfill disposal of milled pavement surfaces is prohibited and RAP usage is as high as 80% in hot mix recycling projects. Obviously, as more RAP containing rubber is incorporated into the hot mix, the concern for recyclability of the RAP material becomes greater. The limited experience in California, Arizona, and Canada reflects that the problem of "blue smoke" in hot mix plants may be overcome when the RAP material containing rubber is applied away from the flame. Generally, for hot recycling applications, the double barrel drum plant offers the best quality material with little or no adverse environmental impact (ASTEC 1992).

Finally, scrap tire recycling in asphalt pavements was envisioned as a major landfill relief factor. However, realistic estimates of sound asphalt applications reveal that only a small portion of waste tires may be incorporated into hot mix asphalt. Additionally, most rubber vendors would like to use clean tires in their shredding and grinding operations, which eliminates the use of tires recovered from dump sites. As a result, it is becoming more obvious that other uses of scrap tires (such as geocomposite, fill, crash cushion, carbon source in power plants. etc.) must be promoted if we are to make a significant change in the tire waste dilemma.

Other Issues

One major issue concerning the use of scrap tires is documentation of the sources of tires. This is primarily an accounting issue that vendors wishing to conduct business with the Transportation Cabinet must provide clear tire import-export equivalencies if the source of their rubber is outside Kentucky.

Finally, the Transportation Cabinet is genuinely interested in engaging in a partnering relationship with contractors on a case by case basis. This offers a unique opportunity for successful implementation of the crumb rubber technology within the time constraints of the ISTEA mandate.

Conclusions - Recommended Criteria for Selection of Potential CRM Technologies

In summary, the following criteria are recommended to be used by the Cabinet for selection of CRM asphalt projects.

Performance

It is clear from the ISTEA mandate that the CRM asphalt must meet the performance requirements of the conventional HMA applications.

Ease of Implementation

Obviously, from the implementation point of view, the Transportation Cabinet would prefer a technology which is least disruptive to current practices and costs.

Potential for Being Cost Effective in the Long Term

Although the primary thrust behind the implementation of the CRM asphalt technology in Kentucky appears to be the ISTEA mandate, this should not diminish the focus on engineering and cost aspects of the technology. Hopefully, wider availability of the technology and its associated market competition will reduce the cost of this technology. At the same time, more experience with the CRM asphalt and its performance will allow cost and performance comparisons to be based on engineering principles.

Environmental Impact

Coordination with environmental agencies is recommended. The cost of monitoring plant emissions could be as high as $10,000 to $50,000 per day. At this time, it appears advisable to await the EPA report before developing plans for monitoring asphalt plant emissions in Kentucky.

References

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Appendix

Recommended Guidelines for a SAMI Project

Submitted to the Kentucky Transportation Cabinet on December 22, 1992

Research Study KYHPR-93-150
Development of Guidelines and Performance for Asphaltic Pavements Containing Rubber

Guidelines for Application of a Double Seal Coat Using Crumb Rubber Modified Asphalt Technology

Developed by Kentucky Transportation Center - *DRAFT*

Project Specific Notes

Location: Bridge Approach, Mason County, Maysville Bridge.
Subgrade: Low CBR (approximately 2).
Other: Use crumb rubber modified asphalt for construction of a double seal coat membrane on top of the subgrade.

Recommended Construction Sequence and Materials Specifications

1. Subgrade compaction at or 2% below the optimum moisture content and tapered along the shoulders for drainage.

2. No prime coat application on the compacted subgrade.

3. Seal coat applications should include all taper areas (shoulder, etc.).

4. First seal coat application:

   a. Rapid set cationic emulsion, preferably CRS-2.
   b. Rubber modified asphalt in the emulsion with 30%-35% water.
   c. Rich spray rate of emulsion, 0.3-0.4 gallon per squared yard.
   d. Cover the emulsion surface immediately after the spray with clean #57 stone with 40%-50% surface coverage.
   e. After application of the #57 stone, cover the surface with the rubber chips. These particles (0.25-0.5 inch) shall fill the voids left on the surface of the emulsion after the #57 application.
   f. Compaction with static steel drum roller (5-7 tons). One pass, one direction coverage only. When rollers are 48-54 inches wide, three rollers in tandem, with a slight overlap, may be necessary to cover the entire echelon.

4. Second seal coat application:

    a. Rapid set cationic emulsion, preferably CRS-2.
    b. ~~Rubber modified asphalt in the emulsion with 30%-35% water.~~
    c. Rich spray rate of emulsion, 0.3-0.4 gallon per squared yard.
    d. Cover the emulsion surface immediately after the spray with clean #9-M or #8, or #11 stone with at least 80% surface coverage.
    e. Compaction with static steel drum roller (5-7 tons). One pass, one direction coverage only. When rollers are 48-54 inches wide, three rollers in tandem, with a slight overlap, may be necessary to cover the entire echelon.

<u>Special Notes</u>

1. There should be no duplicate handling of the emulsion. The emulsion should be delivered from the transport tank to the distributer tank as needed.

2. Pavement thickness design should not include a structural value for the double seal layer.

3. Pavement edge drains are recommended.

4. Subgrade instrumentation for temperature and moisture is highly recommended. This type of instrumentation will provide scientific data for reasons behind the success or failure of this project.

5. Use of Special Provision No. 99(91) dealing with partnering is highly recommended.