Asphalt-Rubber Standard Practice Guide – An Overview

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ABSTRACT. *The objective of this paper is to provide an overview of the basic information about the design and use of asphalt-rubber (AR) in the form of a manual practice guide for engineers, researchers, students, and technicians. The guide was prepared for the Rubber Pavements Association (RPA) and provides suggested best practices for the manufacture of AR, and the use of AR as a seal coat material or in hot mix asphalt and other related uses. Also, this manual will be helpful in producing a quality product to meet the needs of the designer or user of the product. AR is a mixture of hot asphalt binder and crumb rubber manufactured from scrap or waste tires. The American Society for Testing and Materials International (ASTM D-8) defines AR as follows: "AR is a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles". This ASTM standard definition was developed in the early 1990s soon after the patents ended for AR, and is a product in the public domain at present. AR is a sustainable product because of its many environmental benefits and excellent engineering performance. This is documented over a period of many years in several very successful international conferences and seminars on AR, which have endorsed and recognized AR's many attributes. Excerpts from the various research studies presented in the reports and papers from these successful conferences have been synthesized into a standard practice guide*

KEYWORDS: *asphalt rubber, practice, guide, RPA*

1. Background

AR is modified asphalt that is used worldwide. The Rubber Pavements Association (RPA) recognized the need to develop a Standard Practice Guide to assist AR users. The RPA commissioned the authors to prepare such a Standard Practice Guide. This Guide provides basic information about the design and use of AR. The information in the guide represents the Rubber Pavements Association (RPA) suggested best practices for the making of AR, and the use of AR as a seal coat material or in hot mix asphalt and other related uses. By the use of this guide, the RPA does not in any way warrant the performance of AR, but rather provides advice and suggestions that should be helpful in producing a quality product to meet the needs of the designer or user of the product.

2. Objective

The objective of this paper is to provide an overview of the basic information about the design and use of AR in the form of a manual practice guide for engineers, researchers, students, and technicians. The guide was prepared for the Rubber Pavements Association (RPA) and provides suggested best practices for the manufacture of AR, and the use of AR as a seal coat material or in hot mix asphalt and other related uses. Also, this guide will be helpful in producing a quality product to meet the needs of the designer or user of the product. AR is a mixture of hot asphalt binder and crumb rubber manufactured from scrap or waste tires. The American Society for Testing and Materials International [1] defines AR as follows: "AR is a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles". This ASTM standard definition was developed in the early 1990s soon after the patents ended for AR, and AR is a product in the public domain at present. AR is a sustainable product because of its many environmental benefits and excellent engineering performance.

3. Standard Practice Table of Contents

The Standard Practice Guide is 122 pages in length and divided into eleven chapters. The following is a list of the chapters and sub-topics of discussion. The complete Guide with Appendices is on the RPA website (www.asphaltrubber.org) and available without charge [2]. Due to the size of the Guide it is not possible to re-print it as part of this report. However, some selected parts of the Guide are presented here to hopefully stimulate persons interested in AR to use the Guide.

Chapter 1 - Brief History
Chapter 2 - Components of Asphalt-Rubber

Asphalt

Rubber

Tires, Scrap Tires and Crumb Rubber

Tires

Scrap tires and Crumb Rubber

Ambient Grinding

Cryogenic Tire Grinding

Chapter 3 - Design and Manufacture

Asphalt-rubber binder design
Apparent Viscosity
Resilience
Softening Point and Penetration
Asphalt and Asphalt Rubber Binder Characterization

Chapter 4 - Chip Seal Applications
Chapter 5 - Hot Mix Use and Design
Chapter 6 - Thickness Design
Mechanistic- Empirical Pavement Design Guide (MEPDG)
Binder Properties
Dynamic Modulus
Chapter 7 - Construction
Chapter 8 - Cost and Benefits
Chapter 9 - Performance
Chapter 10 - Environmental Benefits
Noise
Energy and CO_2
Recycling
Fumes
Tire Wear
Heat Island
Chapter 11 - Closure

4. Selected Parts of the Guide

4.1.What is Asphalt-Rubber?

Asphalt-rubber as described in the guide is a mixture of hot asphalt (bitumen) with ground tire rubber from waste tires as defined in ASTM D-8, [3], where asphalt-rubber is “a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles". In addition to this asphalt-rubber conforms to the specification requirements of ASTM Standard D 6114, [4]. Asphalt-rubber contains visible particles of scrap tire rubber, Figure 1.

Figure 1. *Asphalt-rubber with rubber particles compared to other forms of asphalt binder*

4.2.Asphalt-RubberBinder

Asphalt-rubber is made by blending and reacting hot asphalt with crumb rubber and other components or additives if specified. The asphalt is paving grade asphalt and it is heated to about 190°C (375°F). Crumb rubber at ambient temperature is added to the hot asphalt and thoroughly mixed. Other specified components or additives may also be included with the blended asphalt and rubber. Examples of such specified components and additives may include natural rubber, extender oil and anti-strip. During the heating and mixing of the asphalt and the rubber the rubber particles swell as shown in Figure 2 which changes the resultant mixture to a gel like material.

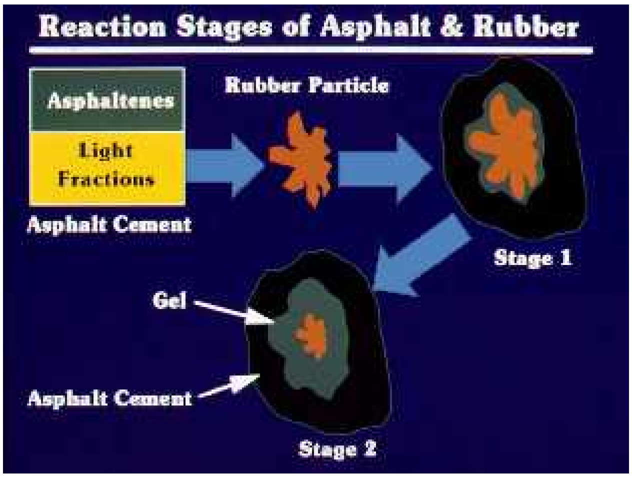

Figure 2. *Asphalt-rubber reaction/blending process*

As more rubber is added to the asphalt the apparent viscosity increases in the manner shown in Figure 3. Likewise the elastic (resilience) properties increase with increasing rubber content as shown in Figure 4. After reaction the AR mixture is kept at a temperature of about 175°C (350°F) until it is introduced into the mixing plant.

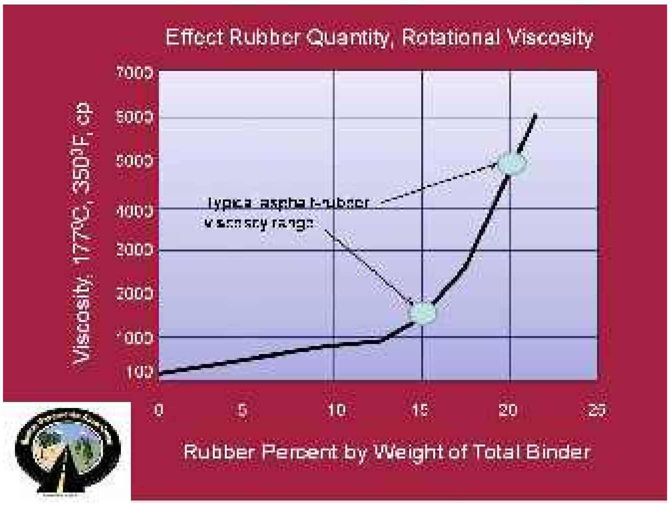

Figure 3. *Example of apparent viscosity increase with scrap tire rubber content [Chehovits, 1989]*

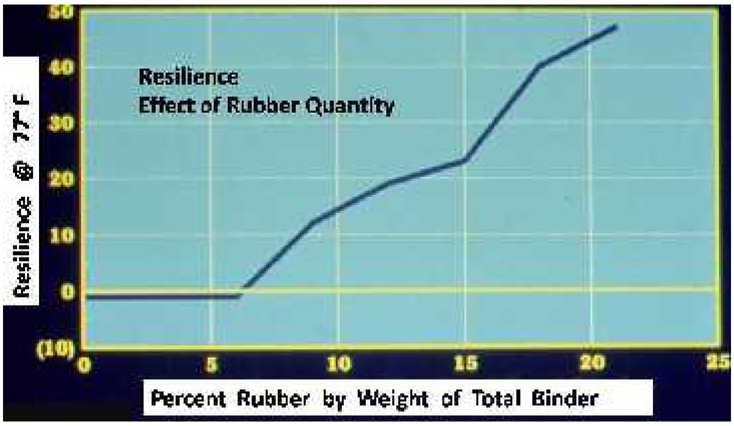

Figure 4. *Example of resilience test [Chehovits, 1989]*

4.3.Asphalt-RubberBinderUses

Asphalt-rubber can be used in a chip seal application or in a hot mix. The chip seal application involves a special distributor truck that keeps the AR properly agitated and heated and has spray nozzles that allow for the rubber particles, Figure 5. The AR chip seal coat is commonly referred to as a Stress Absorbing Membrane (SAM), and when used in conjunction with an overlay it is called a Stress Absorbing Membrane Interlayer (SAMI), Figure 6 and 7. Both the SAM and SAMI applications showed great promise in reducing reflective cracking [5].

Figure 5. *Asphalt-rubber Distributor Truck Applying Stress Absorbing Membrane (SAM)*

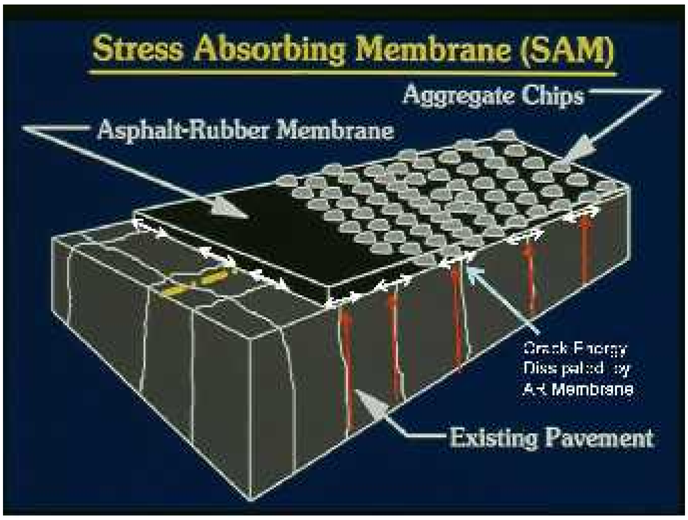

Figure 6. *Asphalt-rubber Stress Absorbing Membrane (SAM)*

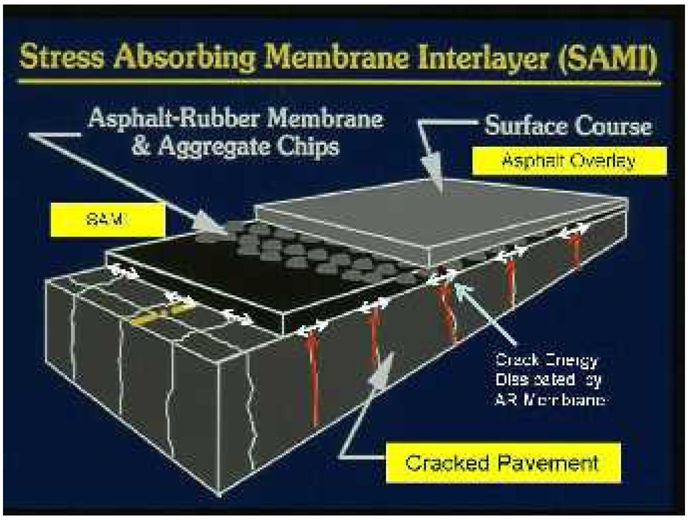

Figure 7. *Asphalt-rubber Stress Absorbing Membrane Interlayer (SAMI)*

AR is also used in hot mixes. The two AR mixes are called an AR open graded friction course (ARFC) and a gap graded AR asphaltic concrete (ARAC), Figures 8 and 9. AR mixes typically have a greater amount of binder.

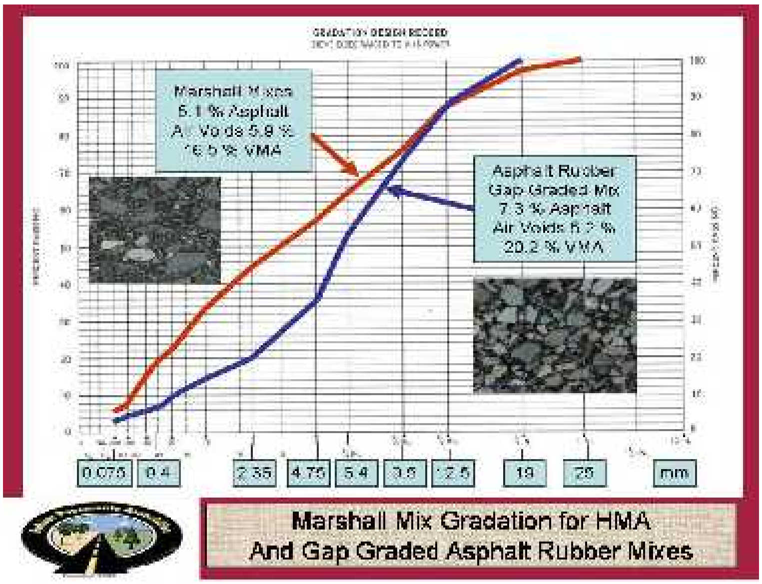

Figure 8. *Marshall Mix HMA and ARAC gradations*

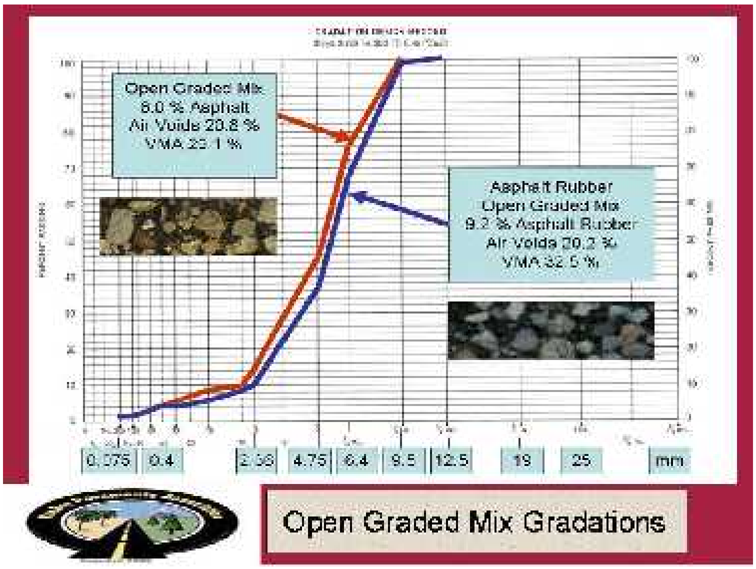

Figure 9. *Open Graded Mix and ARFC gradations*

4.4.Construction

The construction of an AR pavement involves mixing the crumb rubber with the hot asphalt as required by specification. A super sack of bagged ground tire rubber is added to the hot base asphalt via a weigh hopper at a metered rate of typically 20 percent by weight of the asphalt cement, Figures 10 and 11. After high speed mixing the resultant batch of reacted AR is heated to a temperature of about 190°C (375°F) and agitated mixing continues in a blend tank for 45 minutes to one hour, Figures 12 and 13.

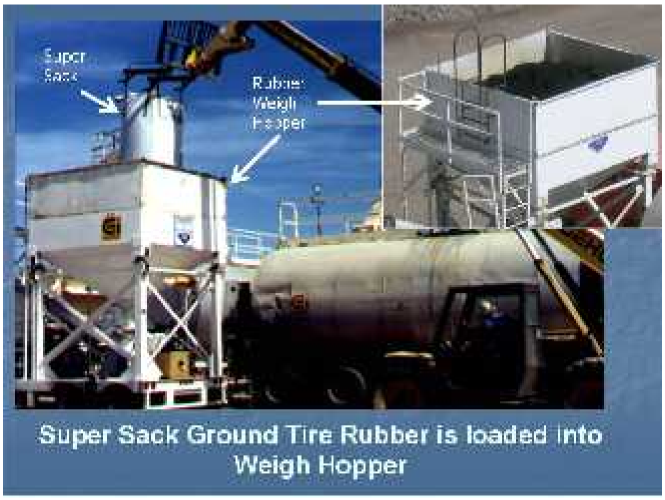

Figure 10. *Loading Ground Tire Rubber into Weigh Hopper*

Figure 11. *Example Ground Tire Rubber and Asphalt Blender Unit*

Figure 12. *Example Asphalt Blender Unit Setup*

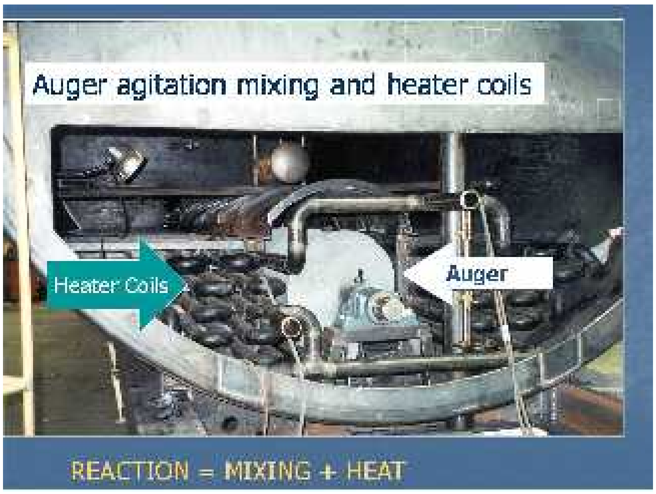

Figure 13. *Example Blend Tank with Heat and Agitation*

After reaction the AR mixture is kept at a temperature of about 177°C (350°F) until it is introduced into the mixing plant. AR is a rather unique liquid and thus some additional special pumping and flow measuring equipment is usually employed. Pumping and metering the proper amount of volume (weight) of such a high viscosity material as AR is somewhat difficult. Currently many equipment users are employing a novel pump with special heat tracing, relief valve and helical gear [6]; and a special mass flow meter [7], Figure 14 and 15. Samples of the rubber, base asphalt, and AR mixture are taken and tested for the apparent viscosity. The AR hot mix which typically has one percent lime added is placed with a conventional laydown machine and immediately rolled with a steel wheel roller, Figure 16. Only steel wheel rollers are used and rubber tire rollers should not be used. Lime water is used on rare occasions (high temperatures) to reduce pickup from tires. Generally one bag of lime is added to a water truck and sprayed on the pavement.

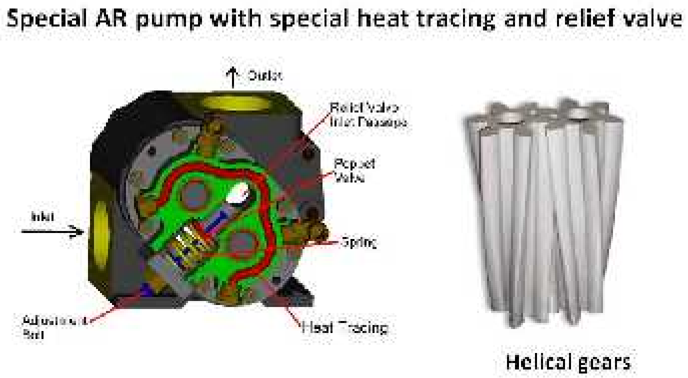

Figure 14. *Unique AR Helical Pump*

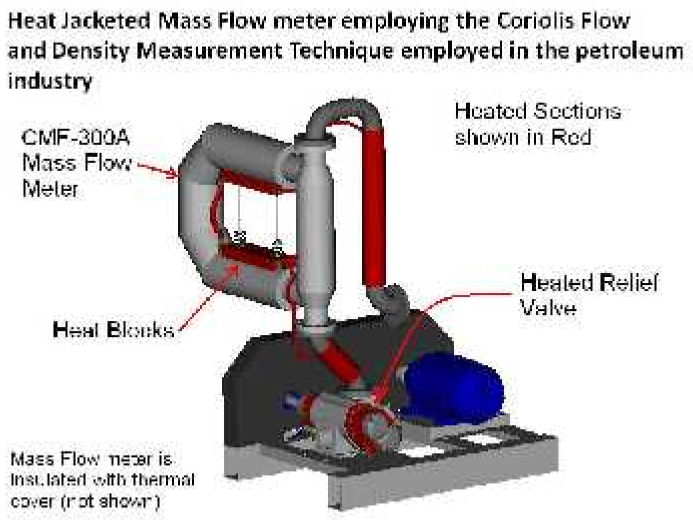

Figure 15. *Mass Flow Meter [Motion, 2011]*

Figure 16. *Example ARAC Paving with Conventional Equipment*

4.5.Asphalt-rubber Warm Mix

Warm Mix Asphalt (WMA) is a very recent technology that allows a reduction in the traditional asphalt mix production and paving temperatures. WMA has become popular because of numerous benefits including; savings in energy, expanded paving season, longer haul distances, improved workability at lower temperatures and less emissions (fumes/odors). Many states have begun to use WMA primarily for dense graded mixes. Both California and Texas have used WMA for gap graded AR mixes. California has also tried WMA with open graded AR mixes. The use of AR-WMA is very new so it is not possible to be able to recommend a standard AR-WMA technology at this time. What is known is that AR-WMA can provide the listed benefits. As an example Figure 17 shows the results of a California special study of gap graded AR-WMA [8]. The gap graded AR-WMA was mixed in either a double barrel green system, multi nozzle device that creates a foamed AR asphalt binder or an Evotherm, MeadWestvaco, emulsion process. Figure 17 shows that plant mix temperature reductions were 20 to 30°C (35 to 55°F) with a gap graded AR-WMA.

RHMA Prod/Place/Comp

	Plant Mix Temp	Mix Behind Paver	Comp. Temp.
RHMA	325 F	290 F/310 F	300 F/275 F
Astec WRHMA	270 F/290 F	250 F/270 F	270 F/230 F
Astec/Evo WRHMA	270 F	240 F/250 F	260 F/220 F

Figure 17. *AR-WMA (RHMA) temperature reduction*

4.6.Cost and Benefits

The cost of asphalt binder has gone up tremendously during 2008 as shown in Figure 18. Although the price or cost of asphalt may not vary directly with the cost or price of a barrel of oil it does track closely in the Arizona market. Given this change in the cost structure it is easy to observe that AR mixes are presently very attractive in cost when particularly examined in light of actual usage as shown in Table 1. It is indeed possible that as the cost of asphalt continues to increase that AR will become very attractive. As Figure 19 shows the trade off in cost in a practical manner is close to even at about $300.

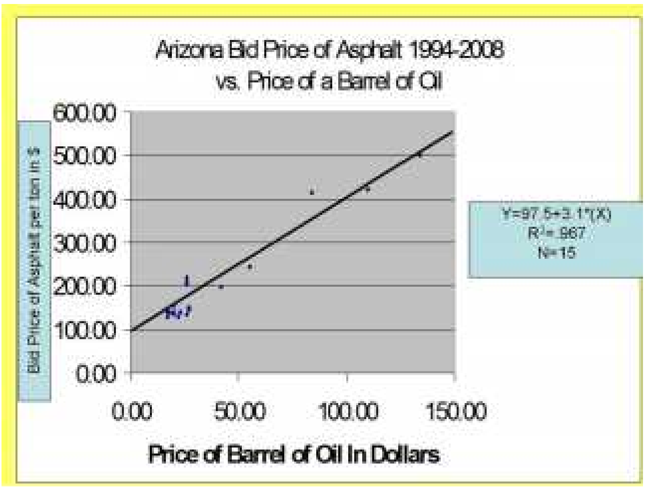

Figure 18. Comparison of *ADOT asphalt bid price to the price of a barrel of oil*

Table 1. *Total Cost (Dollars Per Sq Meter Per 25 mm thickness)*

Year	AC	ARAC	ACFC	AR-ACFC
1992	1.89	3.71	2.09	3.18
1996	1.60	2.93	1.85	2.72
1997	1.59	2.99	1.84	2.56
1998	1.61	2.38	1.86	2.02
1999	1.64	2.77	1.84	2.10
2000	1.65	2.76	1.86	2.30
2001	1.66	2.99	1.90	2.49
2002	1.67	3.00	1.92	2.50
2003	1.68	3.02	1.93	2.52
2004	1.68	3.03	1.94	2.53
2005	1.71	3.15	1.99	2.59
2008	4.66	5.42	3.72	4.05

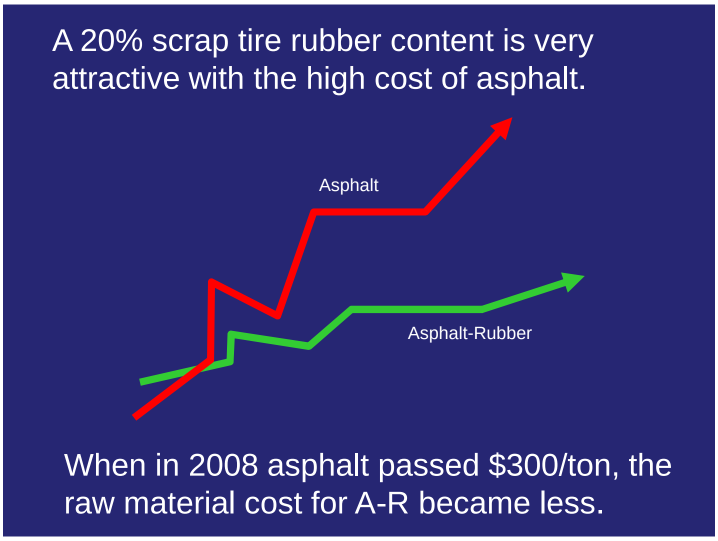

Figure 19. *Attractive tradeoff between asphalt-rubber and unmodified asphalt as asphalt price increases*

In general, objective pavement performance measurements taken over time all indicate that AR is a very good modified asphalt binder which when properly utilized can impart a great deal of durability to a surface wearing course material and improve performance, Figure 20. AR mixes can generally be placed much thinner than conventional dense mixes and thus can be cost effective. With 40 plus years of successful service and cost effectiveness AR is a viable alternate form of modified asphalt binder. In addition AR has the advantage of utilizing millions of scrap tires in an engineering beneficial and sustainable manner. Table 2 is a summary of benefits derived from using AR.

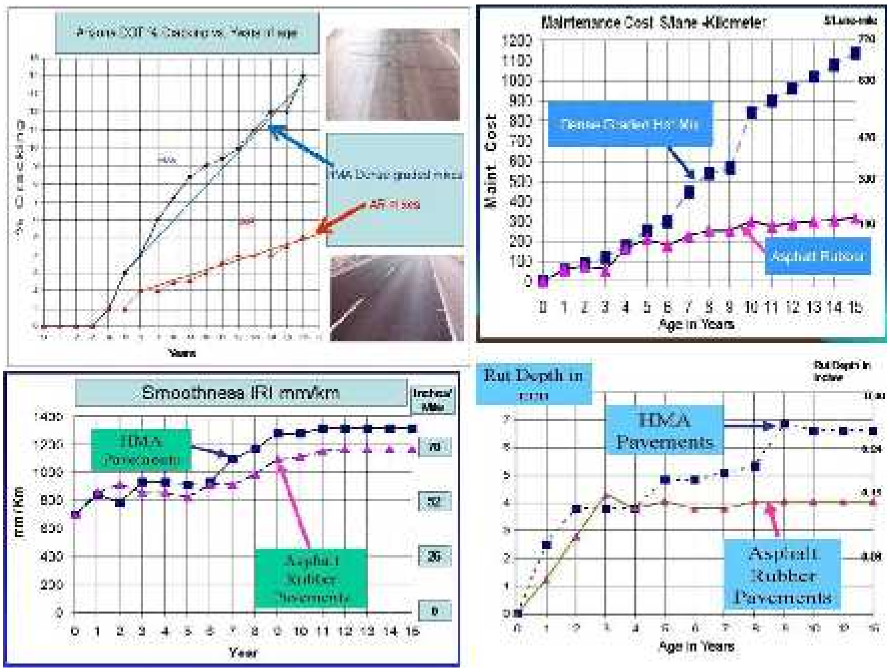

Figure 20. *Attractive tradeoff between asphalt-rubber and unmodified asphalt as asphalt price increases*

Table 2. *Asphalt-rubber benefits as a pavement surfacing material*

- Less reflective cracking, and cracking in general
- Greater durability
- Less thickness
- Less maintenance
- Less raveling
- Smooth ride
- Good rut resistance

- Good skid resistance
- Less splash and spray
- Provide a safe wet weather surface
- Good in hot and cold climates
- Less Noise
- Cost effective
- Beneficial use of scrap tires
- Recyclable
- Environmentally friendly
- Less energy consumption
- Less CO_2 produced
- Sustainable building material
- Compatible with routine construction practices
- Highly controlled material with modern computerization
- Standard specification by states and ASTM
- Warm Mix compatible

5. Conclusions

This paper presents a brief overview of the standard practice guide of asphalt-rubber which was developed for the Rubber Pavements Association (RPA). The complete Guide can be found on the RPA website (www.asphaltrubber.org) and available without charge [2]. Much has changed from the first days of the development of AR in the late 1960's to the present. The knowledge about what AR is and why it has worked so well, AR field bleeding equipment, and environmental advantages of using AR have all advanced by an enormous amount over this approximately 50 year period. The AR Standard Practice Guide provides a state of the knowledge and practice as of 2011 but even since then there have been changes and a second edition will be forthcoming in a year or two.

6. Disclaimer

The contents of this report reflect only the views of the authors. The authors do not endorse specific standards, proprietary products or manufacturers. Associations', trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

7. Bibliography

[1]American Society of Testing Materials, 2012

[2] Rubber Pavement Association, 2012

[3] ASTM D8, “Standard Terminology Relating to Materials for Roads and Pavements, American Society for Testing and Materials,” ASTM International Standards Worldwide, Volume 04.03, Road and Paving Materials; Vehicle-Pavement Systems, 2009.

[4]ASTM D6114, “Standard Specification for Asphalt-Rubber Binder, American Society for Testing and Materials,” ASTM International Standards Worldwide, Volume 04.03, Road and Paving Materials; Vehicle-Pavement Systems, 2009.

[5]Way, G. B., Prevention of Reflective Cracking Minnetonka-East, Report Number 1979GWI, Arizona Department of Transportation, August 1979.

[6]Hill, Kevin. T., "Metering Rubberized Asphalt", www.bearcatpumps.com, 2011.

[7]Motion, Micro Motion, Inc., Emerson Process Management, www.micromotion.com, www.EmersonProcess.com, ©2008.

[8]Van Kirk, Jack, “Contractor’s Perspective: RHMA Warm Mix Asphalt Project,” 2009 California Warm Mix Asphalt Conference, NCAPA - Northern California Asphalt Pavement Association, http://www.californiapavements.org/vankirk.pdf, April, 2009.