Mitigation Strategies to Avoid Asphalt-Rubber Placement & Early Traffic Related Concerns

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ABSTRACT. *Asphalt-rubber (AR) as a seal coat or stress absorbing membrane interlayer (SAMI) has been successfully used in the United States of America (USA) for over 40 years to primarily reduce reflective cracking. Furthermore, AR has been effectively used for over 20 years as an overlay surfacing to reduce the following: reflective cracking, maintenance, splash and spray, and tire/pavement interface noise. AR binder is a mixture of 80 percent hot asphalt (bitumen) and 20 percent ground scrap tire crumb rubber. AR has been used as a seal coat / SAMI, gap-graded and open-graded hot mixes for many decades in the USA and more recently in countries around the world such as Portugal, Spain, Italy, Sweden, and China to name a few. AR, like any other binder material (i.e. in any form it may be used) is subject to concerns early in the life of the pavement potentially associated with placement and early traffic related issues. For instance, a few problems could be loss of stone chips (in the case of seal coats); segregation, flushing, bleeding, raveling, moisture damage (stripping), and rutting in the mixes. This paper documents a handful of mitigation strategies to address these rather uncommon surface related anomalies. Mitigation strategies include proper care in the mix design, manufacture and placement of the pavement surfaces. Furthermore, this paper reviews examples of a few challenges associated with the placement of AR mixes, and presents practices, procedures and hints that will help prevent the rare occurrences of such premature difficulties.*

KEYWORDS: *Asphalt-rubber, mitigation strategies, premature difficulties*

1. Introduction

Asphalt-rubber (AR) is a mixture of hot asphalt (bitumen) and crumb rubber derived from waste or scrap tires. It is used extensively in the highway paving industry, particularly in the states of Arizona, California, Texas and Florida. It is a material that can be used to seal cracks and joints, be applied as a chip seal coat and added to hot mineral aggregate to make a unique asphalt paving material. The American Society of Testing and Materials (ASTM) defines AR as "a blend of asphalt cement (bitumen), 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," [1]. This definition was developed in the late 1990's along with an ASTM specification for AR, D 6114 [2]. Since the mid 1980's AR hot mix has been used as a thin overlay or wearing course (50 mm or less in thickness) to reduce reflective cracking, reduce maintenance, provide a smooth riding surface with good skid resistance and less splash and spray. More recently AR has been used in an open grade friction course to reduce the tire pavement noise. The purpose of this paper is to provide suggestions on how to design and build an AR wearing course to avoid hot mix failures.

2. History of AR

The initial development of asphalt-rubber started in the mid 1960's when Charles McDonald, then City of Phoenix, Arizona, Materials Engineer, began searching for a method of maintaining pavements that were in a failed pavement condition as a result of primarily cracking [3]. After several early trial and error field experiments by industry, and in cooperation with the City of Phoenix and the Arizona Department of Transportation (ADOT), AR was patented in the early 1970's. Soon after specialized equipment was developed to spray apply AR as a chip seal coat, Figure 1. Following many years of use of AR as a chip seal coat AR's use was expanded to hot mix. Later in the mid 1980's AR was used in two types of hot mixes commonly referred to as gap graded and open graded. The subject of this paper is the two types of AR hot mix. Note, there are several good references about the historical and present use of AR as a chip seal or as an interlayer [4,5,6].

3. AR Gap graded and open graded mixes

Given the good results with AR as a chip seal coat material and improvements in hot mix construction equipment, and AR blending equipment it seemed appropriate to experiment with the use of AR in hot mix. Early in the 1980's the City of Phoenix built several trial sections of an AR gap graded mix. At about that same time ADOT constructed trial pavement sections with an AR open graded mix.

Both of these mixes are used as overlay or wearing courses to reduce cracking and resist surface raveling. To fully utilize the unique AR properties two aggregate gradations were developed to provide for a large amount of voids in the mineral aggregate (VMA). The Gap Graded and Open Graded gradations along with their typical properties are shown in Figures 2 and 3 along with comparisons to typical hot mixes without AR.

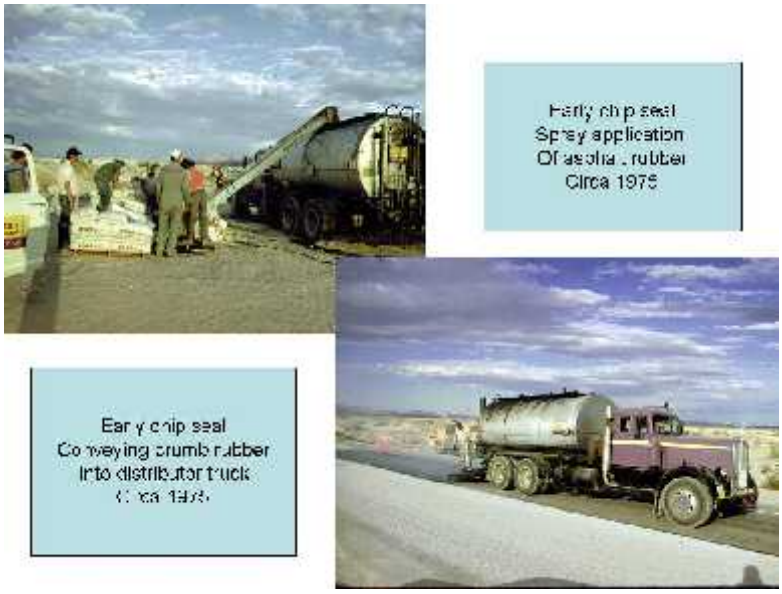

Figure 1. *Specially built equipment for AR chip seal*

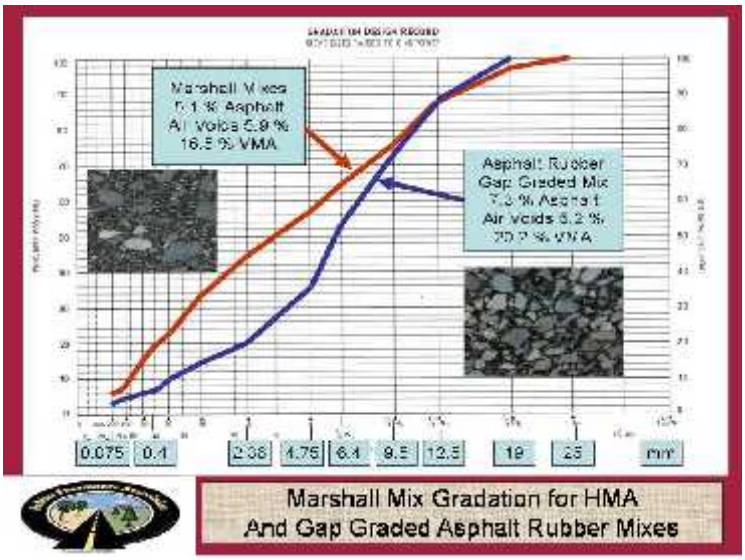

Figure 2. *Typical gradation and properties of dense graded and AR gap graded mix*

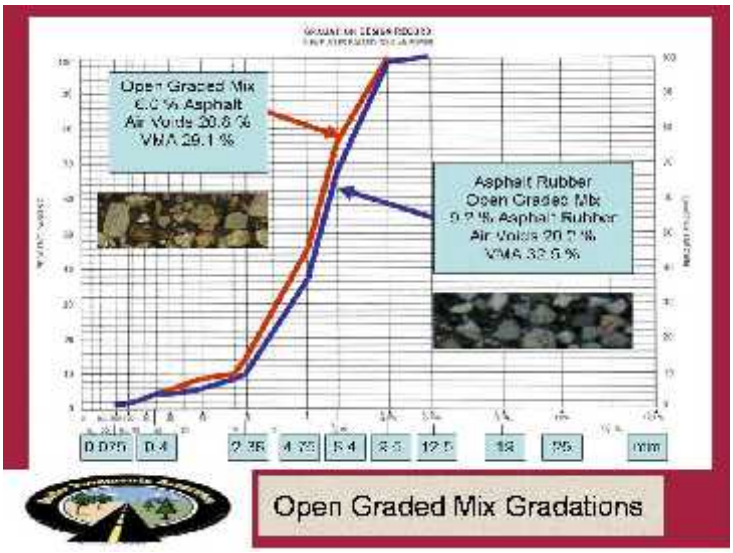

Figure 3. *Typical gradation and properties of open graded no AR and AR open graded mix*

As the figures show the AR mixes have a higher degree of VMA and a higher amount of AR binder compared to typical conventional mixes without AR. The reason for this is that the AR binder contains as much as 20 percent ground tire

rubber and thus a need for greater amount of VMA to make room for the rubber particles. Likewise the rubber when mixed with the asphalt produces a binder that has higher viscosity at hot temperatures than typical asphalt. The nature of the AR binder and AR gap graded mixes ultimately reflect upon the nature of design and construction practices to avoid failures. Much additional information about AR binder and the AR gap graded and open graded mixes can be found in the Proceedings of four AR International Conferences referred to as AR2000 held in Portugal, AR2003 in Brazil, AR2006 in Palm Springs, California and AR2009 in Nanjing, China [7,8,9,10]. From this body of information and considerable experience based on the design and construction of hundreds of projects in Arizona and other states and countries the following thoughts are offered in how to avoid AR hot mix failures.

4. Best practices of AR hot mix design

As noted earlier the AR binder should contain a minimum of 15% by weight of the total blend and conform to the requirements of ASTM D6114 as shown in Table 1.

Table 1. *Typical asphalt-rubber binder requirements*

Binder Designation Climate Zone		CRA 1 Hot Desert	CRA 2 Mild Coastal	CRA 3 Cold Snow & Ice
Grade of base asphalt PG ; Pen		PG 64-16 Pen 60/70	PG 58-22 Pen 85/110	PG 52-28 Pen 120/200
Rotational Viscosity; 177°C Spindle 3, 20 RPM, ASTMD2196	Pa·s	1.5-4.0	1.5-4.0	1.5-4.0
Penetration; 4°C, 200 g,60 sec.(ASTM D 5)	Min	10	15	25
Softening Point; (AASHTO T-53 or ASTM D 36) °C	Min	57	54	52
Resilience, 25°C ASTM D 5329 %, min.	Min	30	25	15

The aggregate requirements for both the AR gap graded and open graded are similar in nature and as follows.

Combined Bulk Specific Gravity

2.35 – 2.85 - To ensure that weak low specific gravity aggregate does not fracture during construction. To ensure that various types of high specific gravity slag aggregate is not used since it may chemically degrade.

Sand Equivalent

Minimum SE=55 - To ensure that there are not excessive amounts of clay particles on the aggregate, done on washed aggregate.

Combined Water Absorption

0-2.5 - To ensure that highly absorptive aggregate does not contribute to moisture damage and freeze thaw damage.

Crushed Faces

Minimum 95% Single Crushed Faces to insure good aggregate particle interlock.

Abrasion

Maximum at 100 rev. 9
at 500 rev. 40

To ensure that the aggregate will hold up to the wear and tear of traffic.

Percent Carbonates – for surface course only

Maximum 30%

To minimize the amount of limestone. Limestone has a tendency to polish under traffic.

Mineral Admixture

1% Lime or Cement is mandatory to help aid against moisture damage, stripping.

The AR gap grade mix design is typically a Marshall volumetric mix design with 75 blows on each face with the specimen compacted at typically 163ºC. The mix is designed for an air voids content of 4 percent or the typical dense grade air voids in the local area. Other compaction equipment such as the Hveem compactor, Superpave compactor or rolling wheel may be used. The final AR binder content generally averages about 7.3 percent by weight of the mix, albeit higher percentages are possible. The gap graded mix is placed in thickness varying from 25 mm to 75 mm. The detailed mix design procedure can be in research conducted by Stonex [11].

The AR open graded mix design procedure is described in some detail in ASTM D7064 [12]. Typically, the AR open graded mix is compacted at 163ºC. After compaction the designed mix should have a VMA of at least 18 percent. The average AR binder content is 9.2 percent by weight of the mix. Various tests are recommended to help ensure against moisture damage and freeze thaw damage as well as traffic wear and tear.

Results of the AR mix design should provide for a mix that will provide good performance over the design period which is generally 10 years or more. Of course the mix design and all attendant specifications now must be constructed and a new set of requirements must be met to ensure against premature failures and good performance.

5. Best practices of AR hot mix construction

Construction of an AR hot mix is similar to a typical hot except for two major differences namely AR binder agitation and most importantly heat management. The AR binder is prepared generally at the project construction hot plant location. The AR binder is prepared by blending hot paving asphalt of the proper grade as determined in the mix design with the proper amount of ground scrap tire rubber. The AR binder must be kept agitated until it is pumped into the hot plant. Figure 4 shows the typical AR blender located at a hot plant and the associated processing temperatures.

Figure 4. *Typical AR binder processing at the hot plant*

After blending the AR binder is kept in the AR blend tank at a temperature between 165 – 190 ºC for 45 to 60 minutes before being pumped into the hot plant. The AR binder consistency is controlled at the hot plant by testing with a hand held viscometer to ensure proper consistency which meets the design requirements, Figure 5.

Figure 5. *Typical AR binder consistency testing at 177 ºC*

The AR binder is pumped into the hot plant and placed and compacted in a manner as shown in Figure 6.

Figure 6. *Typical AR mix compaction at greater than 135 ºC*

On rare occasions something goes wrong and the best practices are not conformed to and a pavement failure occurs as shown in Figure 7.

Figure 7. *Failures associated with paving in poor weather and/or associated moisture damage*

Best construction practices are summarized as follows:

AR hot mix should not be placed during periods of cold or wet weather, or both. The existing surface shall be warm, clean, and dry while paving the mix.

Typically the minimum air temperature should be 16°C in the shade and rising and the minimum surface temperature should be 21°C in the shade and rising before starting the operation. For night time paving the air temperature should be above 16°C or in conformance with local successful paving practices.

AR mixtures placed 12.5 mm to 25 mm in thickness will cool very rapidly and thus a higher minimum air and surface temperature if possible may be advisable. Thus the specifying agency in setting the minimum air and surface temperature should consider their normal good paving practices and as a minimum the operation should not be permitted when the temperature falls below such normal agency temperature thresholds. The specifying organization may want to consider setting or designating paving seasons to ensure optimal paving conditions.

The paving operation should not be carried out in the rain, or when rain is threatening.

The open-graded mixture should be placed as the final surface course with its edges exposed to ensure free draining at the edges. If it is placed in a curb and gutter section, it should be placed above the gutter.

The open-graded mixture is not a structural pavement layer and thus should not be expected to correct obvious pavement structural defects such as potholes or weak underlying pavement or foundation support. Some caution should be exercised in placing this mix on a surface that might be permeable or a cracked surface that would allow water to enter.

Patch potholes, fill cracks, and repair damaged areas in existing pavements.

The surface to be covered should be cleaned with rotary broom or other approved means. A tack coat should be applied to the paved surface before placement of the AR hot mix. The tack coat is typically paving grade liquid asphalt applied at the rate of 0.4 L/m^2. The temperature of the AR mix during compaction should be at least 135°C. However, it is advisable that the supplier of the AR binder be consulted for the proper mixing and compaction temperature ranges to be used in the field.

Compact the AR hot mix by using self-propelled rollers, either steel wheel rollers. For the AR open graded mix the non-vibratory mode following immediately behind the laydown machine. For AR mixtures, only steel wheeled rollers should be used for compaction, due to the high probability for particle pick-up by pneumatic tired rollers. The compaction equipment and method of rolling should be selected and done in a manner that it does not fracture the aggregate or damage the mix.

It may be advisable to place a test section to determine an adequate rolling pattern (typically 2 to 3 passes) and to ensure adequate compaction.

In many jurisdictions a tack coat of paving grade asphalt is specified which is the same as the material used as the base asphalt in the production of the AR binder, i.e., PG 64-16. Applied at common application rates, this tack material can create significant issues during construction related to “track out” where the hotmix delivery truck tires pick up the tack coat and redeposit it in unwanted areas. Figure 8 shows a common occurrence of this problem.

While control of the “track out” can be problematic throughout the project, one effective strategy is to keep the area exiting the project wet with a water truck using lime water. Lime water, typically fifty pounds of hydrated lime mixed in about two thousand gallons of water, sprayed on the road tends to impede the tack coat on the truck tires from depositing on the non-paving surfaces. New “trackless” tacks are being developed that could substantially control this problem also.

Figure 8. *"Track out" caused by hotmix delivery trucks picking up tack coat on their tires at the paving site and depositing the residue on roads off the project as they leave*

6. Conclusions

Like all paving operations the successful performance depends on a myriad of things being done properly. Likewise compliance to good design and construction practices are necessary to avoid AR hot mix failures. In addition practices noted in section 5 and 6 there are other important practical considerations helpful to minimize premature failures and construct a successful project:

- Experienced Binder Designer
- Experienced Mix Designer
- Blender / Hot Plant Compatibility (Electronics)
- Appropriate AR Heat and Agitation
- On-site contractor quality control
- Tarp loads
- Shorten windrows when paving with belly dump trucks or use heated transfer devices
- Keep rollers close to laydown
- Heat management at all phases of construction from blender to laydown to compaction
- Weather forecast, avoid inclement weather
- Wind within reason
- Long range outlook on weather, not to pave before a cold front or in the rain
- Nighttime temperatures within acceptable level

- Knowledgeable agency inspection
- Common Sense

7. Acknowledgments

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