DEVELOPMENT AND CONSTRUCTION OF ASPHALT RUBBER STRESS ABSORBING MEMBRANE

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ABSTRACT

This paper first covers a brief history of the asphalt-rubber experiments and development by the Arizona Department of Transportation beginning with the first seal coat placed in 1967. It covers knowledge gained through laboratory experiments as to the reaction that occurs when variations of asphalt and rubber are combined. It reports the various uses that have been made with the asphalt rubber mixture as well as research projects currently underway.

Second, the paper emphasizes the need for strict adherence to specifications when placing the material. Emphasis is made of considerations that should be given to temperature, material handling and equipment used during placement.
INTRODUCTION

In 1967, the Arizona Highway Department authorized the first experimental project utilizing reclaimed rubber in combination with asphalt for use as a binder on chip seal coats. They felt that this type of application would prolong the life of badly deteriorated asphalt pavements. In cooperation with Charles H. McDonald and the City of Phoenix, which had previously been experimenting with this material, experimental sections were placed at several locations. These early experiments utilized either a slurry seal type of operation or application of the asphalt-rubber material with conventional distributor trucks. Construction problems encountered with these application procedures were such that the final product left a great deal to be desired. In 1968, Sahuaro Petroleum and Asphalt Company of Phoenix, Arizona became interested in the potential of this process and began work to develop equipment and procedures to overcome these problems. Their development of the distributor trucks presently being used has contributed significantly to the present day success of this type of application. As with any new product or procedure, there were many problems to be resolved and some of these early asphalt-rubber seal coats looked like disasters. In spite of the problems, and the appearance, these early experimental sections are generally performing very well today.

Seven or eight years ago, we had no idea of just what was occurring when asphalt and rubber were combined. We now know that the rubber is reacting primarily with the resin portion of the asphalt.
The rubber particles, whose size fall within the #16 and #25 sieve swell to approximately twice their original size. (See photos 1 & 2).

Using hot asphalt, this reaction takes place in a rather short period of time, thereby allowing for immediate use of the material for seal coats, crack sealants, etc. Also, instead of one mixture incorporating a specific gradation of rubber and a specific asphalt, we now have the potential of modifying the asphalt and/or the rubber to achieve the final characteristics desirable for a particular function. A research project is underway now at Arizona Department of Transportation to develop further knowledge about this reaction and how to modify it.

**BRIEF HISTORY**

In the summer of 1968, the Arizona Department of Transportation constructed an asphalt-rubber chip seal over 2-1/2 miles of frontage and access roads of the Black Canyon Freeway in Phoenix, Arizona. This experiment, placed over severely fatigue cracked pavement, was placed to evaluate this material's ability to prevent reflection of "alligator pattern" cracking.

In the spring of 1971, a thirteen mile National Experimental and Evaluation Project was constructed on I-40 east of Winslow, Arizona. Two of the test sections on this project involved the placement of asphalt-rubber as a stress absorbing membrane interlayer (SAMI) to study the potential of this material in preventing reflective cracking through overlays. One other test section utilized this material as a chip seal coat or stress absorbing membrane (SAM). This test was placed to evaluate its characteristics of providing a waterproof membrane over an area exhibiting extreme fatigue distress. (See photos 3 & 4).
Two additional full-scale projects placed by Arizona Department of Transportation need to be mentioned here as they also played an important role in the development of current specifications and application procedures.

The first of these full-scale projects consisted of six miles on U.S. 60 and six miles on State Route 71 near Aguila which were treated in July, 1972. The second project involved a ten-mile section of US 89 north of Flagstaff, Arizona treated in the summer of 1973. These two projects were chosen because their locations were in extremely different climatic conditions. Aguila is situated in the southern desert-like part of the State. (See photos 5, 6, & 7)

The project north of Flagstaff, on the other hand, was over 7200 feet in elevation with winter temperatures as low as 40 below zero. (Photos 8 & 9)

Both projects were severely "alligatored" and, therefore, excellent sites to evaluate this material's capabilities of preventing reflective cracking under two extremely different climatic conditions. Conclusions from these projects and years of work are clear. The asphalt rubber membrane when placed as an interlayer (SAMI) will control the reflection of all cracking.

As a result of the several years work and seven years experience with full-scale projects, the State Engineer recently ordered that the SAMI be incorporated on all projects where overlays of less than four inches are to be placed over badly cracked pavement. On the basis of this usage only, it is estimated that for 1975-76 fiscal year the State of Arizona will utilize approximately 19 million pounds of recycled ground tire rubber. The asphalt-rubber when placed as a seal coat (SAM) will control reflection of fatigue cracks, and is an effective alternate to a major overlay or reconstruction.
OTHER USES OF ASPHALT RUBBER

The knowledge we now have of the basic reaction between asphalt and rubber has resulted in a potential that appears unlimited. As an example, an asphalt-rubber seal was "inadvertently" carried over a structure spanning the Black Canyon Freeway in Phoenix. Subsequent testing of the Bridge Deck indicated that the seal coat provided an excellent barrier to moisture penetration. As a result of this "oversight," a bridge deck on an I-40 project east of Holbrook has received an application of an asphalt-rubber membrane to determine its waterproofing capabilities where deicing salt applications have led to reinforcement corrosion problems. This, also, has particular significance where these problems involve older structures that may not be structurally capable of handling the heavier overlays.

Also, experiments have been made to test the effectiveness of this material as a membrane to prevent moisture intrusion into the base materials to eliminate heaving of existing pavements constructed over expansive clays. As a result of this, two major construction projects on I-40 east of Holbrook, Arizona, were selected for the placement of a membrane across the entire pavement section including the shoulders in both the cut and fill sections. (See photos 10, 11, 12, and 13).

Approximately one and one-half years ago, the Arizona Department of Transportation began a research program, primarily concerned with improving methods and materials for sealing cracks in highways. To date, we have worked with cracks in both concrete and asphalt pavements. This program is centered around the same sealing material..
being used in the previously mentioned seal coats and interlayer section. We have used various grades of asphalt in our experiments and have experimented with different rubber gradations and proportions as well as various additives to the combined mixture to increase resilience, improve adhesion, and to reduce viscosity for better adaptability in sealing the narrower highway cracks. (See photos 14 thru 21).

This past year, another oil company, Arizona Refinery Company of Phoenix, Arizona, has shown an interest in this type of work and have placed several small experiments utilizing their process which differs somewhat from the specifications we are presently using. We will be watching the performance of their experiments closely for the next two years to determine the possibility of issuing bid proposals whereby either of the methods could be looked upon as equal for bidding purposes.

SPECIFICATIONS AND CONSTRUCTION

This background on the development of asphalt rubber in Arizona has been presented to emphasize the extensive experimentation that has been carried out, from which construction techniques have been developed for its application. With the exception of the asphalt distributor truck, developed by Sahuaro Petroleum and Asphalt Company, the other equipment used in the placement of this product is the same as used for conventional seal coats. The enforcement of specifications, however, is more critical for the placement of asphalt rubber than for a conventional seal coat.
The key to a successful job lies in the fact that the material is placed at relatively high temperatures. Climatic conditions are very critical and work performed during cooler temperatures must be handled differently from work done during high temperature periods. Pavement temperatures, amount of wind, etc. must be taken into consideration if a satisfactory application is to be achieved. Chip embedment must be accomplished while the mixture is hot. After the mixture has cooled, it is impossible to achieve embedment.

As an example, the air temperature might well be above the minimum requirements; however, asphalt-rubber material placed on a pavement shaded from the sun by a roadway cut section, will cool more rapidly thereby reducing the time for the setting of the chips in such an area. (See photos 22 & 23).

It is very important that the roadway to be sealed is inspected carefully and that the proper application rate of binder and cover material is determined. The field calculations of the binder application rate should be made on a hot gallon basis with no temperatures correction.

Some of our field people, during the early stages of this work, being used to making temperature corrections for payment of hot paving asphalt products, were attempting to apply temperature corrections to the hot asphalt-rubber binder. This, of course, can't be done.

While the material is placed at relatively high temperature, the elastomeric qualities of this material demands that the chips be applied immediately and rolled immediately. Unlike an emulsion type binder which seems to allow a longer period of time for rolling, chip embedment in an asphalt-rubber mixture must be made prior to cooling of the mixture. (See photo 24).
It has been theorized that this problem is due, in fact, to the early gain of elasticity in the asphalt-rubber mixture after application. If the mixture cools sufficiently before the chip is fully seated, the elasticity refuses to allow this seating. Improperly seated chips will result in stripping soon after the roadway is opened to high speed traffic.

One other point that should be mentioned here is the blotter sand which is now a part of our specifications. (See photo 25).

The sand helps set the chips and prevent chip roll-over, particularly if the sand is applied right behind the first pass of the rollers. We require two to three pounds per square yard to be applied.

Another very important specification is the use of dry chips. Wet chips are not compatible with hot asphalt and will not adhere to the asphalt-rubber membrane.

Sahuaro Petroleum and Asphalt's process includes the addition of from five to seven percent kerosene to the mixture. This kerosene acts as a chip wetting agent as well as improving the material's spraying characteristics. On projects that were constructed prior to the use of kerosene, it was almost impossible to get a uniform distribution through the spray bar and the cover material would not embed in the mixture because a film would form quickly on the mixture and the asphalt-rubber would not adhere to the chip.

Stripping, of course, can also be caused by too light an application of binder, and sections missed by the rollers, particularly on the first pass. (See photo 26).
Some state inspectors, being used to the lighter application rates of conventional emulsified asphalt binders, have made the mistake of directing the contractor to reduce the specified rate of application of asphalt-rubber material. They were possibly thinking of saving the State money or concerned with bleeding, or that it just wasn't necessary. This just isn't true. Specified application rates of .55 to .60 gsy have been changed downward to as little as .33 gsy. Considerable stripping was noted in these areas. The application rates that are specified are not only necessary for chip retention but are also necessary to provide a membrane thickness that will prevent reflective cracking. (See photo 27).

If stripping does become evident soon after the completion of an asphalt-rubber seal coat, an application of a light emulsion flush can be used to stop this condition. Also, chips are not fully embedded from compaction effort and require traffic for full embedment. This is true on all seal coats, but because of the elastic nature of asphalt rubber, it is more so on this process. Those areas such as left turn bays, distress lanes, etc., that only receive light traffic also have a tendency to strip. This again can be prevented by a light flush of emulsified asphalt.

Our specifications require a four-inch lap between all longitudinal joints. A more desirable butt joint has been found to be almost impossible to place accurately, especially on curves. On a conventional seal coat, the edge of the previous pass is broomed back a couple of inches. The next binder application is then lapped over this broomed area. Because of the tenacious nature of the asphalt rubber material, the chips embedded in the binder along this edge can't be broomed back.
Brooming of the loose chips along this edge is, of course, necessary prior to placement of an adjacent pass. The lap joints have been found to eliminate the skips without detrimental effects. (See photo 28).

Faulty equipment is another problem area to be watched. An example is a chip spreader with "grabbing" brakes. (See photos 29 & 30).

As the brakes lock, the wheels shove chips and binder ahead into a lumpy mess leaving a hole in the membrane, a spot in a seal coat to be patched or a rich spot of mixture to be picked up on roller tires creating a compound problem. Another problem with equipment is breakdown. The entire operation should be halted immediately in the event of equipment breakdown - that is, with the exception of the rollers which should continue to operate until the required four passes we specify have been made. Usually, three rollers are a minimum required on one of these projects. Depending on the width of spray being applied, two of the rollers should follow "immediately" behind the chip spreader with the third roller working behind, blanketing the spread for the remaining required passes.

Direct contact between the tires and the asphalt-rubber mixture can destroy the effect of a membrane or seal coat as illustrated in Photo 31.

Some contractors have used a pickup truck loaded with chips immediately behind the spreader box placing chips on any rich spots before they are rolled. This problem is sometimes caused by a piece of oversized aggregate getting through a screen and lodging at the bottom of the chip spreader thereby disrupting the proper flow of chips to the roadway. Another problem that can occur, if for some reason there is a delay in the time material remains in a distributor truck, is what they refer to as "roping" of the mixture. (See photo 32).
This condition can also be caused by an attempt to apply the material at too low a temperature or improper mixing of the ingredients. If this should occur, the operation should be stopped and the material rejected.

CONCLUSIONS

The first thing we have learned from these experiences, is that this type of seal should be used only where it will function properly and at a cost equal to or lower than other adequate solutions. Often a new product is offered which has many good attributes. Engineers, being basically conservative, and in our case, guardians of public funds, are hesitant to use these products without being reasonably sure of success. If tests prove successful, we sometimes think we have found the answer to all our prayers and use the product in areas where it does not function properly. We then conclude that the product is worthless, while, in fact, it may be a great asset when used properly. This is true in the case of the asphalt-rubber seal coat.

An asphalt-rubber chip seal, properly applied, is a good product and a very useful maintenance tool. This seal provides no additional structural strength. The life of pavements which have failed due to elastic deformation can definitely be extended by this seal as an alternative to more costly reconstruction. If there is failure due to elastic deformation, the pavement life can be extended by the seal as it holds the surface together during flexure and seals out moisture. Asphalt rubber applied as a seal coat (SAM) will greatly reduce or eliminate the reflection of fatigue type cracking, but is still subject to reflection of thermal or shrinkage type of cracking. However, these reflected cracks are narrow and do not spall. If the roadway is rough,
or consists of potholes, it must be preleveled and patched. The asphalt-rubber membrane when applied as a membrane interlayer (SAMI) will virtually eliminate the reflection of all cracking.

After considering the cost of the preliminary work and the seal coat itself, we should project the life expectancy and prorate the costs. If these costs appear excessive in comparison to normal maintenance costs or other means of rehabilitation, alternative solutions should be investigated.

The major problem that we have had to overcome for the successful placement of asphalt-rubber has been human, and specification enforcement. I am sure you have noticed, there are no exotic formulas or methods, simply strict adherence to the specifications.

I believe that asphalt rubber is an extremely useful maintenance tool, and if properly applied can assist the highway engineer in controlling cracks and extending the life of thin overlays.
Photo 1 - Unreacted rubber particle
Magnification 75 x 1 Division = .0005 inch

Photo 2 - Rubber particle - reacted with extender oil
(Dutrex 739 @ 250° F. for 4 hours.)
Photo 3 - Taken in March, 1972 prior to any work being accomplished. Indicates approximately 25% cracking.

Photo 4 - Taken in March, 1975, several years after overlay was placed. Overlay consists of 1-1/4 inch of Asphaltic Concrete with SMI (0.55 gals/sq.yd.) on top of AC covered with 1/2 inch of Asphaltic Concrete Friction Course. Indicates 2% reflected cracking.

Photo 6 - Aguila (before) - Typical pavement condition
Photo 7 - Aguila (after) Note crack pattern (obvious)
Photo 9 - US 89 Close up.

Photo 10 - Asphalt-rubber applied to the shoulder area, the motor grader is placing 6 inches of fill material to protect the membrane.
Photo 11 - Asphalt-rubber applied to the shoulder area. The motor grader is placing 6 inches of fill material to protect the membrane.

Photo 12 - Arrangement of the spray bars on the asphalt distributor that placed the membrane on the shoulders. A regular spray bar was used to place the membrane on the existing pavement.
Photo 13 - Arrangement of the spray bars on the asphalt distributor that placed the membrane on the shoulders. A regular spray bar was used to place the membrane on the existing pavement.

Photo 14 - I-19 south of Tucson. Spalling of a construction joint.
Photo 15 - I-19 south of Tucson - Sealing spalled construction joints with Asphalt-Rubber.

Photo 16 - I-19 south of Tucson - spalled joint sealed with Asphalt-Rubber.
Photo 17 - Tennant Routing Machine.

Photo 18 - Tennant machine routing Portland Cement concrete pavement joint.
Photo 19 - Random crack routed with a Tennant machine.

Photo 20 - Crack next to PCCP routed with Tennant machine.
Photo 21 - Placing Asphalt-Rubber in joint between PCCP and Asphalitic Concrete distress lane.

Photo 22 - Illustration of the need to consider variations in pavement temperatures during the placement of Asphalt-Rubber, particularly during cooler weather.
Photo 23 - Illustration of the need to consider variations in pavement temperatures during the placement of Asphalt-Rubber, particularly during cooler weather.

Photo 24 - Taken the morning after placement. Shows pock marks in the Asphalt-Rubber membrane where chips were applied too late for proper seating.
Photo 25 - Taken February 21, 1973. Illustrates the benefit of blotter sand. This entire roadway was treated with an Asphalt-Rubber lightweight aggregate (expanded clay shale), chip seal coat in July, 1972. The outside passes were sanded. The two center passes were not.

Photo 26 - Notice the area through the center of the picture where no rolling allowed the chips to strip soon after placement.
Photo 27 - Shows how an Asphalt-Rubber chip seal (lower portion) has prevented crack reflection after 3 years of service on a street in the City of Phoenix carrying 6,000 v.p.d.

Photo 28 - Shows the skips that can occur when a butt joint is used. The lab joint now being used eliminates these skips and eventually irons out under traffic and presents no problem.
Photo 29 - An example of problems created by faulty equipment.

Photo 30 - Another example of grabbing brakes on a chip spreader. Also, the chip spreader should be moving along immediately behind the distributor truck. This is an example of poor coordination between project personnel.
Photo 31 - Illustrates the problems that can occur when roller tires come in contact with binder material.

Photo 32 - An example of "roping" conditions could be caused by material being too cool, improper mixing of the ingredients, or "getting" of the mixture.
APPENDIX

STRESS ABSORBING MEMBRANE
STRESS-ABSORBING MEMBRANE (Interlayer):

Construction Materials:

Asphalt-Rubber Material:

Asphalt shall conform to the requirements of Table 705-1 of the Supplemental Specifications for Asphalt Cement AR-1000, except that the absolute viscosity of the aged residue, AASHTO T-240, shall not exceed 1700 poises when tested in accordance with the requirements of AASHTO T-202.

The granulated rubber shall meet the following requirements:

<table>
<thead>
<tr>
<th>Passing Sieve</th>
<th>Percent</th>
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<tbody>
<tr>
<td>No. 10</td>
<td>100</td>
</tr>
<tr>
<td>No. 16</td>
<td>90-100</td>
</tr>
<tr>
<td>No. 25</td>
<td>5-40</td>
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<tr>
<td>No. 40</td>
<td>0-5</td>
</tr>
</tbody>
</table>

The sieves shall comply with the requirements of AASHTO-92.

The specific gravity of the material shall be 1.15±0.02 and shall be free of fabric, wire or other contaminating materials, except that up to four percent of calcium carbonate may be included to prevent the particles from sticking together.

Cover Material:

Cover material may be obtained from any source provided that the material meets the requirements of the Specifications.

Cover material shall be produced from any material other than limestone, sandstone or synthetic materials. The aggregate shall be relatively free from clay balls, clay coating, organic matter or foreign substances.

Cover material shall conform to the requirements of Table 704-1 for Type CM-11, except that the maximum percentage of wear at 100 revolutions shall be nine percent and the bulk specific gravity shall be a maximum of 2.9 as determined in accordance with the requirements of AASHTO T-85.
The contractor shall submit a minimum 75 pound sample of cover material to the engineer at least ten calendar days prior to the application of cover material for testing.

The specific gravity of cover material varies from one source to another. As an example, aggregate from the Salt River weighs approximately 86.5 pounds per cubic foot loose and has a specific gravity of approximately 2.63, while aggregate from West Sunset Mountain near Winslow weighs approximately 63.2 pounds per cubic foot loose and has a specific gravity of approximately 2.05.

The rate of application shall be only the amount deemed necessary by the engineer to protect the membrane from construction equipment required for the placement of the asphaltic concrete. If traffic is carried over the membrane prior to the placement of the asphaltic concrete, it will be necessary to increase the rate of application to maintain the integrity of the stress-absorbing membrane.

Cover material (Type CM-11) will be measured by the ton. Payment for this work will be made at the contract unit price per ton for ITEM 4040120 - COVER MATERIAL (Type CM-11), which price shall be full compensation for the item complete, including rolling and brooming, as hereinafter described and specified.

The Bidding Schedule reflects a quantity based on one application as herein after specified; however, no adjustment in the contract unit price will be made because of an increase or decrease in the quantity utilized to complete the work under this item, as provided for in subsection 109.03.

Construction Details:

Mixing Asphalt-Rubber Material:

The proportions of the asphalt and the granulated rubber, by weight, shall be 75 percent ±2 percent asphalt and 25 percent ±2 percent granulated rubber.

All equipment utilized in the mixing and application of the asphalt-rubber material shall meet the requirements for equipment specified for the placement of asphalt materials as called for in the Standard Specifications.
The method and equipment for combining the asphalt and rubber shall be so designed and accessible that the engineer can readily determine the percentage, by weight, of each of the two materials being incorporated into the mixture.

The materials shall be combined as rapidly as possible for such a time and at such a temperature that the consistency of the mix approaches that of a semifluid material. The temperature of the asphalt shall be between 350 degrees F. and 450 degrees F.

After the full reaction described has occurred, the mix shall be cut back with Kerosene. The maximum amount of Kerosene used shall not exceed 7 1/2 percent, by volume, of the hot asphalt-rubber composition as required for adjusting the viscosity for spraying or better "wetting" of the cover material.

The Kerosene shall have a boiling point of not less than 350 degrees F. and the temperature of the hot asphalt-rubber shall not exceed 350 degrees F. at the time of adding the Kerosene.

Application of the Asphalt-Rubber Stress-Absorbing Membrane:

The existing pavement shall be cleaned in accordance with the requirements of subsection 404-3.01 of the Standard Specifications.

After cleaning and prior to the application of the membrane seal, the existing pavement surface shall be treated with a tack coat as hereinbefore specified under ITEM 4011142 - LIQUID ASPHALT (For Tack Coat) (Grade RC-250 or MC-250).

Placement of the asphalt rubber stress-absorbing membrane shall be made only under the following conditions:

(1) The ambient air temperature is above 50 degrees F.,

(2) The pavement is absolutely dry, and

(3) The wind conditions are such that a satisfactory membrane can be achieved.

The distributor shall be capable of spreading the asphalt-rubber mixture in accordance with the tolerances called for in subsection 401-3.02 of the Standard Specifications, except that the maximum deviation from the specified rate shall not exceed 0.06 of a gallon per square yard.
After reaching the proper consistency, application of the material shall proceed immediately and in no case shall the material be held at a temperature over 330 degrees F. for more than one hour after reaching the proper consistency.

The hot asphalt-rubber mixture shall be applied at a minimum rate of 0.60 of a gallon per square yard (based on 7 1/2 pounds per hot gallon).

All transverse joints shall be made by placing building paper over the end of the previous application, and the joining application shall start on the building paper. Once the application process has progressed beyond the paper, the paper shall be disposed of as directed by the engineer.

All longitudinal joints shall be lapped approximately four inches.

Application of Cover Material:

Cover material shall be applied in accordance with the requirements of Section 404 of the Supplemental Specifications at a rate specified by the engineer.

At the time of application to the roadway, cover material shall be at least as dry as material dried in accordance with the Requirements of Section 4.2 of AASHTO T-85.

Rolling:

At least three pneumatic rollers conforming to the requirements of subsection 406-3.05(F)(2), of the Standard Specifications shall be provided to accomplish the required rolling. At some locations or where production rates require, fewer rollers may be utilized as directed by the engineer.

Sufficient rollers shall be furnished to cover the width of the spread with one pass. It is imperative that the first pass be made immediately behind the spreader and if the spreading is stopped for any reason, the spreader shall be moved ahead so that all cover material spread may be immediately rolled. The rolling shall continue until four complete coverages have been made. Final rolling shall be completed within two hours after the application of the cover material.
Removing Loose Cover Material:

The power broom used in removing loose cover material shall be a rotary sweeper type.

Excess loose cover material should be removed prior to placement of the asphaltic concrete. Care should be taken to maintain the broom pressure so that only the loose material will be removed and there will be a minimum dislodgement of imbedded cover material.

Method of Measurement and Basis of Payment:

The Asphalt-Rubber will be measured and paid for per ton of the mixture under ITEM 4010721 - ASPHALT CEMENT (For Membrane Seal) (Grade AR-1000) (Rubberized), in accordance with Section 401 of the Specifications and including asphalt, granulated rubber and Kerosene.

The Cover Material will be measured and paid for under ITEM 4040120 - COVER MATERIAL (Type CM-11), as hereinbefore specified.