THE USE OF ASPHALT–RUBBER PRODUCTS IN MINNESOTA

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# Table of Contents

INTRODUCTION .............................................. 1  

STRESS ABSORBING MEMBRANES ...................................... 1  
  
  - SAM Project One–T.H 63 near Rochester. .......................... 1  
  - SAM Project Two–Xerxes Avenue in Minneapolis .................. 2  
  - SUMMARY, STRESS ABSORBING MEMBRANES .................... 2  

STRESS ABSORBING MEMBRANE INTERLAYERS ...................... 3  
  
  - SAMI Project One–T.H. 63 near Rochester ........................ 3  
  - SAMI PROJECT TWO–T.H. 10 from Hawley to Detroit Lakes ....... 4  
  - SAMI Project Three–T.H. 19 from T.H. 68 to Redwood Falls .... 5  
  - SUMMARY, STRESS ABSORBING MEMBRANE INTERLAYERS .......... 6  

DENSE GRADED ASPHALT–RUBBER CONCRETE .................... 6  

PLUS–RIDE (TM) .............................................. 7  

REPORT CONCLUSIONS: ........................................ 7  

DISCUSSION .................................................. 8  

REFERENCES .................................................. 10  

APPENDIX ................................................... 11
INTRODUCTION

This report is a compilation of completed and soon to be completed asphalt rubber studies undertaken by the Minnesota Department of Transportation (MN/DOT). The goals of each study vary with the manner in which the asphalt–rubber was utilized. Asphalt–rubber has been utilized in hopes of limiting reflective cracking by means of a stress absorbing membrane or a stress absorbing membrane interlayer. Using asphalt–rubber in a dense graded bituminous mixture was also attempted with the intent to limit reflective cracking while also resisting stripping due to greater film thickness on the aggregate and greater impermeability to water. The Plus–Ride(TM) system of using granular rubber and a gap graded aggregate in a plant–mixed bituminous surface was employed in hopes of creating a self–deicing pavement. The results from these test projects vary from site to site but overall the Department remains cautiously optimistic that asphalt–rubber can be an effective tool in pavement maintenance and reconstruction.

STRESS ABSORBING MEMBRANES

A stress absorbing membrane (SAM) is a chip sealcoat consisting of an asphalt rubber tack coat with a cover aggregate. The asphalt rubber is said to provide better aggregate retention while flexing with the stresses from the underlying pavement and thus limit cracking. Two such projects have been constructed in Minnesota, one on T.H. 63 near the city of Rochester and a second on Xerxes Avenue in the city of Minneapolis.

SAM Project One — T.H. 63 near Rochester.

This SAM test section was constructed in the spring of 1979 as part of a project to evaluate a number of ideas to limit reflective cracks. Other types of construction included were asphalt–rubber stress absorbing membrane interlayers, full coverage paving fabric, carbon black asphalt additive, sulfur–extended asphalt, and three different penetration grades of asphalt cement (85/100, 120/150, 200/300). A final report on this project is available (1).

The inplace structure was a 25 year old, 3 inch thick plant mixed bituminous surface which was badly cracked throughout. The base consisted of 6 inches of crushed rock on 12 inches of select granular; the soil in the area is sand to plastic sandy–loam. Traffic at the time of construction was 8000 ADT.

The typical or “control” treatment for this area was a 1 inch MN/DOT specification 2331 levelling course followed by a plant–mixed 3/4 inch 2361 spec. (high type, 100% crushed, 3/8” minus) wearing surface. The 1 inch levelling was also applied prior to the application of the SAM. The asphalt–rubber for this project, formulated by Sahuaro Inc. of Phoenix, Arizona, consisted of 75% 120/150 pen asphalt and 25% crumb rubber plus extender oil. The asphalt–rubber was applied at a the specified rate of 0.55 gal/sq yd. The aggregate employed was a single size 1/2” minus crushed New Ulm quartzite chip. (MN/DOT spec 3127, FA–4; see appendix for gradation). The aggregate was pre–coated with 0.5% by weight 120/150 pen AC and spread at a rate of 42 lbs/sq yd.

Evaluation of these sections consisted primarily of friction measurements and crack counts. MN/DOT utilizes the Locked–wheel Pavement Friction Test (ASTM E–274) at 40 mph to determine friction numbers. Both the control and the SAM section exhibited acceptable friction numbers throughout the seven year evaluation period, with the control section yielding slightly higher results. Both sections showed similar amounts of cracking. “The Asphalt–Rubber seal coat is performing effectively as a wearing course when compared to the adjacent 2361 wearing course”(1). At this time the SAM is providing a somewhat better surface than the standard wear mixture.
Unit cost for the two treatments, based on 1978 prices with asphalt costing $65.00 per ton, were as follows:

1. Stress Absorbing Membrane $1.48 per square yard
2. Control (3/4" 2361 *) $0.94 per square yard

* Minimum thickness of 2361 wear course has since been changed to 1 inch.

SAM Project Two—Xerxes Avenue in Minneapolis

This project was undertaken by Hennepin County in September of 1985 with some direction and input from MN/DOT personnel. This roadway is an urban section with curb and gutter which had a non-uniform surface due to cracking and patching. A section using standard Minnesota seal coat methods was constructed as part of this project. The standard seal coat consisted of a coat of CRS-2 emulsion applied at a rate of 0.26 gal/sq yd covered with a 1/2" minus single sized crushed granite cover aggregate (MN/DOT spec 3127, FA-3 see appendix for gradation) spread at 0.25 lbs/sq yd.

Crafco International Surfacing Inc. of Chandler, Arizona was the asphalt-rubber supplier with the County providing all other equipment, manpower and materials. This project was part of a circuit of a number of states in which Crafco intended to construct pilot projects. In this regard, there was a set time frame for their forces to set up, construct the section and move on. Unfortunately this limited time frame included several rainy days which led to using aggregate with a high percentage of moisture. Two sections using the asphalt rubber binder and the same aggregate as the emulsion sealcoat were constructed. The asphalt-rubber binder was applied at a rate of 0.55 gal/sq yd and the chips at 42.5 lbs/sq yd on the first section. The second section included asphalt rubber at a rate of 0.40 gal/sq yd and chips at a rate of 31 lbs/sq yd.

Both asphalt-rubber sections suffered extensive loss of aggregate. Too much rock dust on the chips and too high moisture content have been identified as the likely causes for the failure. The CRS-2 emulsion section performed satisfactorily. Lock-wheeled friction tests were run at 30 mph one month after construction. All sections yielded acceptable friction number results with the emulsion sections being somewhat higher. The surfaces were evaluated using the procedure in NCHRP 10-9 “Bituminous Pavement Seal Coat Programming Procedures and Guidelines, Surface Condition Rating System.” (6) The ratings reflect a slight rating increase in the surface characteristics for the emulsion sealed areas and also denote the failure of the asphalt-rubber sections. The unit cost for the asphalt-rubber for this project was $2.31/gal; other unit costs were not readily available since all other materials and equipment were supplied in-house by the County.

SUMMARY, STRESS ABSORBING MEMBRANES

Of the two projects constructed, one can be considered a success, the other a failure. The difference between failure and success appears to have been the aggregate. A resilient surface comparable to a hot-mix wear course was the result when a precoated chip was used. If the wet aggregate used on the Xerxes Avenue project had been precoated the degradation which occurred may have been avoided. The cost for precoating, 1978 prices, was $0.01 per square yard.

This information seems to lead to a strong argument for precoating chips for stress absorbing membranes. It should also be recalled that the weather coupled with the limited time frame allowed for construction led to the use of the questionable aggregate. These types of problems escalate the general uneasiness of specifying construction methods which can be furnished only by suppliers from outside of the state.

It appears that, when properly placed, there is a niche for stress absorbing membranes somewhere between a hot-mix overlay and an emulsion chip seal. While used in limited amounts on rural roads by the Department of Transportation, emulsion seals are prevalent at the municipal and county level. Many of these seal
coats are being placed on sections where traffic may require a more resilient surface such as the one demonstrated on T.H. 63 near Rochester.

**STRESS ABSORBING MEMBRANE INTERLAYERS**

A stress absorbing membrane interlayer (SAMI) is a stress absorbing membrane which is overlayed with bituminous. The intent is to reduce reflective cracking by cushioning or dissipating the stresses from the underlying pavement before they are transferred to the new overlay. A total of eight interlayer test sections on three projects have been placed over bituminous and Portland cement concrete and covered with a variety of overlay schemes. While none of the sections eliminated reflective cracking, most have exhibited a reduction in cracking vs. control sections placed on the same project.

**SAMI Project One—T.H. 63 near Rochester**

As was previously mentioned this project was constructed in hopes of evaluating several reflective crack reduction strategies. A more complete discussion of the project and inplace structure can be found under SAMI Project One.

The same formula of asphalt—rubber used on the SAMI section of this project was employed on the SAMIs. The cross—sections constructed are shown below.

![Figure 1. T.H. 63 Test Sections](image)

Application rates for the SAMI materials were; 0.55 gal/sq yd of asphalt—rubber and 44 lb/sq yd of crushed limestone. (MN/DOT spec 3127, FA—5) The interlayer appeared to be quite tender during construction and some damage was caused by the paver as the wearing course was placed.

The amount of cracking on the test sections was documented during the study. The study found that "the asphalt—rubber interlayer's (SAMI's) were somewhat effective in reducing reflective cracking. The test section with one and one-half inch wearing course over the SAMI was somewhat more effective than the test section with three—quarters inch wearing surface." (1)

The costs for the project were as follows;

1. Interlayer with 3/4” 2331 wear course $2.30 per square yard
2. Interlayer with 1.5” 2361 wear course $2.22 per square yard
3. Control, 3/4” 2361 wear course $0.94 per square yard
4. Control, 1.5” 2331 wear course $0.86 per square yard
SAMI Project Two—T.H. 10 from Hawley to Detroit Lakes

This project contained several strategies for reflective crack reduction in bituminous overlays on Portland cement concrete (PCC). Along with the SAMI, sections entailing sawing relief joints into the 39'4" panels, full coverage fabric and strip fabric placed on the joints were tested. The existing 8 inch thick PCC pavement was 22 years old and exhibiting severe “D” cracking. The typical overlay cross-section, constructed in 1980, is shown below.

The stress absorbing membrane interlayer was placed at three different depths in the overlay: directly on the inplace concrete, on the first inch of the bituminous overlay and after the first three inches of hot mix had been placed. In all cases the SAMI consisted of an application of 0.60 gal/sq yd asphalt-rubber and 20–35 lbs/sq yd crushed rock. Two minor problems were experienced during construction. The first entailed the loss of aggregate from the construction traffic and pickup of the asphalt-rubber. This was easily dealt with by spreading small amounts of hot mix on the effected areas. Too heavy of an application of asphalt rubber in a limited area (175 ft in length) created the second problem. When the overlay was placed on this area instability developed. The overlay and SAMI was removed from this area and replaced, excluding the SAMI. Careful application of the asphalt–rubber alleviated this problem.

The evaluation of this project consisted of monitoring the amount of transverse cracks. The number of cracks per mile was assessed with partial (1/4, 1/2, 3/4, etc.) combined to provide a single unit of measure; full–width transverse cracks.

<table>
<thead>
<tr>
<th>TYPES OF CONSTRUCTION</th>
<th>NUMBER OF CRACKS/MILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMI over 1” bituminous overlay</td>
<td>90</td>
</tr>
<tr>
<td>SAMI over existing PCC</td>
<td>91</td>
</tr>
<tr>
<td>5 saw cuts/panel</td>
<td>123</td>
</tr>
<tr>
<td>Control section—No saw cuts</td>
<td>125</td>
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<tr>
<td>SAMI over 3” of bituminous</td>
<td>126</td>
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<tr>
<td>Petromat over 3” of bituminous overlay</td>
<td>130</td>
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<tr>
<td>Control section—2 saw cuts/panel</td>
<td>132</td>
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<tr>
<td>Petromat over 1” of bituminous overlay</td>
<td>133</td>
</tr>
<tr>
<td>Strip fabric over existing PCC pavement</td>
<td>171</td>
</tr>
</tbody>
</table>

CRACK COUNT DATA, 1984 (Four years after construction)
Costs for this project were as follows:

- Sawing concrete pavement, 5 cuts per panel: $14,797.62/mile
- Sawing concrete pavement, 2 cuts per panel: $5,909.40/mile
- Full width Petromat with AC tack: $13,657.60/mile
- Asphalt-rubber SAMI: $21,817.48/mile

SAMI Project Three—T.H. 19 from T.H. 68 to Redwood Falls

This project was constructed in 1983 as a follow up on the two previous projects. The cross-sections for the various test sections are shown below.

Prior to the construction of the SAMI, the existing concrete pavement was cracked. The asphalt-rubber was applied at a rate of 0.60 gal/sq yd; the crushed aggregate was spread as a rate of 25 to 30 lbs/sq yd. The presence of reflective cracks was noted shortly after the binder course was placed on Test Section 2 (the thinnest section).
This project was monitored with the Mays Meter to assess the smoothness of the roadway. Results from these tests show no significant difference between the sections constructed. Crack counts were also taken periodically. "The four inch asphalt concrete overlay (T.S. 1,3,4) had significantly less reflective cracking than did the three inch asphalt concrete overlay with an asphalt-rubber interlayer. The asphalt-rubber interlayer (T.S. 3,4) has not significantly reduced the amount of reflective cracking when compared to the test section with no asphalt-rubber interlayer (T.S. 1)." (3)

The cost per mile for the SAMI inplace was $24,750.

SUMMARY, STRESS ABSORBING MEMBRANE INTERLAYERS

A SAMI has been proven to be relatively simple to construct. Only minor problems were experienced during construction and each was easily remedied.

The Stress Absorbing Membrane Interlayers on these jobs did not eliminate reflective cracking. On two of the three projects a reduction in cracking was apparent, with the third project showing little or no benefit.

A cost benefit analysis is difficult to make since the payback of reducing cracking is not easily given a value. Due to the variability in techniques, a maintenance cost per lineal foot of crack is not available. Precise information of the severity of cracks in the SAMI and non-SAMI sections is not available. Unless there were significant differences in severity, even though the amount of cracking is reduced, a SAMI's ability to extend an overlay's life span is arguable.

DENSE GRADED ASPHALT-RUBBER CONCRETE

One project employing asphalt rubber as the binder in a dense graded mix was constructed in 1984. Final analysis of this project is presently underway, only preliminary information from this final analysis is presented. A construction report is available. (4) The asphalt-rubber was supplied through a supplemental agreement by Arizona Refining Company of Phoenix, Arizona. The cross sections constructed are shown below.

DENSE GRADED ASPHALT RUBBER SECTIONS

Figure 4. T.H. 7 Test Sections
The asphalt–rubber used on this project consisted of 80% 120/150 pen asphalt cement and 20% crumb rubber. No changes in the standard gradations (see appendix) were made, however a separate trial mix design for the asphalt–rubber binder was employed. No special construction techniques or equipment were needed beyond the asphalt–rubber blending unit.

Complete results for this project are not yet available. A recent crack count revealed no difference in cracking between the A-R overlay section and the conventional overlay area. Within the areas of complete reconstruction, the section with both A-R wear and binder displays less cracking than the other sections on the project.

SUMMARY, DENSE GRADED ASPHALT–RUBBER CONCRETE

For this test project, the average cost per ton for the A–R courses was $56.58. For the conventional material the average price per ton was $23.27. With these costs in mind and the limited results achieved, no future sections of dense graded A–R mix are planned unless further evaluations reveal more specific benefits with direct applications (rut resistance, cost effective stripping reduction or cohesion enhancement, etc.).

PLUS–RIDE (TM)

Two sections using the Plus–Ride system were constructed in 1984. Plus–Ride is created by removing a portion of the finer material in a regular dense graded aggregate and replacing it with ground scrap rubber. The mixture is employed as a plant-mixed bituminous wearing surface with the hopes of enhancing skid resistance, deterring reflective cracking and creating a self de-icing pavement. An interim/construction report is available for this project (5); a final report is presently being prepared.

PLUS–RIDE Project One—T.H. 61 near Forest Lake, Mn.

This section was paved under cold and wet conditions. The material subsequently ravelled shortly after placement and was removed.

PLUS–RIDE Project Two—Interstate 94 near Collegeville, Mn.

Construction difficulties were not experienced on this project. However, documented observation by maintenance personnel have not revealed significant de-icing benefits. Preliminary investigations have not revealed enhanced friction resistance or other attributes; final evaluations are underway.

SUMMARY, PLUS–RIDE

The cost information for the two projects is as follows;

<table>
<thead>
<tr>
<th>Project</th>
<th>Project One</th>
<th>Project Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>$ 25.18</td>
<td>$ 19.95</td>
</tr>
<tr>
<td>Plus Ride</td>
<td>$ 52.60</td>
<td>$ 41.60</td>
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</table>

To date, the Plus–Ride pavement has not shown benefits which offset the above costs.

REPORT CONCLUSIONS:

In general, these projects have shown some benefits in terms of reducing cracking and providing a pavement equal to conventional methods. These benefits to the pavement have been limited and difficult to assess. Therefore, implementing asphalt–rubber technology at the given costs, with the possible exception of SAMs, without factoring in environmental concerns (see DISCUSSION) is not foreseeable.
STRESS ABSORBING MEMBRANE-

One of the projects constructed created a resilient surface with good friction numbers at a reasonable cost when compared to a hot mix overlay. The second project experienced loss of aggregate probably due to the moisture content and/or the amount of dust on the chips. If made readily available and placed properly this material may prove cost competitive for certain conditions.

STRESS ABSORBING MEMBRANE INTERLAYER-

While relatively easy to construct, the studies have shown that a SAMI will not eliminate but can decrease the amount of cracking in a bituminous overlay. The benefit of decreasing cracking is difficult to assess; these benefits do not appear to justify the costs incurred on the test projects.

DENSE GRADED AR MIX-

The asphalt–rubber and conventional overlays experienced an equal amount of cracking. When used in a completely reconstructed pavement, the section with asphalt rubber in the binder and wear courses exhibited less cracking than the other sections on the project. Unless findings from further analysis yield significant results, the 100% increase in price over conventional mixtures does not appear to be justified.

PLUS–RIDE–

When properly constructed, the Plus–Ride system, while performing equally as well as the adjacent conventional material, has not shown beneficial characteristics equal to the increase in cost.

DISCUSSION

Environmental Considerations/Future of Asphalt–Rubber

To this point the presented information has been limited to the technical/paving aspects of asphalt rubber. Of course asphalt rubber utilizes a difficult to dispose of material; waste tires. Until recently this has been a benefit which also was difficult to assess. Increasing concern about landfilling waste materials has created conditions where coordination for projects including funds is being made available. The relative effectiveness of this co-ordination for asphalt–rubber can be described in terms of the following diagram, “Bridge to Implementing Asphalt–Rubber Products.”

![Diagram: Bridge to Implementing Asphalt–Rubber Products]

The “bridge” is presently divided into two fairly solid units at each agency end with a limited amount of connection at the middle. The Pollution Control–Waste Tire Management Unit is very familiar with the
extent and location of the waste tires in Minnesota as well as who in the state is presently processing these tires. Most of the processed tires are being used as tire derived fuel (a process with environmental implications of its own), as light-weight fills in low-volume-road swamp crossings or shipped out of state for processing. The Department of Transportation has a good understanding of the ways asphalt rubber can be utilized and the benefits to the pavement. The high costs incurred on these projects presented were due in part to the crumb rubber being shipped in from out-of-state, the relative size and nature of the projects (small test sections) and the asphalt-rubber producers mobilization costs for such small quantities.

Presently the Department of Transportation and the Pollution Control–Waste Tire Management Unit are conducting preliminary discussions on the feasibility of using asphalt–rubber as a means to improve pavement performance and assist the waste tire abatement program. The amount of resources each agency is able to commit and relative benefits to each agency must be determined. Also the concern of earmarking money which will be used for a proprietary system must be addressed. However, the gap in the "Bridge" which needs the most attention is between the tire processor and the asphalt–rubber producers. It is an undeniable requirement that resources put towards waste tire applications abate the tire dumps within the county or state which is funding the efforts. Therefore, the link between tire processors and asphalt rubber producers must be established to utilize local waste tires.

One use of waste tires which has eliminated this gap between tire processor and application is the light weight fill. The Minnesota Department of Natural Resources has experimented with whole tire mats and tire chunks as a material to replace corduroy logs in logging road embankments over swamps. This technology is spreading to other roadway projects. The PCA has embarked on a study to develop design standards and to ensure that there are no environmental hazards from this concept.

Employing waste tires as light weight fill is a simple and cost competitive application which may use a significant amounts of local tires. Asphalt–rubber technologies could also become an implementable system once it is apparent that local waste tires can be employed to improve pavement performance while also satisfying other tire abatement and highway agency’s concerns.
References,


APPENDIX – MN/DOT SPECIFICATION 3127
Fine Aggregate for Bituminous Seal Coat.

Total Percent Passing

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<tr>
<td>1/2 inch</td>
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<td>No. 16</td>
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