Development and Application of the Asphalt Rubber Three Layer Cape Seal Pavement Preservation System

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ABSTRACT: Asphalt rubber binder has been used in chip seal applications for over 40 years and has proven to be very cost-effective. However, even asphalt rubber chip seals are limited to where they can be placed successfully. Asphalt rubber chip seals have proven to be very cost-effective in cape seal applications. In order to improve the smoothness and ride qualities in many applications a leveling course can be placed on the existing surface prior to placing the chip seal. By utilizing high quality slurry surfacing (microsurfacing) as a leveling material the cost and time can be significantly reduced in these types of applications. The purpose of this paper is to illustrate the cost-effectiveness of three layer cape seal pavement preservation strategies using asphalt rubber binder in combination with slurry surfacing. The paper will illustrate how the strategy has become a viable preservation alternative when considering the rehabilitation of severely deteriorated hot mix asphalt pavements

KEY WORDS: asphalt rubber, asphalt rubber chip seal, asphalt rubber cape seal, stress absorbing membrane interlayer, slurry surfacing, microsurfacing, pavement preservation.

1. Introduction

The first routine use of asphalt rubber chip seal applications was in the 1960's (SCH 85). In the early 1970's the asphalt rubber chip seals were first used as a stress absorbing membrane interlayer (SAMI) (VAN 99). Asphalt rubber has been used in hot mix applications since the middle 1970's, however this paper will focus on the use of asphalt rubber chip seals used in a 3-layer cape seal pavement preservation systems which utilize slurry seal and microsurfacing as a final pavement surfacing. When designed and placed properly this pavement preservation system has proven to provide superior field performance and at reduced cost. In many cases the pavement is in such bad condition that the only alternative is the remove and replace strategy or complete reconstruction. This paper will illustrate that the relatively thin 3- layer strategy presented is a cost effective long lasting alternative to the remove and replace alternative or even complete reconstruction.

2. Background

Asphalt rubber has unique properties as a binder and probably its most important characteristic is its extremely high viscosity. As a result it can be used in chip seals in much higher application rates when compared to other binders (conventional and polymer modified). Asphalt rubber binder also ages at a much slower rate than other binders and this allows it to stay flexible for a much longer period of time which results in improved performance. Figure 1 illustrates the long term flexibility of the binder after 1 year and 13 years of service life. These properties, which are well validated and documented in field performance, were also validated in the laboratory through research in the early 1990's (AND 92). The crumb rubber used in asphalt rubber binder is ground scrap tires and it has a fairly coarse grading (maximum 2mm size). Because of the required high percentage (20 % +/- 2 %) and the grading of the crumb rubber, asphalt rubber has to be produced in the field at the job site with specialized equipment. The interaction of the crumb rubber and the base asphalt results in a binder with unique properties. Because of the percentage and size of the crumb rubber required in the binder it has never been produced in a refinery in its over 40 year history.

Figure 1. *1-year old (left) and 13-year old (right, Rt.19, Rosemead Blvd., Los Angeles.) asphalt rubber chip seal placed over alligator cracked pavement (still flexible),*

The viscosity of asphalt rubber binder is higher than any other binder used in chip seal applications. Because of its viscosity and other exceptional properties asphalt rubber can be placed in extremely thick applications as a membrane and the result provides a significant resistance to reflective cracking (Figure 2.). This unique quality of asphalt rubber chip seals to mitigate reflective cracking is the key to the 3-layer pavement

preservation strategy. There is no other binder that will provide this degree of crack mitigation.

Figure 2. *Asphalt rubber chip seal over a distressed pavement (alligator cracking)*

3. Successful 3-Layer Pavement Strategies Using Asphalt Rubber Cape Seals

3.1 Asphalt Rubber Chip Seals/ Stress Absorbing Membrane Interlayers

The asphalt rubber chip seal has been shown in actual field performance to provide extremely long service lives (VAN 03). Figures 3 shows an asphalt rubber chip seal used in a successful application that has resisted reflection cracking for a very long time. Because of its ability to resist reflective cracking and its proven field performance it was used as a SAMI in pavement designs. The asphalt rubber SAMIs also exhibited exceptional performance in multi-layer pavement strategies. But none as good as its use in the cape seal applications. The asphalt rubber chip seal plays the key role in the performance of multi-layer strategies (VAN 06). Figure 4 shows an asphalt rubber SAMI used in successful multi-layer pavement application that have resisted the cracking and performed for a very long time. Because asphalt rubber binder has the unique property of resisting reflection cracking the surface preparation prior to placement of multi-layer asphalt rubber pavement strategies is significantly reduced or even eliminated in most cases. Wide cracks (greater than 6 mm) are normally recommended to be crack sealed prior to the placement of the overlays, but this is not usually required when using asphalt rubber binder in the pavement strategy. In some cases cracks have been over 25 mm wide and in many other cases it has been alligator type cracking of various widths. These relatively thin pavement strategies using a SAMI have shown to provide excellent performance in the resistance to reflection of alligator type cracking. It is recommended not to crack fill alligator type cracking prior to the placement of these pavement strategies.

Figure 3. *13 year old asphalt rubber chip seal (cracks have not reflected through), Rosemead Blvd. (St. Rte. 19) Los Angeles, CA 1990*

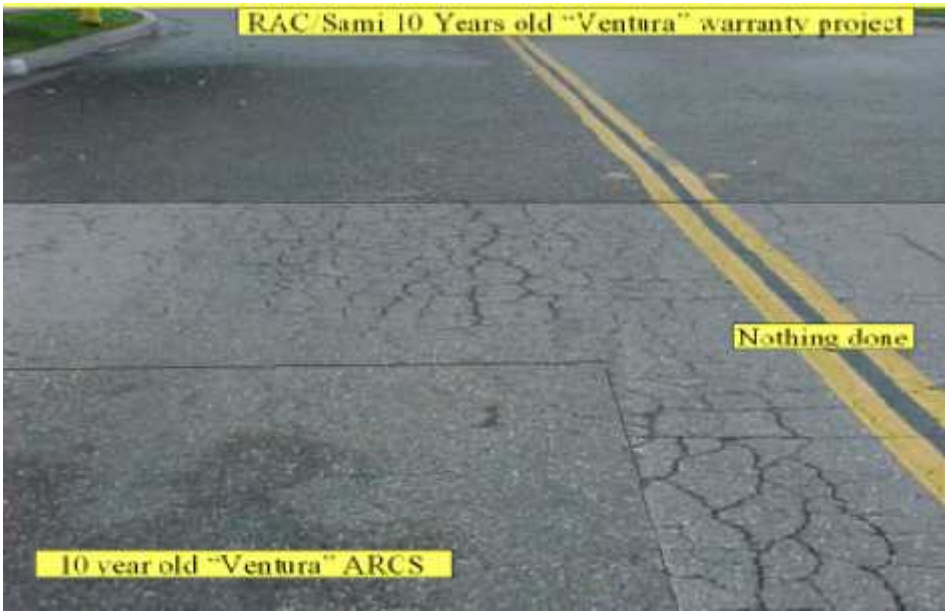

Figure 4. *10 year old asphalt rubber SAMI*, Ventura, CA

3.2 Asphalt Rubber Cape Seals

The cape seal was first used in Cape Town South Africa in the early 1080's. The chip seal was combined with a slurry seal as the final surfacing and the cape seal was developed. The placement of the cape seal is very quick and eliminates the long construction times that are required with conventional HMA overlay pavement strategies. The use of the asphalt rubber cape seal has significantly expanded in recent years. It is now a routine strategy for severely cracked pavements in California. With many years of proven performance history the asphalt rubber cape seal now provides agencies with a cost-effective pavement maintenance strategy that can be placed with minimal traffic disruption. Figure 5 shows asphalt rubber cape seal that have resisted reflective cracking for 10 years. The cape seal strategy has provided significantly lower initial costs when compared to other much thicker pavement strategies, yet have also provided reduced long-term maintenance costs.

Figure 5. *10 year old asphalt rubber cape seal (before and after)* Gregory Street, Fairfield, CA 1998/2008

3.3 Development of the 3-Layer System

The 3-layer system evolved over a long period of time. Its origin first started with the development of the asphalt rubber chip seal. After many years of successful performance the asphalt rubber chip seal was next used in as a SAMI application. It also proved very successful (VAN 03). 3-layer strategies first used a thin conventional hot mix asphalt (HMA) leveling course, an asphalt rubber SAMI and finally an overlay of conventional or asphalt rubber hot mix as a surface course. These strategies have provided significant cost savings to California agencies while providing superior performance (KLE 90) (MAR 04) (REC 89) (VAN 06) (COS 03) (COS 03-2). Multi-layer strategies using conventional asphalt concrete as a base coarse, asphalt rubber hot mix as a second coarse and finally a high binder content open graded friction course as the final surface have provided superior performance in Arizona (WAY 99). The advantages of using asphalt rubber strategies have been validated by many research efforts (VAN 06). The cost effectiveness of asphalt rubber strategies has also been validated in a Life Cycle Cost Analysis research effort (HIC 99).

In conventional pavement design the deflection of the base layer plays a major role in the determination of the overlay thickness to provide a certain pavement life. Most all agencies use a deflection-based design procedure for rehabilitation of flexible pavements. However, this conventional rehabilitation design wisdom does not apply when using asphalt rubber strategies and especially when using asphalt rubber chip seals as a SAMI in multi-layer strategies. The use of the SAMI in pavement design produces a very conservative design. This is because the value of SAMI is not given an appropriate value in the determination of the new pavement overlay thickness. The pavement design can be significantly altered when using asphalt rubber because it has been proven in actual field performance that asphalt rubber strategies can tolerate significantly higher deflections. This property allows the reduction of the pavement thickness while still providing the same service life or provides an extended service life at the same conventional design thickness. This has been validated in many research efforts (VAN 92). However, this design procedure also does not apply when maintenance type treatments are used in a multi-layer rehabilitation technique. When a cape seal is used in a multi-layer strategy it can last as long or longer than the conventional overlay strategy and at a significantly reduced cost. But the cape seal alone does not provide any significant improvement to smoothness. The placement of a leveling course can significantly improve the smoothness of the existing pavement and the resulting pavement rehabilitation strategy. As mentioned earlier the placement of a conventional HMA leveling course can be very expensive and time consuming. As cost- effective alternative to the conventional HMA leveling course was replaced with the application of microsurfacing as the leveling course. The use of microsurfacing provides many advantages and significantly lowers the overall cost of the 3-layer system. The placement of the microsurfacing drastically reduces the time for the placement of the leveling course as it is a quick application, it is a self leveling material and it needs no compaction effort.

The use of the asphalt rubber cape seal with the addition of the microsurfacing as the leveling course finally brought a very cost-effective 3-layer system strategy to the agencies for use as an alternative to conventional pavement rehabilitation strategy. This strategy has been in use for about seven years on city and county residential and major arterial roadways. Because the asphalt rubber cape seal has a very proven field performance history the use of the microsurfacing leveling course has now improved the smoothness of the final strategy and provided a long lasting cost-effective pavement rehabilitation strategy.

3.4 Consideration of Pavement Condition

The consideration of pavement condition is always the overriding factor in the selection of pavement preservation strategies. When a pavement is in good condition there are a lot of inexpensive alternative preventive maintenance strategies that can be used to prolong the life of the pavement. However, when the pavement is neglected and the condition is poor or very poor the only conventional alternative is very likely the remove and replace or even complete reconstruction. Figure 6 shows some typical pavement conditions that are appropriate candidates for 3-layer systems. The asphalt rubber 3-layer pavement preservation system can be used on the pavements and does not involve the time consuming and costly alternatives just mentioned. This is the unique advantage that this strategy brings to an agency. There is very little if any pavement preparation required when using this alternative. Required digouts are at a minimum. As mentioned before most cracking including extensive alligator cracking need not be repaired. However, if there is base failure and pumping present it must first be removed and replaced. These are the only repairs that are necessary prior to the placement of the 3-layer system. Costly crack sealing is also eliminated.

Figure 6. *Typical pavement conditions appropriate for the asphalt rubber 3-layer system*

3.5 How and Why the 3-layer System Works

When a conventional HMA leveling course is first placed, wide cracks reflect through the leveling course relatively quickly, however, these cracks now are changed into two smaller cracks (i.e. hairline) at the top of the leveling course which is at the bottom of the SAMI. This allows the SAMI to resist the reflection of smaller cracks extremely well and provide even greater resistance of reflective cracking through the overlay on top. The significant difference when using asphalt rubber binder as compared to other binders is the application rate. Using 9.5 mm maximum size aggregate the application rate for asphalt rubber binder is about 2.0 – 3.0 liters per square meter compared to 1.4 – 1.8 liters per square meter for other types of modified binders. This higher application rate

gives it a significant advantage in not only sealing the pavement surface, but also in resisting reflecting cracking (VAN 03). This high application rate helps relieve the stresses that are transmitted through the leveling course to the SAMI and finally to the pavement surface. This can significantly extend the life of an overlay when it comes to retarding reflective cracking regardless of the type of binder used in the overlay. The application rate along with the improved binder properties makes it superior for use in a SAMI application. SAMI's using asphalt rubber binder coupled with asphalt rubber hot mix as the overlay can provide superior performance resulting in significant cost savings to the user (VAN 92) (DEL 88) (DOT 88). However, when agencies cannot afford this type of multi-layer strategy they have turned to the use of asphalt rubber cape seals.

3.6 Improvement of Smoothness and Ride

In a recent Federal Highways Administration (FHWA) survey the number one complaint from the traveling public was poor ride. If the pavement was smooth and the ride was good the perception of the public was that the pavement was in good condition. However, that may not be the case. Pavements can have a good ride and still require repairs or pavement preservation strategies to attain a long or extended service life. This is the one drawback of the asphalt rubber cape seal. It does not significantly improve the smoothness and resulting ride of the pavement. Even though it can seal the pavement and significantly extend the life of the pavement structure at a reduced cost the traveling public mostly recognizes the ride. This ride issue is recognized more on higher speed roadways and is not as much of an issue on residential streets. However, this issue has been eliminated with the addition of the microsurfacing leveling course. Now the smoothness can be improved and the resulting cape seal can do its job of prolonging the pavement service life with a cost-effective solution.

3.7 Placement of the Microsurfacing Leveling Course

Microsurfacing is a type of slurry surfacing. It has improved properties when compared to conventional slurry seal. It is a mixture of high quality crushed aggregate, asphalt emulsion, water, mineral fillers, and advanced chemical additives. While conventional slurry seal is used around the world as an economical treatment for sealing and extending the service life of both urban and rural roads, microsurfacing has added capabilities. Microsurfacing uses a chemical break system and it introduces advanced chemical additives to create a quick break system.

Microsurfacing was pioneered in Germany in the late 1960s and early 1970s. German scientists began experimenting with conventional slurry to find a way to use it in thicker applications which could be applied in narrow courses for wheel ruts, and not destroy the expensive road striping lines on the autobahns.

Microsurfacing was developed when the scientists used highly selected aggregates and bitumen, and then incorporated special polymers and emulsifiers that allowed the product to remain stable even when applied in multi-stone thicknesses.

Introduced in the United States in 1980, microsurfacing is now recognized not only as the most cost-effective way to treat the surface wheel-rutting problem, but also a variety of other road surface problems. Microsurfacing is now used throughout world.

Because of the special advantages that the microsurfacing exhibits it can be placed in a single lift, similar to slurry seal or can be placed in multiple aggregate thicknesses and can be placed during the night or day and under cooler conditions. This allows the microsurfacing to be used as a rut filling material. It can be placed on uneven or rutted pavements and it will level the pavement. It does not require any compaction after placement. After placement it cures out and provides a hard rut resistant level surface.

In the asphalt rubber 3-layer system the microsurfacing is first placed to level the pavement and fill any irregularities in the pavement surface. Any wide cracks will be filled with the microsurfacing (Figure 7). It will provide a level surface for the asphalt rubber chip seal to be placed (Figure 8).

Figure 7. *Placement of the microsurfacing leveling course over wide cracks, Turlock, CA, 2010*

Figure 8. *Microsurfacing leveling course for the asphalt rubber chip seal, Watsonville, CA, 2005*

3.8 Placement of the Asphalt Rubber Cape Seal

Once the Microsurfacing cures uncontrolled traffic is allowed on the surface. This will iron out any irregularities in surface of the microsurfacing and help consolidate the surface. The surface will then be swept to remove any loose aggregate. The asphalt rubber chip seal will then be placed (Figure 9). First the asphalt rubber binder will be sprayed on the surface using a specially modified distributor truck and then the cover aggregate will be placed and rolled. Any loose aggregate will be swept off after the rolling operation and the surface will be ready to receive the final surface of slurry seal or microsurfacing. Slurry seal will be used on low volume roads during daytime placement. On heavy volume roads or during nighttime or cool weather placement microsurfacing will be used as the final surfacing (Figure 10).

Figure 9. *Placement of the asphalt rubber chip seal, Watsonville, CA, 2005*

Figure 10. *Placement of the final slurry surfacing, Watsonville, CA, 2005*

4.0 A Long Lasting 3-Layer System – Case Studies

There have been a number of projects which have utilized the asphalt rubber 3-layer system. This 3-layer strategy using microsurfacing as a leveling course has been used for about seven years and has been very successful to date. Three example projects will be discussed in this paper. The 3-layer system was used on projects in the City of Sacramento, the City of San Leandro and the City of Watsonville (Figures 11 - 16). On all three projects microsurfacing was first used as a leveling course, an asphalt rubber chip seal was then placed, and finally a slurry surfacing (slurry seal or microsurfacing) was placed as the final surfacing. All three projects exhibited extensive alligator cracking, longitudinal and transverse cracking, and large block cracking, with some cracks as wide as two inches. The microsurfacing leveling course was first placed up to or slightly over the curb and gutter joint. The microsurfacing was also tapered down at this location with a squeegee. The chip seal was held back about 4-10 inches from the gutter joint to reduce the total height of the treatment at the edge of the pavement. Finally the final lift of slurry surfacing was placed.

Figure 11. *Asphalt rubber 3-layer system, V Street, Sacramento, CA 2008 (original condition, microsurfacing leveling course, asphalt rubber chip seal, final slurry surfacing)*

Figure 12. *Asphalt rubber 3-layer system, San Leandro, CA, 2010 (original condition, microsurfacing leveling course, asphalt rubber chip seal, final slurry surfacing)*

Figure 13. *Asphalt rubber 3-layer system, San Leandro, CA, 2010 (chip seal held back from edge of gutter)*

Figure 14. *Asphalt rubber 3-layer system, West 5th Street, Watsonville, CA 2005/2009 (original condition, microsurfacing leveling course, asphalt rubber chip seal, final slurry surfacing 41/2 years later)*

Figure 15. *Asphalt rubber 3-layer system, Marchant Street, Watsonville, CA 2005/2009 (original condition and 4 ½ years later)*

Figure 16. *Asphalt rubber 3-layer system, Ford Street, Watsonville, CA, 2009 (4 ½ years later resisting cracking)*

5.0 A Cost-Effective Pavement Preservation Alternative for Severely Deteriorated Pavements

The savings that can be realized with asphalt rubber 3-layer systems can be significant. The cost of the 3-layer system is about $10 - $12 per square yard compared to $30 - $40 per square yard for the conventional remove and replace or full reconstruction alternative. This is an average cost savings of over 65%. These systems can provide significant cost savings when compared to conventional HMA pavement strategies. In California, city, county, and state agencies have realized savings of tens of thousands of dollars to millions of dollars on a single project. It should be noted that this average savings does not include savings from user delay costs, energy costs, savings in natural resources, or impacts to public safety and public inconvenience. These types of savings are real and city, county, and state agencies are using these relatively thin asphalt rubber 3-layer systems to stretch their road budgets.

Most cities chose the asphalt rubber 3-layer strategy because of the savings in cost, but there are a number of other reasons that should be considered. They include construction time, environmental and recycling aspects, and most importantly the reduced disruption to the traveling public. User delay costs can be substantial and should be considered when choosing project alternatives. These are all very important factors which must be included in the decision to select project design alternatives. But, above all performance is a very important factor. These 3-layer systems should provide service lives of 10 to 15 years with minimal to no maintenance costs. This is based on actual long term performance of asphalt rubber cape seal projects. The past performance lives of these asphalt rubber cape seal projects has been in many cases in excess of ten years. With the inclusion of the microsurfacing leveling course the cape seal service life should be considerably extended.

6.0 Conclusions

1. Asphalt rubber chip seals and asphalt rubber cape seals have a documented proven performance history when designed and placed properly.
2. Asphalt rubber cape seals have documented service lives of over 10 years over severely cracked pavements.
3. With the addition of the microsurfacing leveling course the asphalt rubber 3-layer cape seal system should provide service lives of 10 to 15 years with little or no maintenance costs.

4. The use of asphalt rubber 3-layer cape seal systems gives agencies a cost-effective alternative to costly conventional pavement preservation design strategies.
5. In California, city, county, and state agencies have realized savings of tens of thousands of dollars to millions of dollars on a single project by using asphalt rubber 3-layer cape seal systems.
6. The use of asphalt rubber 3-layer cape seal systems, when compared to conventional pavement preservation designs, are not only less expensive, but result in a savings in user delay costs, energy costs, natural resources, and results in less impacts to public safety and public inconvenience.

7.0 Recommendations

1. Agencies need to become educated on the proper selection, design and construction of asphalt rubber 3-layer cape seal systems.
2. Agencies should utilize asphalt rubber 3-layer cape seal systems when choosing pavement preservation alternatives.

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