Innovations and Successes of Hot Applied Mastic Patching Materials for Asphalt and Portland Cement Concrete Pavements

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ABSTRACT

Voids in the form of potholes, depressions, fractures and saw cuts are present in pavements. These voids must be patched or otherwise repaired to maintain a smooth and safe pavement. Many times these voids occur at or over moving joints or cracks. The joints or cracks involved in the voids have temperature induced horizontal movements, or traffic induced, load related vertical movements. These movements cause subsequent failure of the traditional more rigid materials used most often in large repairs. Standard sealant products cannot be used if these voids are larger than 1 ½ inches because of the sealants lack of load carrying capability.

Hot applied mastic patching materials are flowable, aggregate filled, flexible binder materials which are applied as a voidless mass in the repair areas to restore the pavement ride. The mastic materials are designed with flexible binders to handle movements which occur because of the underlying crack or joint. The binder can be varied in stiffness and extension capabilities for the various temperatures and movements necessary and the aggregate can be varied in size and percentage for thickness and stability requirements.

This paper will review some of the innovations in the formulations of these materials and the novel uses. It will also cover the documented successes of Hot applied mastic patching materials.

INTRODUCTION

Binders in asphalt cement concrete pavements serve the purpose of binding together the aggregate. In this capacity the binders must maintain a degree of flexibility to withstand the expansion and contraction caused by the thermal cycles without cracking. It has also long been known that polymers and oils can be used to modify binders to decrease the binders low temperature susceptibility. The binders have their best low temperature properties when the pavement is first laid down. Heat, traffic and oxygen age the binder and increase the modulus and reduce the stress relieving capability of the visco-elastic binder. Because of the mechanisms of aging as well as the purpose of the binder, higher binder content and lower air voids leads to less detrimental aging of the pavement.
The aggregate serves as the load bearing material for the pavement. The proper gradation and shape of aggregate designed with the appropriate amount and grade of binder is a key to a successful asphalt pavement. Pavements can have aggregates that are dense graded or gap graded and these pavements will still perform acceptably if designed properly.

In the late 1960’s (Jared) the original experimentation with Stone Matrix Asphalts (SMA) began. The SMA had higher binder contents for reduced aging and better low temperature properties and gap graded aggregate with crushed faces to provide the interlock for rutting prevention. With the theory that higher binder contents can increase durability, higher binder content products can be used as patching materials to patch over the top of the moving cracks or joints in pavements and still perform. This is dependent upon the binder being designed correctly for the conditions and the patch being large enough on both sides of the joint or crack that the stresses can be relieved through the mass of material. The first materials used in this way were the asphalt plug joints installed in England in the late 1970’s (Bramel, Charles, Pucket and Ksaibati). The asphalt plug joints were constructed by field blending pre-heated, relatively single sized aggregated with a modified binder and pouring this mix in lifts into a prepared cut out over the joint. This mix was then subsequently rolled and opened to traffic when cooled. These plug joints then led the way to 1-part pre-blended and packaged materials which are hot applied and flowable materials that are pre-designed to perform for specific applications.

**HOT APPLIED PATCHING MASTIC USAGE**

Portland cement concrete pavements have joints. Voids in the form of spalls often occur on one side or both sides of a joint. The joint will still have movement even after the spall has been repaired.

Asphalt cement pavements crack. If these cracks are not properly sealed quickly, water will seep through the crack and begin to affect the base and this will lead to pavement voids such as potholes around the cracks. The original crack underlying the void formed as a stress relief mechanism. Because of this there is still movement at the crack.

Certain pavements, whether because of design faults, poor maintenance or base conditions will form cracks larger than 1½ inches (Figure 1 Wide Crack) or joints will have expanded to larger than 1½ inches. These joints or cracks will still have the movement but will require a material with load bearing capabilities.
These distresses represent the major uses of hot applied patching mastics, but they do not represent the only uses however. Hot applied patching mastic have been successfully used for skin patches, depressed pavement around large cracks (Figure 2 Depressed Thermal Crack, Figure 3 Application), skin patches, corner breaks, deteriorated pavement joints (Figure 4 Deteriorated Pavement Joint) and as discussed below bridge joints.
HOT APPLIED Patching Mastic Design

The patching mastics must be hot applied, 1-package, flowable at application temperatures, easy to work with, flexible and yet have load bearing capabilities. The amount of each of the properties listed can be varied depending on the desired usage of the material. The aggregate size, amount and angularity can be increased when greater load bearing is needed such as large spalls. The size of the aggregate can be decreased for skin patches. The amount of the aggregate can be decreased to allow more flexible binder for large crack repair. The binder itself can be varied in flexibility for different climatic conditions.

Concrete Repair Mastics

The first concrete repair mastic was marketed in 1995 also in England (Highways)\textsuperscript{iii}. This mastic represents hot-applied mastics as described above and is generally applied in lifts no more than 2 inches deep to avoid any aggregate segregation. These repair mastics generally have 10 – 20% organic binder according to data listed on manufacturer’s product data sheets and graded, crushed face aggregates. The large amounts of binder allow for greater elongation capacities for the product. The formulations are designed to have significant recovery but also enough relaxation properties to relieve stresses that may build up internally within the mass of the mastic. Because of the high binder content, the aggregate must be properly designed to carry the traffic load. Figure 1 shows testing conducted using the following the BS 598-110 Standard at 50°C (122°F) 530 N (119 pounds) rutted 4.3 mm after 1890 passes. This is more than a typical Hot applied AC pavement but the material does not necessarily need the rutting resistance of the pavement mix as even in the bigger repairs, the mastic is constrained by the surrounding pavement on four sides and the bottom.
Proof of the required rutting resistance of the product can be seen in the NTPEP 2004 test deck of concrete repair material in Ohio (NTPEP). The patched areas were sawed nominally 4 inches deep and were 1.2m x 2.7m (4 feet x 9 feet). The photos (Figure 6 Mastic Installed October 2004) show the repair mastic when initially applied and (Figure 7 Two Year Field Evaluation, Figure 8 Two Year Field Evaluation) the mastic at the two year evaluation. Table 1 (NTPEP Report 9005.2 Two year field performance AASHTO 2007) shows the overall top rated overall performance grading of the repair material used in this test deck.
Table 1. NTPEP Report 9005.2 Two year field performance AASHTO 2007

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<th>SUBJECTIVE RATING *</th>
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The major benefit of using the hot applied patching mastics over a cementitious repair material is the flexibility of the material and the ability to withstand movements in the pavements. Shown (Figure 9 July 2003) is a photograph taken in July of 2003 of newly installed material on Lakeland Drive in Jackson, MS. The photograph shows the repair material extending across the joint in a sawed cut out. The distance cut out across the joint depends on expected joint movements. These materials are not joint sealants and would not perform if the material were just applied up to the joint. By spanning the joint, the stresses are spread further allowing the mastic to withstand the movement without failure. The adjacent photograph (Figure 10 May 2004) was taken 10 months later in May 2004 clearly indicating that the material has not cracked or debonded.

Below is a photograph (Figure 11 May 2002) of an installation on Grant McConachie Way, Richmond, BC taken in May 2002. The repair material is again extended 4 inches passed the joint. Shown (Figure 12 September 2004) is a photograph taken in September 2004 of the same repair showing no signs of adhesion loss cracking or rutting.
Random cracks in concrete have also been successfully spanned with repair mastics. The first photograph below (Figure 13 October 2001) taken in October 2001 on Route 17 in New York State shows repair mastic in cut outs spanning a random crack in concrete immediately after the repairs were made. The single patch photograph below (Figure 14 September 2006) is of a patch spanning the crack taken in September 2006, 4 years and 11 months after installation and is performing perfectly. The third photograph in the series (Figure 15 April 2002) was taken 6 months later showing the major crack through the cementitious material while the mastic material continues to perform.

**ASPHALT REPAIR MASTICS**

Repair mastics can be designed for stability and withstand small movements, or they can be designed to withstand more significant movements with enough stability in smaller repair areas. This section will discuss a mastic designed to withstand the greater movements.

The photographs below show a job using asphalt repair material on concrete road on Route 4 near Lebanon, IL. This section was designed as an experimental section with 40 foot joint spacings. Large transverse cracks appeared over time mid slab as can be seen in the first photo below (Figure 16 Crack With Previous Repair). Because of the unevenness of the cracks and previous repair attempts, the cracks were routed (Figure 17 Routing the Crack) to create a proper reservoir for the mastic.
The repairs were completed in March of 2004 (Figure 18 March 2004). The job site was examined in December 2004 and as can be seen in the photo (Figure 19 December 2004), the material was performing very well.

Another application for this repair material is badly deteriorated longitudinal construction joints. The first photograph (Figure 20 I-295 New Jersey Longitudinal Crack) below is of the longitudinal joint on I-295 outside Trenton, NJ. The next photo (Figure 21 Application of Mastic) shows the repair being completed in 2002.
The photograph below (Figure 22 I-295 New Jersey Repair 2005) shows the repair in 2005 after 3 winters in the pavement.
In the introduction, it was discussed that the idea for hot-applied mastic patching materials in England came from the bridge plug joints. Traditionally the bridge asphalt plug joints have been constructed by first making a cutout typically 500 mm wide centered over the joint. The cut out is then primed and “tanked” with the binder. A metal bridging plate is then installed over the original joint and it is coated with the binder. The next step is to blend the heated binder with heated aggregate on the job site and level into the joint, typically in lifts no more than 50 mm deep. A layer of binder is poured over the mastic to fill in the voids, and if more lifts are necessary they follow this step. Typically, the joint is slightly overfilled and then rolled to bridge driving surface level. A layer of finer aggregate is typically cast over the top of the plug joint to finish the job. Although a mastic patching material was created on site, this is a bit different than the pre-packaged mastic patching materials discussed in this paper.

The disadvantage to this procedure is that the mix design of the joint material itself is left to the contractor or maintenance crew constructing the joint as they will be measuring the binder and aggregate. It is possible to get too much binder and have a plug that will rut badly and shove. It is also possible to have a dry mix which may not be watertight and will be move likely to cohesively crack.

In 2008, a plug joint mastic was developed to have the mastic material pre-mixed to the correct binder content and size of aggregate. This material was installed in a plug joint in September of 2008 on the Dutchess Turnpike in Poughkeepsie, New York. The bridge engineer responsible for the bridge stated that the joint was designed for ±3/4 inches movement. The cutout made was 22 inches wide by 2 ½ inches deep. With the pre-measured mastic it is still required that the cutout be tanked as can be seen in the picture below (Figure 23 Tanked Joint Cut-out).

The pre-blended mastic is then dispensed into the cutout and spread evenly (Figure 24 Applying the Mastic, Figure 25 Leveling the Mastic).
The joint was first examined in January of 2009 to evaluate cold temperature performance. The pictures (Figure 26 January 2009 Mastic Plug Joint, Figure 27 January 2009 Mastic Plug Joint) below show that the material is not showing signs of adhesive or cohesive failure.

The joint was then examined in July of 2009 for summer distresses (Figure 28 July 2009 Poughkeepsie Plug Joint 1, Figure 29 July 2009 Poughkeepsie Plug Joint).

Although there is some marking of the surface of the plug joint, the joint is neither rutting nor shoving.
CONCLUSION

Patching mastics have been used successfully in repair applications for different types of voids in different climatic conditions throughout the world. There is a definite place for them in pavement maintenance. The mastics can be designed for differing amounts of stability and movement depending on the designed distress that will be repaired. Repairs requiring more movement are designed with higher binder contents and coarser aggregates. Materials requiring greater stability are designed with stiffer binders and greater degrees of aggregate interlock.

REFERENCES


