EVALUATION OF RHEOLOGY AND ENGINEERING PROPERTIES OF A BRIDGE DECK THERMO-PLASTIC WATERPROOFING MATERIAL

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ABSTRACT

Rational specification parameters are discussed for a bridge-deck thermo-plastic water proofing material using tests developed in the past 20-years currently being implement for highway materials by various state DOTs. Information is presented on a specialized modification system, Rosphalt, which has been used with considerable success for over 20-years. The system exhibits effective impermeability, good flexure/fatigue resistance and low permanent deformation.

INTRODUCTION

Bridge deck surfacings have made use of the highest quality asphalt materials to meet the specialized requirements that are needed. Traffic on bridge decks is constrained between physical limits to a much greater extent than typical highways resulting in a much greater degree of channelization of traffic flow. This in turn results in a much greater degree of loading in wheel tracks that in turn can result in deformation if a material is not designed with extreme care. In addition, these materials have to be waterproof to ensure that salts and other harmful effects of water penetration do not result in deterioration to the bridge structure and flexible to cope with the movements that occur on different types of bridge decks.

The need to provide waterproofing results in the HMA material requiring a very low void content, typically in the range 1 to 2%. This generally ensures that the hydraulic conductivity of material will be less that $1x10^{-7}$ cm/sec when assessed with the ASTM D5084 test method. This low void requirement would for conventional asphalt binder result in a material which will be prone to deformation. Consequently, the adopted materials have made extensive use of those which have thermo-plastic properties and at the normal range of working temperatures the binders exhibit material behavior that approximates a visco-elastic solid.

Considerable experience has been obtained with a system of modification referred to as “Rosphalt 50” for approximately 20 years. This is a plant mix additive that is typically added at a rate of 40 pounds per ton of hot mix. The material has an excellent performance history but the data obtained over the past years has been largely based upon quantification of empirical properties and performance history

In recent years it has become increasingly important to evaluate material properties in terms of fundamental characteristics since these are required by specifying agencies and are an essential part of risk reduction with assessment of material performance. To assess the material behavior binder has been evaluated using frequency sweep methods, the multiple stress creep recovery test and standard PG grade tests (AASHTO M320). Mixture evaluations have included tests conducted in the APA wheel tracking device to evaluated deformation potential and fatigue testing to assess the flexibility. In addition, some suggestions are made with regard to suitable specification parameters for a bridge deck material.

Rosphalt is added to HMA via either bagged products in batch plants or bulk feed systems in drum mix plants. The resulting mixture is placed with conventional equipment. This paper discusses the engineering properties as applied to different bridge decks.

BACKGROUND

The need for high performance materials for use in bridge deck surfacing is well establish (Hicks et al. (1)). Asphalt materials have been used for bridge deck surfacing for over 100 years in prominent bridge structures, Boorman (2). These have included a variety of materials including Mastic Asphalt, Guasphalt, Hot Rolled Asphalt, Asphalt Concrete and Epoxy Asphalt to name a few. Some of these materials have good water-proofing properties such as Mastic Asphalt and Guasphalt but if used with conventional binders these materials can have significant problems with deformation performance if in high temperature locations or those with very heavy traffic. Other systems such as Hot Rolled Asphalt, Epoxy Asphalt and Asphalt Concrete have been traditionally used with other layers which impart water-proofing properties to the combined layers over the bridge deck.

Bridge decks have traffic which is generally channelized into narrower widths thus promoting application of repeated loading over a narrower width. In addition, steel decks, will result in a greater need for the need for flexure and fatigue performance. Further, to protect the decks from salt and the harmful effects of water intrusion it is important that the deck surfacing materials have a very low void content thus rendering effective impermeability.

With conventional asphalt materials high deformation resistance results partially from a good aggregate skeleton in the mixture. However, when the void content is reduced to less than 3% the aggregate skeleton is significantly reduce. Rosphalt effectively modifies a standard visco-elastic binder with liquid like properties into a binder which has properties that are closer in performance to a visco-elastic-plastic solid material. The unique range of modifiers adopted, enable a high deformation mixture with a very low void content to be produced. In addition, the choice of elastomers and plastomers in the modified mixture results in a material that has inherent flexibility characteristics sufficient to withstand the deflections that typically occur in the most extreme conditions encountered such as those found on orthotropic steel bridge decks.

The performance requirements of a mixture for a bridge are therefore summarized by three main requirements, flexibility, deformation resistance and low hydraulic conductivity. Flexibility is considered in two manners; 1) resistance to load associated cracking and 2) resistance to thermally induced fatigue cracking.

Often with material little data is available that defines the performance in a structured manner. For fatigue, if a detailed evaluation is considered it is preferable to construction a fatigue curve in which life is expressed as a function of strain level or strain and stiffness. Alternatively life can be assessed at a single strain level. Thermal cracking performance is assessed according to both binder and mixture performance. Generally, most agencies require information on the typical “equivalent” PG grade that is being obtained with the Rosphalt modification. In the PG grading system a binders low temperature grade is evaluated either by assessment of bending beam rheometer data or by use of this data with the direct tension test in an evaluation of the critical cracking temperature. Mixture testing is accomplished by testing in the Indirect Tensile Test and then determination of the critical cracking temperature using the methods developed by the SHRP researchers (Lytton et al., (3)). Deformation properties at high temperature are considered in a similar manner with both mixture and binder tests. Binder testing considers the high temperature performance according to the PG grading system. This has recently been extended with the evaluation of the Jnr parameter. The concept of this parameter is very important for ensuring that the material adopted tends to maintain good behavior characteristics as the magnitude of stress increases. When evaluating Rosphalt bridge deck materials in accordance with this parameter it is apparent that the modification results in a material which more closely approximates a visco-elastic solid due to the very high degree of elastic recovery which is obtained. In addition, wheel tracking studies have been performed to assess the deformation aspects of mix behavior. Data from these various tests are discussed in this paper.

MATERIALS EVALUATED

Rosphalt is supplied in a powder form and added to the asphalt mixture at a rate that approximates 2.25% of the total mixture. A typical mixture suitable for modification will have a 10mm (⅜-inch) maximum aggregate size and the resulting mixture will have a void content when compacted less than 2% air voids. The material is supplied in various forms but generally either in polyethylene bags or tanker load. Bag form is generally preferred for batch plant this and bulk supply in the form of tanker loads of the product is the preferred method with drum mix plants.

For this paper various tests have been conducted using a standard mixture made with a NuStar PG64-22 grade binder mixed with a Trap Rock aggregate. The mix design information is given in Table 1. The modification of a typical mixture such as this results in significant changes to the volumetric structure of the mixture. Figure 1 shows a chart that represents all the standard volumetric parameters in a single volumetric chart (Edwards, (4)). In this chart, when 45 lbs of Rosphalt modifier is added to a mixture, we observe the following:

1. The base designs completed with the unmodified materials show a difference in VMA associated with aggregate structure packing with additional compaction of approximately ½%.
2. The addition of 45# of Rosphalt increases the volume of binder by approximately 5.5%. At the same time the VMA is increased by approximately 3%.
3. At a PG64-22 binder content of approximately 5.25 to 5.5% the effect of adding further additional Rosphalt results in no further reduction in void content but rather only affects the VMA. Until this level of binder is reached both the void content and VMA are changed by adding the Rosphalt.

Table 1: Mix design for standard Rosphalt mix using Trap Rock aggregate

	Averages	Marshall Information		
% Asphalt	5.50	Actual Values		
% Voids	0.99	0.89	1.11	0.98
% VMA	18.7	18.6	18.7	18.6
% VFA	94.7	95.2	94.1	94.7
% Vb	17.66	17.68	17.64	17.66
% Vs	81.35	81.43	81.26	81.36
Stability	2225	2289	2207	2180
Flow	24.8	25.5	24.0	25.0
Gmm	2.568	2.568	2.568	2.568
Gmb	2.542	2.545	2.540	2.543

	Materials	Bulk Specific Gravities	% Agg Only	% Total Corrected for AC & Rosphalt	Weight (#) Aggregate per Ton Mix
Agg #1	8's	2.932	48.0	44.2800	885.600
Agg #2	10's	2.921	37.0	34.1325	682.650
Agg #3	Sand	2.657	15.0	13.8375	276.750
Asphalt	PG 64-22	1.035		5.5000	110.000
Additive	Rosphalt 50	0.984		2.2500	45.000
			Totals	100.00	2000.00

Gsb	2.883
Gse	2.947

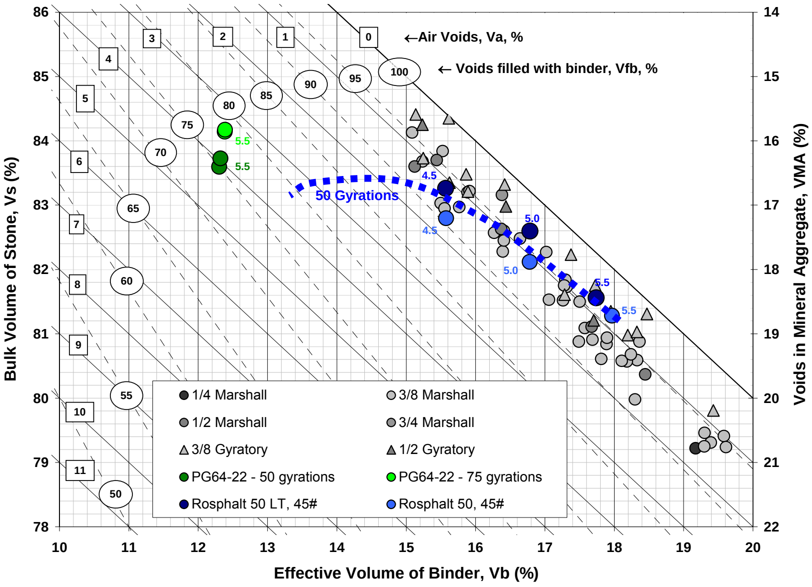
Sieve Size		Percent (%) Passing				
		Agg #1	Agg #2	Agg #3	Designed Blend	Wet Sieve Data
3/4"	19.0 mm	100.0	100.0	100.0	100.0	100.0
1/2"	12.5 mm	100.0	100.0	100.0	100.0	100.0
3/8"	9.5 mm	96.0	100.0	100.0	98.1	98.3
#4	4.75 mm	25.9	100.0	100.0	64.4	64.5
#8	2.36 mm	7.0	75.0	98.1	45.8	46.1
#16	1.18 mm	5.9	53.6	91.8	36.4	37.0
#30	600 micro	4.3	36.3	76.1	26.9	28.2
#50	300 micro	2.1	30.0	31.0	16.8	19.1
#100	150 micro	1.6	18.5	5.0	8.4	9.9
#200	75 micro	1.5	14.8	1.0	6.3	7.6
% in Designed Blend		48.0	37.0	15.0		

The change in the aggregate structure results in a mixture that can not be considered to behave as a traditional asphalt concrete which relies upon much of its strength from an aggregate skeleton within the mix. Rather the Rosphalt materials relies upon a minimal aggregate skeleton and more significantly upon a mastic of modified binder and fine aggregate which has approached a saturation level. This mastic is effectively working as a material which closely approximates visco-elastic solid structure between the larger aggregate particles thus preventing flow and deformation.

The Rosphalt modifier materials have then been used in some recent paving trials with differing aggregate types to yield additional material samples so that field compacted materials can be compared to laboratory prepared materials. A total of three trial pavements were constructed towards the end of 2009 by contractors in different parts of the country to yield materials for testing. The contractors who assisted with this work are as follows:

1. Tully Construction, Willets Point, NY
2. PJ Keating, Dracut, MA
3. Payne & Dolan, Waukesha, WI

During the paving trials, one part of the work conducted, enabled the evaluation of placement and compaction of the Rosphalt at significantly cooler temperatures than those used in previously. The results obtained demonstrated that compaction could be readily achieved with as few as five roller passes as demonstrated in Figure 2, which shows the development of density with roller passes.



Notes:

1. Numbers in blue or green, adjacent to the data points represent the amount of unmodified PG64-22 within the mixture.
2. Data in grey points represents historical database of various designs conducted over 20-year period for projects in USA (States – NY, NJ, KY, MA, IA, WI, OH, ME, IN, WV) and Canada (Provinces – ON, NB, NS).
3. LT denotes use of reduced compaction temperature in production.
4. All data points in blue have used 50 gyrations in gyratory compaction device.

Figure 1: Volumetric mix design properties for Rosphalt Modified materials

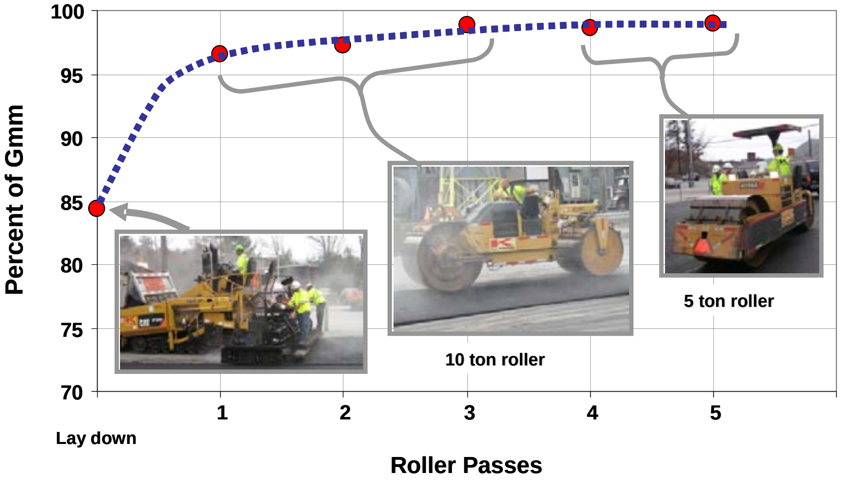


Figure 2: Development of density during compaction process

TEST PROCEDURES

Binder test methods

The behavior of the modified binder can be evaluated by traditional tests such as Penetration and Softening, Superpave® binder specification test as specified in AASHTO M320 standard specification. In addition, testing was also performed in the newer Multiple Stress Creep and Recovery (MSCR) test (D'Angelo et al. (5)) as recently introduced to better define the binder performance in relationship to permanent deformation. For materials considered at formulation stage material was prepared by mixing the modifier with unmodified asphalt binder by combining the material in a high-shear mixing device at a temperature of 180°C. In addition, some tests were conducted on binder recovered from the mixture by using a solvent extraction procedure. It should be noted that traditional binder testing with Rosphalt additives is complex since the material is added to the hot aggregate, not the liquid binder, in the mixing process thus resulting in Rosphalt being better defined as a mix modifier rather than an asphalt modifier.

Mixture test methods

The mix samples have been evaluated for hydraulic conductivity, fatigue endurance and permanent deformation characteristics. The hydraulic conductivity tests were performed using the procedures described in ASTM D5084 using the constant head method on specimens removed from the trial pavement areas. Fatigue testing was conducted using a bending beam protocol in accordance with ASTM D4760. For this testing beams were fabricated using the kneading compaction device and beams then sawed from the slabs of resulting mixture. The slabs were compacted to a void content of 1 to 2% for this work. Permanent deformation tests were conducted using both laboratory prepared specimens and specimens removed from the trial pavement structures by coring.

BINDER TEST RESULTS

Testing of binder performance has been conducted by various laboratories over the past 10-years with evaluation of the PG grade. PG grades as high as high as PG94-34 have been reported in past testing (Buchanan, (6)) but it should be noted that the expected performance grade will depend upon the source of the binder and the original grade being modified. It should be noted that as is common with other heavily modified binders that this material is somewhat difficult to age in a RTFOT bottle. With one of the laboratories conducting evaluations some "balling up" was observed with material being expelled from the RTFOT bottle while the aging process was being performed. However, regardless of these issues it is possible to evaluate the grade using AASHTO M320 criteria if care is taken with the aging process. Regardless of the base binder grade the effect of modification will result in an improvement to both high and low temperature performance. Having evaluated different base grade the level of improvement can be equated to a minimum of +2 grade bump improvement at the high temperature end of the specification and -1 grade improvement at the low temperature end when considering the current AASHTO M320 Tables 1 or 2 specification, although this may even be greater (e.g. as high as +5 grade bump has been achieved in the past).

The performance change can be explained by inspecting the curves of stiffness produced when testing the modified materials over a range of frequencies and temperatures. A standard technique (Rowe and Sharrock, (7)) is used to convert the test data to a "master curve" of stiffness and phase angle which represents the performance over a wide range of frequencies and temperatures. For convenience the data is all reported at a single temperature called the reference temperature with the high stiffness being associated with the low temperature tests and the low stiffnesses being those evaluated at high temperatures. The data collected for Rosphalt modified materials are compared to a standard PG64-22 binder used in the testing. From inspection of the data in this master curve representation it can be clearly seen that the stiffness (complex shear modulus, G*) of the binder is reduced at the high frequency end of the master curve (low temperature tests) but increased at the low frequency end of the master curve (high temperature tests). While the changes may appear relatively small on the graph it should be noted that the G* is plotted on a logarithmic scale and consequently the stiffness changes, particularly at the high temperature, end are very significant.

While the change in performance can be demonstrated in the frequency sweep master curve results the key performance at high temperatures can be best demonstrated by conducting repeated load tests at varying stress levels. In this case we have evaluated the materials at 70^{o}C in the multi-stress creep recovery tests, see Table 2. This is an important step in verifying the performance since the binders' sensitivity to stress can then be determined. The normal specification criterion for a conventional binder is the material shall have a value of Jnr less than 4 (1/kPa) with this value reducing to 2, 1 and 0.5 for heavy duty, very heavy and extreme grades respectively. It can be seen that at 70^{o}C the PG64-22 binder fails the standard requirement as would be expected since this binder is designed to pass at 64^{o}C. However, when modified the binders performance exceeds that of the extreme grade at the 70^{o}C temperature.

It should be noted that the binder test results provide only a guide to the way the mixture will behavior. The true mix behavior can only be fully understood by conducting mixture tests as described in the next section of this paper.

EVALUATION OF MIX PERFORMANCE

Hydraulic conductivity

One of the key requirements of bridge deck surfacing materials is that they offer a water barrier and offer effective protection from the harmful effects that can be associated with Chloride penetration into bridge decks. Asphalt materials have been used for their waterproofing properties for thousands of years with well documented uses. In recent years, it has been long established that the hydraulic conductivity (or permeability) of asphalt materials can be related to the mixture volumetrics and type of gradation adopted. For asphalt mixes with voids below 3%, no water can be forced through a specimen 5 cm thick, under a pressure of 3 atm. For mixes with voids ratios of about 8% the permeability coefficient is about 10^{-8}m/s (Nijboer, (8)). Work conducted by Goode and Lufsey (9) demonstrated the importance of gradation when evaluating the air permeability of asphalt materials. However, his data suggest at the low values of void content the effect of gradation was not particularly significant. Currently, most laboratories conducting specialized work to evaluate the flow of materials through asphalt concrete use the ASTM D5084 method which was originally developed for testing of soil materials. Generally, materials with a hydraulic conductivity below 1×10^{-7} cm/sec in this test can be considered impermeable (TAI, (10)). This test has been routinely applied to Rosphalt modified materials and when the material is compacted in accordance with the normal guideline the material can be described as impermeable. An example which demonstrates the importance of void content on the hydraulic conductivity is demonstrated by the results of one the trial recently constructed. In this case a specimen with a lower degree of compaction (taken from a joint location) was included in the analysis and it can be seen that as the void content increases the standard requirement for hydraulic conductivity is no longer achieved. For this reason Rosphalt guide specifications require that minimum density of 96% of Gmm (or 4% air voids) is achieved across the full width paved. To achieve this level of air voids at the joint locations a void content of 1 to 2% is often achieved in the material in the center of the paved area.

In the known instances where hydraulic conductivity has not been achieved on site, in all cases significant evidence suggests that inadequate compaction and high void contents has been the major contributory cause. For this reason it is recommended that on any project involving significant quantities of material that a paving trial is conducted to establish adequate construction quality control measures. When satisfactory construction procedures are adopted on site then Rosphalt becomes both the wearing surface and the principle water-proofing solution for the bridge deck.

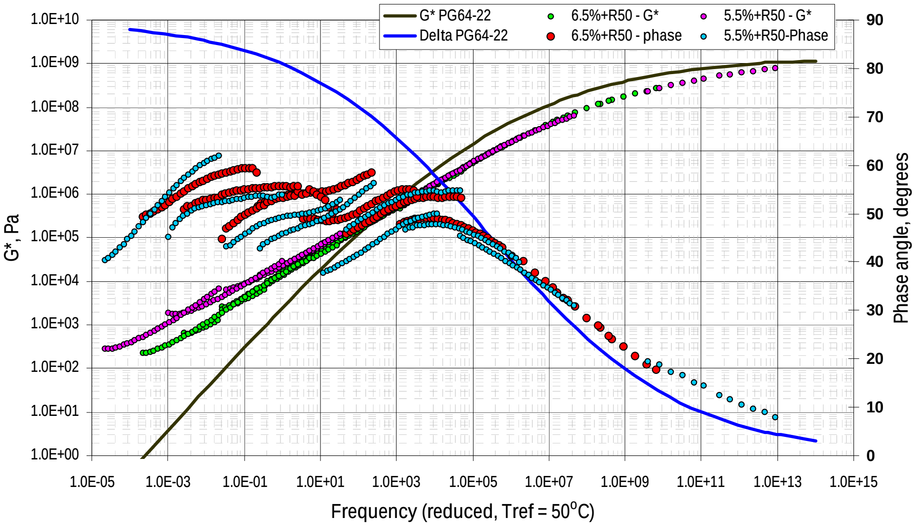


Figure 3: Rheology of PG64-22 modified with Rosphalt LT modifier

Table 2: Performance of PG64-22 binder modified at two different concentration levels in Multi stress creep recovery (MSCR) at a test temperature of 70°C

Performance measure	Stress level	PG64-22	5.5% + Rosphalt LT	6.5% + Rosphalt LT
Jnr (non-recoverable creep compliance), 1/kPa	100 Pa	5.39	0.0002	0.008
	3200 Pa	6.09	0.027	0.122
Elastic recovery, %	100 Pa	1	100	93
	3200 Pa	0	75	59
Total permanent strain, %	100 Pa	543	0.103	0.793
	3200 Pa	20,144	95.7	374
Percent of strain compared to unmodified PG64-22, %	100 Pa	100	0.0	0.1
	3200 Pa	100	0.5	1.9

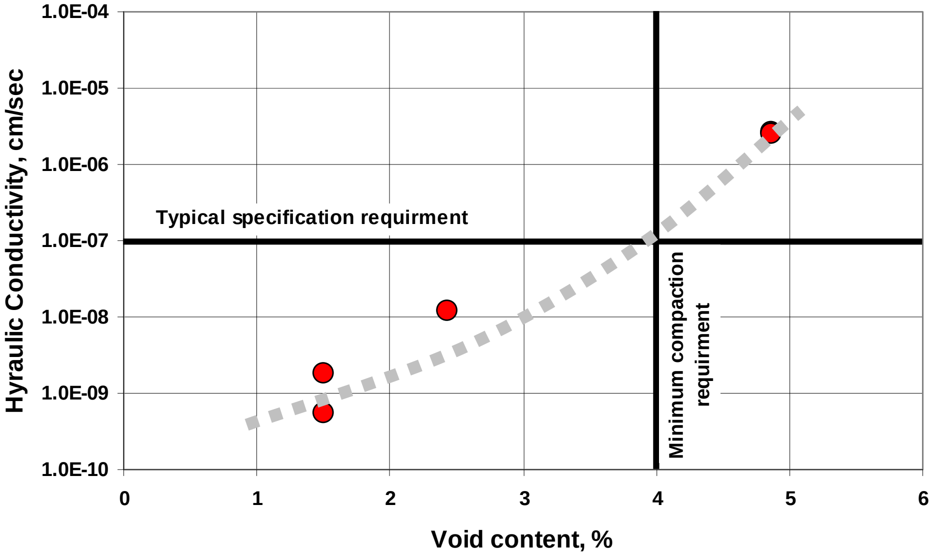


Figure 4: Data from paving trial showing typical hydraulic conductivity relationship with void content

Fatigue and flexure endurance

Different type of bridge decks result in differing fatigue and flexibility demand. Generally, the flexure that occurs on concrete bridge decks is relatively small when compared to steel decks and quite different demands on the material performance exist when comparing the two types of deck response. Typically steel bridge decks can have a wide range of strain response as illustrated by the strain gauge results shown in Figure 5 which is the response to a 45 ton truck on an orthotropic steel deck which was instrumented in manner to capture various strains at critical locations in the deck (De Backer, (11)). The maximum magnitude of strain is approximately 500 microstrain in this figure. Medani (12) conducted detailed Finite Element analysis of an orthotropic steel deck bridges to study the need for correct modeling to understand stress and strain states that occur in the deck and asphalt materials. The response under a 14.5 ton duel wheel load is illustrated in Figure 6 with maximum tensile strains around 900 microstrain. In other work, for example that conducted by Houel et al. (13), where specialized devices have been fabricated to conduct tests that closely resembles the geometry of an asphalt material indicates initial strain amplitudes in the range 500 to 1500 microstrain. The evolution of damage in this more sophisticated device appears similar to that which would be expected in a controlled load bending beam fatigue test.

In the USA data collected by CAIT (14) for a study for materials laid on an orthotropic bridge deck in New York State used a value of 900 microstrain to evaluate materials in a four point controlled strain bending beam test. It should be noted that the materials being used in bridge decks tend to have a fatigue relationship which can be typically represented by a log-log relationship between tensile strain and fatigue life. While different agencies have used differing values for the evaluation of materials we would note that the performance of the materials in steel deck structures would suggest that values of strain are generally below 1,000 microstrain. Consequently, for Rosphalt materials we have generally adopted a standard testing level of 750 microstrain since most of the current DOT specifications have adopted this value. In addition, this value is consistent with the experience gained by others as discussed above. Life at other strain values can be estimated by fatigue lines produced by testing the materials at different strain levels.

The performance of the Rosphalt modified material compared to a conventional asphalt concrete material was evaluated at two specific stages of the work conducted; 1) mix design and 2) with material placed in paving trials. In addition, we have compared the data obtained with other historical data collected by PRI Asphalt Technologies and CAIT (14). The resulting data is illustrated in Figure 7 which demonstrates that the R50 modification results in a fatigue life which is approximately ten times greater than the conventional material. The improvement in fatigue is supported by observations of performance on steel structures such as the George Washington Bridge, New York were material that was placed in the 2006 is still performing in a satisfactory manner in one of the most heavily trafficked bridges in the world with approximately 1,000,000 vehicles passing over the structure every month. Based upon these observations a reasonable specification requirement for the performance of materials for orthotropic steel bridge decks would be the requirement to achieve 1,000,000 load applications at a 750 microstrain level. For concrete decks the requirement for flexure is lower and this value could be considerably reduced.

In addition to fatigue performance the mix was also evaluated in the indirect tensile test for creep and strength properties (AASTHO TP9). The stiffness obtained from the creep test was used to calculate the estimated stresses in the mixture when subjected to a standard cooling rate. This resulting thermal stresses generated were then used with the tensile strength data obtained from the testing to estimate the low temperature cracking temperature. This gave a result of -36^{o}C as the mixture estimated critical cracking temperature. This temperature is significantly lower than that of the unmodified binder which was graded as a -22. The two material characteristics that impacted this calculation significantly are the lower stiffness and the high tensile strength of the materials of that the Rosphalt modification achieves.

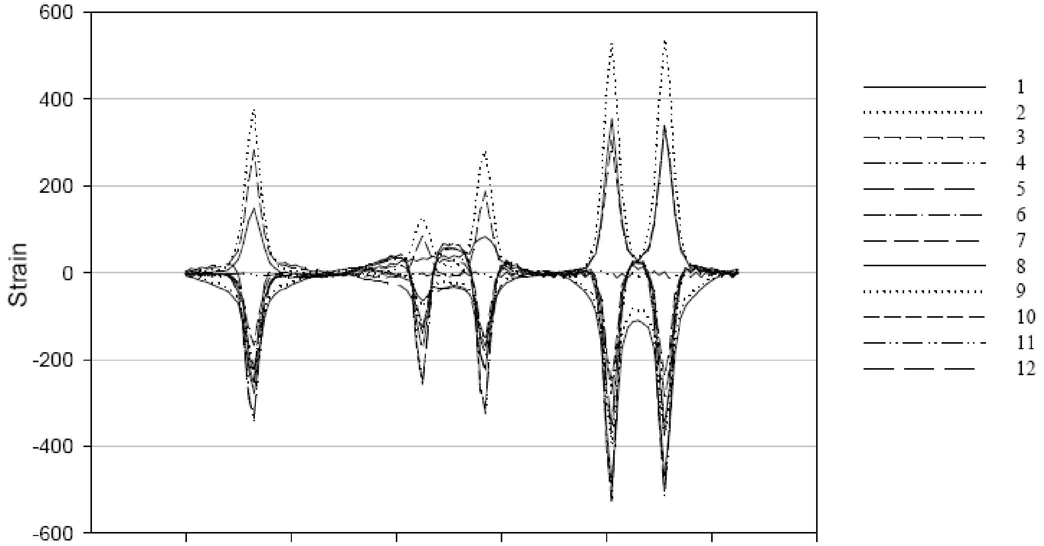


Figure 5: Strain response of orthotropic steel deck bridge (after De Backer et al. (11))

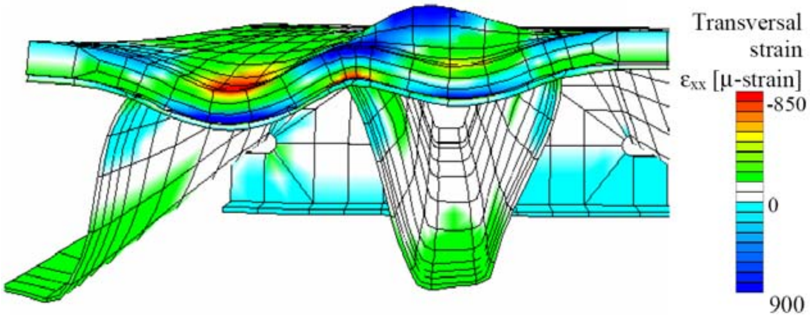


Figure 6: Deformed bridge deck (250x) with transversal strain under a 14.5 tons (3mm water-proof layer an 50mm mastic asphalt) (after Medani (12))

Deformation performance

The deformation performance of asphalt materials is very difficult to assess due to the complex interaction that exist between loading speed, stress applied, state of confinement of test specimens and other factors. Consequently, many agencies prefer to evaluate materials in wheel tracking experiments that appear to be intuitively representative of the actual loading on site. In the work with Rosphalt materials a wide variety of wheel tracking experiments have been conducted. Lai (15) assessed the performance of the material in the Georgia Wheel Tracking (GWT) for use in Racetracks whereas Mallick et al. (16) studied the by conducting tests in a "model mobile load simulator." More recently, we have extended this data set by performing tests in the Asphalt Pavement Analyzer (which is the commercial development of the GWT) and the Hamburg Wheel Tracking (HWT) tests. The HWT test was conducted on a laboratory prepared specimen at 50°C in the "wet condition" with a total deformation of 6.2mm after 20,000 load passes. The result in the APA (AASHTO TP63) on actual cores taken from the trial pavement areas gave an average deformation of 2.4mm at 8000 cycles (100 psi, Load - 100 lbs, test temperature 64°C). Both these results indicate that the material has a good propensity to withstand permanent deformation. The key parameter that results in this excellent performance is the modification of the binder that results in practically all the strain associated with loading is recovered.

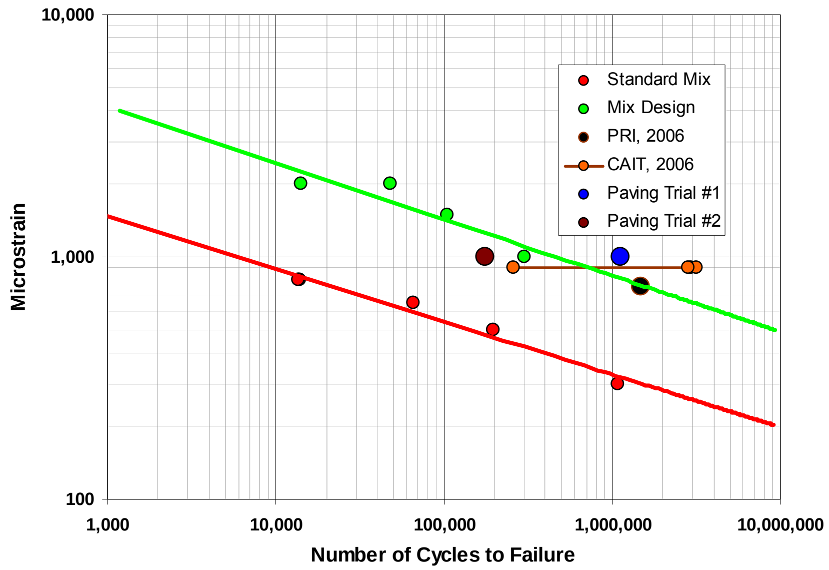


Figure 7: Fatigue performance of Rosphalt modified mixtures compared to conventional Asphaltic Concrete

SUMMARY

The evaluation of Rosphalt as an alternate bridge deck waterproofing system has required extensive laboratory and field evaluation. The key functionality requirements after the material has been placed are the ability of the material to act as a water-proofing layer, demonstrate good flexibility and resist permanent deformation. The Rosphalt modification achieves all three of these performance criteria via a unique "dry-process" modification. Each of these requirements rely upon a characteristic of the mixture or binder modification to achieve the desired functionality as summarized:

1. **Hydraulic conductivity**, ASTM D5084 - <$1\text{x}10^{-7}$ cm/sec. Volumetric design enables achievement of low hydraulic conductivity. It is vital to ensure that the desired volumetrics are achieved in the field and this is normally obtained via the use of paving trials before the materials are placed and careful quality control on site.
2. **Fatigue and Flexure**, ASTM D4760 - >1,000,000 cycles, 20°C, 750$\mu\varepsilon$. The reduction is binder stiffness through modification and the use of thermo-plastic elastomeric modifiers enables an increase of fatigue and flexibility when this material is compared to conventional asphalt mixtures.
3. **Low temperature performance,** AASHTO TP9, <-30°C. The modification of a -22 grade results in a grade which is lower than -30 due to the lower stiffness and higher strength of the modified materials.
4. **Permanent deformation**, AASHTO TP 63 - <10mm, 8,000 cycles, 64°C. The stiffness and elastic recovery of the binder modification at a high temperature and low loading speed enables deformation to be recovered after each loading pass whereas a conventional binder would develop significant deformation.

The Rosphalt materials enable an alternate solution for bridge deck waterproofing that can be easily specified and implemented. This method offers some additional benefits of ease of maintenance and rapid construction time and can assist with the need for effective project delivery in today’s market.

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