Effects of hot storage on polymer modified binder properties and field performance

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Digital Object Identifier (DOI): dx.doi.org/10.14311/EE.2016.064

ABSTRACT

Polymer modified binders (PMBs) are widely used in road construction as they provide enhanced performance properties (e.g. rutting and cracking resistance) compared with conventional bitumen. Even though they show enhanced service properties, they may show degradation or changes in test properties during hot storage. This study investigated the effects of hot storage (up to 6 days at 180°C) on the test properties and field performance of PMBs containing low (3.5% by weight) and high (6% by weight) levels of styrene-butadiene-styrene (SBS) polymer. The chemical changes that occurred during storage were also monitored using Fourier transform infra-red spectroscopy (FTIR) and gel permeation chromatography (GPC). The field performance of the PMBs was assessed by conducting wheel tracking and fatigue tests in a single laboratory dense graded asphalt mix.

Both PMBs showed changes in conventional test properties and chemical composition during storage with the PMB containing 6% SBS showing the largest changes in penetration at 25°C and softening point results. Chemical tests indicated that the polymer in both PMBs was degrading during storage by breaking into smaller fragments. Even though the polymer in the PMBs was degrading, there was no change in the wheel tracking performance of the 6% SBS PMB at 60°C when it was stored. The 3.5% SBS PMB showed better wheel tracking performance after 2 and 4 days storage than prior to it being stored. Both PMBs showed an improvement in their fatigue performance at 10°C after they were stored. The results obtained during this study appear to indicate that degradation of the SBS polymer in a PMB during storage may not necessarily reduce its performance on the road.

Keywords: Chemical properties, Fatigue Cracking, Modified Binders, Permanent Deformation, Polymers

1. INTRODUCTION

Polymer modified binders (PMBs) are increasingly used in road construction as they provide enhanced performance properties compared with conventional bitumen. Even though they show enhanced performance properties, a number of studies have indicated that styrene-butadiene-styrene (SBS) based PMBs may show degradation or changes in test properties during hot storage and transport [1-4], or on exposure to a combination of heat and air [5-8]. Studies of SBS-based PMBs which have been aged using thin film oven (TFO), rolling thin film oven (RTFO) or pressure ageing vessel (PAV) treatments have indicated that the test property changes observed when these types of materials are exposed to a combination of heat and air are due to the effects of both bitumen oxidation and polymer degradation [5, 7-9]. Gel permeation chromatography (GPC) experiments have indicated that polymer degradation is most commonly due to a reduction in the size or molecular weight of the SBS polymer during ageing.

Even though changes in PMB test properties and chemistry have been observed when SBS-based PMBs have been subjected to hot storage, there has been little research into how these changes affect the performance of these materials on the road. The main aim of the research described in this paper was to investigate the effects of hot storage on the test properties and field performance of PMBs containing two levels of SBS polymer (i.e. 3.5% and 6% by weight). These polymer levels were chosen to be representative of those used to produce commercial PMBs in Australia [10]. PMB samples containing the desired levels of polymer were initially produced in the laboratory. Subsamples of each of the materials were then stored in an oven at 180°C for periods up to 6 days and the changes in test properties and chemical nature of the PMBs was monitored as a function of storage time. The chemical properties of the PMBs were investigated using Fourier transform infrared spectroscopy (FTIR) and gel permeation chromatography (GPC). The relative road performance of the binders was assessed as a function of storage time by conducting wheel tracking and fatigue tests on binder samples after they had been incorporated into a single type of dense graded asphalt mix. The contribution of the non-polymer components in the PMBs to test property and asphalt performance changes was also investigated.

2. EXPERIMENTAL DESIGN

2.1 Binder test procedures

Viscosity at 165°C and torsional recovery at 25°C tests were performed in this study using Austroads test methods AGPT/T111 [11], AGPT/T122 [12], respectively. Penetration at 25°C, storage stability and viscosity at 60°C tests were performed using AS 2341.12 [13], EN 13399 [14] and AS 2341.2 [15], respectively. Softening point tests were performed on PMB samples using Austroads test method AGPT/T131 [16]. Softening point tests were conducted on bitumen samples, and blends of bitumen and polymer combining oil, using AS 2341.18 [17]. The torsional recovery at 25°C test gives an indication of the elastic properties of a binder and typically has a single operator variability of ±2%. Torsional recovery tests are performed by manually rotating an aluminium cylinder which is embedded in a cup of binder through an angle of 180° over a 10 second period, and then determining the percentage of angular recovery that occurs after 30 seconds. Softening point tests were conducted in this study without stirring the bath liquid as required by AGPT/T131 and AS 2341.18.

2.2 PMB sample manufacture

PMB samples were manufactured in the laboratory at 185±5°C using a Silverson laboratory high shear mixer (Model L5M) with a Duplex mixing assembly under an inert carbon dioxide atmosphere. PMB blending was performed under an inert atmosphere to ensure that the bitumen did not oxidise during the blending process. Each 3100 g blend that was produced was prepared by adding appropriate masses of Class 170 (C170) bitumen and polymer combining oil to a metal tin and heating the mixture to 180°C prior to adding the polymer. The polymer was dispersed by subjecting each blend to high shear mixing at 4000±100 rpm for 60 minutes. In order that sufficient material would be available for the storage experiments, ten separate blends of PMBs containing 3.5 and 6% SBS polymer were produced.

The 6% SBS PMB contained 85% C170 bitumen, 6% SBS polymer and 9% polymer combining oil by weight, while the 3.5% SBS PMB contained 92.5% C170 bitumen, 3.5% SBS polymer and 4% polymer combining oil by weight. These PMB formulations were used as previous studies [18] had indicated that they would produce materials which would show test properties that met the requirements of specific PMB grades in the Australian PMB specification [19]. The C170 bitumen used in the PMB blends had a viscosity at 60°C of 170 Pa s, a penetration at 25°C of 71 (0.1 mm) and a softening point of 47.0°C. The SBS polymer (Kraton D1101) and polymer combining oil (Permaflux) used in the PMB blends was obtained from Kraton Polymers and Shell Australia, respectively. The polymer combining oil had a viscosity at 60°C of 0.49 Pa s when tested using AGPT/T111.

2.3 Hot storage experiments

Hot storage experiments utilising both the 3.5% and 6% SBS PMBs were conducted by initially adding 7100 g of each type of binder to three identical metal tins. The lids were then placed on the tins (to reduce binder oxidation due to air) and the tins were then stored in an oven at 180°C for different periods of time. Each sample was stirred daily with a spatula (except for days which occurred on a weekend) and the lid replaced after mixing. These processes were followed so that the storage experiments more closely simulated the conditions in a bitumen storage tank or truck. After each sample had been heated for the required time, it was removed, stirred, and then split into appropriate sized samples for testing. The samples were then allowed to cool and were stored at ambient temperature until required for testing.

2.4 Chemical characterisation tests

Fourier transform infrared (FTIR) spectroscopy measurements were conducted using a Perkin Elmer Frontier FTIR spectrometer which included a universal attenuated total reflectance (ATR) sampling accessory. The measurement process involved placing drops of heated binder onto a piece of paper and allowing them to cool. The drops of binder were then placed on the surface of zinc selenide crystal which was part of the sampling accessory. FTIR spectra were obtained by averaging the results of 10 spectral scans on each sample using an instrument resolution of 4 cm^{-1}.
Gel permeation chromatography (GPC) measurements were conducted using a Shimadzu GPC system fitted with a Wyatt Optilab EOS interferometric refractometer which measured the change in the refractive index of the eluted sample over time using red (690 nm) light. Experiments were conducted by injecting 50 μL of a 10 g/litre solution of each binder in tetrahydrofuran (THF) into the GPC apparatus. Samples were passed through three Phenomenex phenogel columns (with effective pore sizes of 0.05, 1 and 100 μm) prior to reaching the detector. The column temperature was 30°C and solution flow rate was 1 mL/minute. THF was used as the mobile phase in the experiments. The retention times obtained for each material were corrected using a polystyrene standard which contained a mixture of polystyrene polymers of known molecular weights (770, 5900, 51100 and 371000 g/mol) so that the results obtained on different days of testing could be directly compared. This accounted for changes in column performance over time.

2.5 Asphalt mix design and test procedures

Asphalt performance tests were conducted using a 10 mm dense graded asphalt mix which met the requirements of a VicRoads Type 10N dense graded mix [20]. This type of mix is used as a light to medium wearing course for use in light to moderately trafficked pavements. Table 1 shows the percentages by weight of each of the components used in the asphalt mix while Table 2 shows the combined grading of the aggregate component in the asphalt mix which was determined using AS 1141.11.1 [21]. All asphalt samples were prepared using identical aggregate components and component percentages. The only difference between the mixes was the type of binder used to prepare the samples. All asphalt samples were prepared using a mixing temperature of 150±3°C.

Table 1: Asphalt mix composition

Component	% weight of total aggregate
10 mm aggregate	31
7 mm aggregate	15
Dust	37.5
Natural sand	15
Limestone	1.5
Binder	5.8

Table 2: Asphalt mix aggregate grading

Sieve size	% aggregate passing (% weight)
13.2 mm	100
9.5 mm	97
6.7 mm	74
4.75 mm	60
2.36 mm	48
1.18 mm	35
600 μm	26
300 μm	17
150 μm	10
75 μm	6.5

Wheel tracking tests were performed at 60°C on duplicate samples containing each of the binders using AGPT/T231 [22] and standard reference conditions using a Cooper wheel tracking device. Wheel tracking depths were recorded after 10000 passes of a weighted loading wheel (700 N), unless otherwise noted, using asphalt specimens which had air void contents in the range of 5.0±1.0%. Four-point bending fatigue tests were performed on triplicate samples using AGPT/T233 and standard reference test conditions [23] except that the temperature during testing was 10.0±0.5°C. Each asphalt beam was subjected to cyclic haversine loading using a loading frequency of 10 Hz and maximum peak tensile strain of 400 με. All asphalt fatigue beams had air voids in the range of 5.0±0.5%. Asphalt fatigue lives were taken to be the number of cycles required to reduce the flexural stiffness of each sample to 50% of its initial value.

3. RESULTS AND DISCUSSION

3.1 Binder tests on PMBs

Table 3 shows the binder test results obtained for the 6% SBS PMB after storage at 180°C for periods up to 5 days. Prior to the storage experiments being conducted on the 3.5% SBS and 6% SBS PMBs, samples of each of the materials were subjected to storage stability tests to determine whether segregation of the polymer in the PMBs would affect the experimental results. Both the 6% SBS PMB and the 3.5% SBS PMB (Table 4) showed quite low results in storage stability tests which indicated that segregation of the SBS polymer would be unlikely to occur during hot storage. The results obtained for the 6% SBS PMB indicated that there was a general reduction in most test properties as the storage time at 180°C was increased. The viscosity at 165°C, torsional recovery at 25°C and softening point of the 6% SBS PMB all showed a general reduction with increased storage time, while the penetration at 25°C of this material showed an overall increase with increased storage time.

Table 3: Changes in the binder properties of the 6% SBS PMB during storage

Storage time at 180°C (days)	**0**	**2**	**4**	**5**
Viscosity at 165°C (Pa s)	0.39	0.36	0.33	0.32
Torsional recovery at 25°C (%)	77	74	64	65
Softening point (°C)	88.0	81.0	76.5	75.5
Penetration at 25°C (0.1 mm)	82	89	93	90
Storage stability (3 days at 180°C)	–1.5	–	–	–
Storage stability: top softening point (°C)	80.5	–	–	–
Storage stability: bottom softening point (°C)	82.0	–	–	–

Table 4 shows the binder test results obtained for the 3.5% SBS PMB after storage at 180°C for periods up to 6 days. The 3.5% SBS was stored for a longer period than the 6% SBS PMB as the changes in softening point observed during hot storage were not as marked as the PMB which contained a higher level of polymer. The 3.5% SBS PMB showed different changes in test properties with storage time than the 6% SBS PMB even though it was subjected to an identical type of storage treatment. The changes in test properties which were observed appeared to depend on the type of test performed. The viscosity at 165°C and penetration at 25°C of the 3.5% SBS PMB did not change markedly on storage. The torsional recovery at 25°C and softening point of the 3.5% SBS PMB showed an initial increase for storage periods of between 2 and 4 days which was followed by a decrease after 6 days of storage.

Table 4: Changes in the binder properties of the 3.5% SBS PMB during storage

Storage time at 180°C (days)	**0**	**2**	**4**	**6**
Viscosity at 165°C (Pa s)	0.21	0.20	0.19	0.19
Torsional recovery at 25°C (%)	25	40	38	31
Softening point (°C)	50.5	53.5	57.0	54.5
Penetration at 25°C (0.1 mm)	74	72	71	72
Storage stability (3 days at 180°C)	–0.5	–	–	–
Storage stability: top softening point (°C)	55.5	–	–	–
Storage stability: bottom softening point (°C)	56.0	–	–	–

3.2 Chemical characterisation tests on PMBs

The FTIR spectra obtained from samples of the 6% SBS PMB after different periods of storage at 180°C are shown in Figure 1 while the corresponding results obtained for the 3.5% SBS PMB are shown in Figure 2. Both figures include an assignment of the chemical species corresponding to each of the main peaks which were obtained by reference to the literature [24-26]. The FTIR spectra of both materials showed a series of peaks which were found to be associated with the bitumen and polymer combining oil components in the PMBs (these are labelled in black in the figures) as well as two peaks associated with the polybutadiene (PBD) and polystyrene (PS) functional groups which are associated with an SBS polymer (these are labelled in red in the figures). The heights of the two polymer related peaks at wavenumbers of 965 cm^{-1} and 699 cm^{-1} were lower for the 3.5% SBS PMB than the 6% SBS PMB. This would be expected as the 3.5% SBS PMB contained a lower level of polymer. There was no significant change in the FTIR spectra of either the 6% SBS PMB or the 3.5% SBS PMB as the storage time was increased. This result indicates that any chemical changes which occurred during storage were not sufficient to cause a marked change in the types or number of chemical functional groups which were present in the PMBs.

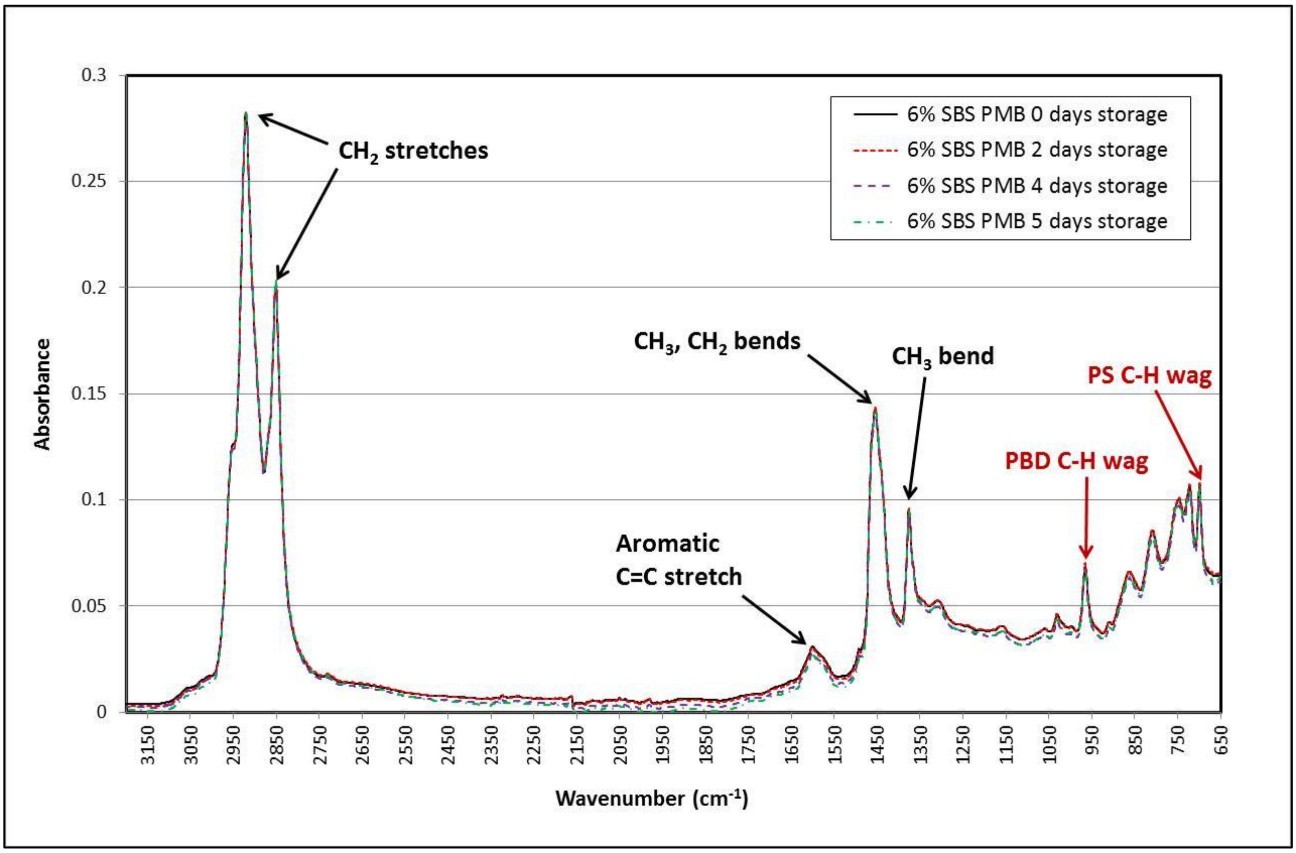

Figure 1: FTIR spectra obtained for the 6% SBS PMB after different periods of storage at 180°C

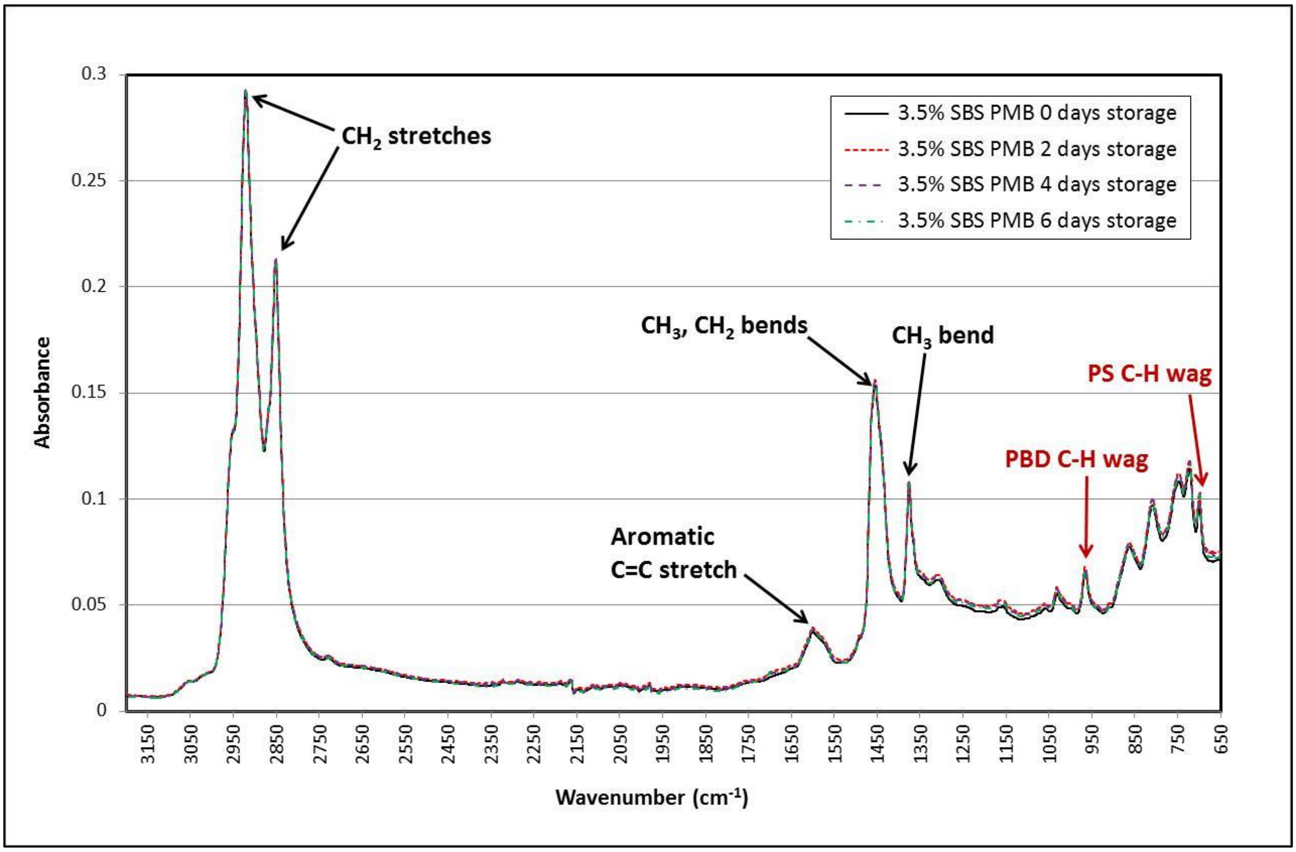

Figure 2: FTIR spectra obtained for the 3.5% SBS PMB after different periods of storage at 180°C

Figures 3 and 4 show the GPC results obtained for the 6% and 3.5% SBS PMBs which were obtained after different storage periods at 180°C. The GPC results shown in each of the figures have been normalised to a maximum differential refractive index value of one at the highest point of the each maximum GPC peak, so that changes in the profiles of the different GPC peaks can be easily compared.

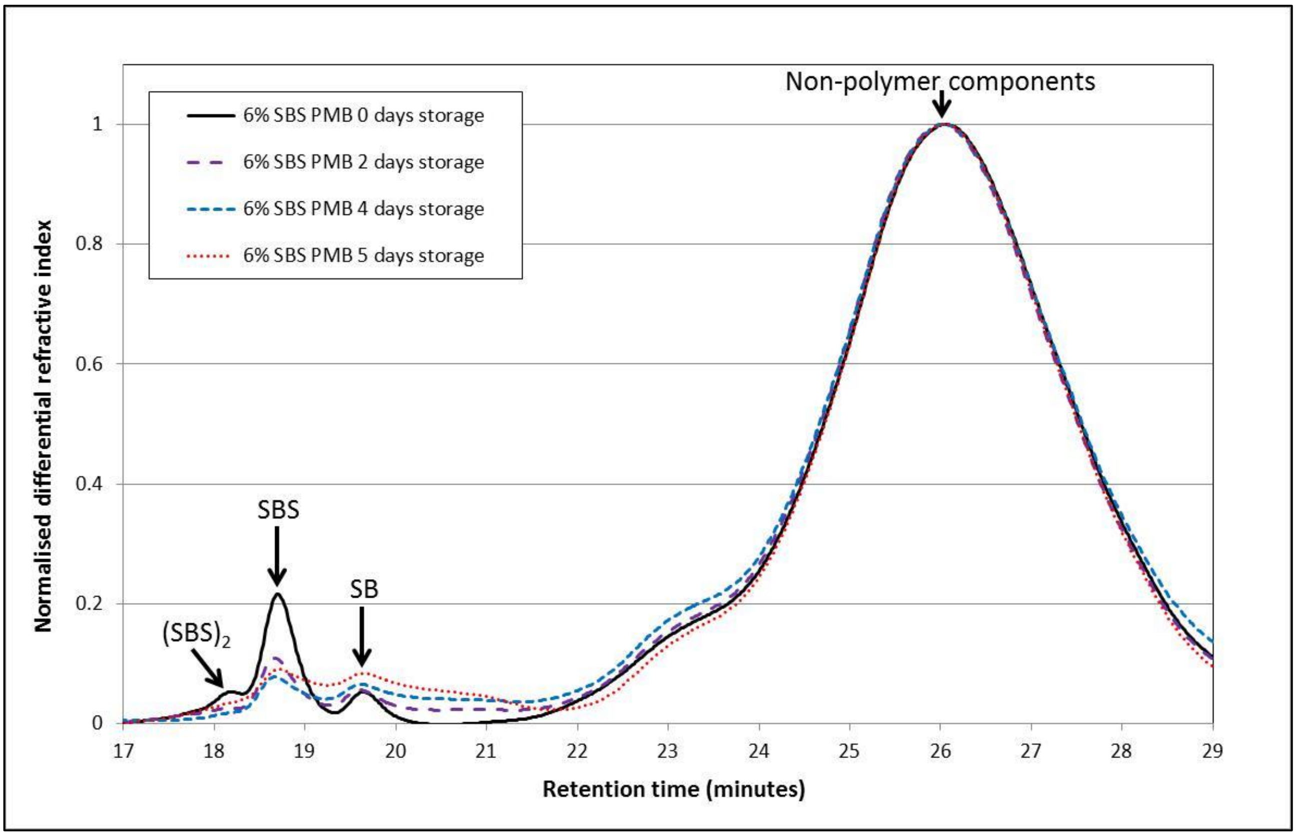

Figure 3: GPC results obtained for the 6% SBS PMB after different periods of storage at 180°C

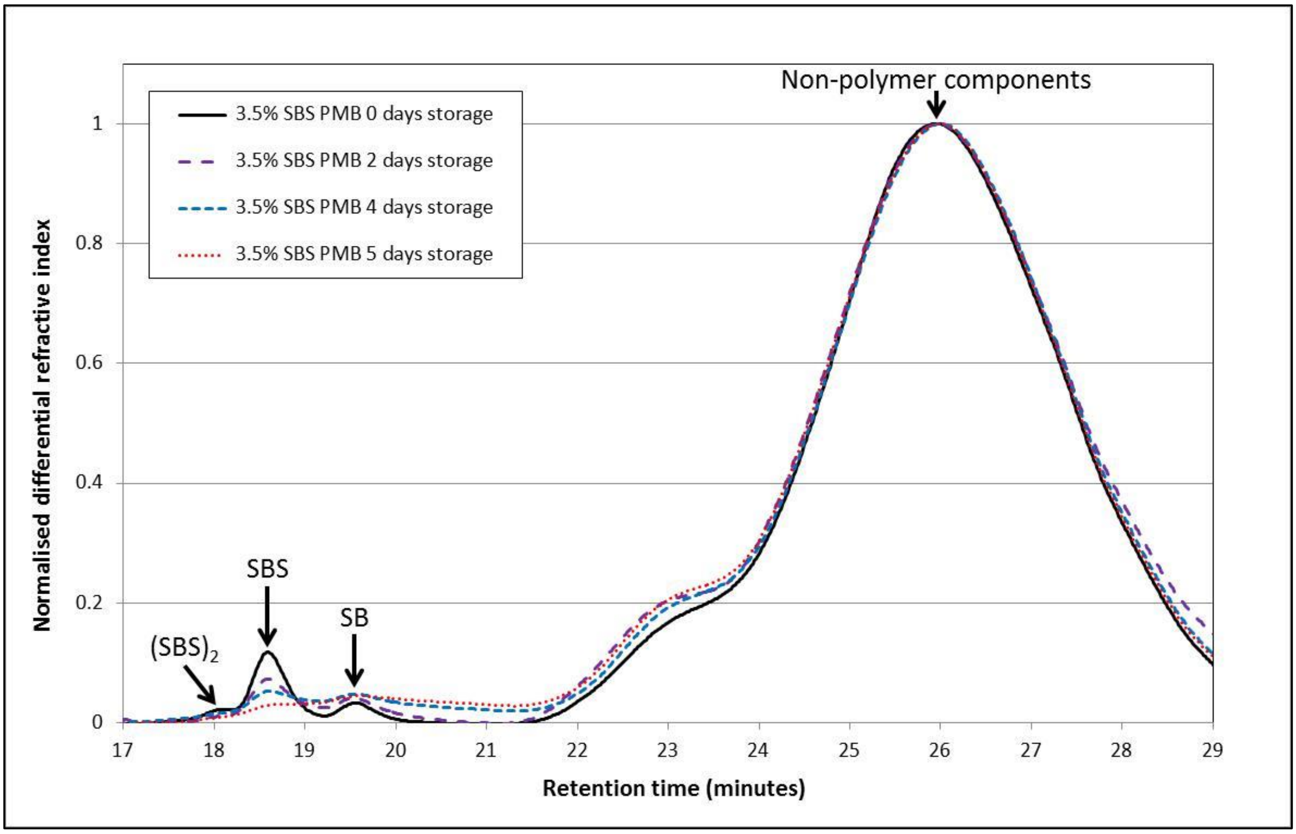

Figure 4: GPC results obtained for the 3.5% SBS PMB after different periods of storage at 180°C

The GPC results obtained for both PMBs prior to hot storage showed the presence of three smaller peaks at retention times of between about 17.5 and 20.5 minutes, as well as a large peak and associated shoulder peak at retention times of approximately 26 minutes and 23 minutes, respectively. GPC experiments conducted on samples of the SBS polymer used to produce the PMBs, as well as samples of the C170 bitumen and the neat bitumen-oil blends used to produce the PMBs, indicated that the three small peaks at low retention times were due to the SBS polymer in the PMBs [27]. The large peak and associated shoulder peak at higher retention times were found to be due to the non-polymer components in the PMBs (i.e. the bitumen and polymer combining oil). Previous GPC studies of the same type of SBS as used in this study [28] indicated that the three smaller peaks were associated with different forms of SBS polymer (i.e. a conventional tri-block SBS polymer (SBS), a dimer of a conventional tri-block SBS polymer ($(SBS)_2$) and a styrene-butadiene di-block co-polymer (SB)). The peaks associated with each of these individual chemical species have been labelled in Figures 3 and 4.

In the case of both the 3.5% and 6% SBS PMBs there was an overall reduction in the size of the GPC peaks associated with the $(SBS)_2$ and SBS polymer species as the storage time at 180°C was increased. At same time this occurred, there was a corresponding increase in the chemical species at slightly higher retention times. In the case of the 6% SBS PMB an increase in chemical species with retention times of between about 19 and 21 minutes was observed as the storage time was increased. This increase occurred at retention times of between about 19.5 and 22 minutes for the 3.5% SBS PMB. As smaller molecules (i.e. those with lower molecular weights) are observed in GPC experiments at higher retention times, the reductions in the peaks associated with the $(SBS)_2$ and SBS polymer species, and the corresponding increases in signals associated with chemical species at slightly higher retention times, indicate that there was an overall reduction in the size of the polymer molecules in both the 3.5% and 6% SBS PMBs as the storage time was increased. This reduction in polymer molecular size implies that the polymer in both PMBs was degrading by chain scission during storage (i.e. the original polymer molecules in the PMBs were breaking into smaller fragments).

The GPC results obtained for the 3.5% SBS PMB indicated that there was a general increase in the height of the shoulder peak observed at a retention time of 23 minutes with increasing storage time. This increase most likely reflects an increase in the size of the non-polymer components (i.e. the bitumen or polymer combining oil) in the PMB on storage. This may also be the case for the 6% SBS PMB, however, the GPC result observed after a storage time of 5 days did not follow the same trend as the other GPC results.

3.3 Asphalt performance tests on PMBs

Table 5 shows the results of wheel tracking and fatigue tests which were performed on asphalt samples containing the 6% SBS PMB after different periods of hot storage. Even though the results of most binder tests showed a general reduction when this material was stored (Section 3.1), and GPC experiments indicated that the polymer in the PMB was degrading during storage (Section 3.2), there did not appear to be a significant change in the wheel tracking performance of the material in asphalt for storage times up to 5 days (as all results were in the range of 4.5±0.2 mm). The fatigue life results obtained for 6% SBS PMB indicated that there was a marked increase in its fatigue performance in asphalt when it was stored. The fatigue life of the 6% SBS PMB increased from 375000 cycles after 0 days of storage, to the order to 4000000 cycles after 4 and 5 days of storage. This change represented an appropriately 10 fold increase in the fatigue life of the PMB in asphalt.

Table 5: Changes in the asphalt properties of the 6% SBS PMB after different periods of storage

Storage time at 180°C (days)	**0**	**2**	**4**	**5**
Wheel tracking test results				
Wheel tracking depth at 60°C (mm)	4.4	4.6	4.5	4.6
Fatigue test results				
Initial flexural stiffness at 10°C (MPa)	6540	5900	5250	5480
Fatigue life at 10°C (cycles)	375000	2164100	4752800	4086400

Table 6 shows the analogous results obtained for 3.5% SBS PMB after different periods of hot storage. The wheel tracking performance of the 3.5% SBS PMB appeared to show some improvement when the results obtained after 0 and 2 days of storage were compared. The wheel tracking performance of the material then appeared to reduce as the storage time was further increased. Even though this occurred, the wheel tracking performance of the 3.5% SBS PMB was better after 2 and 4 days of storage than after 0 days of storage. The fatigue life results obtained for the 3.5% SBS PMB also indicated that there was increase in its fatigue performance even though the results of GPC experiments (Section 3.2) indicated that the polymer in the PMB was degrading during storage. The fatigue life of the 3.5% SBS PMB increased from 63800 cycles after 0 days of storage to the order to 300000 cycles after 4 and 5 days of storage (this corresponded to an appropriately 5 fold increase in the fatigue life of the binder). The changes in binder test properties which were observed for the 3.5% SBS PMB during storage (Table 4) were compared to the changes observed during asphalt performance tests (Table 6). No simple correlation could be found between the changes in either the wheel tracking depth or fatigue life results obtained for the 3.5% SBS PMB in asphalt and the changes in any specific binder test parameter which occurred during storage.

Table 6: Changes in the asphalt properties of the 3.5% SBS PMB after different periods of storage

Storage time at 180°C (days)	**0**	**2**	**4**	**6**
Wheel tracking test results				
Wheel tracking depth at 60°C (mm)	8.7	6.0	7.8	11.0
Fatigue test results				
Initial flexural stiffness (MPa)	8990	7880	7530	7840
Fatigue life at 10°C (cycles)	63800	235200	300400	331900

3.4 Binder and asphalt performance tests on non-polymer components

In order to investigate how the changes in test properties and asphalt performance results observed for the PMBs on storage were influenced by the changes in the properties of the bitumen and polymer combining oil in the PMBs, a single tin containing 7100 g of the C170 bitumen used to produce the PMBs, and a single tin containing 7100 g of the bitumen/polymer combining oil blend used to produce the 3.5% SBS PMB, were subjected to the same hot storage conditions as the PMB samples. The bitumen/polymer combining oil blend contained 95.9% C170 bitumen and 4.1% polymer combining oil by weight. Samples of the bitumen and the bitumen/polymer combining oil blend were subjected to binder tests after different periods of storage for periods up to 6 days. The sample of C170 bitumen was incorporated into the same asphalt mix as that used for the PMB samples and its wheel tracking and fatigue performance was determined after 0 and 6 days of storage. Table 7 shows the binder test results obtained for the samples.

Table 7: Changes in the binder properties of a C170 bitumen sample and C170 bitumen/polymer combining oil blend on storage

C170 bitumen				
Storage time at 180°C (days)	**0**	**2**	**5**	**6**
Viscosity at 165°C (Pa s)	0.09	–	–	0.11
Torsional recovery at 25°C (%)	2	–	–	2
Softening point (°C)	47.0	48.0	49.0	49.5
Penetration at 25°C (0.1 mm)	71	–	–	57
Viscosity at 60°C (Pa s)	170	174	232	234
C170 bitumen/polymer combining oil blend				
Storage time at 180°C (days)	**0**	**2**	**5**	**6**
Viscosity at 165°C (Pa s)	0.08	–	–	0.09
Torsional recovery at 25°C (%)	2	–	–	2
Softening point (°C)	44.5	44.8	47.5	47.5
Penetration at 25°C (0.1 mm)	90	–	–	71
Viscosity at 60°C (Pa s)	117	118	156	166

Both samples showed steady increases in softening point and viscosity at 60°C, and a reduction in penetration at 25°C results, which was consistent with oxidation of the materials during storage. The torsional recovery at 25°C and viscosity at 165°C results did markedly change during storage.

A comparison of the trends in the results shown in Table 7 with those observed for the 6% SBS PMB (Table 3) implied that the reduction in viscosity at 165°C, torsional recovery at 25°C and softening point results, and the concurrent increase in penetration at 25°C results, which were observed for the PMB on storage mainly reflected changes to the polymer in the PMB. This conclusion was made as the softening point and penetration at 25°C results obtained for the sample of bitumen and the bitumen/polymer combining oil blend showed the opposite trends to those observed for the 6% SBS PMB as the materials were stored for longer periods. The viscosity at 165°C and torsional recovery results obtained for the samples which did not contain polymer did not change markedly during storage while they reduced when the 6% SBS PMB was stored.

A similar comparison of the results shown in Table 7 and Table 4 suggests that for the case of the 3.5% SBS PMB, the observed trends in torsional recovery at 25°C and penetration at 25°C results on storage appear to be mostly influenced by changes to the polymer in the PMB. If the softening point results obtained after 0 and 6 days of storage are compared, the 3% SBS PMB showed a softening point increase of 4°C (Table 4) while the bitumen and bitumen/polymer combining oil blend (Table 7) showed softening point increases of between 2.5°C and 3°C on storage. Based on these results, it is likely that the changes in softening point observed for the 3% SBS PMB are influenced by both oxidation of the non-polymer components in the PMB and changes to the polymer during storage.

Table 8 shows the results of wheel tracking and fatigue tests which were conducted on the sample of C170 bitumen after 0 and 6 days of storage. The bitumen sample showed a significant degree of rutting in the asphalt mix used in this study which was greater than the AGPT/T231 test limit of 15mm after 10000 passes. Due to this, wheel tracking depths are shown after 3800 passes as none of duplicate specimens exceeded the 15mm limit after 3800 passes. The wheel tracking performance of the bitumen increased on storage. The fatigue performance of the bitumen showed a very slight increase after storage.

Table 8: Changes in the asphalt properties of C170 bitumen after different periods of storage

Storage time at 180°C (days)	**0**	**6**
Wheel tracking depth at 60°C after 3800 passes (mm)	13.7	9.8
Initial flexural stiffness at 10°C (MPa)	11150	10600
Fatigue life at 10°C (cycles)	21200	26000

As the bitumen sample showed an improvement in wheel tracking performance after it was stored for 6 days whereas the 6% SBS PMB did not show a change in wheel tracking performance during storage (Table 5) it appears that the wheel tracking performance of the 6% SBS PMB is significantly influenced by the polymer in the PMB. For the case of the 3.5% SBS PMB, an improvement in wheel tracking performance was observed between 0 and 2 days of storage (Table 6). The wheel tracking performance on the 3.5% SBS PMB then decreased as the storage time was further increased. As the trends in wheel tracking performance of 3.5% SBS PMB followed the opposite trend to the bitumen sample for storage periods of greater than 2 days, it appears that the wheel tracking performance of the 3.5% SBS PMB is mainly influenced by changes to the polymer in the PMB for storage periods greater than 2 days. As the bitumen sample did not show a marked change in fatigue life during storage, the observed fatigue life increases observed for the PMBs appear to be a result of the changes to the polymer that occurred during storage

As asphalt performance tests were not conducted on the bitumen/polymer combining oil blend it is possible that the changes in PMB asphalt performance are due to changes to the polymer combining oil in the PMBs. This, however, appears unlikely as the polymer combining oil used in this study is a type of brightstock extract/de-asphalted oil which is manufactured by purifying materials with very similar nature to bitumen.

3.5 Discussion

Based on the results of this study, it does not appear that polymer degradation in SBS-based PMBs, or test property reductions (e.g. torsional recovery at 25°C, softening point) during storage, will necessarily result in reduced binder performance on the road. The 6% SBS PMB showed a reduction in most binder test properties during storage and GPC results indicated that the polymer in the PMB was degrading by breaking into smaller fragments. Even though this was the case, there was no change in the wheel tracking performance of the material in asphalt for storage periods up to 5 days and its fatigue performance in asphalt increased on storage. The changes in test properties of the 6% SBS PMB appeared to be mainly influenced by changes to the polymer during storage. The 3.5% SBS PMB showed changes in binder test properties which depended on the type of test performed and GPC results indicated the polymer was also degrading in this PMB during storage. Even though the polymer was degrading, the fatigue performance of the PMB in asphalt increased on storage and its wheel tracking performance in asphalt after 2 and 4 days of storage was better than after 0 days of storage. The test property changes observed for the 3.5% SBS PMB appeared to be influenced by both changes to the polymer and oxidation of the non-polymer components in the PMB during storage.

4. CONCLUSIONS

Studies of PMB samples containing 3.5% and 6% by weight SBS polymer were conducted to investigate the effects of hot storage on the test properties and field performance of these types of materials. The test property changes observed for the 6% SBS PMB on storage differed from those observed for the 3.5% SBS PMB even though both materials were subjected to an identical type of storage treatment. FTIR tests indicated that the chemical changes which occurred during storage were not sufficient to cause a marked change in the types or number of chemical functional groups which were present in the PMBs, while GPC tests indicated that the polymer in both PMBs was degrading during storage by breaking into smaller fragments. Based on the results obtained during wheel tracking and fatigue tests, it does not appear that polymer degradation in SBS-based PMBs, or test property reductions (e.g. torsional recovery at 25°C, softening point) during storage, will necessarily result in reduced performance of these types of materials when they are used in asphalt.

ACKNOWLEDGEMENTS

We would like to thank Dr Alex Duan of the University of Melbourne for his assistance with the gel permeation chromatography (GPC) measurements. Thanks also to Austroads Ltd. for providing funds for this work.

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