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Effect of storage stability on chemical and rheological properties of polymer-modified asphalt binders for road pavement construction

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HIGHLIGHTS

- Storage stability of five polymer-modified binders was evaluated.
- Advanced indices were developed to identify storage stability properties of PMBs.
- Physical, rheological, and chemical properties were analyzed.

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ABSTRACT

Polymer modified asphalt binders (PMB) are being commonly used instead of neat binders when superior performance is needed during the road service life. The addition of polymer improves the binder's properties at high, low and mid-range temperatures. However, the effectiveness of polymer modification in improving road performance depends on a chemical-structural modification in the binder's composition to be effective and durable. The phase inversion phenomenon between asphalt components and the added polymer leads the binder to assimilate the polymer characteristics. PMBs can have stability problems and separation; in fact, polymers and bitumen components can lose most of the benefits from the modification due to separation during the storage phase. Common testing for storage stability assessment includes the cigar tuben test (EN 13399, 2010) which provides an indication of whether separation has occurred. To evaluate the effects of separation on performance-related properties of the binder, the present study analyzed the storage stability and separation phenomena of five PMBs by performing an advanced-rheological storage stability test, based on frequency sweep tests on samples taken from the top and bottom part of 3, 5 and 7-day stored cigar tuben specimens. Master curves were developed for newly mixed and several storage conditions and were compared to identify possible separation phenomena between top and bottom samples. Indices were also developed to quantify separation of samples. Results showed that storage stability problems commonly start at the third day of storage. Binders which were seriously affected by separation, seemed to incrementally lose their homogeneity (top and bottom part) between 3 and 7 days. Other binders preserved their rheological characteristics during storage, maintaining equal values between the top and bottom samples. All stored binders were affected by an aging factor.

1. Introduction

Changes in the asphalt binder structure due to polymer modification procedures can cause several problems during the storage phase. Binder in the asphalt storage tank, before being mixed with the aggregates at the plant, can suffer from separation between polymer and bitumen phase, for instance. Low density polymers float to the top of the tank, while asphaltenes segregate and move to the bottom part of the tank. The separation process leads to a consequent failure of the polymer modified binder's properties and loss of all the benefits coming from the modification. Binders weakened by separation can therefore suffer from both poor rutting performance at high temperatures and poor fatigue and thermal cracking performance at medium-low temperatures. To preserve binders from these flaws several precautions seem to be

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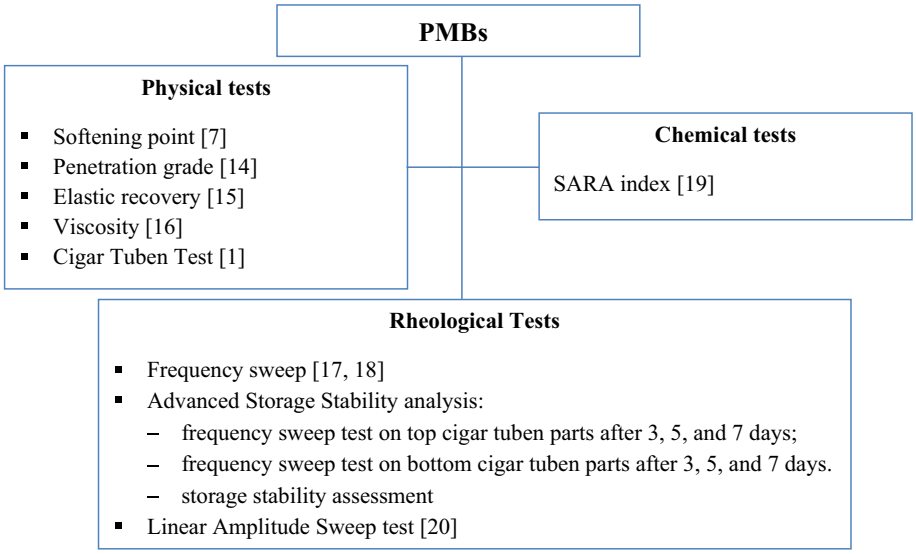

Fig. 1. Storage stability of polymer-modified asphalt binders – Experimental plan.

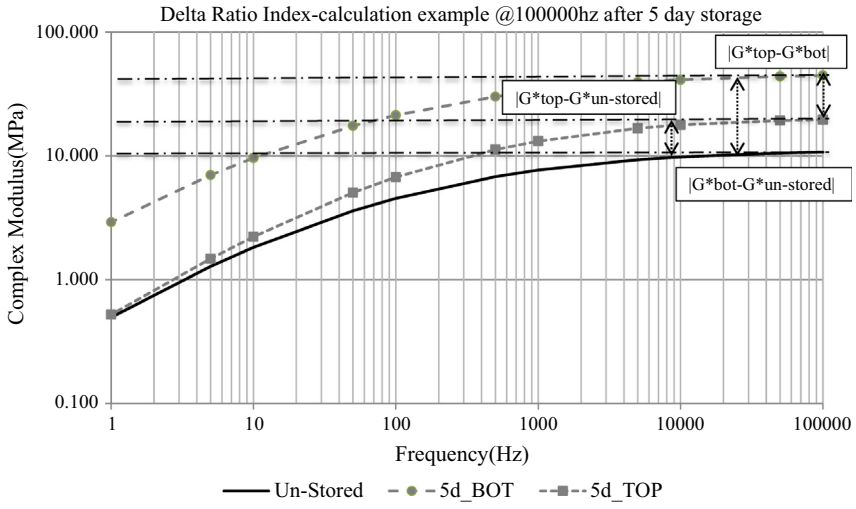

Fig. 2. Delta Ratio index.

necessary: a stabilizing agent can be added into the binder for building a durable bitumen-polymer network that is difficult to break and a continuous mixing action in the storage tank can be provided to avoid the physical separation. Storage stability problems are commonly evaluated through a simple physical test [1,2] which measures the difference between the softening point of samples taken from the top and bottom parts of a standard cigar tube after vertical storage in an oven at high temperature (i.e.; 150–180 °C). However, the softening point test itself is not sufficient to evaluate the storage stability effects on performance related properties and, in this study, rheological modifications due to storage were also taken into account.

PMBs were stored vertically in cigars for 3, 5 and 7 days in an oven kept at 180 °C. After each period, samples were taken from the top and bottom sections and frequency sweep tests were performed at multiple temperatures. This test provided information about complex modulus (G^*) and phase angle (δ) trends with increasing storage time. A comparison between master curves from stored and un-stored binders of top and bottom sections evaluated the storage effect. However, when studying the change in binder properties over time at high temperature, it is important to consider the difference between separation issues and unavoidable aging effects, which affect the binder by showing increased complex modulus and reduced phase angle. Several separation indices were therefore adopted to evaluate the storage stability of PMBs.

Table 1
Standard physical characterization of PMBs.

Binder	Softening Point [°C] [7]	Penetration [dmm] [14]	Elastic recovery [%] [15]
PMB_1	77.5	51.5	92.5
PMB_2	62.1	62.0	94.2
PMB_3	72.5	56.0	93.7
PMB_4	75.5	47.0	96.4
PMB_5	65.6	64.0	96.7

2. Background

Polymer Modified Binders have superior performance-related properties compared with neat bitumen after a chemical process