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Influence of soft bitumens on the chemical and rheological properties of reclaimed polymer-modified binders from the "old" surface-layer asphalt

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HIGHLIGHTS

- Residual characteristics of the polymer modification are found in the reclaimed binders.
- The soft bitumen influences the chemistry and rheology of reclaimed binder significantly.
- Mixing with soft PMB binder makes it possible to restore the rheological properties of the reclaimed PMB binder.

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ABSTRACT

Reclaimed asphalt (RA) that contains polymer-modified bitumen (PMB) offers a potential premium material contribution for recycling. This study investigated the influence of soft virgin bitumens on the chemical and rheological properties of three reclaimed PMBs from different "old" surface-layer asphalt mixtures in Europe. Although the PMB degrades during the service life of the asphalt pavement, residual characteristics of the polymer modification are found in the reclaimed binder and can be manifested when blending with virgin paving grade bitumen or with virgin PMB binder. The soft bitumen influences the chemistry and rheology of reclaimed binder significantly, but these chemical and rheological changes are not consistent. Mixing with soft PMB binder makes it possible to restore the rheological properties of the reclaimed PMB binder. It means that the polymer from the reclaimed binder can function in a new mixture when recycled.

1. Introduction

Polymer modified bitumens (PMBs) are used extensively all over the word to improve the durability and functionality of premium asphalt pavements [1–4]. PMB is often manufactured by the incorporation of a polymer in the bitumen using mechanical mixing or chemical reaction. Styrenic block copolymers, such as styrene–butadiene–styrene (SBS), are typical modifiers and have shown the greatest potential when blended with bitumen [5–8].

The physical and chemical characteristics of PMBs can change during production, storage, transportation, and in-service life of asphalt pavement [9,10]. Some reactions happen during these processes, such as bitumen oxidation, polymer degradation, dehydrogenation and loss of volatiles [11–14]. These factors may cause PMB to be stiff and brittle, and consequently fail the pavement. At present, the road sector is facing a rapidly increasing source of polymer modified asphalt pavements which are now more and more reaching their end of life. These pavements offer a potential premium material contribution for recycling.

Although recycling of asphalt is a common practice in Europe, and the RA content is up to 60% in base layers in some countries, recycling using the added functionality of polymer modification present in the RA has not been thoroughly investigated. When a normal paving grade bitumen is used, the recycled bitumen can

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be mixed with a softer one to create a new asphalt mix. Since polymer modified bitumen has different rheological properties compared to paving grade bitumen both at normal and elevated temperatures, the recycling method needs adjustments with respect to the type of addition and the temperature needed during mixing and compaction [15]. The binder in the RA containing polymer modification may be extremely stiff, and it could be a challenge to "rejuvenate" the old PMB to utilise its potential contribution to new asphalt.

ERA-NET ROAD initiated a joint research project in Europe entitled "Possibilities for High Quality Recycling of Polymer Modified Asphalt". The aim of this project is to investigate the possibilities for recycling polymer modified asphalt from surface layers into new high quality surface layers by means of hot mix recycling. As part of the project, this study investigated the influence of virgin soft bitumens on the chemical and rheological properties of three representative PMB-containing RA binders in Europe. The results are expected to help the pavement manager recycle polymer modified asphalt.

2. Experimental

2.1. Materials

2.1.1. PMB-containing RA binders

Three "old" PMB-containing asphalt mixtures were reclaimed from typical surface layers of premium pavements in three different counties: porous asphalt (PA4/8) in The Netherlands, dense asphalt (AC11) in Slovakia, and stone mastic asphalt (SMA11) in Denmark. The PA4/8 mixture was produced in 2006 and from the top layer of a double porous asphalt system located at one section between Den Bosch and Eindhoven on Expressway A2 in The Netherlands; the original binder was Styrene–Butadiene Rubber (SBR) modified bitumen with a penetration (Pen.) ranging from 40 to 100 × 0.1 mm and a softening point (S.P.) value above 65 °C. The AC11 mixture was constructed in 1996 on a section of motorway in the vicinity of the town Sered, Slovakia; the original binder was styrene–butadiene–styrene (SBS) modified bitumen with a Pen. value from 50 to 100 × 0.1 mm and a S.P. value above 70 °C. The SMA11 was produced in 1989 and paved on a motorway in Denmark (Jutland, north of the town of Vejle); the original binder was a high content SBS modified bitumen with a Pen. value from 70 to 100 × 0.1 mm and a S.P. value above 75 °C.

Following European norms EN 12697-1 and EN 12697-3 [16,17], extraction and recovery were performed using dichloromethane on these three reclaimed mixtures to obtain three PMB-containing binders with abbreviations as RAN (from The Netherlands), RAS (from Slovakia), and RAD (from Denmark). Especially, the original binder of RAD had been kept for 23 years after the construction of the pavement and its chemical and rheological properties were also characterised in this study.

2.1.2. Soft virgin binders

Soft virgin bitumens, Base1 and PMB1 were used to blend with RAN and RAS. Base1 is a straight run bitumen with paving grade 70/100, provided by Kuwait Petroleum, Nederland, B.V.; PMB1, provided by Kraton Polymers Nederland, B.V., is a modified bitumen produced by mixing 10% of SBS in straight run bitumen with paving grade 160/220.

Soft virgin bitumens, Base2 and PMB2, were used to blend with RAD. Base2 was produced by blending two different bitumens with paving grade 70/100 and 40/60 in the proportion 71.2% and 28.8%, and the Pen. value and the S.P. value are 91 × 0.1 mm and 44.0 °C. SBS polymer modified bitumen PMB2 was provided by a Danish asphalt contractor as a reference sample from their production, with a Pen. value of 115 × 0.1 mm and a S.P. value of 90.4 °C. More information about the soft virgin binders can be found elsewhere [18].

Table 1
Codes of blended binders.

Codes	RA* content [%]
15%RAN + Base1	15
40%RAN + Base1	40
15%RAN + PMB1	15
40%RAN + PMB1	40
15%RAS + Base1	15
40%RAS + Base1	40
15%RAS + PMB1	15
40%RAS + PMB1	40
15%RAD + Base2	13.66
40%RAD + Base2	36.89
15%RAD + PMB2	13.66
40%RAD + PMB2	36.89

* There are three RA binders: RAN from The Netherlands, RAS from Slovakia, and RAD from Denmark.

Table 2
GPC test conditions for bitumen.

Items	Content
Mobile phase	Tetrahydrofuran (THF)
Solvent (sample preparation)	THF (30 min, 100 rpm @ room temperature)
Sample concentration	30 ± 3 mg/25 ml
Injection volume	50 μl
Flow rate	1,5 ml/min
Test temperature	35 °C
Detector	Photodiode array, (PDA)
Columns	Shodex KF 802; KF 802,5; KF 803; and KF 805
Calibration standards	Polystyrene

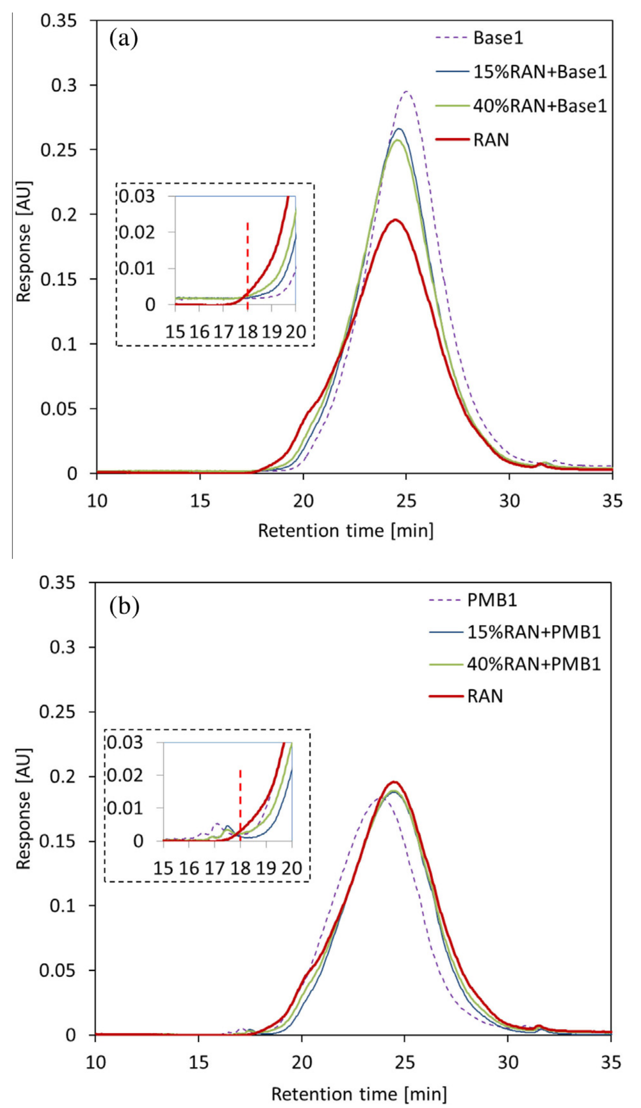

Fig. 1. Molecular weight distribution of (a) RAN + Base1 group and (b) RAN + PMB1 group.

2.1.3. Blended binders

Two realistic ratios, 15% and 40% by mass of the PMB RA binder were chosen to blend with soft virgin binder. In total, 12 blended binders were prepared and their codes are given in Table 1. Note that the Danish blended binder has a slightly different RA percentage, since the Danish mix design was based on adding 40% RA to