Construction and Building Materials 136 (2017) 474–481

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effect of ageing process on bitumen and rejuvenated bitumen

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HIGHLIGHTS

- Potentialities of a specific rejuvenator.
- Effect of ageing process on the rejuvenated bitumen.
- Ageing is an evolutive process that affects the bitumen even after the PAV procedure.
- Ageing has a similar effect on virgin bitumen and rejuvenated bitumen.

ARTICLE INFO

Article history:
Received 3 September 2016
Received in revised form 26 December 2016
Accepted 8 January 2017

Keywords:
Hot recycling
Bitumen ageing process
Rejuvenator

ABSTRACT

In the last few decades, highway agencies and the paving companies have invested huge efforts on increasing the amount of reclaimed asphalt (RA) to be introduced in the production of new asphalt concrete (AC). This technique, so-called hot recycling of RA, offers several economical and environmental advantages tightly related to the replacing of natural materials, such as aggregates and bitumen, with recycled one. Indeed, the hot recycling of RA implies a reduction of the virgin aggregate and bitumen supply to produce AC. Additionally, hot recycling allows decreasing the amount of RA disposal. However, when a high amount of RA is hot recycled, the mechanical properties of aged bitumen must be considered for an appropriate mix design. In this case, recycling additives are used to achieve good mechanical performance.

This paper deals with the effect of ageing and of a specific rejuvenator on mechanical properties of a paving grade bitumen. Moreover, the effect of ageing on mechanical properties of the rejuvenated bitumen is investigated. The results showed that the stiffening effect of ageing can be reduced or restored by the use of the rejuvenator. In addition, the ageing process affects the rejuvenated bitumen as well as it does for paving grade bitumen.

1. Introduction

The most common method of asphalt pavement rehabilitation consists in milling the distressed asphalt concrete (AC) and resurfacing using new AC. The milled AC, so called reclaimed asphalt (RA) contains aged bitumen and mineral aggregates that still have appreciable residual properties.

In the last few decades, highway agencies and the paving companies have invested huge efforts on increasing the amount of RA to be introduced in the production of new AC.

The two main factors that stimulate the use of RA in AC are economic savings and environmental benefits. Indeed, the hot recycling of RA implies a reduction of the virgin aggregate and bitumen supply to produce AC without penalizing the AC performance. Additionally, hot recycling allows the amount of RA disposal to be decreased.

In regards to the type and properties of residual bitumen, aging of bitumen should be considered for an appropriate design of the new AC containing RA.

As well known, the bitumen undergoes two different aging phases: short-term and long-term aging [1].

The short-term aging occurs during the production and laying of AC caused by high temperatures. Therefore the first significant aging is due to volatilization of bitumen light component, which occurs during the mixing, storage, transportation, laying and compaction phases when AC keeps high temperatures.

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http://dx.doi.org/10.1016/j.conbuildmat.2017.01.027
0950-0618/

The long-term aging occurs after the opening to traffic and evolves during the service life of the AC mainly due to oxidation and environment factors.

The degree of long-term aging depends on water, light exposition, climatic conditions, thickness of bitumen film around the aggregates and, mostly, on the air void content of AC and layer position in the pavement because they influence the interaction between oxygen and bitumen.

Generally, aging process causes a progressive change of the mechanical and chemical properties of the bitumen leading to a stiff behaviour, poor adhesion and reduced coating properties [2,3].

For these reasons, when a significant amount of RA (typically above 20% by mix weight) is introduced in the production of new AC, it is recommended to add a recycling additive [3–5].

Among recycling additives, a distinction can be made between rejuvenators and softening agents [6–8]. The softening agents have the purpose of decreasing viscosity of the aged binder, while rejuvenators are used to restore the chemical and mechanical properties of aged bitumen ensuring long lasting AC [9–11].

Even if numerous studies have been undertaken on restoring aged bitumen by means of recycling additives [4–6,8,10,11], the aging process of rejuvenated bitumens is still a challenge. Indeed, the ageing process of a rejuvenated bitumen depends on the chemical composition of the rejuvenator and the long-term interaction between rejuvenator and bitumen which is still an open task.

2. Objectives

The overall service life of bitumen considering its reuse in hot recycling can be divided into three main phases: the first service life (service life of virgin bitumen, ageing of the virgin bitumen), hot recycling process using a rejuvenator (bitumen rejuvenation) and second service life (service life of rejuvenated bitumen, ageing of rejuvenated bitumen).

The main objectives of this research can be summarised as follows:

- evaluation of the effects of the ageing process on mechanical properties of a paving grade bitumen (change of the mechanical behaviour of bitumen after the first service life);
- determination of the effect of a selected rejuvenator on mechanical properties of the aged bitumen (hot recycling using a specific rejuvenator);
- investigation on the effects of aging on rejuvenated bitumen (change of the mechanical behaviour of rejuvenated bitumen after the second service life).

3. Experimental programme

The bitumens were artificially manufactured in order to reproduce the three phases of the service life cycle of a bitumen (ageing of the virgin bitumen, bitumen rejuvenation and ageing of rejuvenated bitumen).

Firstly, the 50/70 paving grade bitumen (EN 12591: 2002) was subjected to a first aging step which consists of a short-term aging using the Rolling Thin Film Oven Test (RTFOT, EN 12607-1: 2002) and a long-term aging using the Pressure Aging Vessel (PAV, EN 14769: 2006).

On the basis of a previous experimentation, a rejuvenator, so-called “A”, was selected for this study. The rejuvenator A is soluble in any bitumen and stable over a wide range of temperatures (flash point >300 °C).

The long-term aged bitumen was heated at 170 °C and mixed with the rejuvenator A, in two different dosages: 3% and 6% on aged bitumen weight. In a previous experimentation based on viscosity tests, 6% of rejuvenator A was established as optimum dosage. Since the optimum dosage was determined only on viscosity assessment, a lower dosage, i.e. 3%, which represents a more economical solution, was investigate to evaluate its influence on fundamental proprieties.

In last step, the rejuvenated bitumen samples were subjected to aging following RTFOT and PAV procedures. This phase intends to reproduce artificially the second service life of the bitumen after being hot recycled using a rejuvenator.

Rheological characterization of the bitumens was carried out by means of sinusoidal oscillatory tests conducted through a Dynamic Shear Rheometer (DSR) using the 8 mm plate-plate geometry (EN 14770: 2012). The analysis of the mechanical behaviour of the selected binders was based on three main parameters: strain limit of the Linear Visco-Elastic (LVE) region γ_{lin}, complex modulus G^* and phase angle δ.

The strain sweep test was performed at three temperatures (30, 15 and 5 °C) and three frequencies (10, 50, 100 rad/s) to determine the LVE region of the bitumens in which the G^* is not influenced by the strain magnitude. In particular, setting a frequency load and temperature, the strain at which the complex modulus G^* deviates by 5% from the initial value (G^*_{in}) indicates the threshold of LVE region (γ_{lin}).

The frequency sweep test pointed out to measure G^* and δ over a range of temperatures from 34 to 4 °C (6 °C intervals) and over a frequency range from 1 to 100 rad/s (1-1,78-3,16-5,6–10-17,8-31, 6-56,2-100 rad/s).

Samples of differently aged bitumens, with or without rejuvenator, were produced to allow a direct comparison of results. Fig. 1 summarises the experimental programme applied on virgin bitumen, differently aged bitumens, rejuvenated bitumen and rejuvenated bitumen after aging process.

The tested binders were coded as follows:

- VIRGIN: virgin paving grade bitumen;
- RTFOT: paving grade bitumen after RTFOT;
- PAV1: RTFOT bitumen after PAV;
- PAV2: PAV1 bitumen (or rejuvenated bitumen) after additional RTFOT and PAV.
- When the bitumen was mixed with the selected rejuvenator, the bitumen code is followed by a number, which identifies the percentage of rejuvenator by bitumen weight (3 or 6) and the rejuvenator acronym, i.e. A.

Two repetitions for each test were carried out and the average values were evaluated for the data analysis.

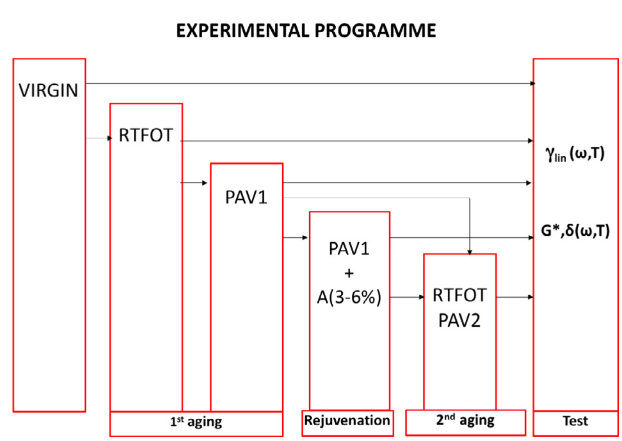

Fig. 1. Experimental programme scheme.