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Laboratory simulation of bitumen aging and rejuvenation to mimic multiple cycles of reuse

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Abstract

A laboratory study on bitumen aging and rejuvenation was conducted to investigate the effect of the multiple cycles of reuse on bitumen properties. The bitumen studied was unmodified conventional paving grade 70/100 pen bitumen which was aged in the laboratory, then rejuvenated with 650/900 bitumen back to 70/100 grade. Four aging-rejuvenation cycles were conducted and properties were tested after each step. The aging procedure consisted of Rolling Thin Film Oven Test (RTFOT) followed by Pressure Aging Vessel (PAV) aging at 90 °C for 20 hours. Results suggest that bitumen hardens the most during the first cycle of aging with the following cycles asserting less influence. The physical bitumen properties could be restored close to the original state. However, the balance of elastic and viscous component was altered towards a more elastic behavior in each cycle. Therefore, it is debatable whether rejuvenation with soft bitumen restores the entire range of performance for the bitumen. The changes cannot be chemically reversed in described process, although the rejuvenator allows for the restoration of some physical properties.

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Keywords: Rejuvenator; aging; rejuvenation; GPC; SARA; DSR

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1. Introduction

In lieu of the availability of bitumen and its price uncertainty, the need to recycle asphalt in road construction has become essential. Therefore, an especial focus has arisen in finding ways to revive aged and hard bitumen concurrently maintaining the quality of the asphalt.

A laboratory study on bitumen aging and rejuvenation was conducted to investigate the effect of the multiple cycles of reuse on bitumen properties. The bitumen studied was unmodified conventional paving grade 70/100 pen (B80) bitumen which was aged in the laboratory, then rejuvenated with 650/900 bitumen (B800) back to 70/100 grade. Four aging-rejuvenation cycles were conducted to simulate multiple reuse of bitumen for hot-in place recycling (HIPR), discussed more by Makowska and Pellinen, (2015).

The Finnish Transport Agency (FTA) allows the hot-in place remixing method to be used only twice in a row due to concerns regarding pavement quality, as discussed in depth by Makowska and Pellinen (2015). HIPR consists of in-situ reheating of the existing pavement followed by milling, addition of the rejuvenator and fresh admixtures, followed by the homogenization of the produced layer before the final compaction.

The objective of the study was to determine the effect of the multiple recycling and rejuvenation in laboratory conditions on the bitumen chemical composition and rheological characteristics; to determine a framework for the best optimization strategies and to evaluate quality control criteria for the rejuvenation process.

2. Materials and methodology

In the aging and rejuvenation procedure, fresh B80 was first RTFO (SFS-EN-12607-1), then PAV (ASTM D6521-13) aged at 90 °C for 20 hours. This mimics short-term aging taking place during asphalt production and long-term aging on the road. After analysis, the aged product was then rejuvenated with B800 targeting a penetration of fresh B80. Four aging-rejuvenation cycles were conducted with the properties tested after each step. Table 1 gives the properties of standard B80 and B800 used in the experiment. The value of G*sin δ = 5000 calculated from straight run bitumen is provided in Table 1, while the fatigue cracking parameter can be found in Table 5 entry A1.

Table 1. Analyses of the test bitumens B80 and B800.

		unit	B80	B800
	Penetration 25 °C	0.1 mm	86	966
	Penetration 15 °C	0.1 mm	na	291
	Viscosity 60 °C	Pas	114	5.03
	Viscosity 135 °C	mm^2/s	296	69.7
	G* at 15 °C, 1.59 Hz	Pa	4 030 000	129 000
	G* at 30 °C, 1.59 Hz	Pa	263 000	7 350
	G* at 60 °C, 1.59 Hz	Pa	1490	70
	Calculated penetration	0,1 mm	90	881
	δ at 30 °C, 1.59 Hz	º	69.7	80.9
	G*/sinδ = 1 kPa	ºC	64	42
	*G*sin δ = 5000 kPa*	*ºC*	*(14)*	*(2)*
After RTFOT	Mass change	%	0,02	-0.17
	Penetration 25 °C	0,1 mm	45	965
	Viscosity 60 °C	Pas	479	8.45
	Retained penetration	%	52	
	Viscosity ratio		4.2	1.7