Binder performance and testing

The effect of rejuvenator on the change in rheological and chemical properties of artificial aged asphalt

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Abstract

The ageing of porous asphalt (PA) binders is one of the most important properties that affect the lifetime of porous top-layers. In the present sustainable economy, increasing the lifetime of PA by understanding the process of ageing is therefore of great importance. The many different parameters in design, production and transportation affecting the lifetime of PA, make it very difficult to predict the durability of the asphalt mixtures. Through time, the binder endures physical and or chemical changes due to temperature cycles, diffusion of vapor, air (oxygen) and UV-radiation, which affect the performance properties of the binder. In general, these changes reduce the durability of the material under traffic intensity. This phenomena emerges with changes in mechanical and rheological properties of the binder. Considering upgrading top layer recycling in our present sustainable economy, one of the biggest challenges is the reversal of the ageing of the bitumen which often leads to the end of the road lifespan. Therefore effective rejuvenators are required which can change the bitumen of the strongly aged porous asphalt top layers back to the original level of performance. Therefore, this paper aims to evaluate the potential gain of the use of rejuvenators for circular asphalt by DSR and FTIR measurements on recovered artificial aged bitumen samples. The laboratory research shows that the rejuvenators are effective in the reparation of the rheological properties of artificial aged asphalt mixtures. Keywords: porous asphalt, ageing, rheology, durability, circularity, rejuvenator

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1. INTRODUCTION

The majority of the Dutch major road network consists of porous asphalt top layers. The advantages of these porous asphalt top layers compared to non-porous top layers are reduction of noise, splash- and spray and permanent deformation. The disadvantage of porous top-layers is their limited lifespan [1].

Within the current road maintenance management system, the remnant lifespan of a porous asphalt top layer is determined based on the assessment of the pavement conditions. This assessment considers different performances as stone loss (ravelling), skid resistance and rutting.

Ravelling is most often the determined factor in achieving the end of the pavement lifespan. The road assessments are focused on the performance rather than material properties. In general, it is accepted that the lifespan of porous asphalt top layers also depends on the ageing of bitumen. The ageing of bitumen causes changes to the asphalt performances with time. The asphalt becomes stiffer and more fragile which results in the quicker formation of (micro)cracks. The alteration process may differ for different types of bitumen [2,3].

The replacement of top-layers due to end of lifespan cost the society millions of euros. These are not only direct cost as for reparations but also indirect cost due to the results from traffic jams and bypasses. Besides that, every replacement has an extra impact on the environment. Therefore, it is important to design pavements with an ultimate lifespan. Circular pavements seem very beneficial to the environment at first sight. However, this is only true when the pavement has enough lifespan, otherwise the advantage vanishes at the moment of early replacement and results in event an extra impact on the environment. The current sustainable economy requires insights in the quality aspects of new developing circular top layers. Upscale recycling seems very valuable. In other words, horizontal recycling of asphalt with the maintenance of the properties. This contrasts with so called ‘downcycling’ to lower pavement layers which have less requirements. Which understanding of quality parameters is required to realise upscale recycling without an increase in the insecurity of the lifespan of the new developed road? One of the biggest challenges is the reversal of the ageing of the bitumen which could lead to the end of the road lifespan [4]. For this effective rejuvenators are required which can change the bitumen of the strongly aged porous asphalt surface layer back to the original level of performance. Therefore, this paper aims to evaluate the potential gain of the use of rejuvenators for circular asphalt by DSR and FTIR measurements on recovered artificial aged bitumen samples.

2. MATERIALS AND METHODS

2.1. Production of the asphalt mixture

Asphalt granulate does not have homogeneous properties, because the granulate is often a mixture composed out of material originating from different layers and locations. Therefore, it was decided to use artificial aged asphalt granulate rather than normal asphalt granulate. This to reach a more homogeneous rejuvenating starting point for the asphalt granulate. Therefore, a standard porous asphalt mixture was produced in the laboratory. The mixture and grading is shown in Table 1.

Table 1. Composition of the ZOAB+ mixture in weight % and sieve fractions

Component	**wt%**
Bitumen	5,2
Cellulose fiber	0,2
Wigro 60K	5
Brekerzand	8,5
Bestone 4/8	19,5
Bestone 8/11	35,6
Bestone 11/16	26
Sieve fraction	
Through sieve	100,0
C22,4	97,1
C16	70,3
C11,2	35,5
C8	20,5
C5,6	13,6
2mm	8,2
500um	5,0
63um	5,0

The mixing of the asphalt mixture was performed in the laboratory of TNO using a batch mixer (Figure 1). The following procedure was followed:

Preparation:

- All granular material was preheated in a stove at 165°C
- The bitumen was preheated in a stove at 180°C

Mixing:

- First the coarse granular material was poured out in the mixer where after the fine fraction, with the ` following sequence (16,11,8,5,6,4,2, filler)
- The mixture was blended shortly (ca. 10 sec).
- Time was required for the granular material to get back at temperature
- Cellulose fibres were added.
- The bitumen was added.

Consequently the mixing procedure of Table 2 was followed to obtain a homogenous mixture.

Table 2. Composition of the ZOAB+ mixture in weight % and sieve fractions

Blend temperature (°C)	Time (s)	Speed (rpm)	Note
160	30	15	
160	90	30	
160	60	30	Optional if no complete wetting was observed.

The mixture is research was mixed for 120 seconds in total (thus, there was no need for the optional and final mixture step).

Figure 1: Batch mixer which was used to produce the asphalt mixture for this research

2.2. Method: Artificial ageing, rejuvenating en the recovering of the bitumen from the mixture

The asphalt mixture as described above was artificial aged for 3 weeks at 60ºC under 100 bar, to obtain a homogenous artificial aged asphalt mixture which may a more homogeneous in composition than asphalt granulate from the field. Consequently, different parts of the artificial aged mixture were treated with different by the industry provided rejuvenators.

Consequently, the artificial aged untreated and treated parts of the asphalt mixture were aged again for 3 weeks at 60 under 100 bar. The varies samples used in this research are described in Table 3. More information on the sample treatment as shown in this table can be found in paragraph 1.3.

Table 3. Various samples which are used in this research

Samples	Abbreviation
Fresh	A
Aged (3 weeks, 60°C, 100 bar) then **not treated** with rejuvenator	A3
Aged (3 weeks, 60°C, 100 bar) then treated with rejuvenator B	B3
Aged (3 weeks, 60°C, 100 bar) then treated with rejuvenator C	C3
Aged (3 weeks, 60°C, 100 bar) then treated with rejuvenator D	D3
Aged (3 weeks, 60°C, 100 bar), (2.5 hour, 130°C) then **not treated** with rejuvenator and again aged (3 weeks, 60°C , 100 bar)	A6
Aged (3 weeks, 60°C, 100 bar), (2.5 hour, 130°C) then treated with rejuvenator B and again aged (3 weeks, 60°C, 100 bar)	B6
Aged (3 weeks, 60°C, 100 bar), (2.5 hour, 130°C) then treated with rejuvenator C and again aged (3 weeks, 60°C, 100 bar)	C6
Aged (3 weeks, 60°C, 100 bar), (2.5 hour, 130°C) then treated with rejuvenator D and again aged (3 weeks, 60°C, 100 bar)	D6

2.3. Rejuvenation of artificial aged asphalt mixture ‘asphalt granulate’

The samples in Table 3 were treated with 5% rejuvenator based on the bitumen mass. This in agreement with the rejuvenation advised dosage of the suppliers.

The following rejuvenator application procedure was used as advised by the suppliers:
- The asphalt granulate was dried and preheated 2.5 hour at 130°C
- The asphalt granulate was mixed with 5% rejuvenator for 30 seconds at room temperature

For a good comparison, the not, with rejuvenation, treated samples were also heated for 2.5 hour at 130°C similar to the rejuvenator application procedure.

2.4. Bitumen recovery

After the artificial ageing in the pressure vessel, the bitumen from all the various asphalt mixtures was recovered according to NEN-EN 12697-1:2012 (extraction apparatus, [6]) and NEN-EN 12697-3:2005 (rotation evaporator, [5]) as described in the work prescriptions of the TNO laboratory [8].

The rheological properties of the recovered bitumen were investigated by frequency sweeps obtained by a Dynamic Shear Rheometer (DSR) according to NEN-EN 14770:2012 [7] Additionally, the chemical compositions (semi-quantities analyses) were determined by using Fourier-Transform-Infrared-Spectroscopy (FTIR) according to the work prescription of the TNO laboratory.

3. RESULTS

3.1. Rheological properties

The frequency sweeps (1-400 rad/s) are performed by a DSR at temperature conditions of 20°C. The results are shown Figure 2 and 3.

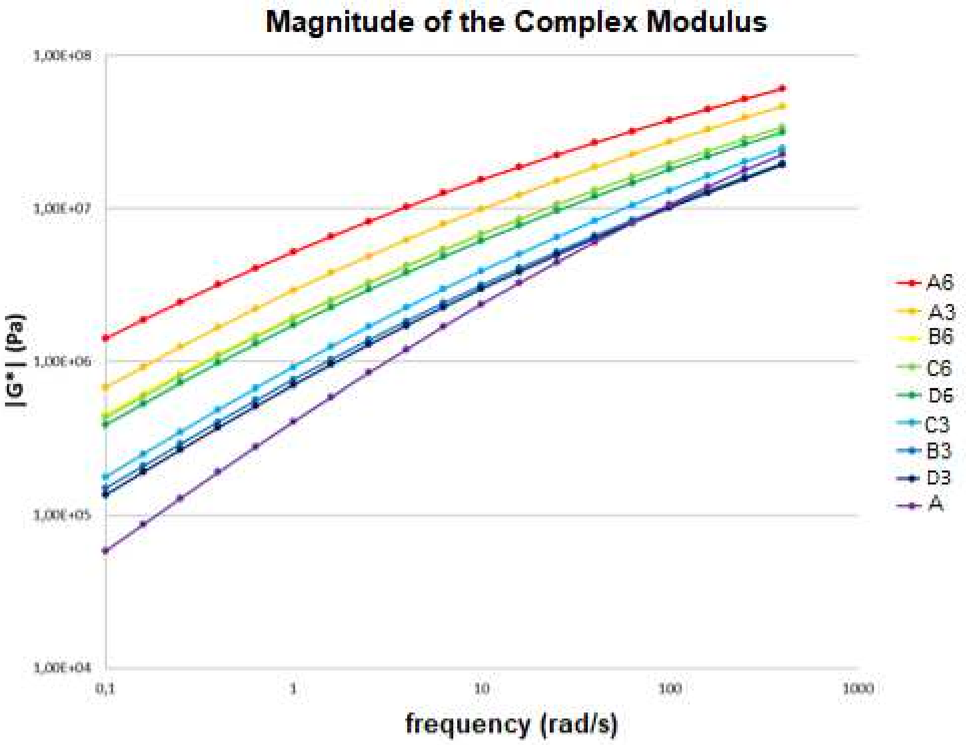

Figure 2: Magnitude of the Complex Modulus (measured by DSR) for the samples in Table 3

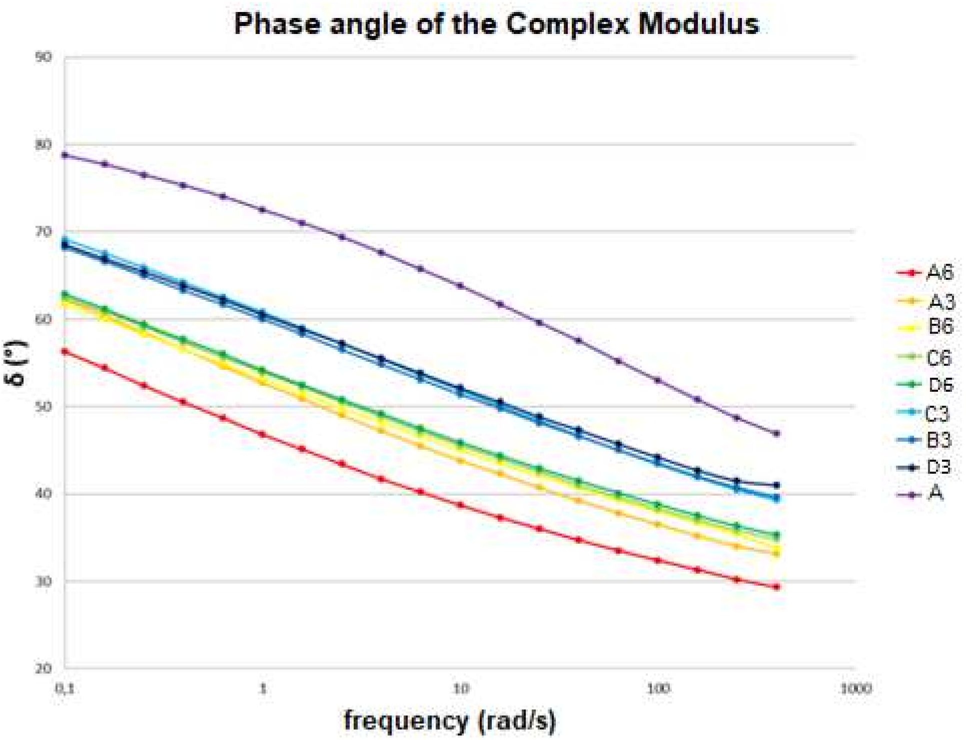

Figure 3: Phase angle of the Complex Modulus (measured by DSR) for the samples in Table 3

The frequency sweeps (1-400 rad/s) are performed by a DSR at temperature conditions of 20°C. The results are shown Figure 2 and 3.

A comparison can be made between the results from this research and (Dutch pavement) field data [9] which is shown in Figure 4. Figure 4 indicates that all the rejuvenators have a comparable rejuvenation effect, based on the in this research selected ageing method and determined rheological properties. The results show that all the with rejuvenator treated samples show a comparable step in ageing development with the untreated mixtures and thus no accelerated ageing.

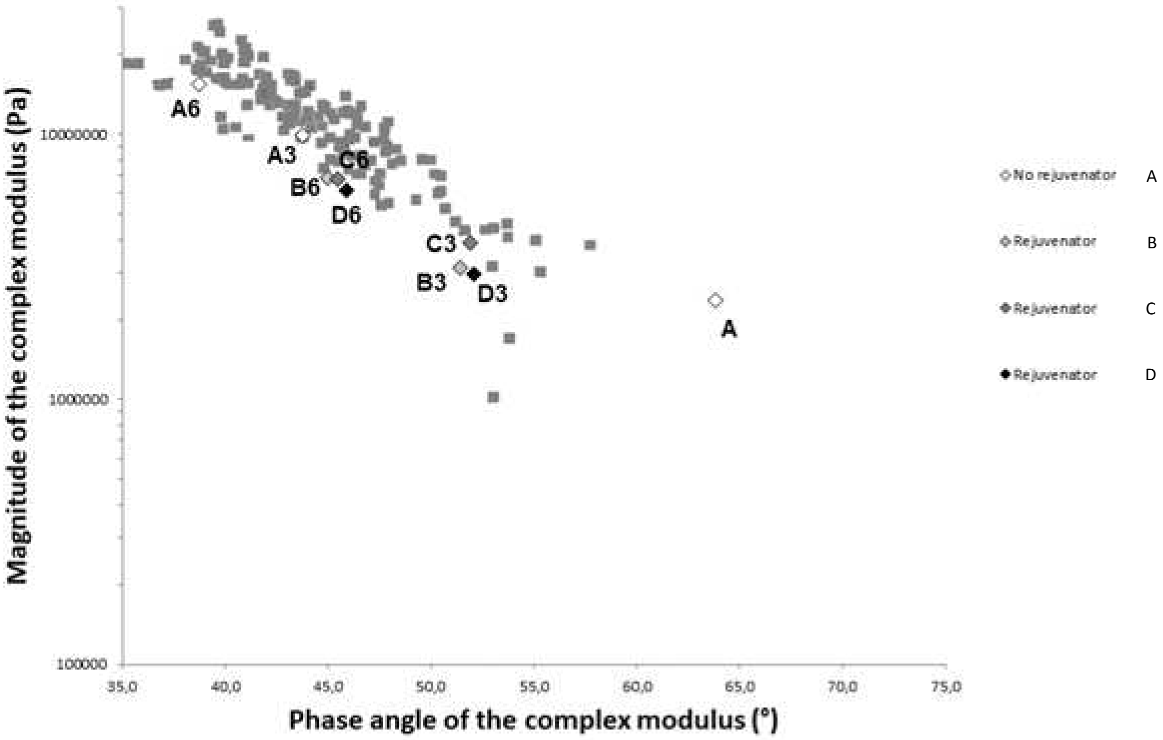

Figure 4: Black space graph with the results of this research compared to field data

3.2. Chemical properties

The FTIR-spectra are shown in Table 4. The results show that the sulphoxide index for the untreated asphalt mixture increases with increasing ageing duration. This is also what one would expect. For the rejuvenator asphalt mixtures this trend is not observed. The results suggest that the oxidative ageing occurs in similar or less extent after the use of rejuvenator compared with the reference samples which were not treated with rejuvenator.

Table 4. Various samples which are used in this research

	Aromats index	Aliphatic index	Branched hydrocarbon index	Long chain hydrocarbon index	Sulphoxide index
A	4,0	19,3	15,0	5,6	1,3
A3	4,3	18,6	15,7	5,4	2,0
A6	5,4	20,1	13,2	5,2	2,4
C3	4,7	18,5	14,9	5,8	1,8
C6	4,9	18,6	14,6	5,9	1,3
B3	4,8	18,7	14,8	5,8	2,2
B6	4,8	18,8	15,0	5,8	1,4
D3	4,3	18,7	15,0	5,9	2,4
D6	4,7	18,5	15,3	5,9	1,4
Rejuvenator B	0,0	19,0	13,0	15,2	0,3
Rejuvenator C	0,0	11,0	0,0	17,1	0,0
Rejuvenator D	0,0	18,9	13,4	14,3	0,1

4. CONCLUSION

The laboratory research shows that the rejuvenators are effective in the reversal of the rheological properties of artificial aged asphalt mixtures. When the rejuvenated mixtures are aged again in the laboratory, they show a comparable ageing development compared to samples where no rejuvenator was used. The impact on the measured chemical parameters mainly indicates that the rejuvenated bitumen is a blend of aged bitumen and the rejuvenator.

Based on the results with the current starting points and conditions, rejuvenators increase the estimated service life of porous asphalt top layers. One critical remark is that this current evaluation is based on oxidative ageing. For recycled asphalt granulate physical hardening ageing may also play an important role.

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