DEVELOPMENT OF A DURABLE NOISE REDUCING THIN SURFACING FOR HEAVY TRAFFIC

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ABSTRACT

In densely populated areas, such as in the Netherlands, traffic noise is a major problem. To enlighten this problem, noise reducing thin surfacings were developed, which became popular in urban areas roughly 10 years ago for (provincial) highways. This type of pavement surface consists in most cases of thin (semi-) open asphalt mixtures (about 10 to 20% air voids).

Mainly due to the fine surface texture and the open structure the noise is reduced. A disadvantage however is, that especially at intersections and roundabouts, there will be torsional forces caused by (truck)tires, which will result in early degradation (stone loss). To prevent this durability problem, stone mastic asphalt (SMA) is then used on critical sections, with the disadvantage of losing the noise reduction.

A laboratory study was performed to improve the properties of thin asphalt mixtures, in such a way that they could be applied at critical road sections. For this, first a heavily polymer modified bitumen was developed. The mechanical mixture properties after artificial ageing and simulation of severe long-term environmental conditions were verified by indirect tensile and Cantabro tests and compared with a standard SMA. Furthermore, the resistance against torsional forces was tested using laboratory compacted slabs with the Rotating Surface Abrasion Test.

The laboratory tests indicated that the new thin noise reducing asphalt layer can be produced with at least equal mechanical properties as a reference standard SMA mixture. To validate this concept, 2 field sections were constructed and evaluated after 1 year under severe traffic conditions.

Keywords: noise reduction, thin surfacings, polymer modified binder, durability, mechanical properties

1. INTRODUCTION

Noise reducing thin surfacings are commonly used for (provincial) highways in the Netherlands for about 10 years now. This type of pavement surface consists in most cases of thin (semi) open asphalt mixtures (about 10 to 20% air voids). The lifetime average noise reduction is approximately 3 dB(A) and the structural lifetime is roughly 7 years for semi-open type mixtures [1; 2]. A disadvantage however is that especially at intersections and roundabouts, there will be torsional forces generated by (truck)tires, which will result in early degradation (ravelling). To prevent this durability problem, stone mastic asphalt (SMA) is then used on critical sections as an (in fact unwanted) alternative, with the disadvantage of losing the noise reduction.

Figure 1: Example of ravelling of a thin surfacing at a junction.

With the use of a newly developed heavily polymer modified bitumen (PmB) a thin surfacing could potentially also be laid down at intersections, tight turns, interchanges and heavy duty roads. To do so, the pavement has to withstand severe shear forces under different environmental conditions with a comparable lifetime as a conventional SMA-NL5 [4].

This paper will describe the (mechanical) performance of this newly developed asphalt mixture. For this the mechanical properties after artificial ageing and severe environmental attack were tested by means of indirect tensile and Cantabro tests. Furthermore, the resistance against torsional pressure was verified using laboratory compacted slabs with the Rotating Surface Abrasion Test. The obtained results were validated by monitoring the performance of 2 trial sections on specific roads.

2. POLYMER MODIFIED BINDERS

Different types of polymer modified binders are available nowadays [5]. Most commonly used types are based on an SBS polymer modification. The performance of a PmB depends on the origin of the used bitumen; the type of polymers; the amount of polymers and the production process itself. With a high amount of polymer the properties will improve.

Table 1: Typical properties different types of (polymer modified) bitumen.

Specification		Test method	Bitumen 70/100	PmB A	PmB B
Penetration	[dmm]	EN 1426	77	100	85
R&B	[°C]	EN 1427	46.0	84.0	95.0
Ductility @ 5 °C; 20-40 mm	[J/cm^2]	EN 13589	-	3.3	7.1
Elastic recovery @ 25 °C	[%]	EN 13398	-	93	96
Viscosity @ 135 °C	[mPa.s]	EN 12596	400	1000	2500

PmB type A (SFB 3-100) is a commonly used type for thin surfacings with 3% radial SBS and PmB type B (SFB 5-90 (HS)) is a newly developed highly modified binder containing in total 7% of different polymers plus additives to improve workability). DSR (dynamic shear rheometer) master curves were determined with these binders after short term oven aging (RTFOT) according to EN 12607-1 and EN 14770 (see figure 1).

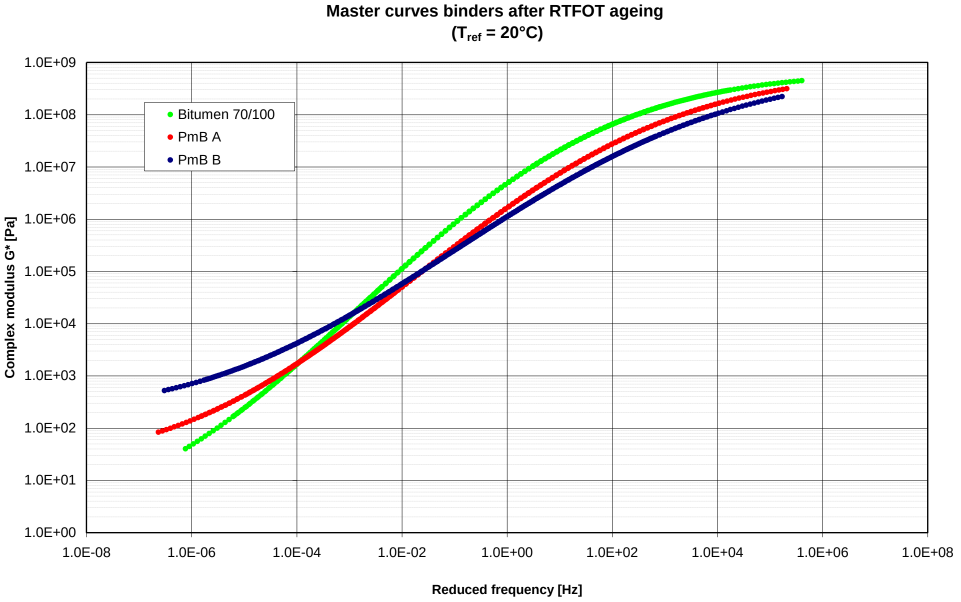

Figure 1. Master curves binders at a reference temperature of 20 ºC.

The graph shows that the PmB's are stiffer at lower frequencies and less stiff at higher frequencies, indicating that the PmB's are less susceptible to changes in temperature and loadings. In combination with the increased (ductility) toughness, the PmB type B binder should have an improved resistance against cracking and ravelling.
In figure 2 the Black diagram (complex modulus against phase angle) is given.

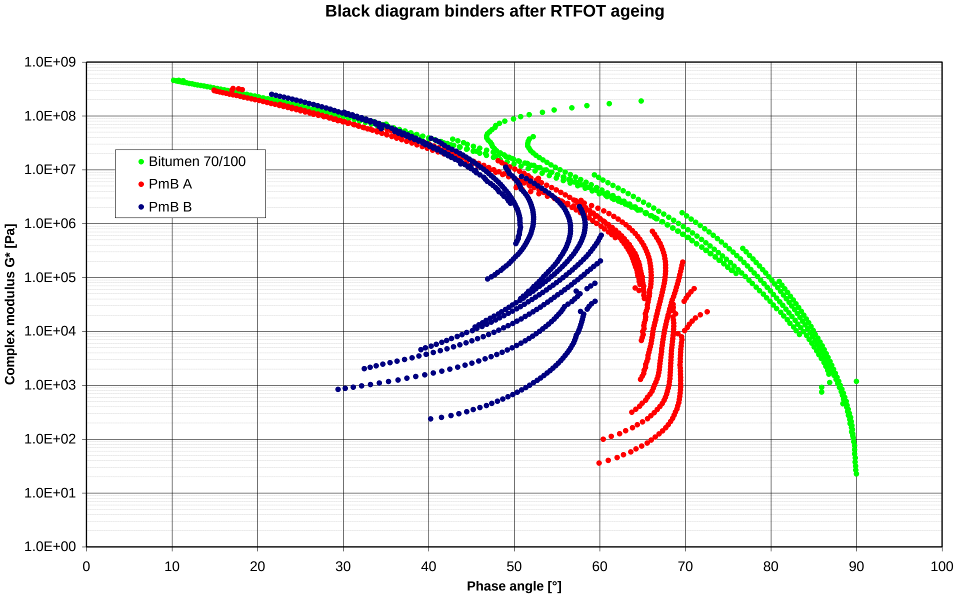

Figure 2. Black diagram binders @ -10 to 60 ºC.

The graph clearly shows that the PmB type B will have a more elastic behavior (lower phase angle) than the type PmB type A. The decrease of the phase angle is typical for PmB's and especially visible at higher contents of SBS polymer.

3. LABORATORY STUDY

Test specimens were prepared with standard SMA 5 according to the Dutch specifications [4] and 2 types of thin surfacings (TS) in combinations with respectively a conventional bitumen 70/100 and the polymer modified binder type B as described in table 2.

Table 2: Overview tested combinations.

Combination	Aggregate size [mm]	Binder content [m/m% 'in']	Air voids [%]
SMA + 70/100	0-5	7.4	3.4
SMA + PmB type B	0-5	7.4	3.6
TS A + 70/100	0-5	5.8	13.0
TS A + PmB type B	0-5	5.8	15.1
TS B + PmB type B	0-5	6.6	11.4

TS A is a thin open graded surfacing (i.e. thickness 20 – 30 mm) designed to reduce traffic noise (-4.0 dB(A) at 50 km/h; passenger cars) on urban and suburban roads and TS B is a thin semi-dense (about 9 to 14% air voids) graded surfacing (i.e. thickness 20 – 30 mm) designed to reduce noise (-3.8 dB(A) at 50 km/h; passenger cars) on heavy traffic roads.

The used aggregates and binders for the different mixtures have been mixed at 165 °C for the bitumen 70/100 samples and at 185 °C for PmB. The Marshall samples were compacted with 2 x 50 blows and the slabs for the RSAT were prepared with the use of a laboratory (hand) roller.

The following tests were performed on the obtained samples:

- Indirect tensile test (EN 12697-23) at 5 ºC on Marshall compacted samples after intensive (laboratory) conditioning.
- Cantabro mass loss (EN 12697-17) at 5 ºC on Marshall compacted samples after intensive (laboratory) conditioning.
- Rotating Surface Abrasion Test on compacted slabs (without ageing).

3.1 Ageing conditioning treatment

The produced Marshall samples were treated as mentioned below (partly on the basis of AASTHO R30):

- 120 hours in oven at 85 ˚C
- Cooling down to room temperature
- Conditioning in accordance with EN 12967-12 (vacuuming of samples in water)
- 48 hours in freezer at -20 ˚C (in water)
- 24 hours forced defrosting at 30 ˚C
- Conditioning in accordance with EN 12967-12 (vacuuming of samples in water)
- 70 hours in water bath at 40 ˚C (according to NEN-EN 12697-12)
- 4 hours in salt water (50 grams salt per liter water) at 5 ˚C
- Drying at room temperature

3.2 Indirect tensile strength

The indirect tensile strength tests on the aged Marshall compacted samples have been carried out according to EN 12697-23 at a temperature of 5 ºC and a displacement rate of 0.85 mm/s. The results can be found in table 3.

Table 3: Indirect tensile test results after ageing (n=6) at 5 ºC.

Combination	Air voids [%]	COV* [%]	Strength [MPa]	COV* [%]	Toughness [N.mm/mm^2]	COV* [%]
SMA + 70/100	3.4	25	3.5	4	15.8	16
SMA + PmB type B	3.6	18	2.4	3	20.0	5
TS A + 70/100	13.0	7	2.8	6	6.6	22
TS A + PmB type B	15.1	12	2.5	8	13.4	8
TS B + PmB type B	11.4	4	2.1	1	14.4	9

*] coefficient of variation

From the results it can be seen that by using a PmB instead of a conventional bitumen, the toughness will increase (for the SMA by 26.6% and for the TS A by 103%). The strength decreases due to the lower stiffness of a PmB. The toughness of both thin surfacings containing a PmB are on the same level as the standard (reference) SMA with conventional bitumen. Important for the field is also that the variability decreases via polymer modification.

3.3 Cantabro

The Cantabro tests on the aged Marshall compacted specimens have been carried out according to EN 12697-17 at a temperature of 5 ºC and 300 revolutions. The results can be found in table 4.

Table 4: Cantabro test results after ageing (n=6) at 5 ºC.

Combination	Air voids [%]	COV* [%]	Mass loss [%]	COV* [%]
SMA + 70/100	3.7	14	7.4	23
SMA + PmB type B	3.5	16	4.0	8
TS A + 70/100	14.2	5	13.6	11
TS A + PmB type B	15.6	4	6.7	8
TS B + PmB type B	12.9	5	3.6	12

*] coefficient of variation

The results clearly show an improvement with the use of a PmB. Especially the TS B shows a very good resistance against abrasion and is comparable to the SMA mix with a PmB. A thin surfacing with a high durability has to have a high toughness / mass loss ratio; at least equal to a conventional SMA mix. As can be seen in figure 3, the TS A + PmB mixture is comparable to the SMA 70/100 and the TS B + PmB mixture is much better and almost comparable to the SMA + PmB mix.

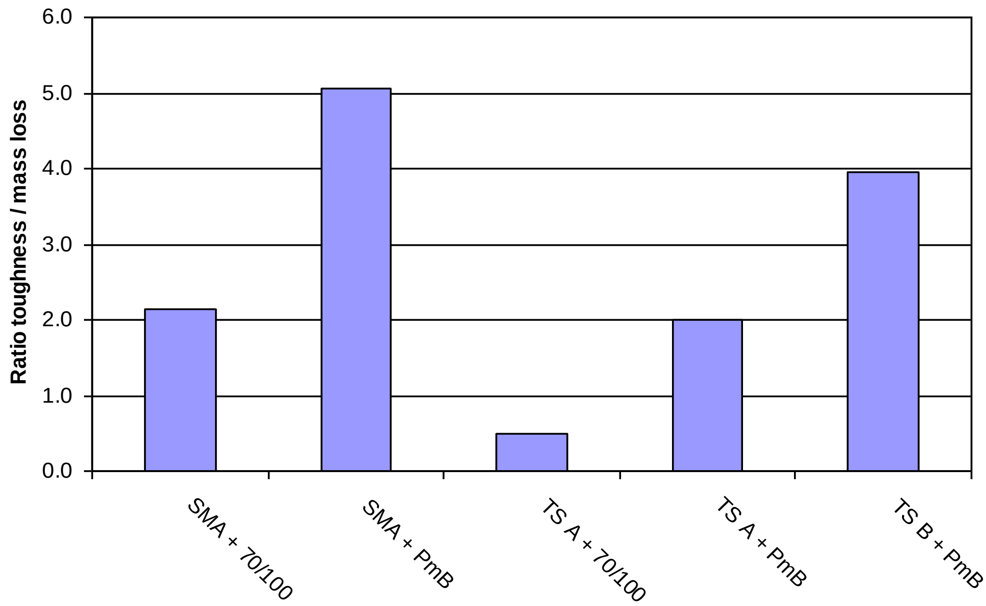

Figure 3. Laboratory abrasion performance indicator.

3.4 Rotating Surface Abrasion Test

For the durability the resistance against ravelling is an important factor. With the use of the so-called Rotating Surface Abrasion Test [6], the resistance against ravelling can be tested under torsional forces. For this, compacted slabs (thickness 30 mm; regular octagon with a span of 50 cm) were prepared in the laboratory with the use of a hand roller. Only the TS B + PmB thin surfacing mix and the (referential) SMA + bitumen 70/100 mixture; (see table 5 for the results).

Table 5: RSAT test results after 24 hours (n=3) at 20 ºC.

Combination	Density [kg/m^3]	COV* [%]	Mass loss [grams]	COV* [%]	Rut depth [mm]	COV* [%]
SMA + 70/100	2288	1	7.9	5	8.0	18
TS B + PmB type B	2127	1	6.0	6	1.4	39

*] coefficient of variation

The results indicate, that the resistance against abrasion for both mixtures are similar and the mass loss is as expected very low. Furthermore, the SMA mixture shows some rutting. An analysis showed that this mixture had too much bitumen (volumetric design was not 100%).

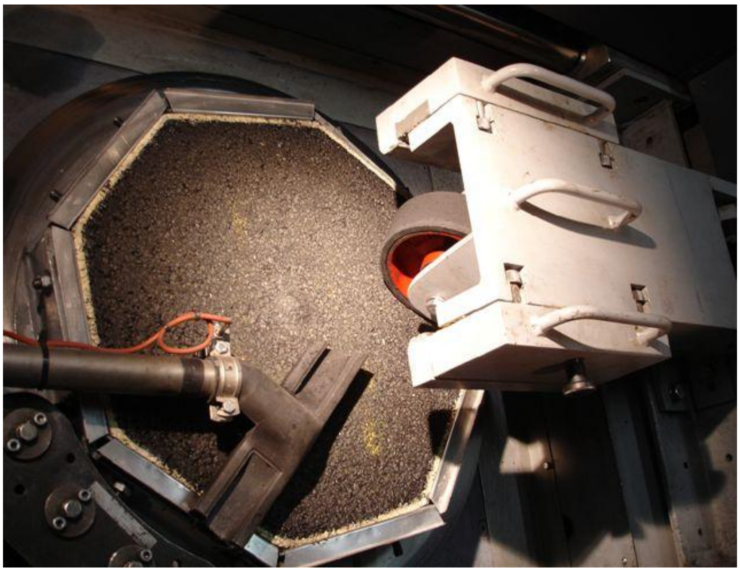

Figure 4: Detail RSAT slab and equipment.

4. TRIAL SECTIONS

In June 2010 the newly developed PmB type B was applied in a thin surfacing at a very busy road in the Dutch city of Zwolle at the intersection IJsselallee – Hanzeallee / B. van Walsumlaan. The section was paved during the night using a standard paving machine on top of the prepared surface of the existing construction (milling old surface and applying tack coat). After 1 year in use, no damage was visible.

Figure 5: Situation IJsselallee Zwolle (the Netherlands) in April 2011.

In August 2010 the TS B + PmB thin surfacing was applied (partly) in a very busy roundabout in the Dutch city of Purmerend (Laan der Continenten / Amazonelaan / Melkweg). This section was paved during the day using a standard paving machine on top of an also new conventional binder course. After 1 year in usage there was no damage visible, except from the part of the surface course containing a conventional binder, which showed some damage in the form of scratches from probably a malfunctioning truck tire.

Figure 6: Situation Purmerend (the Netherlands) in July 2011

5. CONCLUDING REMARKS

The use of a (heavily) polymer modified binder has the potential of improving the durability of noise reducing thin surfacings in such a way that the durability is at least equal to a conventional SMA surfacing. Field trials have been made to validate this conclusion from laboratory investigations. The sites show no damage after being in use for 1 year. It thus looks as if a thin noise reducing surfacing containing a high-quality PmB could be used as an alternative for a conventional SMA surface course at intersections, junctions and heavy duty roads.

Apart from the mix constituents, the method (and resulting quality) of paving and compaction is also of importance. Poor compaction, too much compaction or an inhomogeneous density pattern will always lead to a reduced life. Furthermore, it is recommended to apply a polymer modified bond coat (with a so-called spray-jet paving machine) to prevent debonding from the substrate in the long run [7].

All in all, it seems that the application range of so-called quiet asphalt surfaces has been extended. It is not needed anymore to fall back to SMA's, because the quality cannot be guaranteed in certain critical application areas.

6. REFERENCES

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