SBUF-projekt

Date
2009-07-31

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Evaluation of high performance bitumens in Sweden

Technical and economic comparison of different test sections of asphalt pavements laid on E18 between the Järva Krog and Bergshamra interchanges

FOREWORD

This project was co-financed by SBUF, Swedish Road Administration (SRA) and Nynas AB.
The reference group consisted of the following persons:

Kenneth Olsson,	Skanska Teknik	*Project leader*
Hamid Sedaghati,	Skanska Teknik	
Thorsten Nordgren,	Swedish Road Administration (SRA)	
Jonas Ekblad,	NCC	
Bengt Sandman,	Nynas AB	

The laboratory work was carried out by Skanska Teknik´s road laboratory in Farsta and Malmö. The test sections were laid by Skanska Asfalt & Betong Mälardalen/Stockholm. Region Stockholm of SRA has financed the road surface measurements on the test sections.

The test sections will be monitored in the future to assess, if the predicted service lives according to this report, are fulfilled for the three different asphalt pavements.

CONTENTS

I. SUMMARY

The use of high performance bitumen will initially result in an increased cost but the asphalt pavement can still be the economically best solution due to the longer service life.

In this project two different types of high performance bitumens have been compared with a conventional standard bitumen (B 70/100). One bitumen is polymer modified and designated Nypol 50/100-75. The other bitumen is a rubber modified bitumen.

The laboratory study by functional test methods shows that the asphalt pavements produced by the high performance bitumens provide considerably better properties than the corresponding reference asphalt pavement with conventional bitumen. This result is in line with former experience.

All three pavements were laid on E18 between the interchanges Järva Krog and Bergshamra, where the development of the long term studded tyre abrasion will be monitored.

According to this study an increased service life of one year for polymer modified pavement to compensate for the additional cost and render the same annual cost as the reference pavement with a service life of 7 years.

For the pavement with the rubber modified bitumen, GAP 16, an increased service life of two years is required to result in the same annual cost.

1. BACKGROUND

The increasing traffic volume on the Swedish road net has caused that the asphalt pavements will be worn faster by studded tyres. As a part of the efforts to slow down the wear rate road trials with surface courses, produced with high performance bitumens, are carried out.

The use of high performance bitumens will initially result in an increased cost but the asphalt pavement can still be the cheapest solution due to the longer service life.

The polymer modified bitumen technology has been applied for a long time in Sweden but the use is still very limited. However, the trends in Europe are that the use is steadily increasing with the increasing rate of traffic volume and loads.

In US the rubber modified bitumen has been successfully used on roads with recurrent cracking. The flexibility of the asphalt pavement with rubber modified bitumen will prevent that the cracking recur in the new road surface.

A crucial issue in Sweden is how resistant surface courses with high performance bitumens are against abrasion from studded tyres. Will the increased cost be compensated by lower abrasion rate on our roads?

In the fast lanes between the interchanges Järva Krog and Bergshamra Region Stockholm of SRA decided to lay some comparative test sections to study the effect of high performance bitumens, used in surface courses. See Figure 1.

Figure 1 Test sections in fast lanes on E18 between the Järva-Krog and Bergshamra interchanges

2. OBJECTIVE

The objective of the test sections is to find out if the extra costs for the different high performance bitumens will be compensated by slower rutting development. Based on functional laboratory testing and field measurements the different asphalt types will be compared with each other. The annual costs for the different performed pavements will be assessed.

3. ACCOMPLISHMENT

Besides sampling asphalt mixes at the asphalt plant test specimens were cored from the laid test sections to be analysed by the following test methods:

- **Wheel-tracking according to Asphalt Pavement Analyzer:**
  A method for measuring the resistance to deformation at +50°C.

- **Prall-test, SS-EN 12697-16:**
  The resistance to abrasion from studded tyres by the method.

- **Water sensitivity, SS-EN 12697-12:**
  This method is used to study the adhesion properties between aggregate and binder (ITSR). See Figure 2.

The asphalt mix was also compacted by rolling in the laboratory and test specimens were cored to study:

- **Dynamic creep test, FAS Metod 468:** Stability test at +40°C

- **Master curves by Indirect Tensile Test (IDT):** Stiffness test

The pavements were surveyed by a Swedish Road Surface Tester (RST) during the autumn to get a so-called zero-value and after the studded tyre season straightedge measurements of the test sections were carried out. The RST survey also provided texture data for each pavement type.

Figure 2: Vacuum saturation at the ITSR-test

4. PRODUCTION OF THE ASPHALT MIXES

The asphalt mixes were produced at the Skanska asphalt plant in Vällsta during 23-25 August 2008. Three types of asphalt mixes were produced:

- 620 tonnes of GAP 16, Nordic abrasion value < 5, rubber modified bitumen
- 240 tonnes of ABS 16 Nypol 50/100, Nordic abrasion value < 5, polymer modified bitumen
- 200 tonnes of ABS 16 70/100, Nordic Abrasion Value < 5, polymer modified bitumen

The composition of the asphalt mixes is given in Table 1.

Table 1 Mix formulations of the different types of asphalt mixes

Mix type	Binder content (% by mass)	Percentage by mass passing sieve					Marshall void content (vol-%)
		0,063	2 mm	4 mm	8 mm	11,2	
GAP 16	8,7	7,5	22,0	24,0	44,0	68,0	2,4
ABS 16 Nypol 50/100-75	5,9	10,5	21,0	23,0	38,0	65,0	2,6
ABS 16 70/100	5,9 %	10,5	21,0	23,0	38,0	65,0	2,6

4.1 GAP 16

SRA provided a mixing unite, where rubber granules (0/1 mm) from torn car tyres can be mixed with a bitumen. The mix of rubber bitumen is allowed to react for about one hour at a temperature of 160-170 °C before it is pumped to the mixer of the asphalt plant. The rubber content of the binder amounts to about 20 %, which means that the rubber content of asphalt mix is 1,5 to 2,0 %. In this trial the target binder content of GAP 16 was 8,7 % by mass.

4.2 ABS 16 Nypol 50/100-75

Nypol 50/100-75 is a polymer modified bitumen, which hitherto has been laid on roads in the region of Stockholm. Polymer modification means that a polymer (normally 3 to 6 %) is mixed with bitumen for example at a bitumen depot or refinery. Then the mixture is handled as a common bitumen binder, before it is added to the mixer of the asphalt plant. The mixing temperature is 165 to 170 °C. The target binder content for this pavement was 5,9 % by mass.

4.3 ABS 16 70/100

The most common asphalt asphalt mix on the intensively trafficked roads in the region of Stockholm is a stone mastic asphalt with a standard bitumen with pen 70/100, designated ABS 16 70/100. The aggregate quality decides primarily the rutting rate caused by studded tyres. The target binder content was 5,9 %. The production temperature is 155 to165 °C.

5. LAYING OF THE ASPHALT MIXES

The asphalt pavements were laid in the fast lanes on E18 between the Järva Krog and Bergshamra interchanges. The client was Region Stockholm of SRA. The former resurfacing of this road section was executed 2003 and the chosen pavement type was a stone mastic asphalt, ABS16 70/100, whose aggregate had a Nordic abrasion value less than 6. The average rut depth was at the time for the resurfacing 13 to14 mm but at some single spots the rut depths exceeded 18 mm.

The traffic volume in each fast lane is around 10 000 vehicles per day and the signed speed limit is 70 km/h.

Figure 3: The fast lanes after one winter (GAP 16 to the left, ABS16 Nypol 50/100-75 to the right)

Around 900 m of GAP 16 was first laid in the direction towards Bergshamra and then around 600 m of ABS16 Nypol 50/100-75 was performed. In the other direction around 1000 m of GAP 16 was first laid and then 500 m of ABS 16 70/100 was performed. A heater was used to heat up the scarified existing surface course and a ‘Shuttle Buggy’ homogenized the asphalt mix before laying. See Figure 4.

Figure 4 'Shuttle Buggy' in action (not from this project)

6. REPORTING OF TEST RESULTS

6.1 Void contents of cores from the road

In order to check if the asphalt pavements have been sufficiently compacted one series of test specimens was cored from each pavement type. The void contents of the cores were determined. See Figure 5. All void content results comply with the requirements according to SRA´s technical specifications for asphalt pavements (permissible range 1,5 to 5,0 vol-%). The reference pavement was very well compacted and the void content was slightly below 2 vol-%. The void content of GAP 16 was slightly below 3 vol-%. The polymer modified pavement obtained the highest void content, slightly greater than 4 vol-%. The initial rutting can for this pavement become somewhat greater due to traffic compaction.

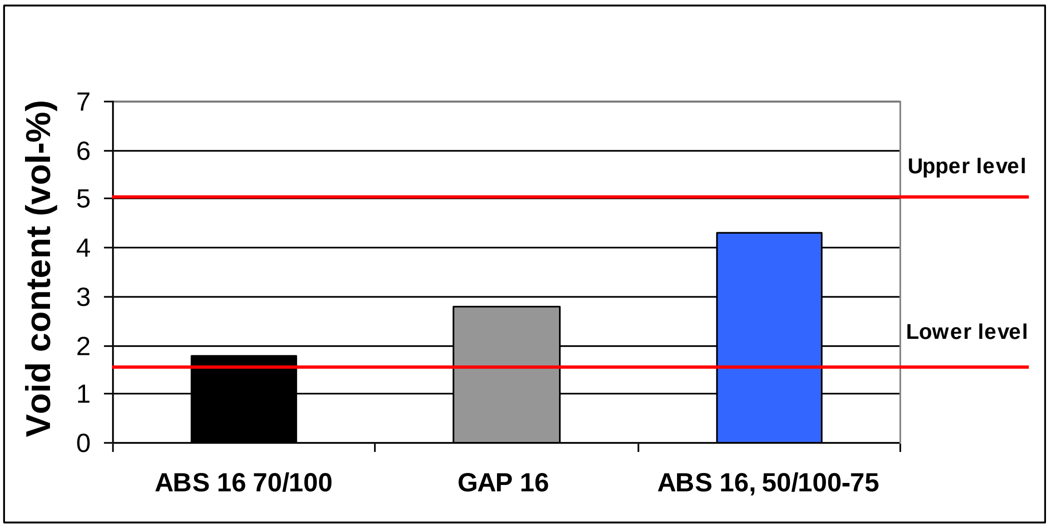

Figure 5 Void contents, based on cores from the road

6.2 Abrasion test according to Prall

The resistance to abrasion from studded tyres of an asphalt pavement can be assessed by the Prall method. Forty (40) steel balls wear the test specimen and after 15 minutes the worn volume is recorded and a so-called Prall-value is calculated. For roads with high traffic volume (> 7000 vehicles per day) the Prall value should be less than 24 cm³ to get an acceptable service life of the pavement. The aggregate chosen for the test sections had a Nordic abrasion value less than 5. The Prall value of the reference pavement was 20 cm³.

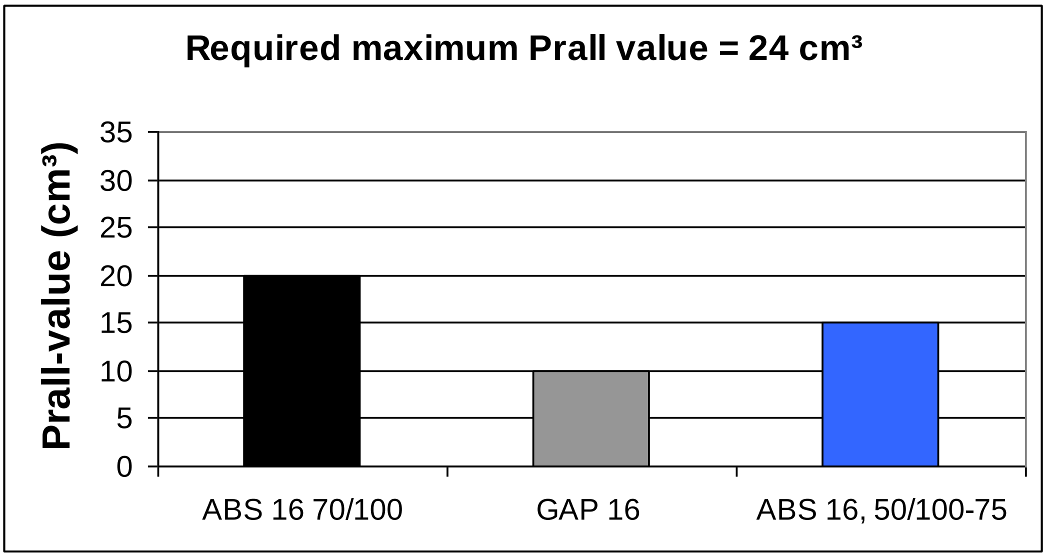

Figure 6: Prall results

The Prall value, determined for the polymer modified pavement, ABS 16 Nypol 50/100-75, was 25 % lower than the Prall value for the reference pavement. The Prall value for the rubber modified pavement, GAP 16, was 50 % lower than the Prall value for the reference pavement pavement. See Figure 6. This favourable result is presumably caused by the very strong mastic, protecting the coarser particles.

6.3 Water sensitivity according to the ITSR-method

The water sensitivity of the asphalt pavements was measured according to the ITSR-method. In this case the wet series of cored test specimens was stored in water for 7 days and the tensile strength was determined at +10 °C. An adhesion agent Wetfix AP 17 was added to all of the pavements. All of the three asphalt pavements have very good ITSR-values (> 90 %), based on the cored test specimens. See Figure 7. The ITSR-value for surface courses shall exceed 75 % according to SRA´s specifications for asphalt pavements.

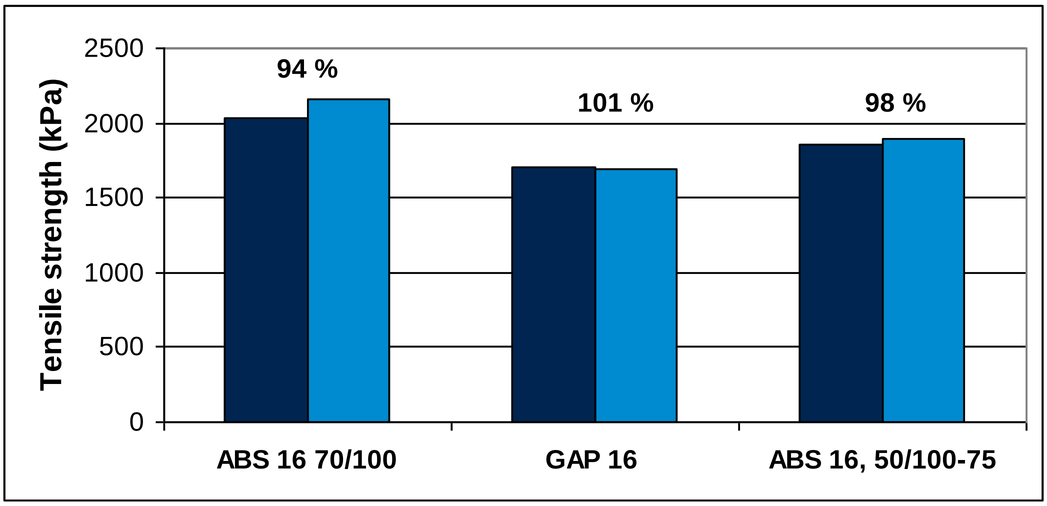

Figure 7 ITSR-results

6.4 Resistance to permanent deformation according to the Wheel Track test and the dynamic creep test

The susceptibility of the upper 80 mm of the asphalt pavements to permanent deformation were measured using 150 mm cores. Since the thickness of the new asphalt courses was in the range of 35 to 40 mm the lower part of the test specimens consisted of the old existing surface course, an asphalt concrete, ABT 16.

The Wheel Track test, also called Asphalt Pavement Analyzer (APA) was used. This test is used in the United States, primarily for research and development and does not correspond with the European standard, EN 12697-22 Wheel tracking. The lowest rutting rate after 8000 passes at +50°C was obtained with the polymer modified pavement (Figure 8).

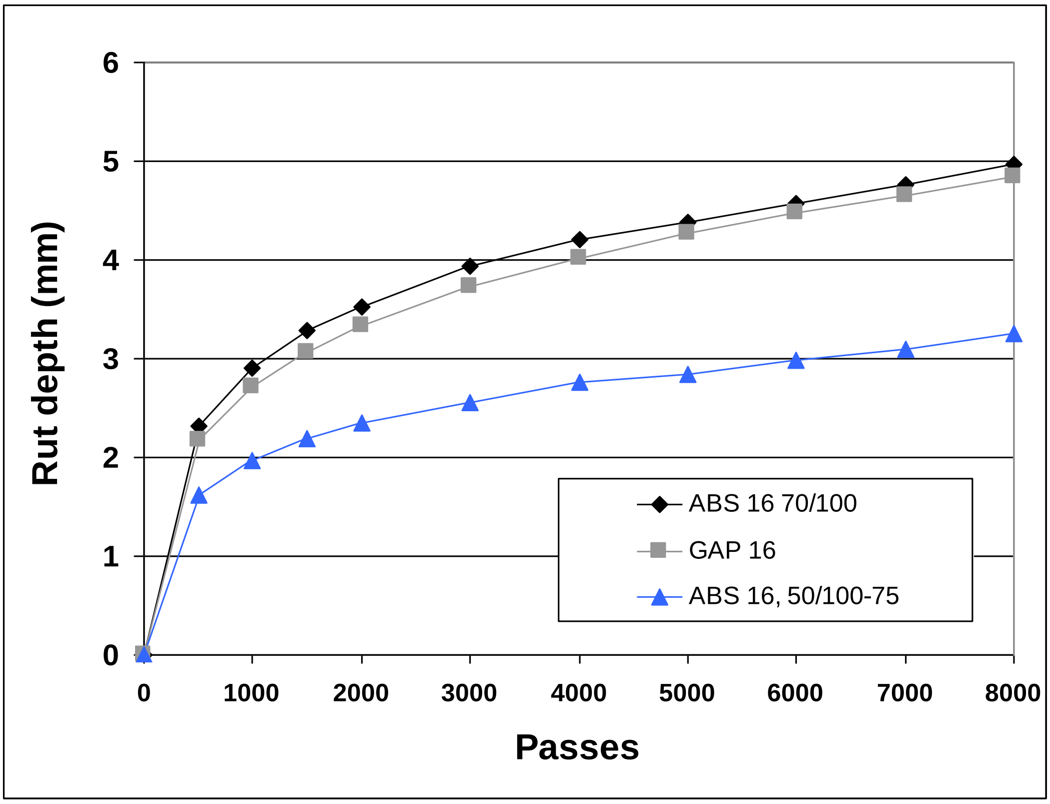

Figure 8 Wheel Track-results at +50°C

To study the deformation properties of the mix types test slabs with a thickness of 40 mm were prepared of the asphalt mixes. Six 150 mm cores were sampled and tested according to the dynamic creep test according to the Swedish FAS Metod 468, which is similar to EN 12697-25 “Uniaxial cyclic compression test with confinement”. This test is carried out during two hours at +40 °C. The mixing temperature was about 160 °C and the slabs were compacted immediately after the mixing.

The attained average void contents of the test specimens were:

- GAP 16 1,0 vol-%
- ABS16 Nypol 50/100-75 2,5 vol-%
- ABS16 70/100 3,0 vol-%

The GAP-mix and the polymer modified mix could be compacted to void contents that was lower than the void contents of the cores from the road. For the reference asphalt mix the result was the opposite.

The polymer modified mix obtained also in this case the most favourable deformation properties with a creep value of about 17 000 microstrain after 4000 load pulses. See Figure 9. The deformation properties of the rubber modified pavement, GAP 16, were somewhat less favourable, while the results for the reference pavement were considerably poorer. This negative result for the reference pavement can, however, depend on its somewhat lower compaction degree.

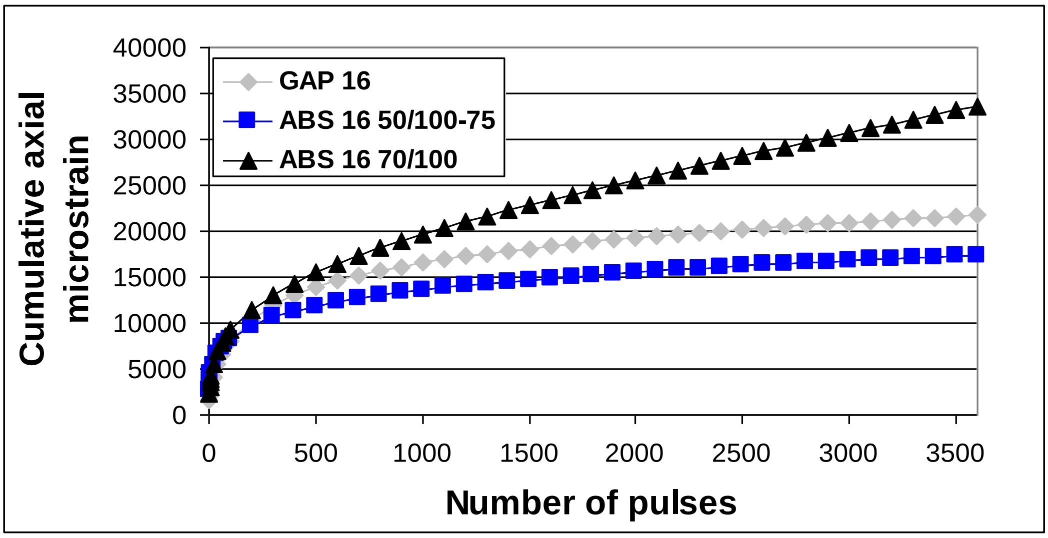

Figure 9 Dynamic creep test results at +40°C

Table 2 Single and mean values and standard deviations at the dynamic creep test (2*30 mm) – microstrain after 3 600 load pulses

Mix type	Single value of test specimen no			Mean value	Standard deviation
	1	**2**	**3**		
GAP 16	19 381	25 332	20 514	**21 700**	3 200
ABS 16 50/100-75	22 991	15 028	14 115	**17 400**	4 900
ABS 16 70/100	30 851	36 260	33 841	**33 600**	2 100

6.5 Master curves

The master curves have been determined by the Indirect Tensile Test (IDT). The greatest advantage with this method is that test specimens, cored from the pavements in the field, can be tested. A methodology for determination of the dynamic modulus and the phase angle from IDT-test data has been developed at NCSU (North Carolina State University).

The attained void contents of the test specimens were:

- GAP 16 1,0 vol-%
- ABS16 Nypol 50/100-75 2,2 vol-%
- ABS16 70/100 2,2 vol-%

The master curve data are graphically shown in Figure 10. From this figures it is evident that there is a certain difference between the mechanical properties of the tested pavements. The polymer modified pavement has higher stiffness moduli at higher temperatures and/or slow loading rates compared with the two other pavements.

Also the linear part in the middle of the master curve for the polymer modified pavement is flatter than the corresponding parts for the other two pavements. This indicates that the mechanical properties are more favourable for the polymer modified pavement.

The reference pavement and the rubber modified pavement have similar properties. There is a tendency that the rubber modified pavement is somewhat stiffer at high temperatures and/or slow loading rates compared with the reference pavement. At low temperatures and/or high loading rates the pavements have roughly the same stiffness moduli.

Statements of such properties as resistance to fatigue and thermal cracking are not possible to make, because they require other type of tests.

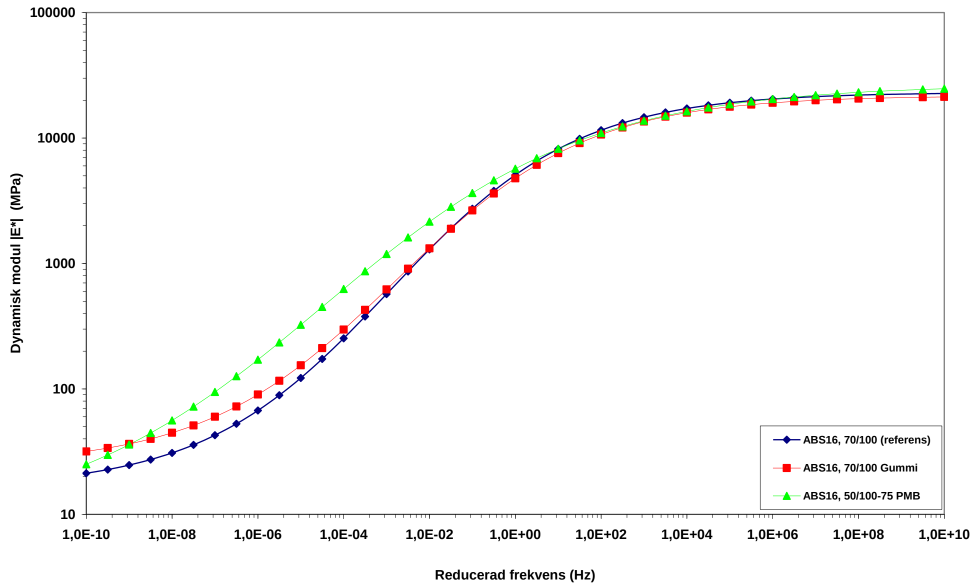

Figure 10 Master curves for the dynamic modulus

7. RUT DEPTH AND TEXTURE MEASUREMENTS

7.1 Initial rut depths, based on RST-measurements

By order of Region Stockholm of SRA a Swedish Road Surface Tester (RST) surveyed the ruts of the test sections about two months after laying of the mixes. The obtained rut depths in Figure 11 are based on 20 m sections and 15 lasers. The lower compaction degree of the polymer modified pavement has caused initial rut depths due to traffic compaction that were greater than those for the rubber modified and reference pavements.

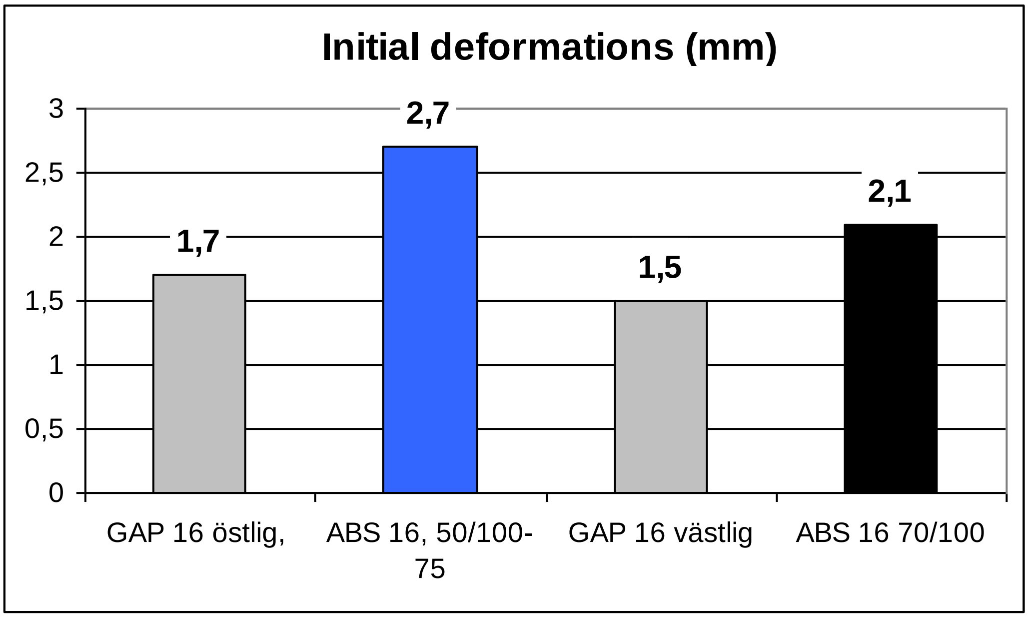

Figure 11 Initial rut depths after laying

7.2 Rut depths, measured by straightedge after the first winter

Rut depth measurements, using straightedge and callipers, were carried out 29 April 2009 in the left and right wheel paths (maximum value) every 100 m. After the first winter season the rutting rate is the lowest for the rubber modified pavement and somewhat higher for the reference and polymer modified -pavements. The rutting development during the forthcoming years will be monitored by annual RST-measurements.

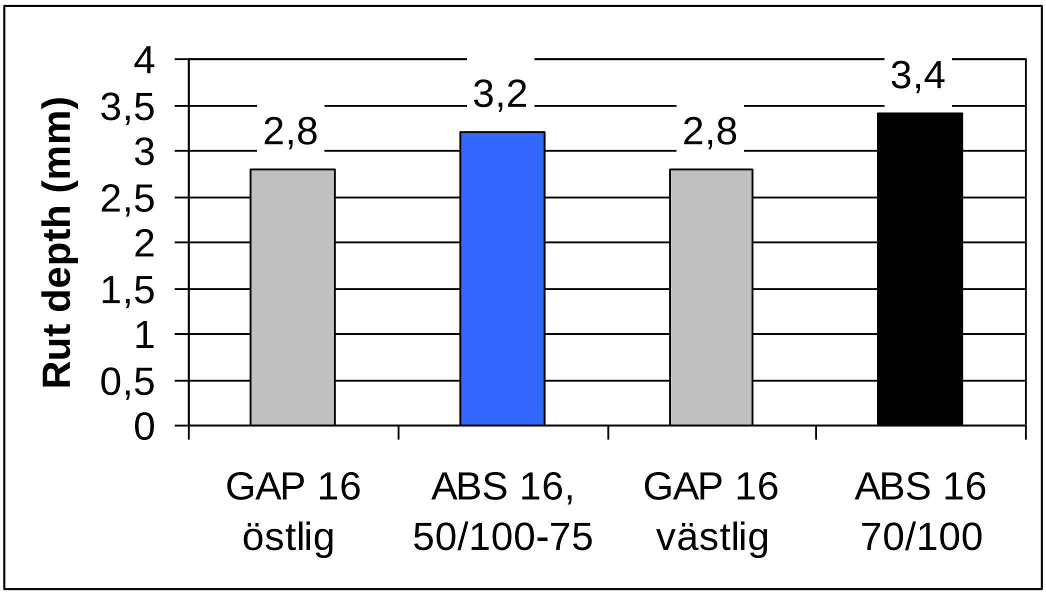

Figure 12 Average rut depths after the first winter, measured by straightedge

7.3 Texture measurements

By order of Region Stockholm of SRA the Road Surface Tester (RST) surveyed the texture of the test sections about two months after the laying of the pavements. A low MPD (Mean Profile Depth)-value indicates a risk of low friction and a high MPD-value indicates a risk of particle loss. The MPD-value for GAP 16 is lower than for the other two pavements. See Figure 13.

The mega texture of the road surface is influenced by the occurrence of such defects as cracks, pot holes and particle loss. A low mega texture value is desirable. High values usually imply increased noise levels, greater wear of car tyres and increased fuel consumption. The mega texture value for GAP 16 is lower than for the other two pavements. See Figure 13.

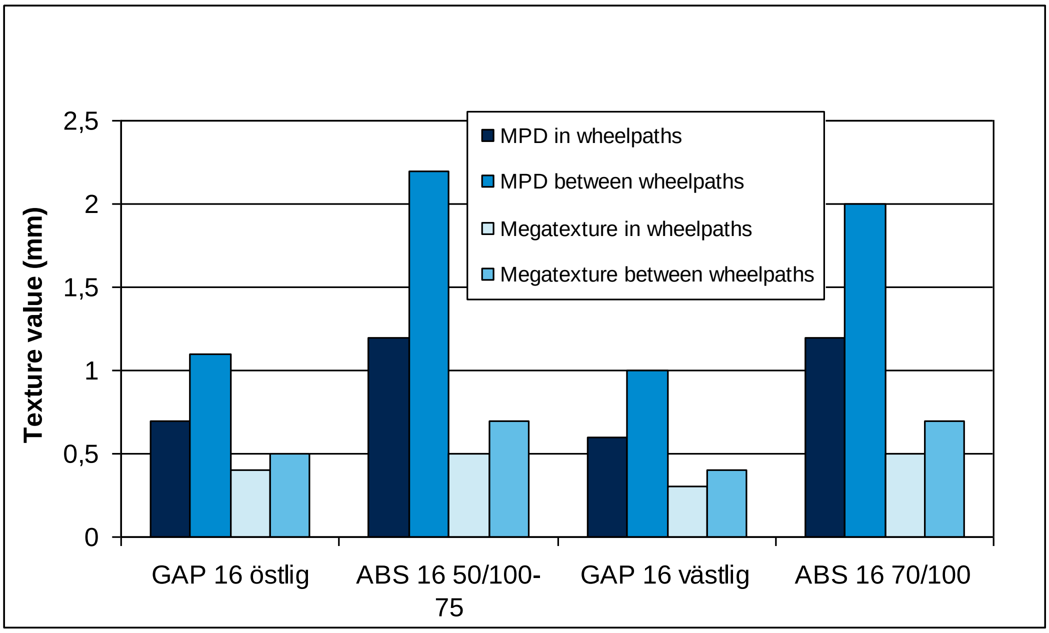

Figure 13 Results of initial texture measurements

8. NOISE MEASUREMENTS

Noise measurements were carried out about one month after the laying by the University of Technology in Gdansk according to the CPX-method (ISO/CD 11819-2), see Figure 14. The noise level for the GAP 16-pavement was about 1 db(A) lower than for the other two pavement types. See Figure 15.

Figure 14 Noise measurements by the CPX-method

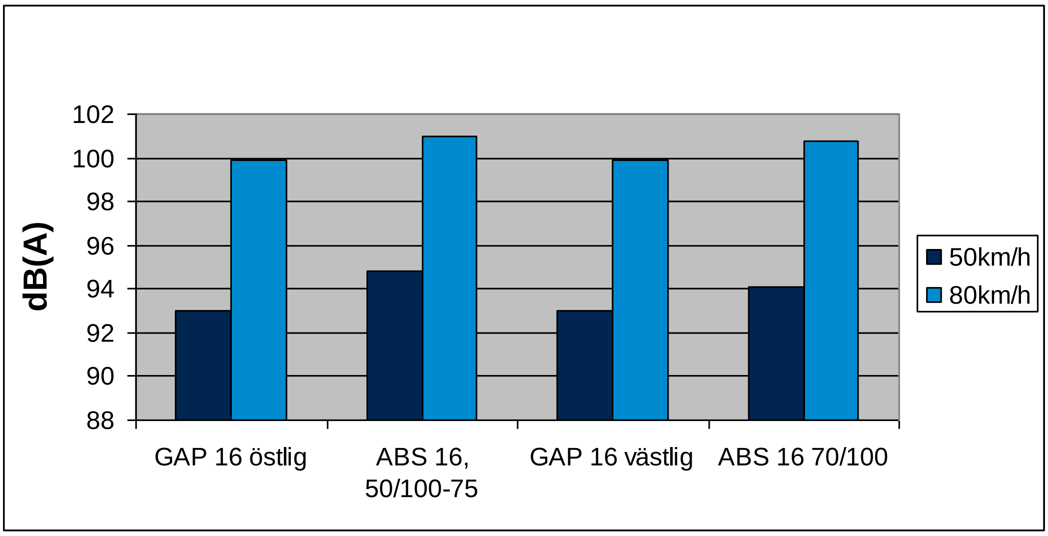

Figure 15 Results of noise measurements

9. ECONOMIC COMPARISON

When choosing more expensive products an important factor is that the time for the next resurfacing is postponed. In this trial the costs for the three asphalt pavements have been compiled in Table 3. The polymer modified alternative is in the order of 18 % more expensive than the reference pavement and the rubber modified alternative is about 32 % more expensive.

Table 3 Cost comparison

Item	ABS 16 70/100	ABS 16 Nypol 70/100 - 45	GAP 16
Bitumen cost (SEK/tonne)	4000	5900	4000
Bitumen content (% by weight)	5,9	5,9	7,3
Rubber cost (SEK/tonne)	-	-	56
Binder cost (SEK/tonne)	236	348	348
Aggregate and mixing (SEK/tonne)	300	300	300
Reduced production capacity cost (SEK/tonne)	0	20	120
Laying (SEK/tonne)	200	200	200
Asphalt cost (SEK/tonne)	736	868	968
Difference in asphalt pavement cost (SEK/tonne)	0	132	232
Difference in asphalt pavement cost (%)	0	18	32

The expected service lives for the different pavements types are shown in Figure 16. The first measurement points after six months are based on the straightedge measurements. The other measurements points are estimated from annual cost calculations.

If the service life for the reference pavement ABS 16 70/100 is supposed to be 7 years, the polymer modified pavement must survive 8 years and the rubber modified pavement 9 years to get the same annual cost.

In the future it is important that the rutting development will be monitored.

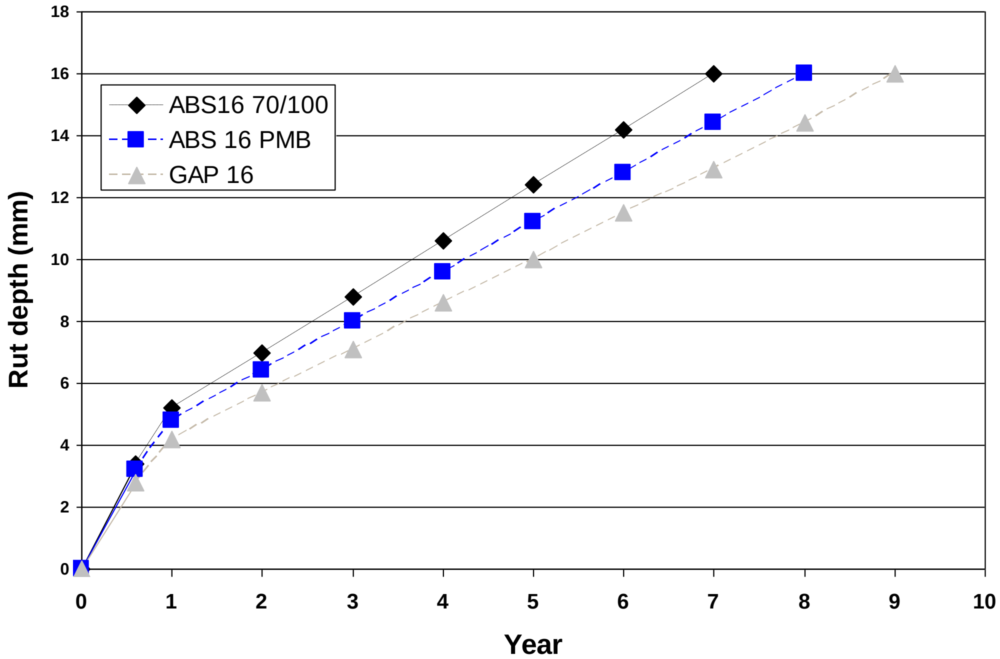

Figure 16 Required service lives for equal annual cost

10. CONCLUSIONS

Also in this report it can be observed that the use of high performance bitumens improves the properties of the asphalt pavement, determined on both laboratory prepared and cored test specimens.

The study in this report also shows that an increased service life of one year is required to compensate for the additional cost of the polymer modified pavement and render the same annual cost as the reference pavement with a service life of 7 years. For the rubber modified bitumen, GAP 16, the corresponding increase in service life is two years.

The monitored actual abrasion of the asphalt test sections will be crucial in the future.