15 YEARS EXPERIENCE ADDING POLYMER POWDER DIRECTLY INTO THE ASPHALT MIXER

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ABSTRACT

15 years ago NCC introduced a polymer modified asphalt on the Danish market. A special polymer powder is added directly to the asphalt pug mill during the mixing process. The polymer is dispersed in the bitumen phase and brings nearly the same functionality to the asphalt as polymer modified bitumen. Compared to asphalt without polymer addition, better fatigue properties and better rut resistance is observed when adding polymer to the asphalt. The binder properties have been measured on extracted bitumen from 15 years old pavements. This binder with polymer shows slower hardening than standard bitumen and the elastic recovery has not changed during 15 years - it is approximately 45 % at 10 °C during all years.

During the last 3 years it has been tried to raise the polymer addition to get even better asphalt characteristics (better rut resistance and better fatigue properties). Laboratory results show improved binder characteristics and field trials on different types of road shows improved functionality of the asphalt pavement (less crack propagation, better rut resistance)

When adding the polymer directly into the asphalt mixer it is possible to modify even small amounts of asphalt with different bitumen hardness, and there is no need for special bitumen storage facilities.

Keywords: modified binders, durability, fatigue cracking, maintenance, permanent deformation

1. INTRODUCTION

The benefits by using modified bitumen in asphalt are well known all over the world, and are described in a lot of papers. Also in Denmark modified bitumen has been used to enhance rut resistance and elastic properties of the asphalt pavements. Because of many very small jobs with quite different traffic volume modified bitumen in different hardness is needed in very small amounts. This means that more than one storage tank is needed at each asphalt plant and these tanks have to be heated most of the time. Therefore asphalt with modified bitumen becomes disproportionately expensive. Based on this fact NCC 15 years ago tried to find a polymer that could be added directly into the asphalt pug mill.

2. LABORATORY TESTS ON BITUMEN AND POLYMER MIXES.

Denmark has a long tradition for using SBS modified bitumen but also SIS has been used. Therefore these two types of polymers were selected for investigation.
Normally special equipment, such as high shear mixers, is needed when SBS or SIS pellets should be incorporated into bitumen. It is easier to incorporate SBS or SIS powder into the bitumen, and some modification plants apply SBS powder without any high shear mixer. A certain reaction time at high temperature is needed to obtain the desired bitumen characteristics. In an asphalt plant the mixing time is 30 – 60 seconds. After the mixing the asphalt is stored in the hot mix bin before transportation to the paving site. This storage and transport time will vary very much but it is seldom the time is below one hour. Because of the low mixing energy and quite short reaction time powders of SBS and SIS was selected for further investigation

2.1 TEST PROTOCOL

Before using the powder directly in the asphalt mixer it was necessary to simulate the low energy mixing of polymer powder and bitumen in the laboratory:

- bitumen is heated to the desired asphalt mixing temperature
- a simple mechanical stirring propeller is placed in the bitumen
- The polymer powder is added
- The bitumen – powder mixture is stirred for one hour at the desired temperature.

After this time the bitumen – powder mixture is poured into the different test moulds. Different bitumen parameters were tested:

- Penetration at 25 °C, EN 1426
- Softening point Ring & Ball, EN 1427
- Elastic recovery at 10 °C and 25 °C, EN 13398
- Breakpoint Fraass, EN 12593
- RTFOT hardening at 163 °C, EN 12607-1
    - Change in mass
    - Change in penetration
    - Change in softening point R&B

2.3 TEST RESULTS

Normal bitumen 70/100 and 330/430 for road application were mixed with different amounts of SBS and SIS. The results are listed in table 1, 2, 3 and 4. The variations in Ring and Ball and elastic recovery are illustrated in figure 1 and 2.
The binder with SIS looked homogeneously and without any polymer particles in the surface for the lower amounts of polymer. With 8 % of polymer there were polymer particles in the surfaces. The SBS seems to be a little more difficult to incorporate and the surfaces of the binder were “gritty” with both 5 % and 8 % polymer.

Table 1: Different amounts of SIS in bitumen 70/100

Polymer addition	Penetration 25°C	R&B	Elastic recovery		RTFOT Δ R&B	RTOFT Retained penetration
			10 °C	25 °C		
% of binder	1/10 mm	°C	%	%	°C	%
0	87	46,0	3	8	5,6	58
1,5	73	48,8	48	10	5,6	62
3,0	66	53,2	58	73	3,4	68
5,0	54	60,4	67	81	3,8	80
8,0	42	68,0	70	84	2,4	95

Table 2: Different amounts of SBS in bitumen 70/100

Polymer addition	Penetration 25 °C	R&B	Elastic recovery		RTFOT Δ R&B	RTOFT Retained penetration
			10 °C	25 °C		
% of binder	1/10 mm	°C	%	%	°C	%
0	82	46,0	13	9	5,4	60
1,5	68	48,0	55	20	5,6	63
3,0	61	49,6	63	44	8,2	64
5,0	54	59,2	76	78	5,4	67
8,0	38	89,0	88	94	-1,2	-

Table 3: Different amounts of SIS in bitumen 330/430

Polymer addition	Penetration 25 °C	R&B	Elastic recovery		RTFOT Δ R&B	RTOFT Retained penetration
			10 °C	25 °C		
% of binder	1/10 mm	°C	%	%	°C	%
0	-	33,4	8	-	4,2	64
1,5	312	34,6	61	-	5,0	62
3,0	262	39,8	70	-	2,0	67
5,0	185	65,6	93	98	-4,0	73
8,0	133	70,4	96	99	-3,0	86

Table 4: Different amounts of SBS in bitumen 330/430

Polymer addition	Penetration 25 °C	R&B	Elastic recovery		RTFOT Δ R&B	RTOFT Retained penetration
			10 °C	25 °C		
% of binder	1/10 mm	°C	%	%	°C	%
0	-	34,4	8	-	6,2	59
1,5	244	37,8	54	-	5,2	63
3,0	211	39,4	71	87	6,2	64
5,0	117	76,2	96	99	-1,0	72
8,0	90	90,0	96	96	2,5	70

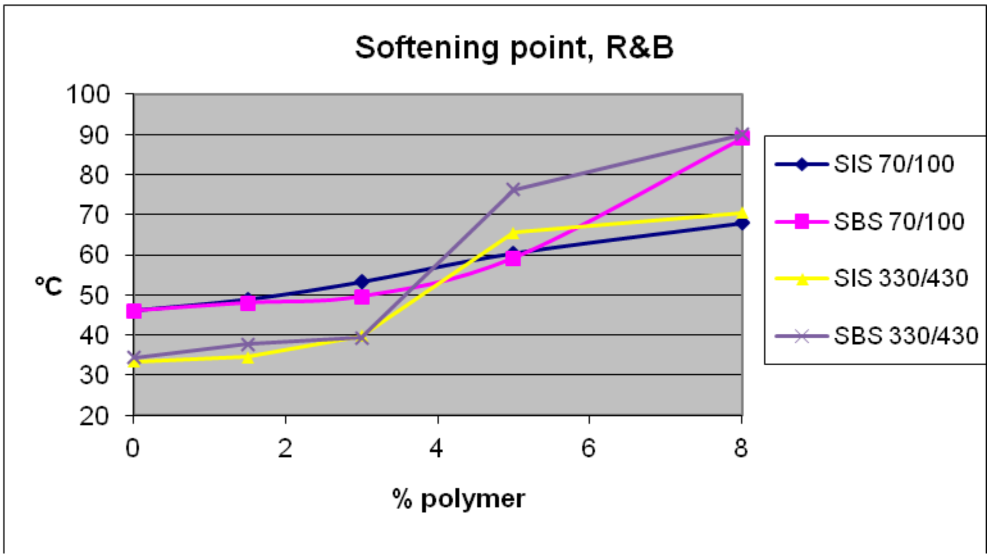

Figure 1: **Variations in Ring and Ball as a function of polymer addition**

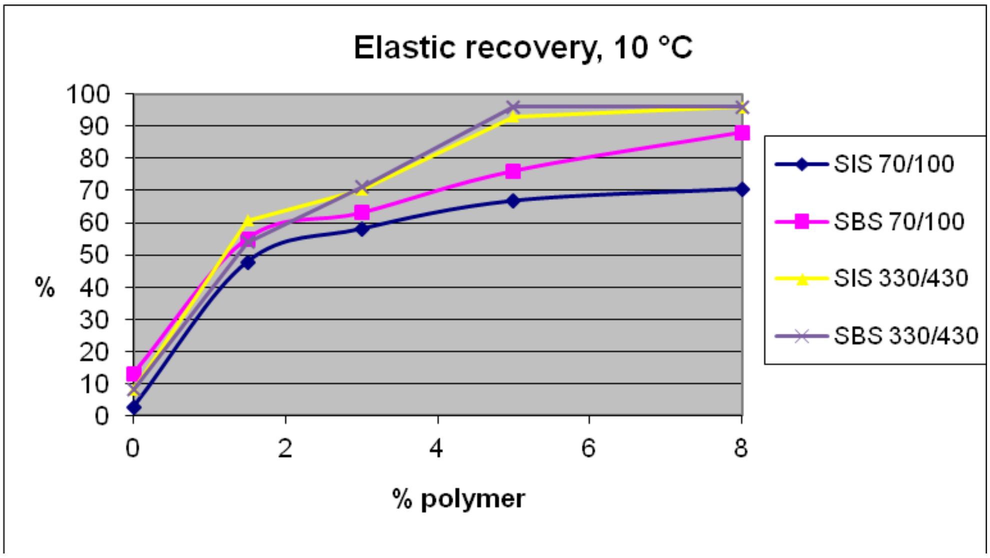

Figure 2: **Variations in Elastic Recovery at 10 °C as a function of polymer addition**

2.2 DISCUSSION OF TEST RESULTS

The results show that it is possible to modify bitumen by simple stirring of the polymer powder into bitumen. As with "normal" modified bitumen the Ring & Ball value is raising when the amount of polymer is raised. The same is the elastic recovery. Even a small addition of polymer (1,5 %) gives a clear improvement of the elastic recovery. When modifying a soft bitumen the Ring & Ball value is clearly raising between 3,0 % and 5,0 % polymer. The change in elastic recovery from 5 % to 8 % polymer is only marginal. The same is the change in Ring and Ball by using SIS. When using SBS the R&B value is raised also from 5 % to 8 %.

From the tables it is recognized that the ΔR&B value is decreasing by increased SIS addition indicating that the hardening tendency of the bitumen is decreased by increasing the polymer content. This decrease in hardening is not as clear when using SBS probably because of less homogeneous binder.

3 LABORATORY TESTS ON ASPHALT MIXES

The main reasons for modifying bitumen are to achieve better elastic properties, better fatigue properties and better rut resistance of the asphalt pavements. Therefore fatigue properties and rut resistance has been tested on different asphalt mixes with and without polymer addition in the asphalt mixer.

3.1 FATIGUE PROPERTIES

A lot of minor roads in Denmark have very thin asphalt pavements and the foundations of the roads are quite often insufficient. Therefore there are movements in the pavement caused by traffic and frost/thaw cycles. The result is a lot of cracks. When such roads are repaved a dense graded asphalt with a soft bitumen (250/330 or 330/430) is used. The cracks are reflected through the new pavement in a relatively short time. Therefore many municipalities are looking for types of asphalt that delay the reflective cracking, a mix with a higher degree of elasticity and better fatigue performance. NCC has adjusted a normal dense graded asphalt by adding more of the larger aggregates, adding more bitumen and applying 1,5 % SIS (calculated on bitumen). In asphalt mix with a maximum aggregate size of 8 mm the amount of aggregate larger than 2 mm is 10 % higher than normal and the bitumen content is raised 0,2 %. The fatigue properties of this mix have been compared with the properties of normal dense graded asphalt by using a Nottingham Asphalt Tester (see figure 3). The adjusted mix with SIS can resist 5 times as many load cycles as the reference mix to reach the same microstrain.

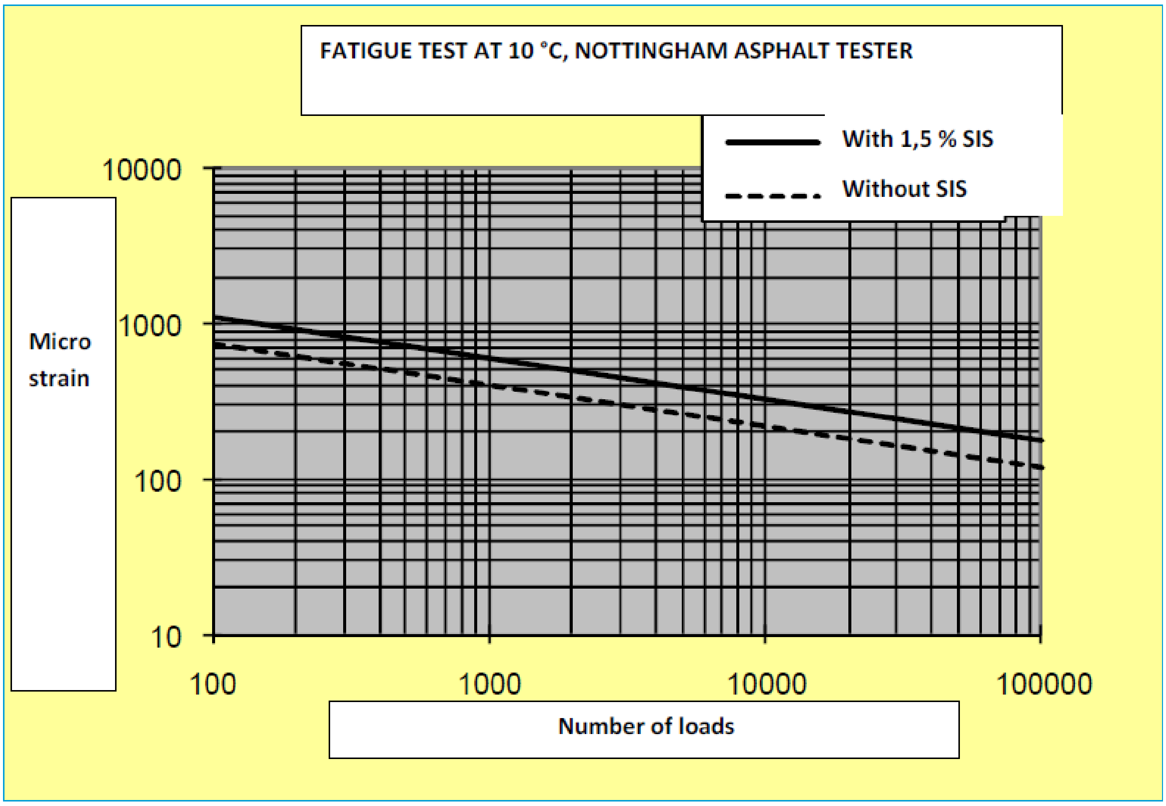

Figure 3: **Fatigue measurement in NAT, comparing mixes with and without SIS**

The same type of mix but with harder bitumen has been tested in dynamic creep test on the Nottingham Asphalt Tester at 40 °C (EN 12697-25). Figure 4 show photography of the two specimens. The standard asphalt collapsed after 1800 load cycles and the SIS modified asphalt did not have any visible defects after 3600 load cycles. This modified asphalt shows better cohesion and better elastic performance than unmodified asphalt with standard bitumen.

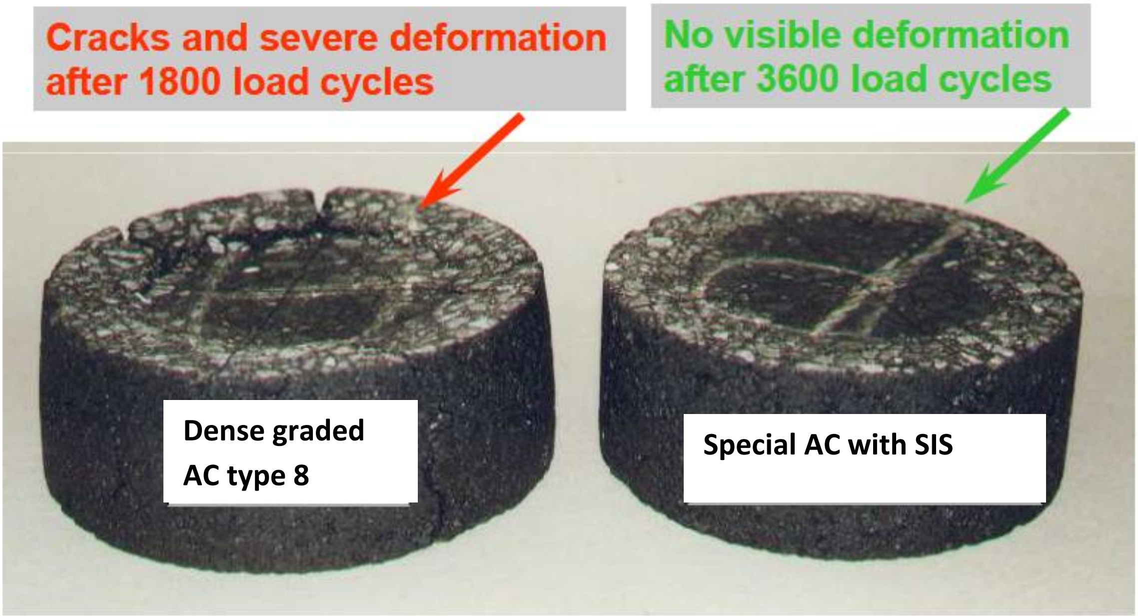

Figure 4: **Comparison of asphalt concrete with and without SIS in dynamic creep test.**

3.2 RUT RESISTANCE

It is well known that asphalt with modified bitumen has better rut resistance than asphalt with normal standard bitumen. Laboratory tests have shown that asphalt produced with addition of SIS in the asphalt mixer also have better rut resistance than asphalt without any polymer. Split mastic asphalt (SMA) with maximum aggregate size of 11 mm has been tested in wheel track equipment according to EN 12697-22. The only deviation from the standard is that the specimens have been tested water instead of air.

The asphalt was produced on a standard asphalt batch plant. The SIS powder was added by using automatic dosing equipment mounted on the asphalt plant. In this way it was possible to sample asphalt with and without SIS produced under similar production conditions.

In the laboratory the two samples were heated to compaction temperature and compacted in a roller segment compactor using vertical sliding plates according to EN 12697-33. After one week the samples were tested at 60 °C and 10.000 load cycles (20.000 passes). The results are illustrated in figure 5.

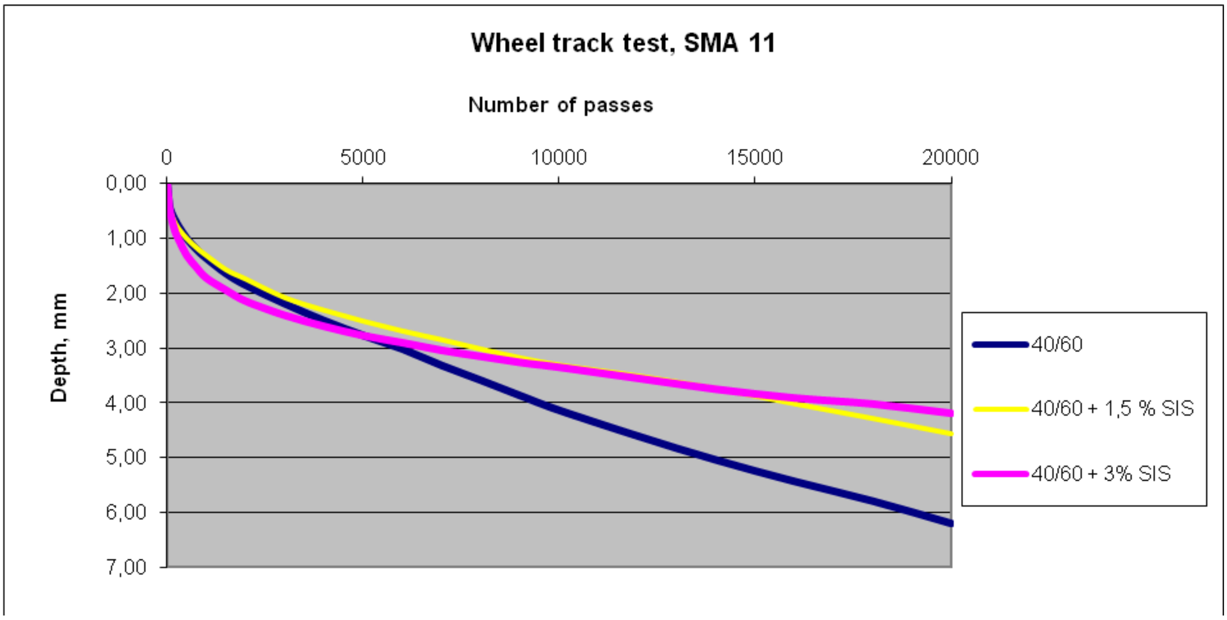

Figure 5: **Wheel track test SMA 11 with different amounts of SIS**

As shown a much better rut resistance is obtained by adding SIS in the asphalt mixer. Nearly same resistance is found with 1,5 % and 3,0 % SIS until the last part of the test. Here the two curves split and the best final result is obtained with 3,0 % SIS.

4 TEST SECTIONS

One of the first test sections on a minor road was made in 1996 in the west part of Denmark named Nørre Farup vej near Ribe. This road is a typical minor road with low traffic intensity. Here the adjusted asphalt mixture was paved. The binder was bitumen 330/430 and 1,5 % SIS of the binder was added during the asphalt mixing. This means 0,9 kg polymer per ton asphalt. As reference normal dense graded asphalt with bitumen 250/330 was laid. Drill cores were taken just after finishing the job and the binder was extracted. Penetration, softening point R&B and elastic recovery were measured. Since then drill cores have been taken from time to time, latest in 2010, and the same parameters have been measured. The results can be seen in figure 6.

Nr. Farupvej Recovered bitumen							
Product:	Test Unit	1996 Paving	1997	1998	2000	2005	2010
Dense graded asphalt bitumen 250/330	R&B °C	36,0	40,5	42,0	46.0	46,5	52.0
	Penetration 1/10 mm	295	207	154	104	89	39
Special designed asphalt 330/430+ SIS	R&B °C	35,5	42,5	43,5	45,0	47.0	49,6
	Penetration 1/10 mm	256	150	135	124	91	56
	Elastic recovery at 10 °C, %	43	42	44	50	44	47

Figure 6: Bitumen data measured on extracted bitumen with and without SIS.

From the figure it can be seen that the hardening of the modified binder is lower than the hardening of the standard bitumen. The elastic recovery of the modified binder does not change over time; it is constant near 45 %. This proves that adding SIS to the asphalt mixer has very positive effect on the asphalt pavement.

4 PERSPECTIVES

Because of many very small jobs with quite different traffic volume it is very difficult to use modified bitumen to enhance the asphalt quality in Denmark. By adding polymer directly into the asphalt mixer an improvement of the asphalt quality is obtained. This improvement can be obtained on even very small productions such as 10 – 15 tons for repairs and other small jobs. For bigger jobs the logistic is simplified. No special tank transport is needed and no bitumen tanks have to be emptied or heated. The job can be prepared by buying a certain number of bigbags with polymer powder in good time before use. Therefore most of the Danish asphalt contractors are able to produce asphalt with this sort of modifications. Since 1996 NCC alone has produced over 1 million tons of polymer modified asphalt by adding the polymer directly into the asphalt mixer. This type of modification has now been introduced into the Danish Road specifications as a routine modification. This year the Road Authorities specify at least 50 % elastic recovery in wearing courses for motorways and this could be obtained by adding 2 – 3 % polymer directly into the asphalt mixer.

Small tests have been made with 5 % polymer directly into the asphalt mixer. The first results looks very fine and the future will show if the durability of this modification is satisfactory.