Effects of sealing on the noise properties of worn pavement

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Summary

As a measure to extend the structural life of noise reducing surfaces, the Danish Road Directorate have tried sealing twenty-one different surfaces. The surfaces where: three different 5 years old two-layer porous asphalts, two with max 5 mm and one with max 8 mm aggregate in the top-layer, seventeen 8-10 years old thin layer pavements: two DA 6, three DA 8, two SRS UTLAC, two open AC and eight SMA pavements, and one 20 years old AC.

These pavements have been studied by Close Proximity (CPX) measurements made with an open measurement trailer before and after the sealing. The two-layer porous asphalts were only measured once after the sealing. The remaining pavements has been measured each year for 2-3 years after the sealing.

The data has been analyzed in order to determine the changes in noise levels before and 6 weeks after the sealing. The initial and the aging effects on the noise properties of the sealed pavements will be studied for all the pavements except the porous asphalt. These were only measured once after the sealing and will only be studied for initial changes. The frequency spectrums will be studied to investigate whether the sealing results in another composition of noise. The study also includes estimates of structural lifetime for the thin-layer pavements before and 3 month after the sealing.

The noise level after six weeks of traffic on the sealed pavements seems to be slightly lower (0,1 - 0,6 dB) than before the sealing for most of the pavements. Only three pavements of the twenty-one had slightly higher (0,1 – 0,8 dB) noise levels after the sealing were performed. The estimated structural life does not change significantly for the thin layer pavements.

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1. Introduction

The Danish Road Directorate administers motorways and highways in Denmark. For more than a decade road traffic noise has been an issue of special concern. A number of projects have been carried out in order to address the challenge of reducing tyre/road noise. Often these projects have led to studies of time histories and thereby the development over time of the traffic noise reduction provided by different types of pavement. Such studies have been carried out in cooperation with national or international partners or by the Danish Road Directorate itself. The main concern of the Road administrators when choosing a noise reducing pavement over a standard pavement is the structural lifetime of the noise reducing pavements. It is commonly assumed that noise reducing pavement have a 2-3 year shorter structural lifetime than standard pavements. When pavements start raveling an often used measure to enhance the lifetime is bitumen sealing. The tyre/road noise effect of the sealing has previously not been investigated in Denmark.

In 2006 a number of test sections with pavements of noise reducing thin layer types were built on a new Danish highway M64 near Herning. Two years later another new highway M68 near Herning were built with new versions of some of the test pavements from M64. These pavements have been monitored ever since with measurements of close proximity noise levels. The intention was to determine the changes in tyre/road noise generated on the different pavements throughout their lifetime and to study the noise reducing abilities.

Some of the noise reducing pavements was in 2014 estimated to have a short structural lifetime before it would be necessary to change the pavements. It was decided to try to enhance the structural lifetime of the pavements with a bitumen sealing. This decision was made as the

highways were about to be redirected in 2017 as they should be connected to each other and led further north thus the combined route was going from Herning to Holsterbro.
In 2015 the municipality of Slagelse decided to try and reduce noise from a highway after massive complaints from the neighbors to the highway. The measure to noise reduction was a sealing of the old worn pavement with a special bitumen mixture adding rockdust. The Danish Road Directorate have monitored the pavement ever since with close proximity measurements.
This paper deals with results of the measurements done shortly before the sealing of the pavements and the measurements done afterwards. It looks into the noise level time histories, i.e. the noise level as a function of the age of the sealing. The frequency spectrum of the measurements will be investigated to study the noise effects of the sealing of old pavements.

2. The Pavements

In the early 2000s the Danish Road Directorate began research into the ability of thin layer asphalt wearing courses to generate less tyre/road noise than dense standard asphalt pavement. Various asphalt mix recipes were tested, with varying results. The wearing courses built on the Danish highways M64 and M68 near Herning were built during this period. The specifics of these pavements are well known to the Danish Road Directorate and have been investigated in several studies such as [1], [2] and [3]. The specifics on the 20 year old and worn pavement near Slagelse are not known to the Danish Road Directorate. The surface types are listed in table I. The types are asphalt concrete (AC), either dense graded (d) or open graded (o), ultra-thin asphalt layers (UTLAC), semi porous asphalt (PA) or stone mastic asphalt (SMA). The numbers shown in connection with the surface type denote the maximum aggregate size, i.e. either 4, 8 or 11 mm. The open graded asphalt concrete and semi porous asphalts, has an open surface which is supposed to lead to a reduction in noise generated by air pumping. The surfaces denoted SMA 6+ or SMA 4+ are stone asphalts with 6 or 4 mm maximum aggregate size to which a small fraction of larger aggregate has been added in order to obtain a more open structure. Table I also states the expected length of the service life of the wearing courses.

Table I. Surface types built on highway M64 and M68 near Herning and the Highway near Slagelse. And their expected service life time, in years.

Surface type	*M64*	*M68*	*Exp. lifetime [years]*
AC 11d	X 2		14
AC 8o	X		12
AC 6o	X	X	12
UTLAC 8	X		12
UTLAC 6	X		12
SMA 11	X 2		14
SMA 8	X		15
SMA 6+	X	X 2	14
SMA 6+(11)		X	14
SMA 6+(8)		X	14
SMA 6	X		14
SMA 4+(8)		X	14
PA 8	X 2	X	12
PA 6	X	X	12
Slagelse:			
Old Worn AC			

AC 11d and SMA 11 are considered reference pavements in Denmark, both present on M64. The reference pavements have been built in both directions in order to have reference surfaces which have had the same traffic load as the test pavements. The pavements on M68 are based on the pavements with the best tyre/road noise reducing properties from M64 and new mixtures which should have even better tyre/road noise reducing properties.
A closer look at Table I reveals that some of the SMA's on M68 are more specific on the aggregate fractions which are added in parenthesis. And all the pavements from M64 with aggregate size from 8mm and above except for the PA 8 are not built on M68. The advantage of smaller maximum aggregate is a smother surface, which is associated with less vibrational noise than a rougher surface.

3. Remaining structural lifetime

The Danish Road Directorate uses a subjective measurement of the remaining structural lifetime of pavements in order to estimate when the pavements should be replaced.

For some of the pavements on M64 and M68 the remaining structural lifetime has been estimated before and the year after sealing, these can be seen in Table II.

Table II. The estimated remaining structural lifetime for some of the pavements on M64 and M68 before the bitumen sealing.

Test site	*Surface type*	*Remaining lifetime before sealing [years]*	*Remaining lifetime after sealing [years]*
M 64	AC 11d	9	
	UTLAC 8	3	3
	UTLAC 6	2	3
	PA 6	3-4	4
	2xPA 8	2-3	3
	SMA 6	5-6	6
	SMA 6+(8)	6-7	7
	SMA 8	6	6
M 68	AC 6o	3-4	4
	PA 6	3-4	4
	PA 8	4	3-4
	SMA 6+(11)	6-7	7
	SMA 6+(8)	6	6
	SMA 4+(8)	7-8	8

When the remaining structural life time is estimated, the overall condition of the pavement is also noted. The seven pavements with a remaining lifetime of 2-4 years have all been noted ill conditioned with extensive raveling. Only two of the PA 8 are noted not to have had any effect of the sealing. While the remaining 5 didn't show signs on further raveling and had good effect of the sealing.
All of the pavements had one or two years added to their estimated remaining structural lifetime.

4. Noise measurements

Tyre/road noise has been measured yearly by the Close Proximity (CPX) method [4] before and after the sealing on M64 and M68. The highway near Slagelse was measure once before the sealing and have been followed yearly ever since.
The CPX measurements were done with the jr/dgmr open noise trailer of the Danish Road Directorate called deciBella with standard reference test tyres (SRTT).
All the measurements on M64 and M68 are done with cruise control on about 80 km/h to make sure that no rapid acceleration or deceleration occurred. The measurements were normalized to 80 km/h. The temperature was measured during noise level measurements and the measurements were normalized to 20 degree Celsius. The Tyre hardness was measured close to the date of the measurement, which was normalized to a ShoreA of 66. The test sections on the highway near Slagelse are speed restricted to 70 km/h, thus the measurement were done at this speed.

4.1. Results from highway M64

The results of the CPX measurements from M64 are sorted by type in Figure 1 to 4. In Figure 1 the results from the AC's are shown. The results from the SMA's are shown in Figure 2. In Figure 3 the results from the UTLAC's are shown and the results from the PA's are shown in Figure 4.

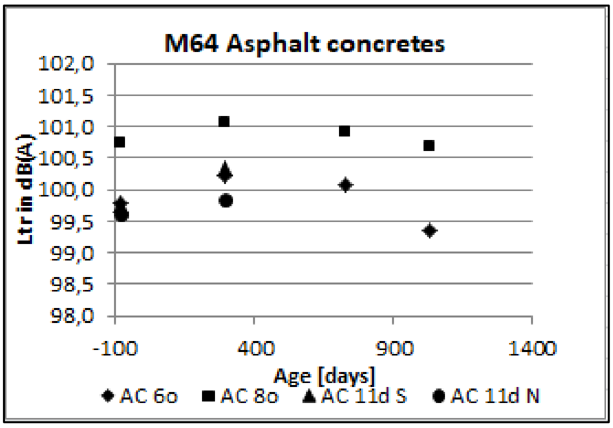


Figure 1.The temperature, speed and shoreA corrected results measured on the ACs on highway M64. The zero point is the day of sealing.

The dense asphalt concretes have only been measured once after the sealing because of the redirection of the road. The open asphalt concretes have not been affected in the connection of M64 and M68, this is why they are measured over a longer period on the AC 6o and AC 8o, see figure 1.

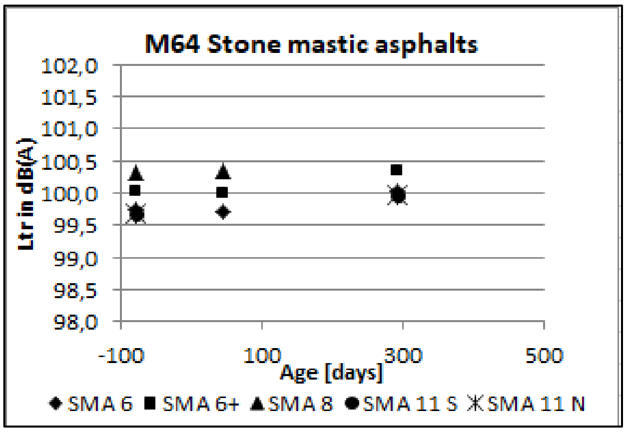


Figure 2. The temperature, speed and ShoreA corrected results measured on the SMAs on highway M64. The zero point is the day of sealing.

The SMA 6s, SMA 8, UTLACs and PAs have been measured earlier after the sealing than the ACs in Figure 1 and the SMA 11, see Figure 2-4. The uncertainty of how long the pavements would remain intact was the reason for the late seasonal measurement. The measurement was done in late October.

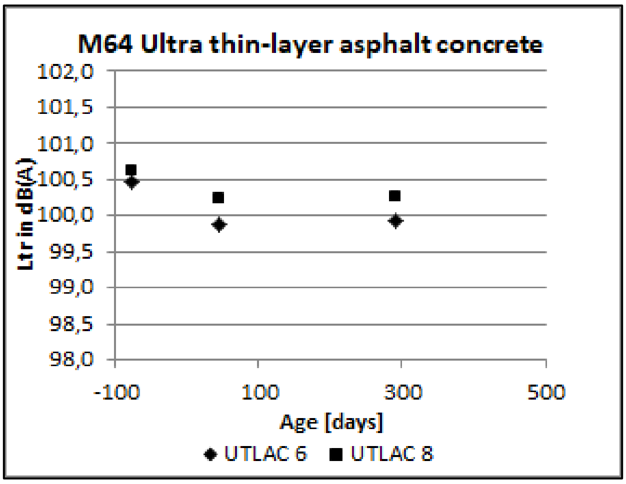


Figure 3. The temperature, speed and shoreA corrected results measured on the UTLACs on highway M64. The zero point is the day of sealing.

The ACs and SMAs in Figure 1 and 2 seems to have had little or none effect of the sealing on the noise properties. The tyre/road noise levels rises only a little during the measurement period, as the pavement is assumed to do during its lifetime. Only the noise levels of AC 6o and AC 8o seems to rise a little (0.3-0.4 dB) after the sealing but decreases again in the period between the measurements. The AC 8o finds its level from before the sealing in the last measurement, while the AC 6o has an even lower noise level (0.4 dB) than before the sealing in the last measurement, see Figure 1.The dense ACs also get a higher noise level (0.2-0.5 dB) after the sealing. The noise levels of the SMAs have increased 0.3 -0.4 dB about 1 year after the sealing.
The noise level of the UTLACs and the PAs all decreases right after the sealing (0.3 - 0.6 dB), see figure 3 and 4, and seems to have stayed at the level until the last measurement or even decreased with 0.1 - 0.2 dB. Except the noise level of the PA 8 cl 2 which has returned to the initial noise level, see figure 4.

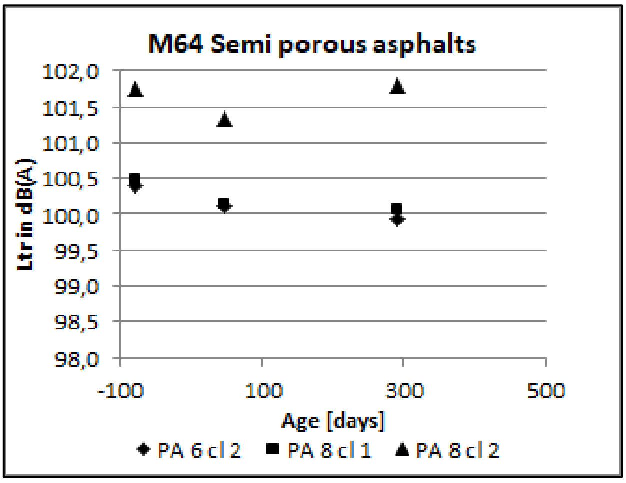


Figure 4. The temperature, speed and ShoreA corrected results measured on the PAs on highway M64. The zero point is the day of sealing.

4.2. Results from highway M68

The results of the CPX measurements are sorted by type and shown in Figure 5 and 6. Figure 5 shows the results of the measurements done on the different SMA pavements while Figure 6 contains the measurements from the PAs and the AC 6o.
The noise level of all of the pavements on M68 does either increase or seems to stay the same after the sealing. The SMA 6+(8) and SMA 4+(8) were measured once more than the other pavements because these were later effected by the connection to M64.

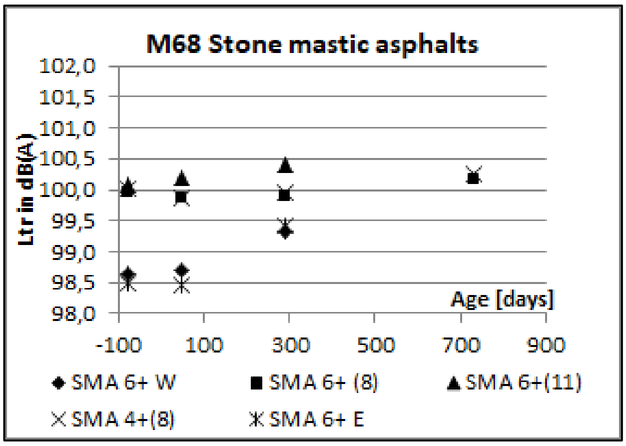


Figure 5. The temperature, speed and shoreA corrected results measured on the SMAs on highway M68. The zero point is the day of sealing.

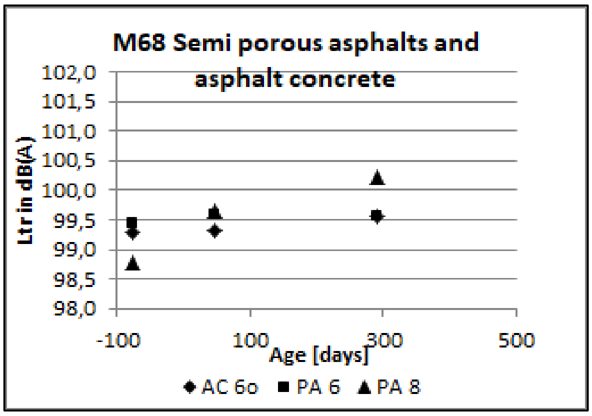


Figure 6. The temperature, speed and shoreA corrected results measured on the PAs and the AC 6o on highway M68. The zero point is the day of sealing.

4.3. Results from the highway near Slagelse

The results from the Highway near Slagelse are shown in Figure 7.

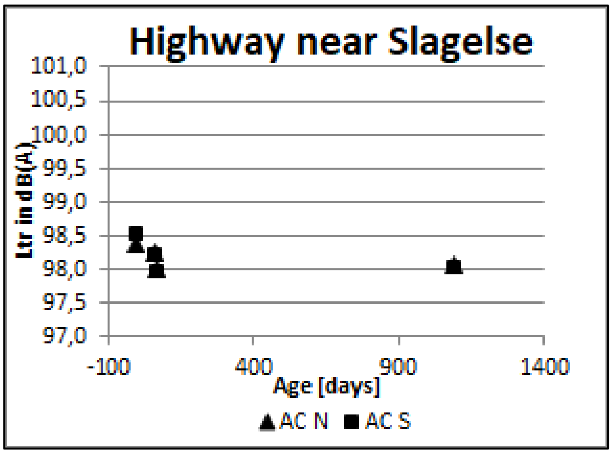


Figure 7. The temperature, speed and shoreA corrected results measured on the old worn AC on the highway near Slagelse. The zero point is the day of sealing.

The noise level of the old worn AC pavement on the highway near Slagelse decreases by about 0,4 dB after the sealing after three years the noise level is still the same as when it was first sealed.

5. Frequency spectra

Tyre/road noise is a combination of two components - air pumping and vibration. For frequencies above 1000 Hz the air pumping effect is considered to be dominating. At low frequencies between 300 and 1000Hz vibrations are considered to be dominating.

A few of the more interesting spectra are studied in the following. One of each type of pavement for each test section is selected.

5.1. Spectra from M64

The spectra from M64 that seems mostly interesting are AC 6o, Figure 8, which had a slide increase in noise level right after the sealing but ended with a lower noise level before the sealing. SMA 8, Figure 9, is chosen because it is commonly used in Denmark on Motorways where a lower noise level is wanted. PA 8 cl 1 and UTLAC 8, Figure 10-11, are chosen because of the large aggregate size.

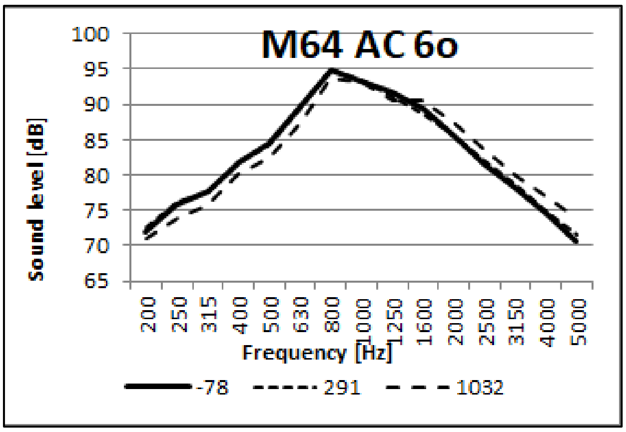


Figure 8. Spectra of measurements done on the AC 6o built in M64 for the days of measurements.

For the AC 6o it can be seen in figure 8 that the measurements of day -78 and 291 the spectra are alike. The spectra from day 1032 after sealing the Sound level is lower at lower frequencies while it is higher at higher frequency. This indicate that the pavement generate les air pumping noise and more vibration noise. This can be due to a more open but rougher surface.

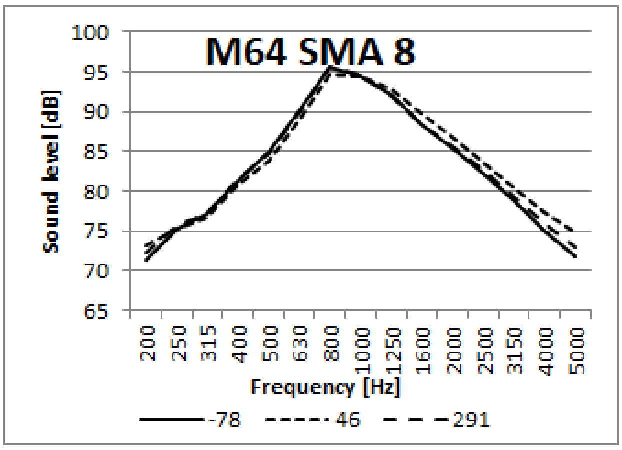


Figure 9. Spectra of measurements done on the SMA 8 built in M64 for the days of measurements.

The same effects are seen for the SMA 8, see Figure 9. The lower sound levels in the lower frequencies are not as significant for the SMA 8 as the AC 6o.

For the PA 8 cl 1, Figure 10, the difference between the frequency spectra from day -78 and 46 are similar to the difference seen between days -78 and 1032 of the AC 6o. But the spectrum of day 291 of the PA 8 cl 1 is lower at all frequencies between 250 Hz and 2000 Hz which indicates both less air pumping noise and vibration noise.

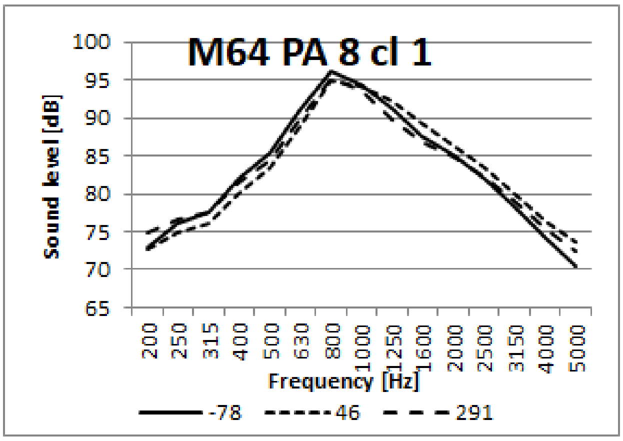
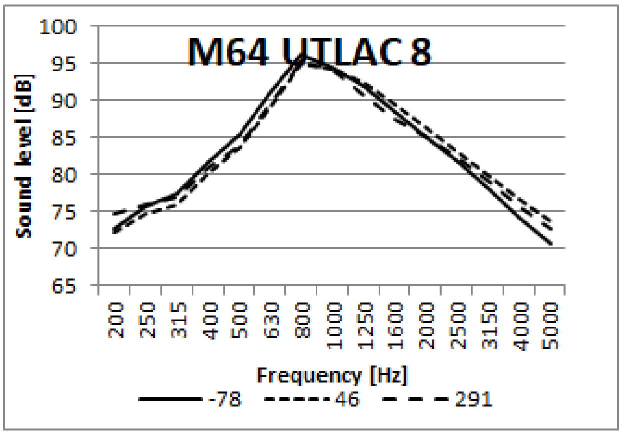


Figure 10. Spectra of measurements done on the PA 8 cl 1 built in M64 for the days of measurements.

The spectra of the UTLAC 8, see Figure 11, and the changes from day -78 to 291 are similar to those of the PA 8 cl 1, see Figure 10.



5.2. Spectra from M68

The spectra studied from M68 are from AC 6o and SMA 6+(8), Figure 12-13.

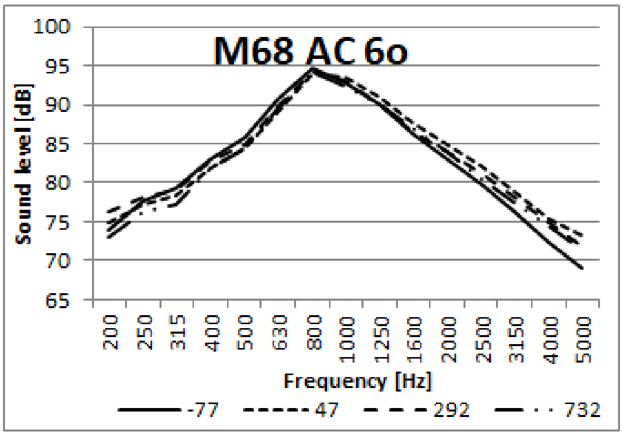


Figure 11. Spectra of measurements done on the UTLAC 8 built in M64 for the days of measurements.

Figure 12. Spectra of measurements done on the AC 6o built in M68 for the days of measurements.

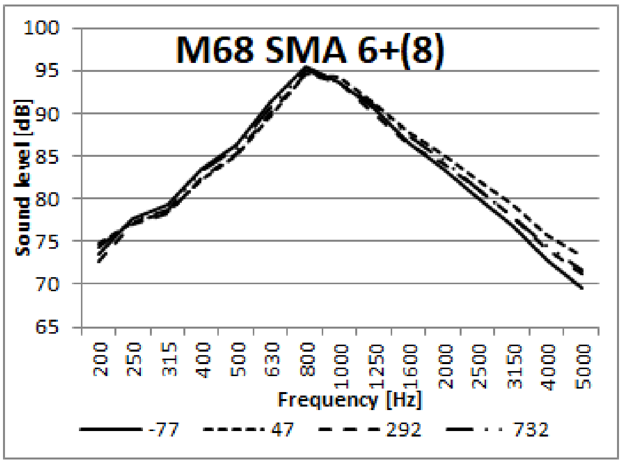


Figure 13. Spectra of measurements done on the SMA 6+(8) built in M68 for the days of measurements.

The AC 6o on M68 does also get a lower sound level in the lower frequencies which indicate less air pumping and a higher sound level in the higher frequencies, see Figure 12. The sound levels of the higher frequencies decreases and almost reaches the level of day -77.

The telling of the spectra of the SMA 6+(8) on highway M68, see figure 13, are the same as for the AC 6o, but the decrease in the lower frequencies is less significant.

5.3. Spectra from Slagelse

Since the pavements on the two lanes are equal the spectra from the section traveling south is chosen. This choice has been made because of a deceleration in the northern part of the section. This deceleration is due to a roundabout at the end of the section.

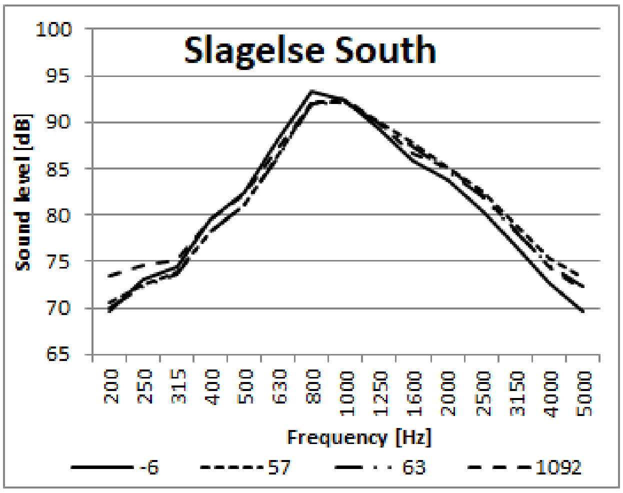


Figure 14. Spectra of measurements done on the old worn AC on the highway near Slagelse traveling south for the days of measurements.

As for the other AC pavements studies in this paper, the spectra of the old worm AC near Slagelse experience a decrease in sound level for the lower frequencies and increase for the higher frequencies, see Figure 14. At day 1092 it seems that the sound levels in the lower frequencies increases an become higher og equal to the level measured before sealing up to 500 Hz.

6. Conclusions

Minor structural enhancements with a longer estimated lifetime of 1-2 years have been seen on the test sections studied in this paper, when old pavements are sealed.

The sealing has very little effect on tyre/road noise properties of the pavements. For some open and porous asphalt there have been noise minor reducing effects.

The frequency spectra shows that when the sealing have minor tyre/road reducing effects it will be for the noise of lower frequencies.

References

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[2] Vejdirektoratet: DRI – DWW Thin Layer Project. Report 159, 2008.

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[4] ISO/CD 11819-2: Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method, 3rd draft, ISO, 2000-12-13.