inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 1.3

PERFORMANCE OF NEW TWIN-LAY DRAINAGE ASPHALT LAID IN DENMARK

J. Kragh*, H. Bendtsen**

* DELTA, Building 356, Akademivej, DK-2800, Lyngby, Denmark

** Danish Transport Research Institute, Niels Juelsgade 13, DK-1020, Copenhagen K, Denmark

Tel.: +45 4593 1211 / Fax: +45 4593 1990 / Email: jk@delta.dk

Keywords:
ROAD SURFACE, TRAFFIC NOISE, NOISE REDUCTION, DRAINAGE ASPHALT

ABSTRACT
The noise from individual vehicles in the normal traffic has been measured according to ISO 11819-1 [1], at three test sections of a city street with twin-lay drainage asphalt with maximum 5 or 8 mm grain size in the top layer, and maximum 16 or 22 mm grain size in the bottom layer. The total layer thickness was 55 mm, 70 mm, and 90 mm, respectively. The noise reduction at the thickest new twin-lay drainage asphalt, when compared to a reference section with dense asphaltic concrete of the same age, was almost 7 dB two weeks after the test section had been opened for traffic. At the two other test sections the corresponding noise reduction was 5 or 6 dB. Compared with the noise level measured six months earlier at the old road surface, a 15-year old asphaltic concrete, the noise level at the new reference surface was in the order of 1 dB lower. The change in traffic noise exposure of the adjacent buildings, as a consequence of replacing the old asphaltic concrete by new twin-lay drainage asphalt, was up to almost 9 dB. Simultaneous measurements at 1.2 m and 5 m height showed noise reduction determined by measuring at 5 m height to be 1 or 1.5 dB lower than the noise reduction determined by measuring at 1.2 m height.

1 - ROAD SURFACES AND MEASUREMENT METHOD
Noise measurements were made at test sections of a two-lane city street with various twin-lay drainage asphalt pavements. The average traffic was 7,000 vehicles/24 hours, 8% heavy vehicles, and the general speed limit is 50 km/h. An overview of the test sections is given in Table 1.

Designation	Description	Top Layer	Bottom Layer
DA8-70	Drainage asphalt	25 mm 5/8	45 mm 11/16
DA5-55	Drainage asphalt	25 mm 2/5	30 mm 11/16
DA5-90	Drainage asphalt	25 mm 2/5	65 mm 16/22
AB8t (ref.)	Dense asphaltic concrete	30 mm 0/8	–

Table 1: Overview of test sections.

Measurements were made in September 1999 just after the test sections had been built. The measurements will be repeated once a year to investigate the effect of ageing and wear and the possible clogging of the air voids in the drainage asphalt. In December 1999 the drainage asphalt was cleaned by high-pressure water / air suction.
Three measurement positions were chosen at each of the four test sections to ensure spatial averaging. The microphones were at distances d of approximately 9 m and 11 m from the center line of the near and far lane, respectively; all results have been corrected to a reference distance of 7.5 m by adding 10 log (d/7.5).
The microphones were placed 1.2 m above the road surface, on reflecting boards mounted on the facing walls of buildings along the street. There were no buildings along the other side of the street. All results

given in the present paper have been corrected by −6 dB to compensate for the effect of reflected sound. In some cases simultaneous recordings were made at 1.2 m and 5 m height.
Pass-by noise from individual vehicles in the normal traffic was analyzed. The specifications of the so-called 'Statistical Pass-By Method' in ISO 11819-1 were followed as far as possible. Maximum noise levels, L_{AFmax}, in 1/3-octave bands were measured as well as the speed of each vehicle. These were divided into four categories: passenger cars, delivery vans, lorries having two axles, and lorries having more than two axles.
For each category, the so-called 'Vehicle Noise Level' L_{veh} at the reference speed 50 km/h was determined by linear regression analysis of the noise level on the logarithm of the speed. Based on these values of L_{veh} the 'Statistical Pass-By Index', *SPBI*, was calculated by means of (1).

$$SPBI = 10 \times \log\left(\sum W_x \times 10^{\frac{L_{veh,x}}{10}}\right) \tag{1}$$

$L_{veh,x}$ is the vehicle noise level for category x, and W_x is the weight for that category shown in Table 2. ISO 11819-1 specifies 90% light vehicles and a total of 10% heavy vehicles. The light vehicles have been assumed to consist of 80% passenger cars and 10% vans.

Category	**Light**		**Heavy**	
		Two-axle	**Multi-axle**	
ISO 11819-1	0.9		0.075	0.025
	Passenger	Van		
This paper	0.8	0.1	0.075	0.025

Table 2: Weights W_x for vehicle categories used when calculating SPBI.

2 - RESULTS

2.1 - Overall A-weighted noise levels

The results are summarized in Tables 3 and 4 and in Figs. 1, 2 and 3. Fig. 1 shows the Statistical Pass-By Index measured before and after building the test sections, while Fig. 2 shows the SPBI at each test section relatively to the average SPBI measured at the same four sections of the old road surface.
The results have been determined by pooling the data from all of the three measurement positions at each test section. The total number of registered passes-by was 2230 on the old road surface, 2567 on the new surfaces. The number of heavy vehicles was smaller than 80, which is required in ISO 11819-1, for three of the four new test sections, probably due to a change in heavy traffic route choice having taken place during the months of road construction work.
The reduction in SPBI caused by replacing the old asphaltic concrete with new asphaltic concrete was 1.2 dB, while the change due to replacing the old asphaltic concrete by new drainage asphalt was between 6.5 and 8.9 dB, see Table 4.
The noise reduction provided by the drainage asphalt − expressed as the SPBI there relatively to the SPBI at the new reference surface AB8t − was 5.2 dB, 5.7 dB and 6.8 dB, respectively, for the three drainage asphalt surfaces, see Table 4.

New	DA8-70			DA5-55			DA5-90			AB8t		
surfaces	L_{veh}	N	u	L_{veh}	N	u	L_{veh}	N	u	L_{veh}	N	u
Category	[dB]	[-]	[dB]	[dB]	[-]	[dB]	[dB]	[-]	[dB]	[dB]	[-]	[dB]
F	75.5	22	1.2	75.4	16	1.1	73.4	15	0.9	79.8	13	1.3
L	69.5	66	0.8	70.6	48	0.8	68.7	47	1.0	75.8	34	0.8
V	66.1	214	0.2	64.5	144	0.3	64.7	159	0.3	71.6	130	0.2
P	64.0	449	0.1	62.8	404	0.1	62.2	429	0.1	69.2	377	0.1
SPBI	66.0	751	0.3	65.5	612	0.3	64.4	650	0.3	71.2	554	0.3
Old road												
F	79.9	31	0.5	81.9	16	1.1	81.2	30	1.3	77.9	21	0.7
L	75.5	77	0.4	76.8	74	0.5	75.8	121	0.5	75.6	89	0.4
V	72.7	122	0.2	71.8	80	0.2	73.4	248	0.2	72.5	159	0.2
P	71.3	291	0.1	71.1	193	0.1	72.1	414	0.1	71.5	264	0.1
SPBI	72.5	521	0.1	72.8	363	0.3	73.3	813	0.2	72.4	533	0.4

Table 3: Vehicle noise level L_{veh} per vehicle category, number n of passes-bys, statistical uncertainty u [2], and Statistical Pass-By Index SPBI for each test section of road.

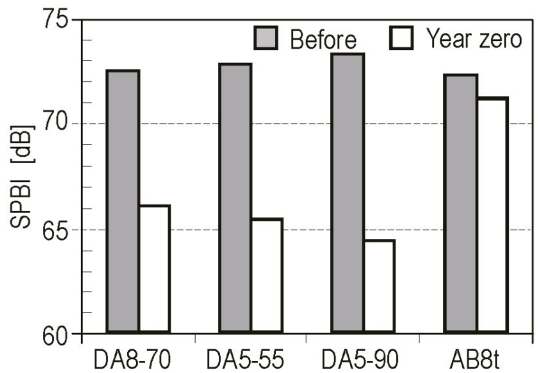


Figure 1: SPBI measured before and after building the test sections.

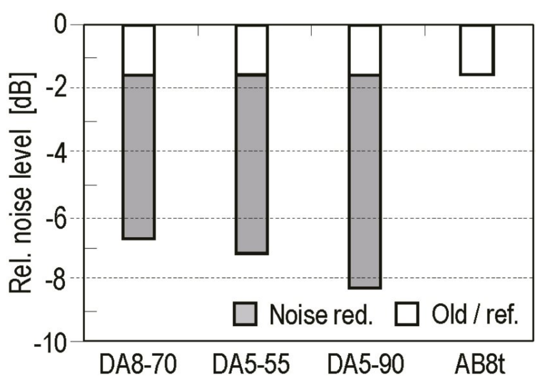


Figure 2: SPBI after building the test sections relatively to the average SPBI at the old road.

	DA8−70	DA5−55	DA5−90	AB8t
Before/after	−6.5	−7.3	−8.9	−1.2
Noise red.	−5.2	−5.7	−6.8	0.0

Table 4: Noise reduction, SPBI [dB], cf. text.

2.2 - Frequency spectra

Figure 4 shows the A-weighted 1/3-octave band frequency spectra of SPBI. The noise levels at the old asphaltic concrete were higher than at the new asphaltic concrete at frequencies below 2 kHz. The

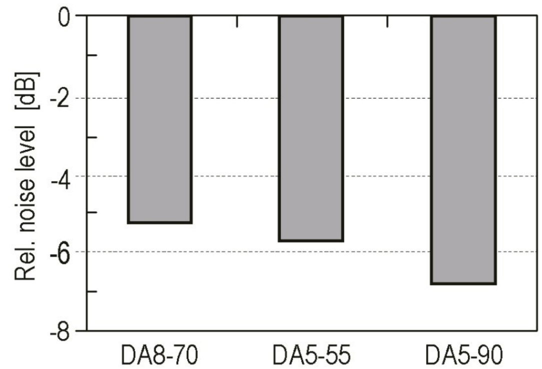


Figure 3: SPBI relatively to SPBI at the reference AB8t.

noise levels at the drainage asphalts were lower than the noise levels at the dense asphalts in the whole frequency range above 250 Hz. There was a dip in each frequency spectrum at the drainage asphalts, at a higher frequency the thinner the drainage asphalt layer. In Table 5 the frequencies of these dips are given together with the frequencies of maximum absorption found in laboratory measurement on drill cores [3] and in−situ using the spot method [4] and the extended surface method [5] of ISO 13472 [6]. The agreement could have been better.

	DA8-70		**DA5-55**		**DA5-90**	
	f [Hz]	Max α [-]	f [Hz]	Max α [-]	f [Hz]	Max α [-]
Figure 4	630	–	800	–	400	–
Drill core	500-630	0.84	500-630	0.72	315	0.54
Spot	608-640	0.88	681-731	0.86	520-575	0.86
Extended	500	–*	500	–*	400	–*

Table 5: Frequency f [Hz] of dip in spectrum and of maximum sound absorption, and maximum absorption coefficient α [-] in laboratory and field measurements; * for unknown reasons the spread in measurement results was large.

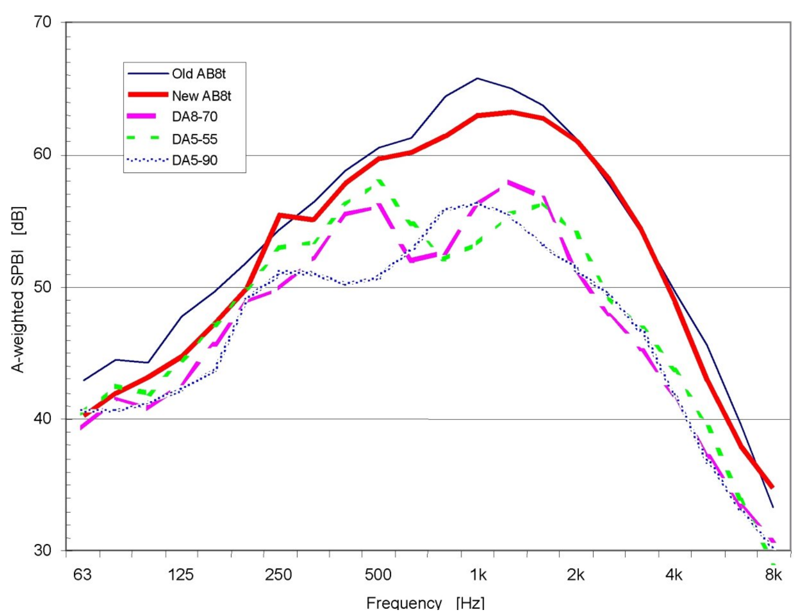


Figure 4: A-weighted frequency spectra of traffic noise at the old surface and at the four new test sections.

2.3 - Noise level and noise reduction at 5 m height

Simultaneous measurements of vehicle pass-by noise were made at two heights in one measurement

position at the reference test section AB8t and at one place at each of two drainage asphalts. The results are shown in Tables 6 and 7 and in Fig. 5. All results have been normalized to a distance of 7.5 m assuming the source to be 0.5 m above the road.
Table 6 shows the vehicle noise levels L_{veh} and the SPBI at each height together with the number of passes-by involved. It also shows the difference in noise levels measured at 5 m and 1.2 m height at each place. The noise levels were higher 5 m above ground than 1.2 m above ground, and the differences were largest at the drainage asphalts.
Table 6 shows the noise reduction at the two drainage asphalts expressed as the difference between the noise level at the drainage asphalt and at the reference asphalt AB8t. There was a trend for the difference to be smaller when measured at 5 m height than when measured at 1.2 m height, in the order of 1 or 2 dB.

Section	L_{veh} [dB]				
DA8-55	Passenger	Van	Two-axle	Multi-axle	SPBI
n [-]	255	82	18	13	368
5 m	64.1	66.8	71.6	78.5	67.3
1.2 m	62.6	65.5	70.2	76.4	65.7
5 m − 1.2 m	1.5	1.3	1.4	2.1	1.6
DA5-90					
n [-]	92	48	24	14	178
5 m	64.5	66.3	68.4	75.0	66.0
1.2 m	62.2	64.5	67.1	73.4	64.1
5 m − 1.2 m	2.3	1.8	1.3	1.6	1.9
AB8t					
n [-]	237	68	18	11	334
5 m	69.1	70.6	75.2	82.1	71.5
1.2 m	69.3	70.5	74.4	80.1	71.0
5 m − 1.2 m	-0.2	0.1	0.8	2.0	0.6

Table 6: Vehicle noise level L_{veh}, SPBI and number of passes-by n during simultaneous measurements at 5 m and 1.2 m height; the difference between noise levels at 5 m and at 1.2 m were largest at the drainage asphalts.

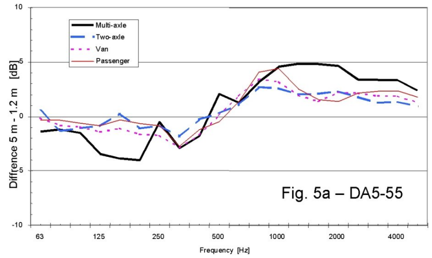
Section	L_{veh} [dB]				SPBI
DA8-55	Passenger	Van	Two-axle	Multi-axle	
5 m	-5.0	-3.9	-3.6	-3.5	-4.2
1.2 m	-6.7	-5.0	-4.1	-3.7	-5.3
1.2 m − 5 m	-1.7	-1.1	-0.6	-0.2	-1.1
DA5-90					
5 m	-4.6	-4.3	-6.8	-7.1	-5.5
1.2 m	-7.1	-6.0	-7.2	-6.7	-6.9
1.2 m − 5 m	-2.5	-1.7	-0.4	0.4	-1.4

Table 7: Noise reduction: noise level at drainage asphalt minus noise level at reference AB8t; the noise reduction measured at 5 m height was smaller than at 1.2 m.

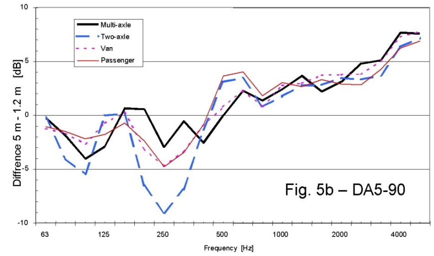
Figure 5 shows the average difference between the noise levels at 5 m height and at 1.2 m height as a function of frequency for each vehicle category. The general trend is that below 500 Hz the noise level at 1.2 m was higher than the noise level at 5 m, whilst the opposite was the case at frequencies above 500 Hz. It is not known whether this difference is due primarily to differences in noise generation or noise propagation.

ACKNOWLEDGEMENTS

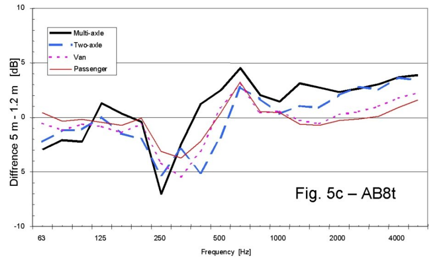
The project comprises pavement technology, acoustics, environment and traffic safety and is financed by the Danish Ministry of Traffic and the Municipality of Copenhagen. The project has the participation of the Municipality of Copenhagen, the Danish Environmental Protection Agency, the Danish Road Directorate Department for Traffic Safety and Environment, the Danish Road Institute, the Danish association of asphalt contractors represented by Phønix Contractors, and DELTA.



(a)



(b)



(c)

Figure 5: Difference between noise levels at 5 m height and at 1.2 m height as a function of frequency for each category of vehicle.

REFERENCES

1. *ISO 11819-1 Acoustics - Method for Measuring the Influence of Road Surfaces on Traffic Noise - Part 1: 'The Statistical Pass-By Method'*

2. **J. Kragh**, Traffic Noise Measurements at Asphaltic Road Surfaces, In *Proceedings INTROC90, Gothenburg*, pp. 103-114, 1990

3. *Sound absorption of porous asphalt drill cores (in Danish)*, DELTA Acoustics & Vibration Report AV 1402/99, 1999

4. *CPX, absorption, and texture measurements on 2-layered porous asphalt at the Øster Søgade in Copenhagen*, M+P report M+P.DRD.99.1.1, 's-Hertogenbosch, 1999

5. *Sound absorption of drainage asphalt on Øster Søgade measured using MLS-technique (in Danish)*, DELTA Acoustics & Vibration Report AV 2055/99, 2000

6. *ISO/DIS 13472 Acoustics - Measurement of sound absorption properties of road surfaces in situ - Part 1: 'Extended surface method', 1999. Part 2: 'Spot method'*, 1st working draft, 1997

7. *Road traffic noise measured at 1.2 m and 5 m height at test sections of Øster Søgade (in Danish)*, DELTA Acoustics & Vibration Report AV 2027/99, 2000