Comparative Study Of Traffic Noise Emission for Characteristic Types of Asphalt Mixtures in Slovenia

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SYNOPSIS

Traffic noise emission for characteristic types of asphalt mixtures, predominantly applied as road surfaces in Slovenia, has been studied. Four main groups of asphalt mixtures have been chosen: asphalt concrete (AC), drainage asphalt (DA), surface dressing and stone mastic asphalt (SMA), respectively. The main intention of the case study was not to find out the absolute value of emitted noise, produced on characteristic road surfaces, but primarily to compare measured noise levels, and to find out how much they differ from each other.

Test sections of road surfaces were chosen according to the type of asphalt mixture laid in the surface course and to the level of the texture depth. Sections where typical asphalt mixtures are laid were taken into consideration.

The level of the texture depth was investigated by two methods:
- using a laser device fitted to the SCRIMTEX vehicle, which provides a sensor-measured texture depth (SMTD) and
- standard sand-patch texture depth measurement.

These two different methods were used to establish more accurately the level of the texture depth. Investigatory levels for this case study were defined in the range from 0.20 mm to 0.90 mm, classified into four categories.

The sound levels produced by the noise emission of the test vehicle passing by at characteristic velocities over the different road surfaces were measured.

In general, drainage asphalt was found to have the lowest noise emission of all the investigated asphalts. Furthermore the SMA's noise emission level is lower than the AC's noise emission level. In the case of surface dressing, it seems that the noise emission is somewhat between the noise emission levels of SMA and AC.

The relation between the surface texture and noise emission for each asphalt mixture was investigated.

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INTRODUCTION

It is well known that the interaction of automobile tyres and the road surface, when a vehicle is driven over it, represents an important part of the overall vehicle noise emission, predominantly at higher vehicle velocities. This type of emitted noise, known as tyre/road noise, depends on the type of tyres and on the type of road surface.

In the years 2002 and 2003 a study was performed whose aim was to get some insight into the influence of typical wearing courses used in Slovenia on the overall road traffic noise. The basic role of the study was to classify the mostly used wearing courses with regard to tyre/road noise. The study was primarily designed to be comparative because on the existing road test sections, which were at that time available for performing measurements, it was not always possible to ensure standard measuring conditions. Test sections were chosen according to the type of asphalt mixture in the wearing course and according to the level of the texture depth.

TEST WEARING COURSES

Typical asphalt mixtures used for wearing courses in Slovenia

The selection of asphalt mixtures used for wearing courses in Slovenia depends on the rank of the road:
- Mastic asphalt with a maximum grain size 11 (MA 11) is used for the wearing course only on some paved footways and on some parking places.
- Asphalt concrete with limestone-crushed stones with a maximum grain size 8 (AC 8) is used as a wearing course on low traffic volume regional roads, on local roads and on parking places.
- Asphalt concrete with limestone-crushed stones with a maximum grain size 11 (AC 11) is used as a wearing course on regional roads with light traffic.
- Asphalt concrete with silicate-crushed stones with a maximum grain size 11 (AC 11s) is used as a wearing course on main roads.
- Stone mastic asphalt with maximum grain sizes 11 (SMA 11s) and 8 (SMA 8s) are commonly used for wearing courses on highways.
- Porous (drainage) asphalt (DA 11s) is used in Slovenia only on sections where the transverse slope of the pavement changes direction.
- Surface dressing is used for maintenance and is still not widely used due to the fact that maintenance measures in Slovenia commonly start too late. At this stage pavements usually need more expansive and expensive maintenance treatment.

Wearing courses on test sections

Seven different types of asphalt mixtures were tested to evaluate the difference in noise emission due to the effect of the different surface of the wearing course.

We performed tests on eight test sections with stone mastic asphalt with maximum grain size 11 (SMA 11s) and eight test sections with stone mastic asphalt with maximum grain size 8 (SMA 8s). We also made tests on two sections with drainage asphalt (DA 11s). Six test sections were selected on asphalt concrete with silicate-crushed stones with maximum grain size 11 (AC 11s). Asphalt concrete with limestone-crushed stones is used as a wearing course on roads with light traffic, which was the case for six test sections. We selected four test sections on asphalt concrete with limestone-crushed stones with maximum grain size 11

(AC 11) and two test sections on asphalt concrete with limestone-crushed stones with maximum grain size 8 (AC 8). One test was made on a section with surface dressing.

TEXTURE DEPTH MEASUREMENTS

Texture depth was measured on the already selected test sections, with known asphalt mixtures. The procedure used consisted of two different types of measurements. Firstly, the texture depth was measured on whole sections with a SCRIMTEX routine investigation machine. Based on the results, 40 m long sub-sections were defined, on which the texture depth was measured again, this time using the sand patch (volumetric patch) method. Finally, the traffic noise emission was also measured on these sub-sections.

Sensor measured texture depth

SCRIM (Sideway Force Coefficient Routine Investigation Machine) equipment was developed for performing measurements of the skidding resistance of road surfaces. Its primary element is the test wheel, which during the test runs on the road surface at an angle of 20° to the longitudinal axis of the vehicle (the test direction). The force transducer senses the sideways load acting on the wheel.

Optionally, on SCRIM vehicles a non-contacting laser displacement transducer is mounted. This is also the case for the Slovenian SCRIMTEX vehicle, which can be seen in Figure 1.

Figure 1: SCRIMTEX vehicle

The laser sensor is mounted in the vehicle wheel-track and it can be seen in Figure 2.

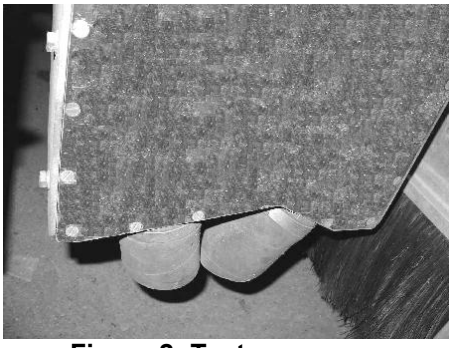

Figure 2: Texture sensor

The laser displacement transducer enables measurement of changes between itself and the road surface. Every 300 mm a number of displacement samples are taken. For each sample length the texture depth is determined, where the procedure involves calculation of standard deviation. Measurements are aggregated and stored as an average value for each 10 m of road traversed. The results are described as the sensor measured texture depth (SMTD).

In practice the sensor is mounted on a moving vehicle which is itself moving up and down relative to the road surface. The effect of this bouncing movement is removed by a computer algorithm, which computes the variance by applying a quadratic least squares regression analysis, the assumed sinusoidal function representing the longer-wave vertical movement of the sensor itself [2].

The SMTD texture depth should therefore be distinguished from the Mean Profile Depth (MPD), determined in the standards [3] and [4].

Mean texture depth

After determination of the sensor measured texture depths for test sections, the results were compared to the requirements given for the texture depth classes. For all the characteristic asphalt mixtures, 40 m long sub-sections were selected to fulfil best these requirements.

The levels of texture depth are shown in Table 1. The given limits for the texture classes were 0.20 mm, 0.35 mm, 0.50 mm, 0.70 mm and 0.90 mm.

Table 1: Applied texture classes

Class	Texture (mm)	
	Lower limit	Upper limit
A	0.20	0.35
B	0.36	0.50
C	0.51	0.70
D	0.71	0.90

As a standard method [5], sand patch measurements were carried out on the selected sub-sections to establish more accurately the level of the texture depth. The used sand was graded to have a minimum 90% by weight passing a 0.25 mm sieve and retained on a 0.125 mm sieve. The sand patch method relies on a given volume of sand that is spread out on a road surface in a circular form. Then the diameter of a circular patch is measured. By dividing the volume of the sand by the area of the circular form, a value that represents the average depth of the sand layer is calculated. The texture depth obtained is called a mean texture depth.

Figure 3: Sand patch measurement

Texture depth measurements results

Taking into account all the SMTD results recorded by the SCRIMTEX vehicle on test sections with different asphalt mixtures, a maximum value of 1.13 mm was obtained, and a least value of 0.29 mm.

The maximum and minimum SMTD values respectively for specific asphalt mixtures were recorded as follows:
- for SMA 8s: 0.63 mm and 0.46 mm,
- for SMA 11s: 0.84 mm and 0.59 mm,
- for AC 8: 0.35 mm and 0.32 mm,
- for AC 11: 0.51 mm and 0.29 mm,
- for AC 11s: 1.13 mm and 0.35 mm and
- for DA 11s: 0.52 mm and 0.51 mm.

Comparing the SMTD results with the texture depth levels (see Table 1) the texture depths for specific asphalt mixtures were found in the following level classes:
- for AC 8: in class A,
- for AC 11: mainly in classes A and B,
- for AC 11s and SMA 8s: in classes B and C,
- for SMA 11s: in classes C and D, and
- for DA 11s: in class C.

Due to the completely different procedures for obtaining the texture depth, the two methods were not expected to give the same numerical results. Still, we compared the averaged values of the countiniously recorded 40 m section sensor measured texture depths with the texture depth values measured at the sand patch positions on the same sub-sections. For each asphalt mixture the results are shown in Figure 4.

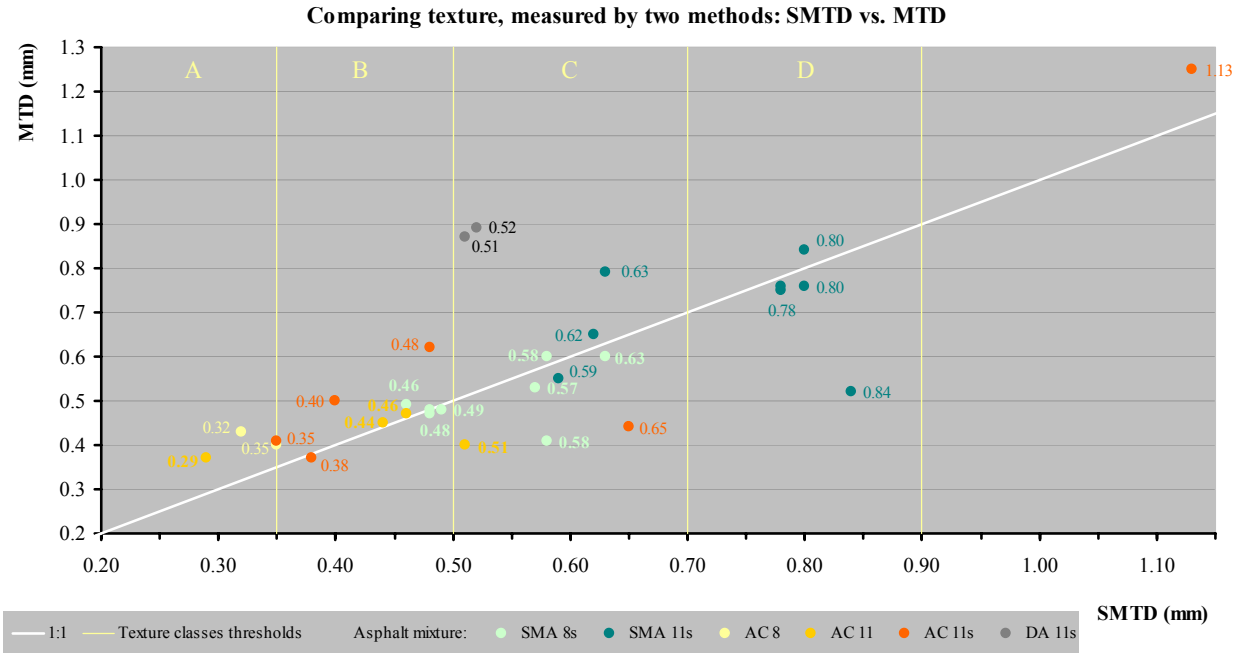

Figure 4: Comparison of the SMTD and MTD values

The yellow vertical lines on the figure represent the texture level boundaries. The white line on the same figure connects the points where the SMTD method and the sand patch method would give identical values for the texture depth.

Ranges for the obtained texture depths for each specific asphalt mixtures are shown in the two following figures. Based on the laser sensor working principle, the standard deviation for texture depth values for the 40 m long sub-sections were calculated and averaged if measured on the same asphalt mixture. Both the value ranges and the averaged standard deviations are shown in Figure 5.

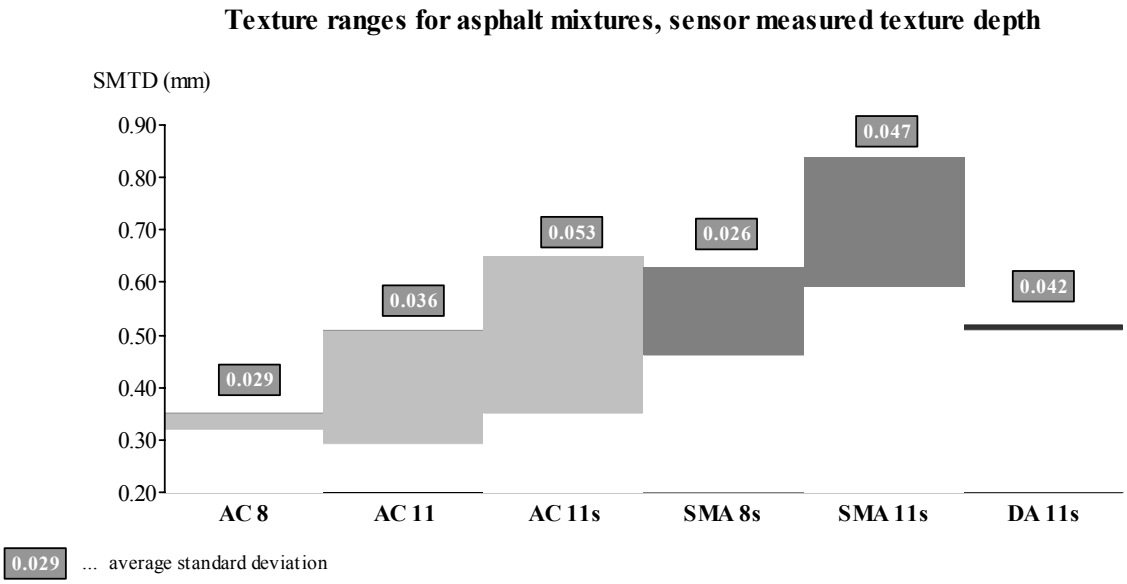

Figure 5: Texture ranges measured with laser sensor

The ranges of the texture depth values, obtained by sand patch measurements, are shown in Figure 6. For each asphalt mixture the standard deviation for MTD values are also shown.

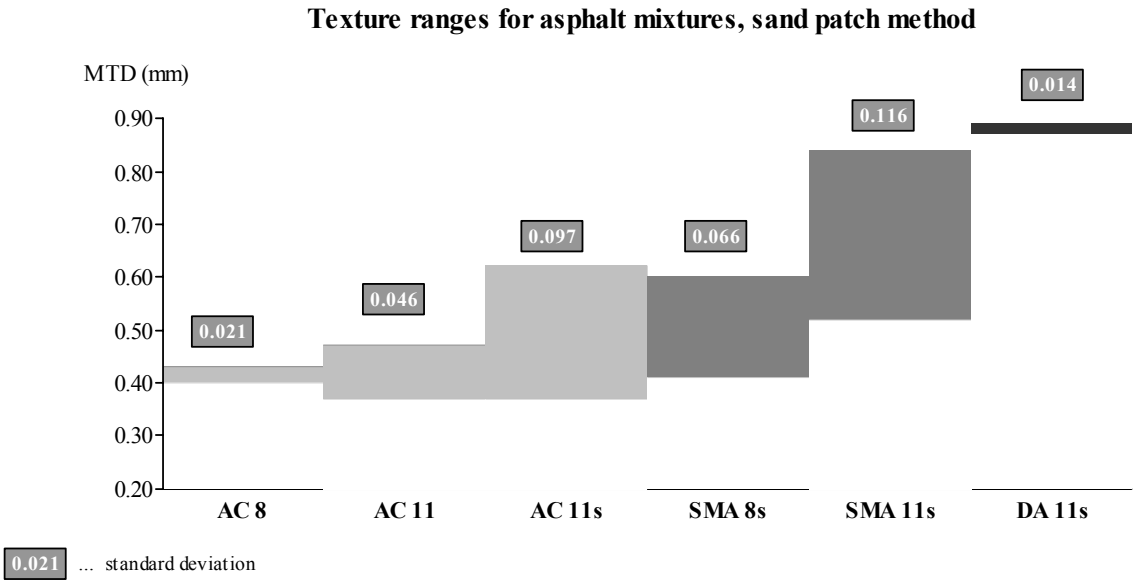

Figure 6: Texture ranges measured with the sand patch method

As expected, the texture depth increases with the nominal grain size of the asphalt mixture. For the SMA mixtures the obtained texture depth was found to be deeper than for the AC ones. A larger discrepancy was found between the obtained texture depth values (comparing the texture depth obtained with sensor measurements to the sand patch method) for the drainage asphalts. In this case, the SMTD values were taken as more accurate ones.

Finally, when comparing the SMTD and MTD values, the regression fit was plotted. It can be seen in Figure 7.

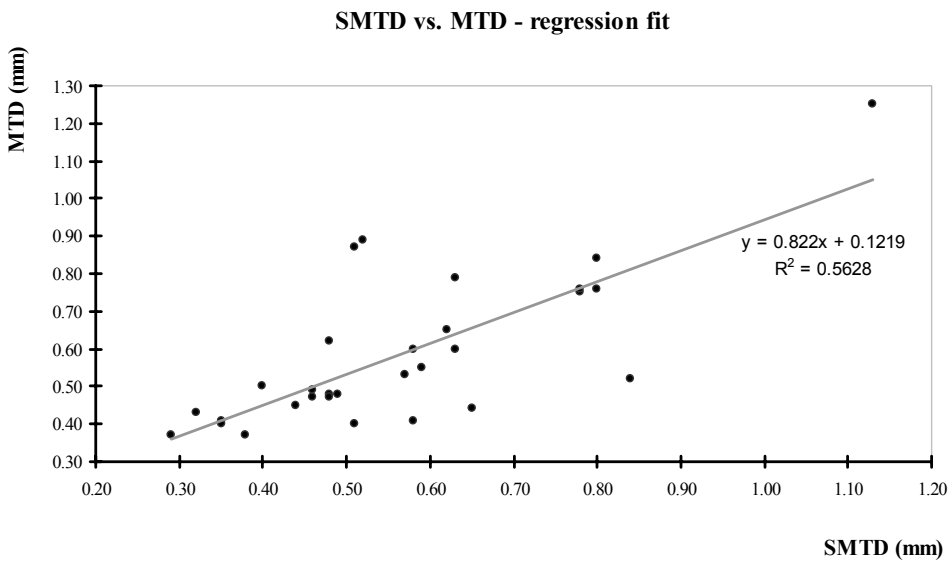

Figure 7: Texture depths comparison with regression fit plot

Following the definition [3], when the Mean Profile Depth (MPD) is used to estimate the Mean Texture Depth (MTD) by means of transformation equation, we obtain the Estimated Texture Depth (ETD). In the older standard the transformation equation was: ETD = 0.2 mm + 0.8 * MPD, and in the new one: ETD = 0.95 * MPD.

In our case ETD would be calculated as follows: ETD = 0.12 + 0.82 * SMTD (ETD, MPD, SMTD in mm). As described above, SMTD is calculated in a very different way to MPD. Nevertheless, although SMTD should not be mistaken for MPD, the equation is quite similar to the transformation equation from [3].

SOUND LEVEL MEASUREMENTS

For the purpose of measurements of emitted sound level, a Hyundai Elantra 1,6 test vehicle equipped with Sava Effecta 185/65 R 15 summer tyres chosen. On different road sections under test the car passed a road-side microphone location at characteristic velocities with the engine switched-off. The microphone was located in the middle of the 40 m long road section under test, 5 m from the centre of the vehicle driving line. The height of the microphone position was 1,2 m. Measurements were performed for the vehicle driving in both directions for characteristic velocities of 50 km/h, 70 km/h, 90 km/h and 110 km/h, respectively. The sound level $L_{A,max}$ was measured in all cases.

The distance of the microphone from the centre of the vehicle driving line is usually 7,5 m [6,7]. As already mentioned, the main reason for choosing the shorter distance was the inability to ensure standard measuring conditions on all the road test sections available. According to the comparative nature of the investigation and according to the measuring conditions on road test sections, respectively, the choice seemed to be a reasonable solution in spite of a certain increase in measuring uncertainty because of possible deviations of the ideal driving line from the actual one [9].

All measurements were performed in good weather conditions, with road surfaces. The wind velocity was in all cases under 1 m/s, and the air temperature was between 15^0C and 31^0C.

RESULTS OF SOUND LEVEL MEASUREMENTS

The results of sound level measurements for the different wearing courses under consideration are presented in figures 8 to 11.

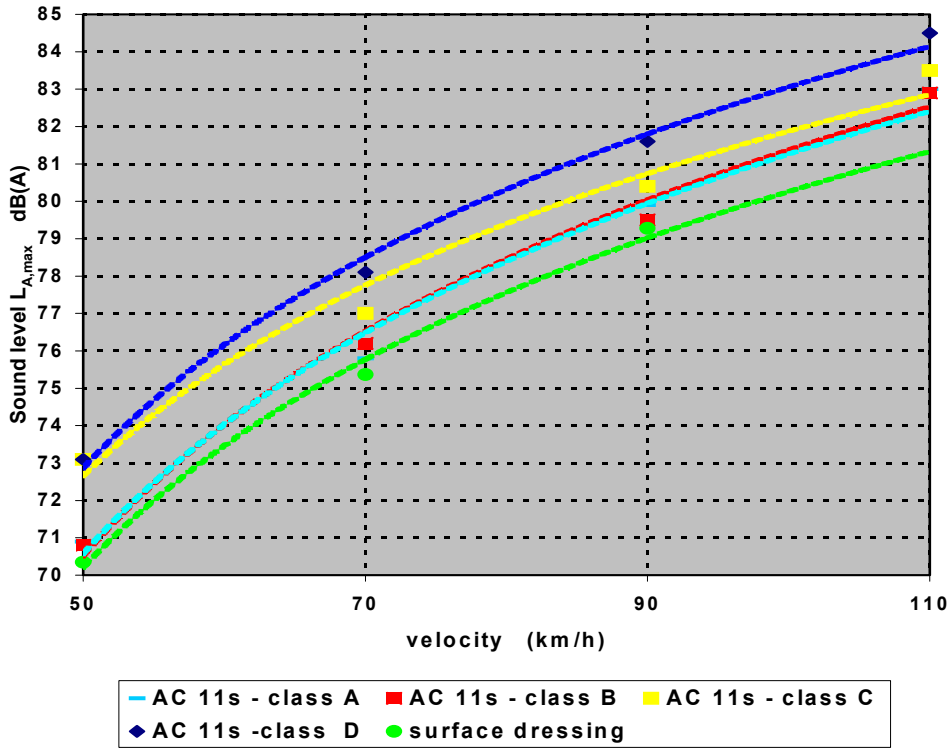

Figure 8: Sound levels for different texture ranges of wearing course AC 11s and for surface dressing

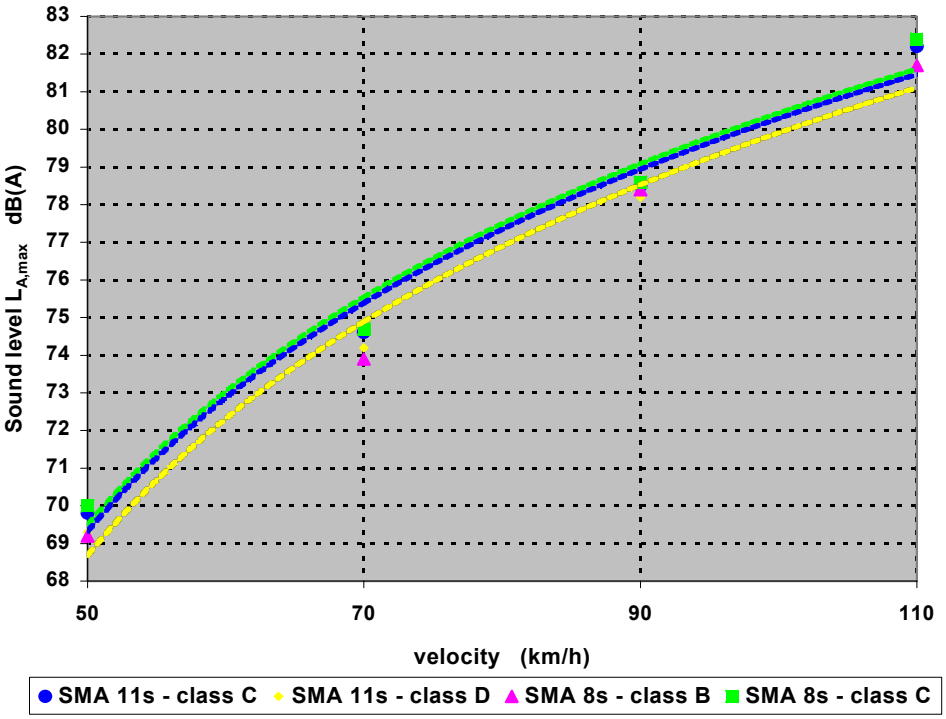

Figure 9: Sound levels for different texture ranges of wearing courses SMA 8s and SMA 11s

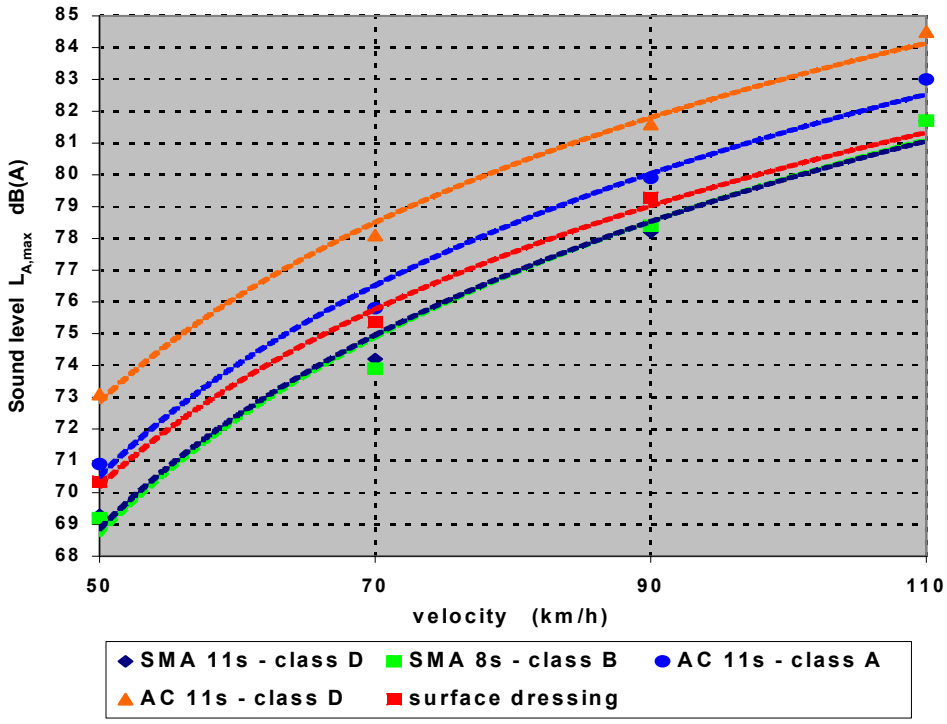

Figure 10: Sound levels for the extreme classes of texture depth level for AC and SMA wearing courses and for surface dressing

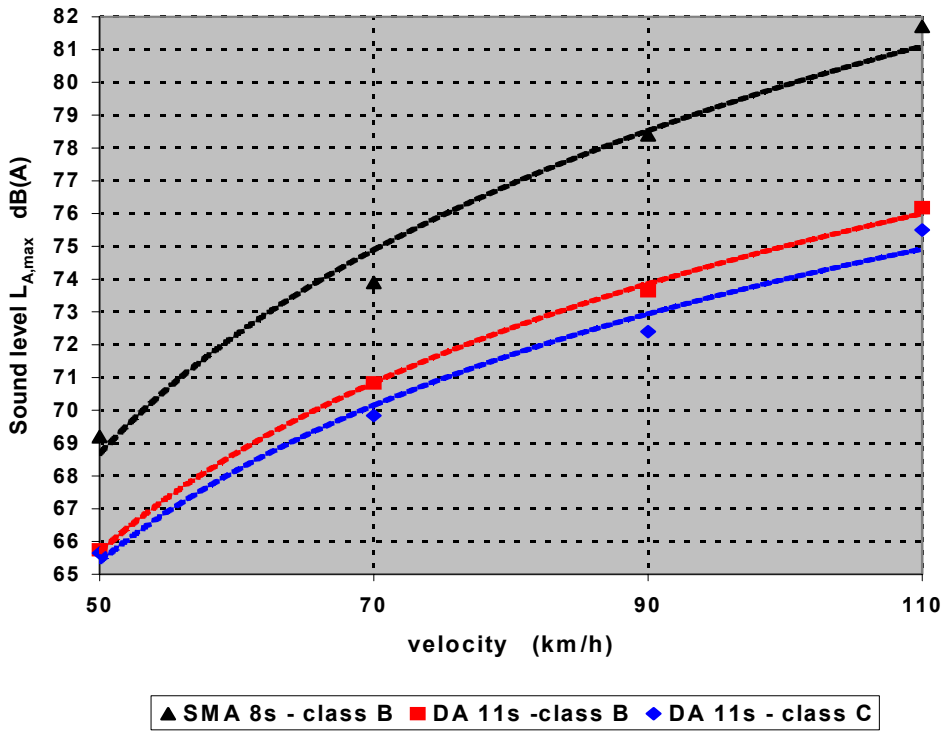

Figure 11: Sound levels for wearing courses with the lowest noise emission

CONCLUSIONS

The results of sound level measurements show that the noise emission in the case of stone mastic asphalt (SMA) is about 1,5 -2 dB(A) lower than in the case of the quietest version of asphalt concrete AC 11s - class A. Noise emission in the case of surface dressing seems to be somewhat between the SMA and AC. When the test vehicle is driving on surface dressing, the emitted noise levels are about 0,5 -1 dB(A) lower than in the case of AC 11s – class A, but at the same time they are about 1 –1,5 dB(A) higher than in the case of SMA. As expected, the lowest noise levels are emitted in the case of porous asphalt concrete (DA), namely between 3 and 6 dB(A) lower with regard to SMA, depending on the vehicle velocity and on the type of DA.

In spite of the fact that level of texture depth is not the parameter which sufficiently describes the characteristics of wearing courses from the noise level emission point of view [9], we attempted to analyse the relation between the level of texture depth and the noise levels for each type of wearing course under consideration. This is the reason why we divided the characteristic range of texture depth, measured on our roads, into four classes.

It was found that within the uncertainty of measurements (the mean standard deviation between ± 0,4 dB and ± 0,7 dB) the level of texture depth does not affect the tyre/road noise emission in the case of SMA, but in the case of AC it seems that the higher level of texture depth causes higher levels of noise emission. The difference between the emitted noise levels in the cases of AC 11s – class A and AC 11s – class D is around 2 dB(A). This result is not in accordance with already known findings [9, page 102]. Namely, the amplitude of texture depth within the wavelength range 0,5 – 10 mm is important at high frequencies (above 1000 Hz), where noise decreases with texture amplitude. Within the range of texture wavelength 50 – 100 mm, noise increases with texture amplitude at low frequencies (under 1000 Hz). That means that the different noise levels in the case of AC 11s cannot be the consequence of varying the chosen classes of texture depth, but is most likely the consequence of megatexture conditions on the investigated road test sections.

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