TYRE RADIATED NOISE LEVEL INFLUENCED BY ROAD SURFACE QUALITY

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Abstract: *Traffic noise emission is highly dependent on the road surface quality, especially on its structure and porosity. Both features influence the tyre/road noise generation, furthermore porosity may influence sound propagation in the vicinity of the road surface. Noise emission from the driver, which is generated higher above the road surface than tyre/road noise, can be during propagation influenced by the porosity of the road surface. These effects may result in differences of sound pressure levels related to the flow of traffic and its composition by different tops of roads up to 15 dB. This addition to sound pressure level affects the quality of environment in the surroundings of communications. For that reason it is important to measure this impact trough the use of standardized techniques and evaluate the road surface considering the traffic noise. The present paper deals with the influence of road surface on the emitted noise. The main goal is to provide information for further traffic noise prediction and noise control measure implementation.*

Keywords: TYRE/ROAD NOISE, ROAD SURFACE, MEASUREMENT, TRAFFIC NOISE

1. Introduction

Nowadays, because of the development of more silent vehicle power units, the main source of noise is the interaction between tyre and road [8], [13]. Tyre/road interaction is recognised as the main source of noise for velocities over the 40 km/h [12]. The interaction between tyre and road is complex and highly non-linear. In the rolling process of the tyre the contact pressure acting on each tyre tread block changes rapidly with time. Only the tyre tread block has contact with the road surface and its roughness predefines the contact between tyre and road. The road surface is composed of stones, sand, filler and binder. The road surface profile comprises a large range of roughness length scales which influences the tyre performance. To describe the contact between a flat rubber tread block and a rough road, the information about the road surface texture is essential. Because of the rough surface of the road, the tyre is in contact with the road only at discrete points. The actual contact area between the tyre and the road depends on the 3D surface profile of the road, on the normal and tangential load, on the static and dynamic material properties and on the contact time [3].

This paper is mainly focused on the influence of the ground on the acoustic radiation. The problem must be solved is to find the sound pressure for a known velocity on the road surface.

2. Categories of urban roads

Urban roads and urban road surfaces can roughly be described as occurring in or close to larger residential agglomerations. This covers small lanes and municipal roads of varying traffic density up to large ring roads and city expressways and motorways. Here are the characteristics of urban roads and urban road surfaces considered:

1.) Speed range 0 – 80 km/h:
Noise emission in this speed range can be characterised as follows:
  - Vehicle noise at velocities below 30 km/h is usually dominated by engine noise and shows small dependence on the road surface type.
  - Common speed limits in residential zones in Europe are around 50 km/h, which is in the middle of the range. As many drivers go at a speed close to the limit, this can also be considered as a kind of “average speed”.
  - Velocities above 80 km/h usually occur on thoroughfares or motorways in urban areas. The measurement methods already used for high-speed roads can be used for the surfaces of those roads [4].

2.) High variability of speed:
Urban streets usually have many intersections. The highly regulated traffic leads to frequent velocity changes.

3.) Low gear setting of many vehicles:
The vehicles circulating on urban roads often use low gear settings, leading to an increased engine noise contribution.

4.) Dense traffic:
Urban roads exhibit typically high traffic densities on the major municipal roads, especially during rush hours. High traffic densities make the identification of the impact of single vehicles especially difficult.

5.) Specific traffic composition:
Most traffic on urban roads is dominated by passenger cars. Heavy trucks contribute much less to the traffic mix than e.g. on highways. Buses, light delivery trucks and motorcycles are also typical for an urban situation.

6.) Short lengths of homogeneous road surface:
Due to the many intersections, buildings and the frequent maintenance and repair work the lengths of uninterrupted homogeneous road surface without too many surface discontinuities can be rather short.

7.) Many reflecting surfaces and objects close to the road:
Urban streets are typically lined by buildings on both sides of the road. These objects give rise to multitudes of reflections and create a highly complex sound field [4].

The requirements for an urban classification method are:

- Accuracy and distinguishability (see fig. 1).
- Repeatability and reproducibility.
- Practicability and cost-effectiveness.
- Compatibility with standards and noise prediction methods.
- Applicability for planning, conformity of production and approval testing, quality control and monitoring.

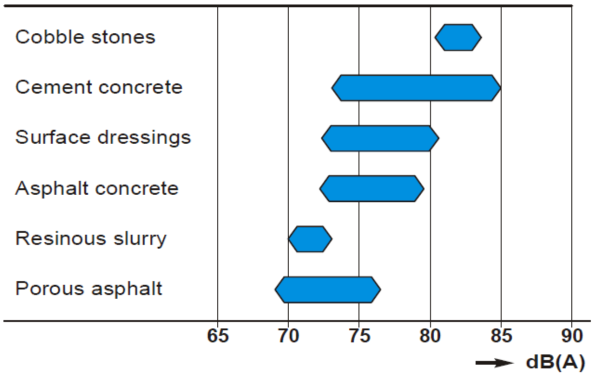

***Fig. 1** Range of CPB tyre/road noise measurement results for surface categories [2].*

3. Measurement methods used for classification

Several methods for investigating the influence of road surfaces on the generation of road traffic noise exist. Apart from simple noise immission measurements taken more or less close to the roadside, two internationally standardized procedures have been developed[6], [7].

The standardized methods are:

- **The Statistical Pass-By Method** (SPB) based on ISO 11819-1.
- **The Close-Proximity Method** (CPX) based on ISO /CD 11819-2.

Both are widely used and recognized as standard tools for investigating the noise emission properties of road surfaces [4].

A third widely used method, the **Controlled Pass-By Method (CPB)**, is basically a variant of the SPB method where a small number of test vehicles are chosen to represent the general types of vehicles required in the **SPB** method. For the measurement of tyre radiated noise level the CPB method was chosen.

4. Measurement set up

The chosen test vehicle was Peugeot 206 with 1.4L petrol engine, power 55kW, weight 1025 kg (see fig. 2). The chosen vehicle was equipped with tyres Pirelli P3000 (summer tire-tread pattern). The characteristic features of the tyre were the followings (see fig. 2):

- width: 175 mm,
- profile: 65 mm,
- radius: 14 inch,
- stress index: 82,
- speed index: T.

Fig. 2 *The test vehicle Peugeot 206 (left); the tyre Pirelli P3000 (right).*

The measurements were carried out according to the CPB method. In measurements area the terrain was controlled that includes the presence of other vehicles and other possible barriers.

Subsequently the starting and ending points of measured line were defined and the noise level meters positioned (see figure 3).

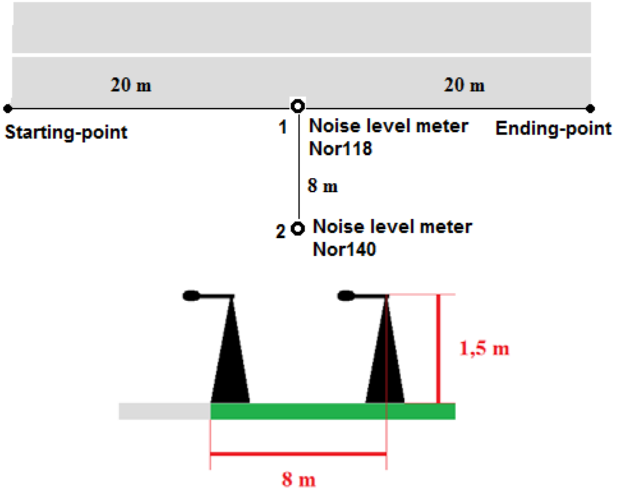

Fig. 3 *Noise level meter positions; measured segment of road surface.*

The tested road surfaces are shown in figure 4. The road surface in fig. 4 left is defined as asphalt concrete with medium structure, smoothed by long-time use (ACS). The road surface shown in fig. 4 right is defined as asphalt concrete with medium structure, roughened (ACR); the mean grain size is between 11 – 16 mm. These definitions result from NMPB Routes 96 method.

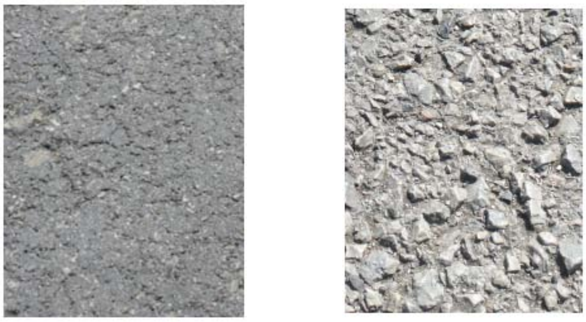

Fig. 4 *The tested road surfaces; left: asphalt-concrete smoothed (ACS); right: asphalt-concrete roughened (ACR).*

The measurement started when the test vehicle passed the starting-point and ended with passing the ending-point. The speed of passing by test vehicle was measured during the measurement. The vehicle was moving with constant speed 50km/h. The test vehicle passing the measurement point is shown in fig. 5.

Fig. 5 *Test vehicle passing the measurement point*

5. Results and discussion

The monitored acoustical parameters in measurement points 1 and 2 were the followings:

- equivalent A-weighted sound pressure level L_{Aeq};[dB],
- maximum A-weighted sound pressure level L_{Amax};[dB],
- equivalent sound pressure level at frequency 50Hz; L_{50eq}[dB],
- equivalent sound pressure level at frequency 1 kHz; L_{1000eq}[dB],
- equivalent sound pressure level at frequency 10 kHz; $L_{10000eq}$[dB],
- maximum sound pressure level at frequency 50 Hz L_{50max};[dB],
- maximum sound pressure level at frequency 1 kHz $L_{1000max}$;[dB],
- maximum sound pressure level at frequency 10 kHz $L_{10000max}$;[dB].

The results of measurement are summarized in table 1. In table 2 are summarised the detailed results at low frequencies represented by 50 Hz, mean frequencies represented by 1 kHz and high frequencies represented by 10 kHz.

Table 1: *Measurement results: equivalent A-weighted sound pressure level LAeq, maximum A-weighted sound pressure level LAmax.*

Acoustic parameters [dB]	ACS surface	ACR surface	Differences [dB]
1. measurement			
L_{Aeq1}	66,3	73,6	7,3
L_{Aeq2}	60,2	62,0	1,8
L_{Amax1}	76,6	79,3	2,7
L_{Amax2}	63,8	67,7	3,9
2. measurement			
L_{Aeq1}	66,1	73,9	7,8
L_{Aeq2}	60,3	62,6	2,3
L_{Amax1}	76,2	79,9	3,7
L_{Amax2}	64,3	68,1	3,8

Table 2: *Measurement results at low, mean and high frequencies.*

Acoustic parameters [dB]	ACS surface	ACR surface	Differences [dB]
1. measurement			
L_{50eq}	58,4	59,3	0,9
L_{1000eq}	58,0	63,8	5,8
$L_{10000eq}$	32,2	41,9	9,7
L_{50max}	65,6	66,0	0,4
$L_{1000max}$	69,2	69,8	0,6
$L_{10000max}$	43,7	48,3	4,6
2. measurement			
L_{50eq}	58,1	59,9	1,8
L_{1000eq}	57,6	63,2	5,6
$L_{10000eq}$	32,0	42,3	10,3
L_{50max}	65,2	66,5	0,3
$L_{1000max}$	68,4	69,3	0,9
$L_{10000max}$	43,4	48,7	5,3

Based on the measurements of noise it is possible to conclude that:

- tyre/road noise emission is dependent on the quality of road surface,
- the ACS surface shows better acoustical properties,
- in the vicinity of the road the difference between ACS and ACR surfaces achieved 7,8 dB for L_{Aeq},
- in distance 8 m from the road border the difference decreases to 2,3 dB for L_{Aeq},
- the differences between parameters L_{Amax} vary from 2,7 to 3,8 dB in both measurement points,
- the differences between the evaluated surfaces is negligible at low frequency range (max 2 dB),
- the differences are considerable at high frequency range ($L_{10000eq}$ = 10,3 dB, $L_{10000max}$ = 5,3 dB).

6. Conclusion

Road traffic noise is the most important source of noise pollution in the industrialized world. Therefore substantial efforts are undertaken to protect the population from the noise it generates. The interest is turning to the generation mechanisms of road traffic noise, because noise reduction at the source promises to be very effective. Tyre/road noise dominates from 30 - 50 km/h upwards and it is heavily dependent on the type of road surface. Low-noise pavements have been successfully used in the high-speed road network to reduce the noise emission of vehicles. Nevertheless the choice of road surface type can also help to alleviate noise problems in urban areas, where the construction of noise barriers is more problematic. Smooth surfaces or using modern porous road surfaces on main streets with speed limits of up to 70 or 80 km/h are possible applications. Sensible decisions in this area can be a powerful tool to achieve noise reduction.

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