HARMONOISE – first experimental road traffic noise campaign: comparison between meteorological and acoustical measurements and existing noise prediction models

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ABSTRACT

In the context of the European Commission funded HARMONOISE Project (Harmonised, Accurate and Reliable Methods for the EU Directive on the Assessment and Management Of Environmental Noise), the first experimental measurement campaign was carried out in La Crau (France) in October 2002.

The measurements were performed over one week period (24 h/day) and aimed at collecting data from road traffic noise (Leq(A) and spectra, road traffic characterisation) produced by a four-lane highway traffic (two lanes per direction), and meteorological data (such as temperature, relative humidity, wind speed and wind direction, gradients, etc.), at six different distances from the source (15m, 50m, 100m, 150m, 300m, 600m) over a flat terrain. The measurement of the ground impedance was also made. All collected data will be used for: (a) the comparison with existing models for the prediction of sound propagation; (b) the implementation of the Harmonoise project reference database; (c) the validation of the harmonised models to be developed in the context of the Harmonoise project for predicting noise propagation taking into account long-term average meteorological conditions.

As a first step, the comparison between the collected experimental data and theoretical existing models was carried out and presented in this paper.

1.1 INTRODUCTION

The HARMONOISE project work-package 4 (WP4) on “Data collection and Validation” is aimed at collecting acoustical and meteorological data under well-defined conditions over a long period of time to be used by other work packages for the validation of the harmonised models under development. In the first experimental campaign of the HARMONOISE project, performed from 18-25 October 2002 in La Crau (Fr), participated the following partners of WP4: LCPC, ARPAT and JRC.

Topography:

The measurement site was a flat terrain adjacent to a four-lane highway (two lanes per direction) connecting the cities of Arles and Fos-sur-Mer. No obstacles were present between the roadside and the different microphones. The measurements were performed over one week period (24 h/day) and aimed at collecting data from road traffic noise (Leq(A) and spectra, road traffic characterisation) produced by a four-lane highway traffic (two lanes per direction), and meteorological data (such as temperature, relative humidity, wind speed and wind direction, gradients, etc.), at six different distances from the source (15m, 50m, 100m, 150m, 300m, 600m).

In Fig.1 a schematic representation of the arrangement of the acoustical and meteorological sensors is given. Mx denotes the position and heights (H) of the acoustical instrumentation (x=1….10), the partner and the type of instrumentation used. More specifically, these positions are the following:

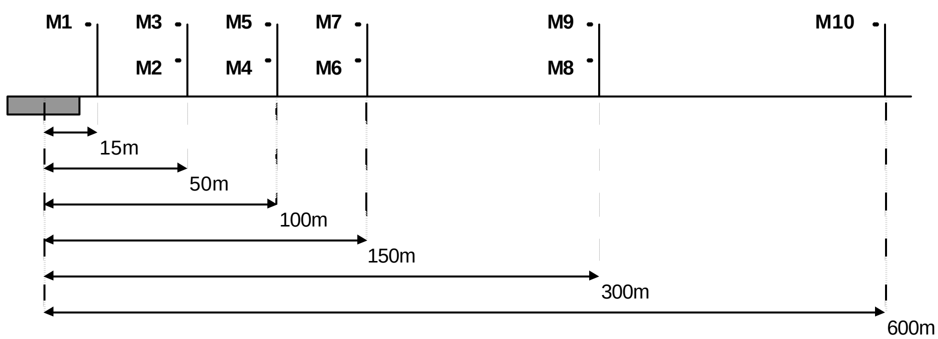

Figure 1 - Schematic representation of the arrangement of the acoustical and meteorological sensors.

Acoustics:
The acoustical sensors were positioned at: M1 : Symphonie 01dB (ARPAT) H = 4m; M2-M7 : SIP TR 01dB (LCPC) H = 1.5m and 4m; M8-M9 : B&K and deBakom (JRC) H = 1.5m and 4m; M10 : SIP TR 01dB (LCPC) H = 4m

Meteorological sensors:
The sonic anemometers were positioned at:18m Young 81000 (ARPAT), 114m Young 81000 (LCPC), 302m Metek (JRC) from the source and H =3m. Two extra anemometers used by JRC at 300m distance and at the heights of 1,5 m and 4 m respectively.

1.2 ANALYSIS OF NOISE AND METEOROLOGICAL DATA

A series of noise & meteorological data were collected by the different groups: Leq, L01, L50, L95, spectra (1/3 octave band from 50 to 4000 Hz), temperature, relative humidity, radiance, wind speed and wind direction, wind speed variance, presence (or not) of rain.

The nature of the noise source was evaluated manually by LCPC and ARPAT and by a pattern recognition software (produced by Debakom) by JRC. By this latter, it is possible to detect 24 types of different sources (Background, Tone, Whistle, Impulse, Local Source, Road Traffic (4 types), Rail Traffic (4 types), Aircraft Traffic (4 types), etc.). This test was important to distinguish between "road traffic" noise and any other undesired noise (called "extraneous" from now on) such as aircraft, rail, birds, air-conditioning system, industrial noise, etc. All audio inputs were recorded which allowed for a posterior evaluation of the measured data. Besides the automatic identification and separation of extraneous noise from the road traffic noise by pattern recognition, in order to minimise the potential errors that might occur, all the audio data file was also listened to correct all the noises erroneously recognised by the automatic procedure.

Firstly, a comparison between $Leq(A)_{tot}$ measured at M8 and M9 was made. The $Leq(A)_{tot}$ (road and extraneous noise), at M8 is almost the same as the one at M9. The wind speed (*ws*) at the two heights was also compared. As it could be expected, *ws* at H_2 is always higher than the one at H_1, this resulting in a positive wind gradient. A similar behaviour for wind speed was observed at the other distances as well.

As the wind speed could affect some parts of the noise time history an upper limit for *ws* was fixed. This was done by considering the fact the "subjective" ratio S/N depends largely on the distance from the noise source. The analysis of the audio file of the measurements showed that for *ws*>4 m/s the noise caused by the wind, bumping against the microphones, have the effect of masking the noise from road traffic. For this reason, at 300m from the source all the data with *ws*>4m/s were not considered for further analysis.

A comparison of the total noise vs road and extraneous was also done. The results showed that for about 85-90 % of the time the noise came from the road traffic (in this case road noise ≈ total noise), while the extraneous noise was almost always 10-12 dB lower than the road noise. This demonstrated that the measurement situation has an ideal configuration for satisfying the requirements of such a measurement campaign.

At 300m from the source the measurements taken by the sonic anemometer and the two anemometers at the heights M8 and M9 made possible the comparison between two different ways of calculating the wind speed gradient and temperature vertical gradient. The sonic anemometer-thermometer observations allowed to use an alternative method of deriving these gradients, by applying the Monin-Obukhov similarity theory. The gradients calculated by the two methods generally showed good agreement, except during some rainy periods (erroneous values) or some short night-time periods (less than one hour), when the lower atmosphere is very stable, leading to very non stationary situations where the similarity theory does not apply.

1.3 COMPARISON BETWEEN NOISE AND METEOROLOGICAL DATA AT DIFFERENT DISTANCES FROM THE SOURCE

1.3.1 Comparison: Leq (time history) at different distances

A comparison of the Leq (dB(A)) from Arpat (M1), LCPC (M3, M5, M7, M10) and JRC (M9) measurements was made. The comparison made at the height of 4 m. For each time history only the values with the corresponding percentage of time greater than 90% were considered.

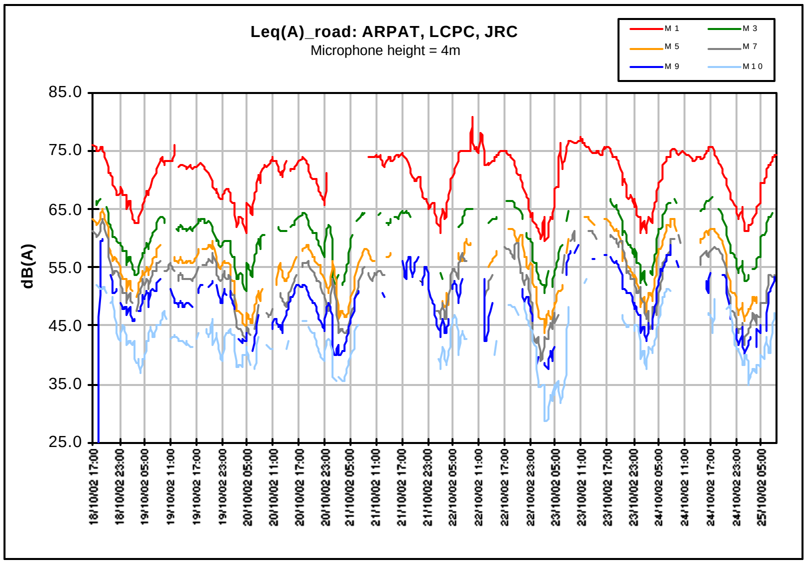

Figure 2 – Time History during the measurement period

As shown in Figure 2, the theoretical relation $\Delta Lp = 10 \cdot Log(r_2/r_1)$ is not respected, on one hand due to the fact that the ground was not perfectly hard nor plane, on the other because in some periods the meteorological conditions strongly affected sound propagation. This effect is more pronounced at high distances (more that 300 m) from the source.

1.3.2 Comparison: spectra at different distances

Starting from the reference point (M1) and looking at the spectra of M9, an attenuation was observed at mid-high frequencies, this being stronger compared to the corresponding at low frequencies (50-125 Hz) (Fig. 3). This can be observed at both, during daytime and night-time. A similar behaviour was also verified when comparing M1 against M10.

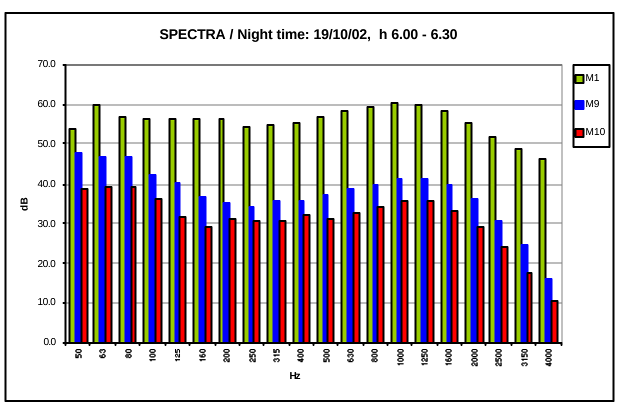

Figure 3 – spectra comparison during one evaluation period

The above chart, shows that the attenuation of noise is in strong relation with the frequency: only 10-12 dB of attenuation at 50-125 Hz (M1 vs M9), and about 20 dB (or more) at the mid-high frequencies.

Another important result is the presence of a hollow at 200-250 Hz, which is very visible at high distances, and which is not observed with the same intensity at the reference point (M1).

During periods in which the meteorological conditions are considered as being stable (for instance, wind speed lower than 0.5 m/s, with very low wind speed variance) the difference between levels at M9 and levels at M10 are almost always the same at all the frequency range (and always bigger than the theoretical ΔLevel (3 dB) (hard ground)); whereas, when the wind speed is higher than 3-4 m/s, at the frequency range of 100-400 Hz, no difference is observed between M9 and M10 (yet sometimes, levels from M10 are higher than the levels at M9).

1.4 NOISE AND METEOROLOGICAL DATA: COMPARISON BETWEEN MEASUREMENTS AND DATA FROM A RAY TRACING MODEL (PROPLIN)

To compare the measurement data against the corresponding of a theoretical model, the ray tracing model PROPLIN developed at LCPC was used. To run the LCPC [1, 2] code some approximations had to be done: perfectly plane ground, homogeneous impedance using Delany & Bazley model, with air flow mean (spatial averaged) resistivity = 500 kNsm^{-4}, as measured on the site during the campaign, sound source height (line source) = 0,1 m, which was considered a good compromise between the equivalent source height of cars and lorries.

In order to have a satisfactory and coherent comparison a selection among all the measurement data had to be done: some typical parameters were considered such as GradT, GradV, θ*, celerity gradient, number of cars and lorries per hour, etc. An isotropic condition (GradV=0, Grad=0,1) in the model, was compared with similar situation in the measurement data (GradT≈0, GradV≈0,1; number of car/lorries per hour: 450-550 (to have constant levels of noise)). Figure 4 shows the measured data as compared to the data from the model.

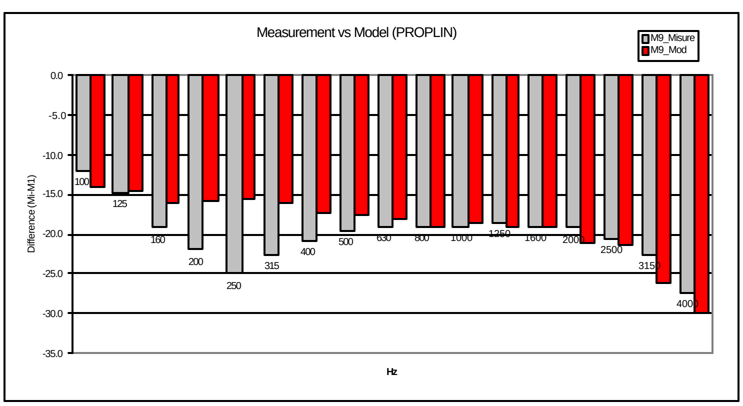

Figure 4 – Measurements vs Model (PROPLIN) – (at M9)

The following table summarises the results at all distances (M3, M5, M7, M9 and M10):

Measurements Points	*Frequency (Hz)*	*Comments*
M3, M5, M7	100 125-800 1k –3.15k	Very good agreement Bad agreement (difference > 6 dB) Very good agreement
M9	100-125 200-500 630-3.15k	Very good agreement Bad agreement Very good agreement
M10	All	Bad agreement

Table 1 – Measured vs. Modelled data at different distances

1.5 CONCLUSIONS

The analysis of the data measured in the first experimental campaign of the HARMONOISE project showed some typical behaviour of sound propagation and some interesting results: at distances from the source higher than 300 m, the attenuation of noise is almost the same at all frequencies (unlike at shorter distances in which the attenuation at high frequencies is normally higher than the one at low frequencies), considering the characteristics of the terrain, and for certain meteorological conditions (absence of wind, etc).

The comparison between the measurements and the predictions of the theoretical model showed generally good results, but the model seems not to take into account the presence of a hollow at 250-315 Hz.

The aforementioned discrepancies show that results the of the HARMONOISE Project will be very important to improve the performance of existing prediction models, taking into account meteorological conditions, above all at long distances.

1.6 ACKNOWLEDGEMENTS

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1.7 REFERENCES

1. T. Hidaka, K. Kageyama, S. Masuda: Sound propagation in the rest atmosphere with linear sound veloc-ity profile. *J. Acoust. Soc. Japan* (E) 6 (1985) 117-125.

2. A. L'Espérance, P. Herzog, G.A. Daigle, J.R. Nicolas: Heuristic model for outdoor sound propagation based on an extension of the geometrical ray theory in the case of a linear sound speed profile. *Applied Acoustics 37* (1992) 111-119.