DOI: 10.61782/fa.2025.0573

MODEL-BASED APPROACH FOR ACOUSTIC PAVEMENT CHARACTERIZATION

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ABSTRACT

The CPX method for pavement characterization is standardized at speeds of 50 and 80 km/h, but its applicability on roads with speed limits of 30 km/h remains uncertain. In a research project, a model-based approach was investigated to estimate acoustic pavement quality from asphalt's sound absorption, airflow resistance, and surface texture. These three parameters were measured in situ on multiple road sections with varying acoustic characteristics, followed by local SPB measurements to derive spectral pavement corrections for the Swiss road traffic noise emission model, sonROAD18. Correlations were observed between surface texture levels and these pavement corrections, partially explaining how texture influences acoustic performance and pavement noise reduction. This work indicates that predictions based on a combination of sound absorption, airflow resistance, and surface texture may offer improved accuracy compared to the traditional CPX method. Except airflow resistance, measurement of the three parameters does not necessarily require a static setup, thus allowing for dynamic measurement approaches. The current dataset needs expansion with other pavement types and the models will be refined to support more comprehensive acoustic pavement quality assessments at speeds below 50 km/h.

Keywords: *CPX method, pavement correction, sound absorption, surface texture*

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1. INTRODUCTION

The Close Proximity (CPX) method for pavement characterization utilizes a trailer equipped with special test tires and microphones positioned near the tires to measure sound pressure levels of tire-road interaction noise. The results of a CPX measurement are specific to a particular speed, with the method standardized for 50 and 80 km/h [1, 2]. When applied to roads with lower speed limits, particularly at 30 km/h, concerns arise regarding the validity of the results. Among other reasons, this is due to the reduced prominence of tire-road interaction noise at lower speeds, where other noise sources, such as engine noise or passing vehicles, become more dominant.

As part of the Swiss Federal Office for the Environment-funded project BELMONTI-II (Dynamic Pavement Quality Measurement at 30 km/h), we explored model-based approaches for pavement characterization. The underlying assumption was that acoustic pavement quality could be inferred from measurable pavement properties such as sound absorption, airflow resistance, and surface texture. In this study, we advanced pavement measurement technology by developing or adapting various in-situ measurement systems for these properties.

Measurements were conducted on 15 different road sections with speed limits of 50 or 80 km/h, where significant variations in acoustic pavement quality were anticipated. Stationary measurements of sound absorption, airflow resistance, and texture were performed, followed by SPB (Statistical Pass-By) measurements to determine the spectral pavement correction of the sonROAD18 road traffic noise emission model [3] for each site. This dataset provided a foundation for subsequent analyses.

Correlation analyses were used to determine relationships between sound absorption, airflow resistance and texture on the one hand, and the sonROAD18 pavement correction on the other hand.

2. MEASUREMENT METHODOLOGY

2.1 Texture measurements

The texture measurements were conducted using a stationary texture scanner from Ames Engineering (Fig. 1). At each measurement point, two lines were scanned with a spatial resolution of 0.03 mm. To ensure a comprehensive analysis, multiple measurement points were recorded across each measurement location. The collected raw data were processed in MATLAB to compute texture level spectra in accordance with ISO/TS 13473-4:2008(E) [4].

Figure 1. Ames engineering model 9400 texture scanner.

2.2 Airflow resistance measurements

The measurement setup for airflow resistance is illustrated in Fig. 2. The contact surface between the flat housing and the seal, made of soft closed-cell foam (see bottom right photo in Fig. 2), is sealed with petroleum jelly to prevent leakage. The housing can be loaded with a vehicle or a person in order to compress the seal. A controlled airflow is introduced into the housing, allowing air to escape through the lining if it possesses a finite airflow resistance. The airflow is produced from a compressor with a storage tank to provide the required compressed air (see Fig. 2 top right photo). Given a fixed airflow, the differential pressure between the interior of the housing and the surrounding environment increases proportionally with the airflow resistance and is measured using an appropriate sensor.

This setup was tested in a preliminary test and was suitable for sealing a comparatively coarse and airtight covering. The specific flow resistance was calculated from the admitted volume flow q, the measured pressure difference Δp and the housing cross-sectional area $A = 78.5$ cm^2:

$$R_S^* = \frac{\Delta p A}{q} \quad (1)$$

Again, several measurement points were taken along the roadway to ensure a thorough analysis.

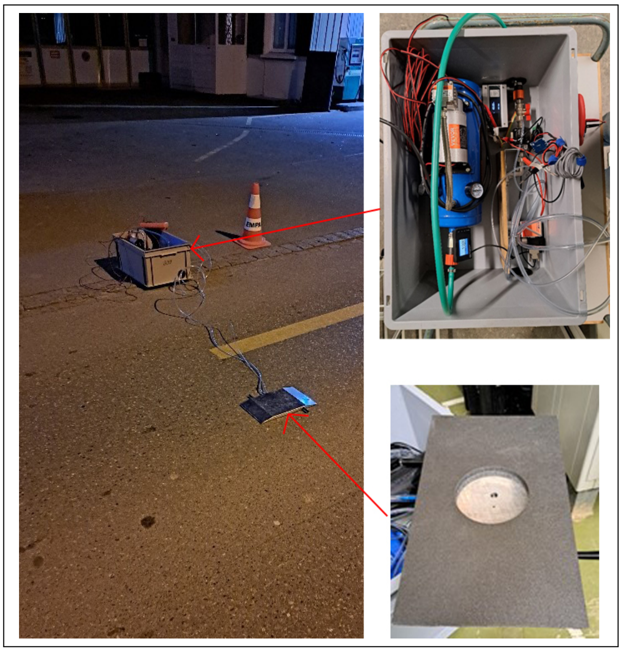

Figure 2. Devices for airflow resistance measurement (left) during field measurements and still without preload (top-right) without the plate and data logger. (bottom-right) Soft closed-cell foam seal used for measuring the airflow resistance.

2.3 Sound absorption measurements

Sound absorption was evaluated using two different methods: (1) the Guard-Tube approach, which primarily consists of an impedance tube designed in accordance with EN ISO 10534-2 [5]; and (2) the free-field approach, where measurements are conducted following ISO 13473-1:2002 [6]. Images of these two setups are shown in Fig. 3

and Fig. 4. However, due to implausible measurement results, the collected data were excluded from the analysis and will be repeated in the future.

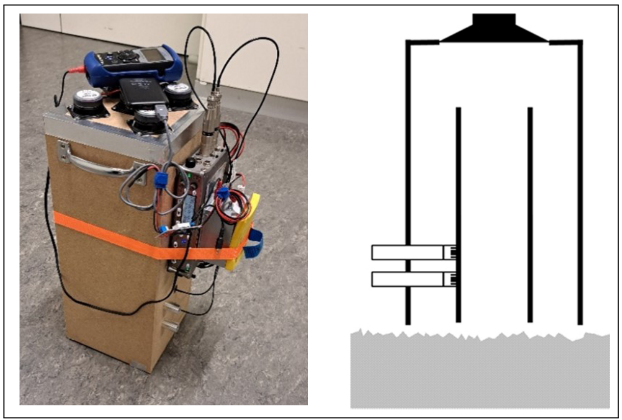

Figure 3. The guard-tube with the data recorder, the power amplifier, the power supply and the signal generator were attached to its housing (left); Principle of the guard-tube (right).

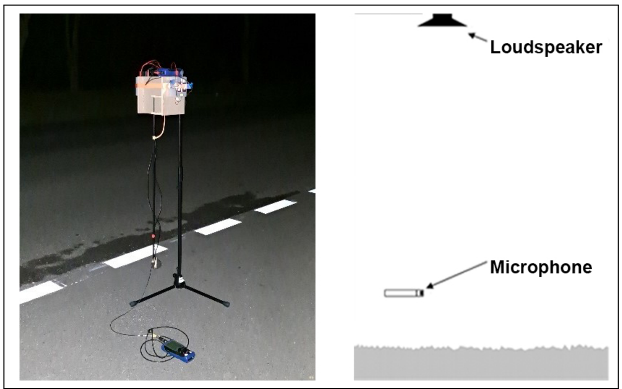

Figure 4. Free-field setup for sound absorption measurement (left); Principle of the free-field setup according to ISO 13473-1 (right).

3. RESULTS

Measurements were conducted at 15 locations across Switzerland. The selected sites met the following criteria: suitability for placing a microphone for SPB measurements while complying with the requirements of ISO 11819-1:2023 [7]. Among these 15 road sections, eight were paved with semi-dense asphalt (SDA), classified as low-noise pavements, while the remaining seven had dense, non-porous asphalt.

Except for one of these locations, in addition to static measurements of sound absorption, airflow resistance and surface texture, SPB measurements were conducted and used as a reference to compute the sonROAD18 pavement correction.

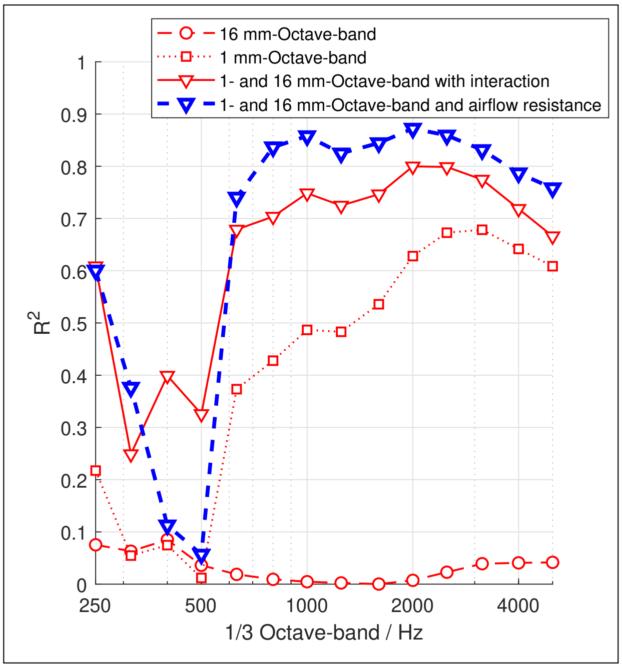

Figure 5. Coefficient of determination of the four different regression models for each third octave-band.

In the first step, a correlation analysis was conducted between spectral sonROAD18 pavement corrections—derived from SPB measurements—and pavement texture levels across various octave wavelength bands. When both pavement classes (SDA and dense asphalt) were analyzed together, a significant correlation was found only when the 1 mm octave band was included. This finding aligns with previous studies [8], which also identified a strong correlation between the 1 mm octave texture level and pavement correction. Furthermore, when the two pavement classes were analyzed separately, the 16 mm octave band also demonstrated a notable correlation with pavement correction.

Subsequently, multiple regression models were developed, incorporating specific airflow resistance along with texture levels at the 1 mm and 16 mm octave bands. The models included various configurations: some with all three variables, others using subsets, and some with or without interaction terms. Fig. 5 presents a comparison between the measured pavement corrections and those predicted by the models expressed as coefficient of determination. The key findings are:

- The 16 mm octave band level alone does not sufficiently explain pavement corrections ($R^2 < 10\%$).
- The 1 mm octave band level alone provides a significantly better model ($R^2 > 35\%$), starting from the 630 Hz third-octave band, with a peak of 68% at the 3.15 kHz third-octave band.
- When both the 1 mm and 16 mm octave band levels are used, the coefficient of determination exceeds 65% for the 630 Hz third-octave band and above.
- Incorporating specific airflow resistance alongside the 1 mm and 16 mm octave-band levels increases the coefficient of determination to at least 74% from the 630 Hz third-octave band, reaching a maximum of 87% at the 2 kHz third-octave band in the regression model without interaction terms.

4. ACKNOWLEDGMENTS

This work was supported by the Swiss Federal Office for the Environment.

5. REFERENCES

[1] R. van Loon, “How well can the close-proximity (cpx) method replace the statistical pass-by (spb) method in the evaluation of the noise reducing perfor-mance of pavements,”

[2] International Organization for Standardization, “Acoustics—Measurement of the Influence of Road Surfaces on Traffic Noise—Part 2: The Close-Proximity Method (ISO Standard No. 11819-2:2017),” tech. rep., International Organization for Standardization, Geneva, Switzerland, 2017.

[3] K. Heutschi, B. Locher, and M. Gerber, “sonroad18: Swiss implementation of the cnossos-eu road traffic noise emission model,” *Acta Acustica united with Acustica*, vol. 104, no. 4, p. 697 – 706, 2018.

[4] International Organization for Standardization, “Characterization of Pavement Texture by Use of Surface Profiles—Part 4: Spectral Analysis of Surface Profiles (ISO/TS Standard No. 13473-4:2008),” tech. rep., International Organization for Standardization, 2008.

[5] International Organization for Standardization, “Determination of Sound Absorption Coefficient and Acoustic Impedance with the Interferometer (ISO Standard No. 10534-2:2001),” tech. rep., International Organization for Standardization, 2001.

[6] International Organization for Standardization, “Characterization of Pavement Texture by Use of Surface Profiles—Part 1: Determination of Mean Profile Depth (ISO Standard No. 13473-1:2019),” tech. rep., International Organization for Standardization, 2019.

[7] International Organization for Standardization, “Acoustics — Measurement of the Influence of Road Surfaces on Traffic Noise — Part 1: Statistical Pass-By (SPB) Method (ISO Standard No. 11819-1:2023),” tech. rep., International Organization for Standardization, 2023.

[8] M. Li, W. van Keulen, H. Ceylan, G. Tang, M. van de Ven, and A. Molenaar, “Influence of road surface characteristics on tire–road noise for thin-layer surfacings,” *Journal of Transportation Engineering*, vol. 141, no. 11, p. 04015024, 2015.