Requirements and testing methods for ISO 10844:2011 test tracks

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The reproducibility of tyre and vehicle noise tests is defined for a large part by the standardization of the road surface properties. Within ISO TC43 WG 42 the TT subgroup has revised the version of 1994 and the outcome was issued in 2011 as ISO 10844:2011. The new 2011 standard formulates tightened requirements for the surface properties and also defines more advanced testing procedures.

This paper explains the background of the improved set of requirements and presents the technical developments in the measurement methods for texture and acoustic absorption. Texture data acquisition can now also be based on a mobile system, running at low speed and thus giving high accuracy. The acoustic absorption is based on the well known impedance tube with two microphone technology, slightly modified to make it fit for in-situ use. The presented version is further modified to suppress the distortion due to the occurrence of destructive interference at a microphone position.

In addition examples are given of the data processing, including the developments in the texture standard 13473-1. The application of the ENDT procedure is presented based on actual input texture data.

1 INTRODUCTION

The noise emission of vehicles and tyres depends strongly on the type of road surface the vehicle is running. In order to be able to determine the acoustic quality of a vehicle it is essential that the surface influence is controlled. The properties of the test surface in terms of texture, acoustic absorption and surface material were defined in ISO standard nr. 10844 issued in 1994. Comparison of several test tracks, all complying with ISO 10844, showed that the pass-by levels

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of vehicles and tyres may vary in the order of 5 dB due to variations in the test surface properties. The ISO Working Group 42, operating under the technical committee 43-Acoustics, has redefined the requirements for the surface with the objective to limit scatter to +/-1 dB. The revised standard was issued last year as ISO 10844:2011.

This paper will address the tighter requirements and will address the testing methods required to check the compliance with the requirements of ISO 10844:2011.

2 REVISED REQUIREMENTS IN ISO 10844

The objective in the development of the new standard was to reduce the spread without shifting the average properties. The outliers in the both the noisy and the silent direction shall be removed. The new standard addresses the same properties, but with tighter specifications and the testing is based on more modern procedures.

2.1 general design of ISO 10844:2011

The standard defines the acoustic quality of a test site for exterior noise measurements for vehicles and tyres. The geometry of the test area is given in Fig. 1.

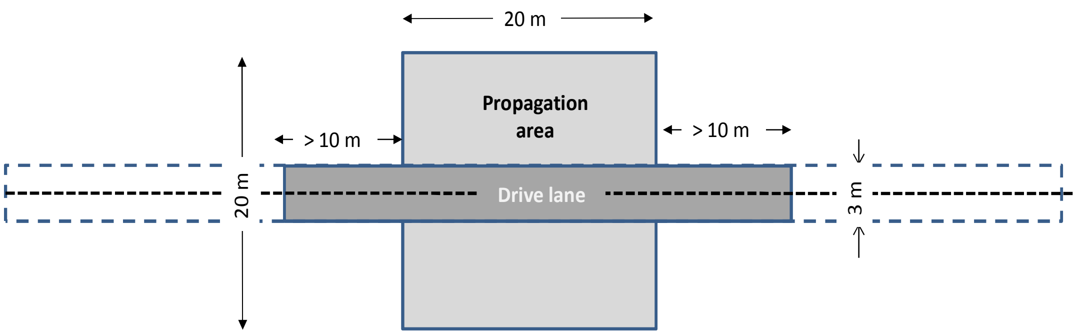

Fig. 1 – geometry of the test track according to ISO 120844:2011

The standard distinguishes three areas:

1. the environment
2. the drive lane
3. the propagation area.

The influence of the properties of each of these areas to the total result is analyzed with the help of the procedure defined in Guide 98 [1)] formerly referred to as the GUM (Guide to the expression of Uncertainties in Measurements). In this way, one can balance the severity of the requirements with the technical possibilities to meet the accuracy in the final result.

The requirements in the drive lane refer to the material, the surface texture, the acoustic absorption and the evenness. Each of these is known to influence exterior noise of vehicles and tyres.

The requirements in the propagation area refer to acoustic absorption and to evenness since both factors affect the reflected component in the propagation path.

The environment is characterized with a background noise level and a free field condition, both required to suppress artificial increments of noise measured sound levels.

2.2 Surface texture in drive lane

Surface texture refers to irregularities in the test track surface with a length scale below 500 mm. These irregularities are known to excite the tyre construction, leading to vibration of the tread band and side wall that eventually evolves as radiated sound from the tyre. Originally the test surface was only used for exterior vehicle noise testing and the definition was focussed on reducing tyre road noise, without being absorptive. Presently it is also used for tyre testing and now it also focusses on being representative and having the ability to detect sound differences between tyres.

MPD

The 1994 version of 10844 defined texture as TD, the texture depth. This quantity is determined with the sand patch method. Since the TD is known for its in accuracy and irreproducibility, it is replaced in the 2011 version by the MPD (Mean Profile Depth) which is calculated from a laser scanned profile. The 2011 version requires an MPD between 0.3 and 0.7 mm.

ENDT

Since it is known that the MPD is not a good descriptor of the effect of texture on the rolling noise of a tyre, the standard presents an informative method, the ENDT[2)] (Estimated Noise Difference due to Texture). This method uses the one-third-octave band wavelength spectrum between 5 mm and 200 mm of the surface and compares that to a reference spectrum. The spectral differences are weighted with a set of coefficients that define the relevance of that spectral band for the rolling sound in a related one-third-octave band. That again is weighted on base of an average rolling noise spectrum, resulting in a single value that estimates the difference in rolling noise level compared to the reference.

The ENDT is not part of the requirements, but due to its potential for an improved description of texture effects on rolling noise, it is recommended to also determine the ENDT and report its value.

The reference spectrum is calculated from a series of measurements of test tracks performed in Europe and in Japan. The outliers and the surfaces not meeting the spread of +/- 1.5 dB are removed and the rest is averaged (see Fig 2).

2.3 acoustic absorption of drive lane

From the overall objective of spread within ISO surfaces of ±1,5 dB (95 % c.i.) it is deduced that the effect of absorption shall be ± 0,7 dB. This objective is met by stating requirements on the maximum absorption coefficient and the frequency range where these requirements shall be met.

Spectral range

Recent work (ref [3]) demonstrated that the effect of acoustic absorption at a certain frequency is reflected in rolling noise at a about 20 to 30% higher frequency.

Figure 3below indicates the attenuation effect of sound absorption as measured with a stationary propagation measurement set-up including the horn effect. For actual rolling noise measurement on porous surfaces, the apparent frequency shift was found to be somewhat higher still than for these stationary measurements.

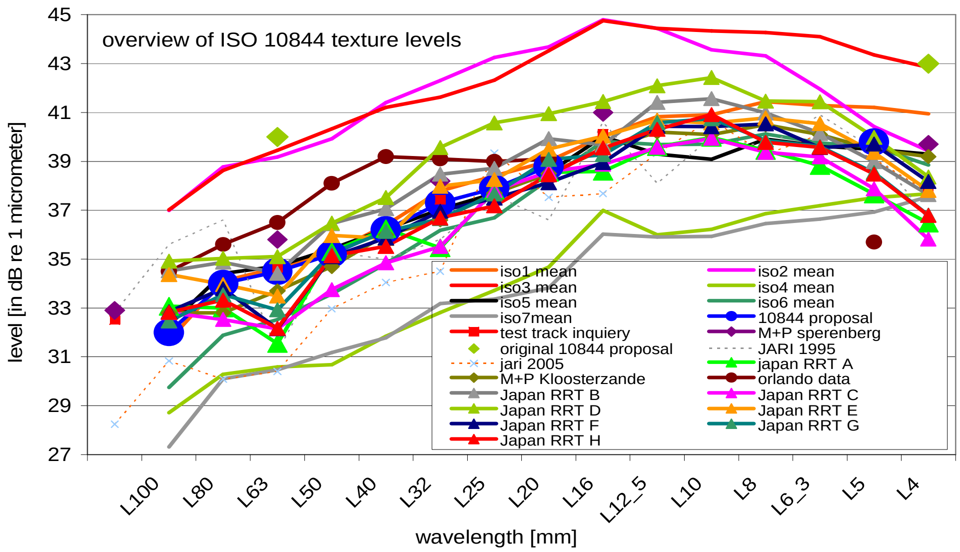

Fig. 2 – texture spectra of about 25 different test tracks in Europe and Japan.The blue dots represent the average value after removing the outliers. These averages define the reference wavelength spectrum for the ENDT calculation.

Since the energy in rolling noise on ISO type surfaces at frequencies above 2000 Hz do not contribute significantly to the overall A-weighted noise level, it is sufficient to control acoustic absorption up to the 1600 Hz frequency band.

Magnitude

The main effect of the acoustic absorption is its reduction of the amplification by the horn effect, i.e. the reduced radiation efficiency of the horn. Secondary is its effect on the propagation of sound from the source to the receiver. A model for the effect of sound absorption on the noise emission was developed [1], which takes into account:

- the reduced efficiency of the horn in the low and high frequency ranges: the horn effect is mainly effective in the 800 – 1600 Hz region;
- the fact that the relation between noise reduction and absorption is non-linear: low to medium absorption coefficients have a relatively larger effect because of multiple reflection inside the tyre horn.

In the left diagram of Fig. 3 below, the effect of sound absorption calculated using this model is given as a function of frequency, for different sound absorption coefficients. For each curve, the absorption coefficient is constant over the frequency range. The fact that absorption works stronger in the 1000 Hz region, is explained by the fact that the horn effect is more effective at these frequencies, and the reduction of noise is thus higher. This is also the region that is most dominant for the overall sound levels.

To estimate the overall noise reduction for any (constant) sound absorption coefficient, these reduction spectra are weighted with a typical passenger car coast-by spectrum. This gives the noise reduction vs. absorption curve of the diagram on the right of figure 3. Based on this curves it is estimated that in order to reach a max. noise reduction of 0,7 dB(A), the sound absorption limit should be less or equal than 8% in all 1/3rd octave bands between 315 Hz and 1600 Hz.

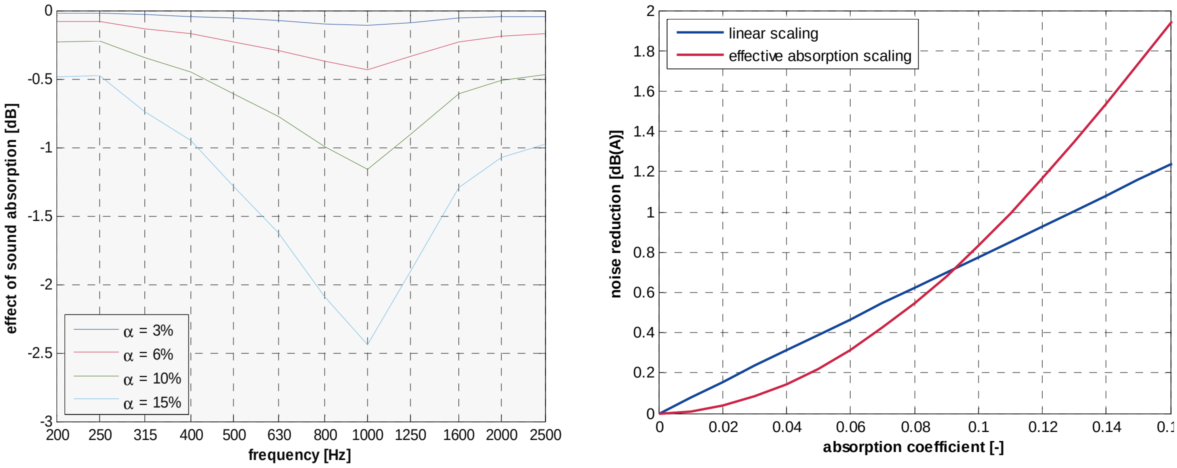

Fig.3 –Left: effect of sound absorption vs. frequency for different absorption coefficients α, constant over frequency; it is clear that absorption works strongest in the 1 kHz frequency region. Right: effect of acoustic absorption on overall rolling noise level.

2.4 Evenness and cross slope of drive lane

Evenness covers wavelengths above 500 mm and as such is not relevant for rolling noise. Excessive longitudinal unevenness may cause varying tyre loading that can affect rolling sound levels. Transversal unevenness and cross slope affects the steering stability leading to shear forces and thus increased rolling sounds. Furthermore, usage of the track with high tyre loads under high ambient temperatures may cause rutting, that affects wheel alignment and the distribution of contact forces in the contact area.

In the revised ISO 19844:2011 additional requirements are formulated for cross slopes and unevenness. Cross slope shall be ≤ 1%, Transversal unevenness in new condition shall be ≤ 3 mm and may increase during usage to max. 5 mm. Longitudinal in new condition shall be ≤ 2 mm and may increase during usage to 5 mm.

2.5 acoustic absorption and evenness of propagation area

The propagation of sound from the vehicle to the microphone consists of a direct and a reflected path. Since this reflection takes (partly) place in the propagation area (see figure 4), its reflecting properties have to be defined in terms of unevenness and acoustic absorption.

The effect of acoustic absorption in the propagation is less than in the horn amplification between tyre and road, so the requirement is set at a slightly relaxed level of ≤10% in each one-one-third-octave band between 315 Hz and 1600 Hz.

The evenness is limited to 20 mm.

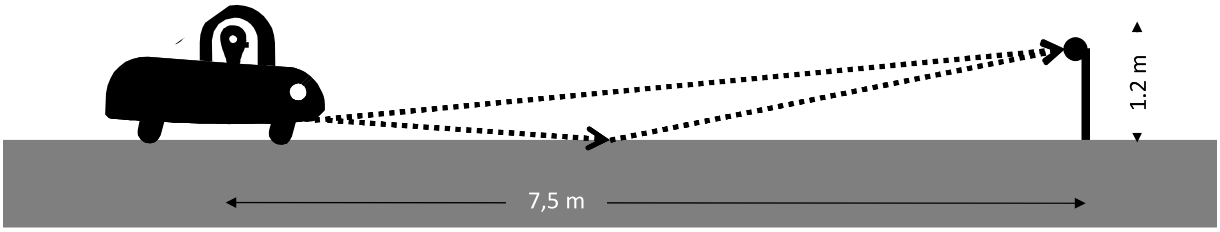

Fig. 4 – A simple ray tracing sketch of the propagation from the passing vehicle to the microphone. The reflection takes place in the propagation area.

2.6 surface material

A complete definition of the surface characteristics requires a more extensive set of surface parameters. Therefore an additional requirement is formulated on the composition of the surface material. That shall be 8 mm Dense Asphalt Concrete with a specified sieving curve for the aggregates.

3 TESTING METHODS

The quality of the compliance testing is defined by the specification of the test methods and test equipment. The ISO 10844:2011 refers to ISO and EN standards for texture, absorption and unevenness testing.

3.1 Texture

For the method for texture measurements, reference is made to ISO 13473-1 for the determination of the MPD, to ISO TS 13473-4 for the calculation of the wavelength spectrum and to 13473-3 for quality criteria of the equipment. Although both stationary and mobile equipment is allowed, we prefer mobile equipment, since that system enables checking over the whole length of the track while stationary devices may only check 20%.

A continuous profile is made over the whole length of the test track, with a 1 mm sample distance and a vertical resolution of about 0.01 mm. The total profile is separated in 5 m sections. For each section we calculate the one-third-octave wavelength spectrum in the range of 5 to 200 mm and we determine the MPD for each consecutive 100 mm segment in the 5 m section.

The present 13473-1 standard for MPD determination is not clear in how to handle invalid readings, spikes and the procedures for low- and high pass filtering. It is therefore revised at the moment. We anticipate on the revised version for our signal processing.

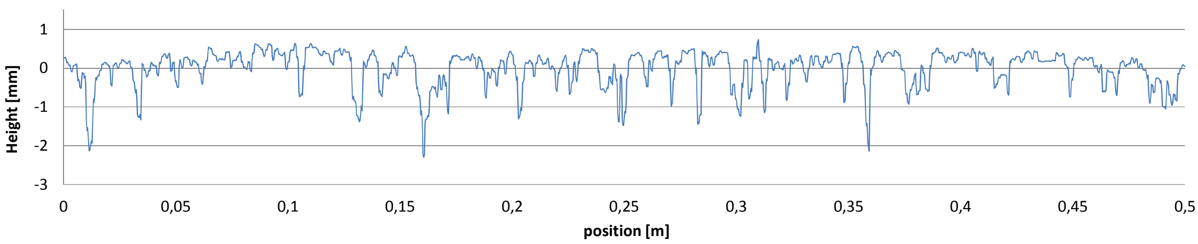

Fig. 5 – Typical profile of test track surface measured with mobile laser profilometer. Presented is a segment of 0.5 m out of a profile of in total 40 m.

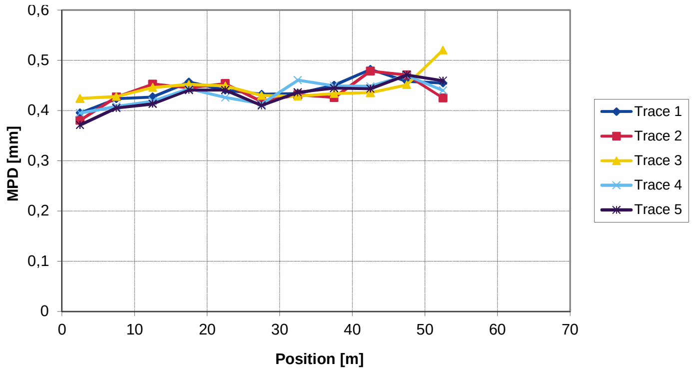

Fig. 6 – Typical result of MPD determined in 5 consecutive traces in the same wheel track. Each point is the average of 50 MPD determinations at each 1000 mm segment.

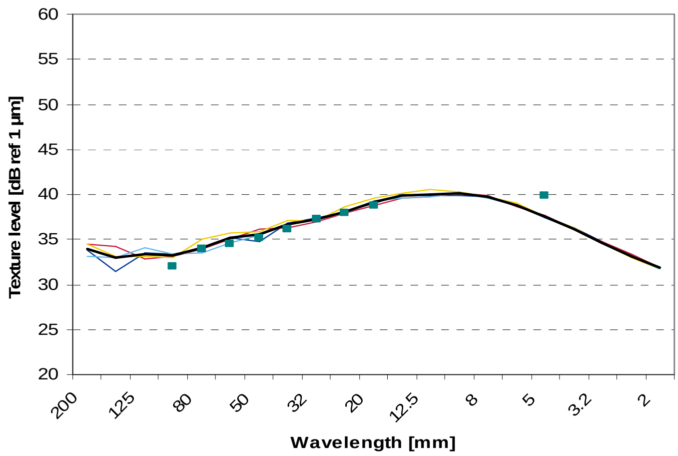

Fig. 7 – Typical result of wavelength spectrum in 5 consecutive traces in the same wheel track. The squares indicate the target values for the ENDT calculation. The ENDT value for this track is +0.66 dB.

3.1 Acoustic absorption

Acoustic absorption is measured with a conventional two microphone impedance tube (standardized in ISO 10534-2). Its application for reflective surfaces and the fixture necessary for sealing are described in ISO 13472-2. A complication of applying the two microphone technique to reflective surfaces is that at each microphone position, at certain frequencies destructive interference will take place. This introduces a significant error in the determination of the transfer function between the two positions.

We developed a procedure where signals are measured continuously at three microphone locations (see Fig. 8).Between each of the three pairs of positions the coherence function is measured. Occurrence of destructive interference at one position will result in loss of coherence for each pair that shares that position. Then we select each individual frequency that pair with the highest coherence, and use that for the calculation of the transfer function.

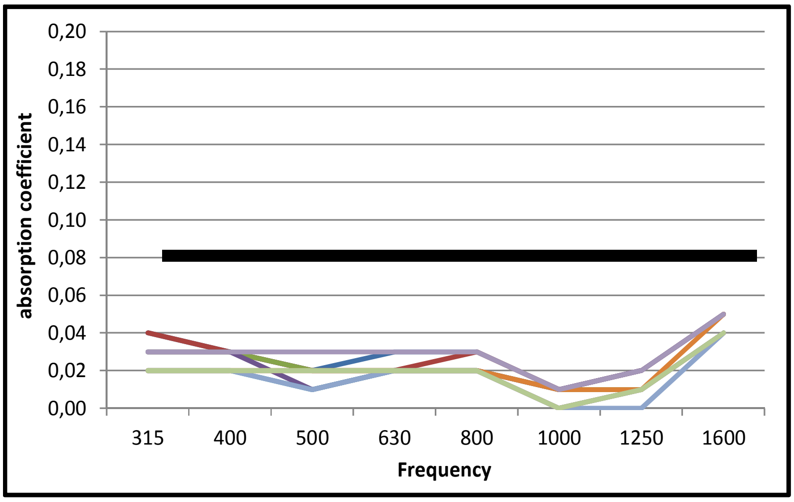

Fig. 8 – Left: picture of the impedance tube for in-situ measurements according to ISO 13472-2. Data processing is extended with respect to ISO 10534-2 by using three microphones and selecting the optimal pair based on the coherence function. Right: typical result for 4 different positions in the drive lane. The black line indicates the allowed maximum absorption.

3.1 Evenness

The evenness is to be measured according to the European Standard EN- EN 13036-7. This implies a straightedge of 3 m length laid and the surface and detection of the maximum deviation of the road under that beam. Application of such beam is considered impractical in case of world-wide travelling. We use a level laser beam as reference for cross profiling of the surface. Then a virtual 3 m beam is laid on the surface and the maximum deviation is calculated (see Fig. below).

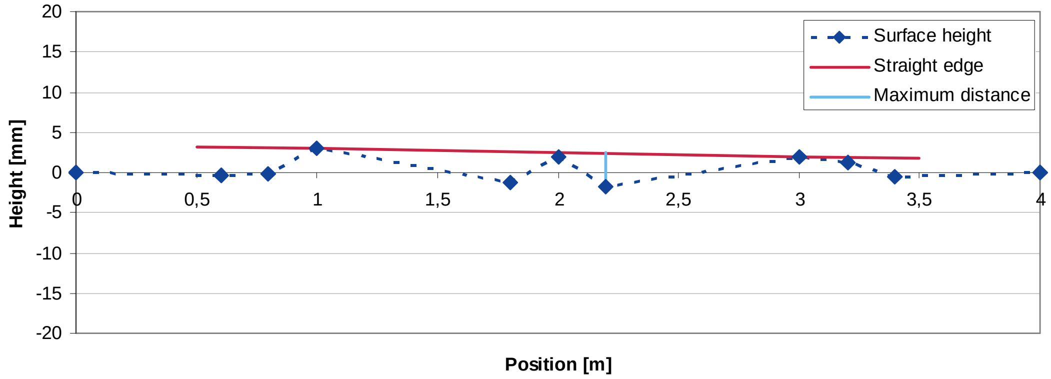

Fig. 9 – Example of a cross profile of a test track and a the positioning of the virtual 3 m beam on top of it. The light blue line segment indicates the maximum deviation.

4 DISCUSSION AND CONCLUSIONS

4.1 ISO 10844 requirements

This paper presented an overview of the modifications of the 2011 version of the ISO standard 10844 with respect to the version of 1994. It can be concluded that in nearly all aspects an improvement has been realized.

The procedures for determination of the surface texture and the acoustic absorption are founded on more modern measurement technologies that are firmly based in ISO standards. For acoustic absorption an additional advantage is that measurements can be done non-invasive in contract to the 1994 version where bore cores have to be taken.

The requirements for both the texture and the absorption have been tightened. For texture there is also a maximum value defined, whereas the original only had a minim value. For absorption, the frequency range is extended, the limit is tightened and the possibility of averaging over frequency bands is omitted.

The MPD as such is a bad predictor for the noisiness of a surface. The ENDT procedure introduced in the 2011 version in an informative annex has the potential of being more accurate in classifying the noisiness of the surface. It is recommended to gather as much data as possible of wavelength spectra and related ENDT values. This will enable the shift from MPD to ENDT as mandatory texture quantity in a possible future revision of ISO 10844.

4.2 ISO 10844 testing methods

The test method ISO 13473-1defined for the determination of the MPD can be considered as out of date. The defined procedures do not fully address modern laser based systems and digital signal processing capabilities. Furthermore, the handling of invalid readings and spikes has to be improved. The text of this standard is at the moment under revision and we urge for a quick finalization of the work.

The test method ISO 10534-2 and 13472-2 for the determination of the acoustic absorption in-situ works satisfactorily. We recommend that the three microphone technique, described in this paper, will in future be part of either 10534-2 or 13472-2 since it can be regarded as a major improvement in case of reflective surfaces and for speeding up the performance of the measurement.

6 REFERENCES

1. ISO Guide 98:1995, Guide to the expression of uncertainty in measurement (GUM)

2. ENDT [13] Klein, P., Hamet, J.-F., "ENDT, Expected pass-by Noise level Difference from Texture level variation of the Road Surface, Technical Report SILVIA-INRETS-021-00-WP2-25/05/05, INRETS, 2005, can be downloaded from SILVIA website: www.trl.co.uk/silvia

3. A. Kuijpers, B. Peeters et al. "Acoustic Optimization Tool, milestone RE4 – models implemented in the final AOT model", M+P.DWW.06.04.7 d.d. November 28, 2008.