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Acoustics — Temperature influence on tyre/road noise measurement —

Part 1: Correction for temperature when testing with the CPX method

Acoustique — Effet de la température sur les essais de bruit pneu/route —

Partie 1: Mode opératoire de correction sur les essais avec la méthode CPX

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 43 *Acoustics*, Subcommittee SC 1 *Noise*.

A list of all the parts in the ISO/TS 13471 series can be found on the ISO website.

Introduction

Air, tyre and road surface temperatures affect noise emission from the tyre/road interaction, as measured by means of, for example, the close-proximity (CPX) method specified in ISO 11819-2. This method allows the user to make measurements within a wide air temperature range (5 °C to 35 °C) which means that temperature influence on the results may be substantial.

In the CPX method, one or two reference tyres may be used, as specified in ISO/TS 11819-3; consequently, the temperature corrections need to be valid for these reference tyres. Tyre properties like rubber hysteresis and tread rubber hardness are affected by temperature, but the latter may also affect road surface properties. Temperature effects on noise, therefore, depend on both the tyre and the road surface, the temperatures of which are affected by ambient air temperature. To make it more complicated, the temperature probably has different effects on different noise generation mechanisms. Ideally, and whenever possible, temperature corrections shall be tailored to the tested tyre/road combination.

The approach to the temperature correction in this document is semi-generic, which means that under certain conditions a correction to noise for temperature is made common to a group of tyres or a group of road surfaces. This document makes a distinction to the two reference tyres and to a few major road pavement categories.

Acoustics — Temperature influence on tyre/road noise measurement —

Part 1:
Correction for temperature when testing with the CPX method

1 Scope

This document specifies procedures for determining the effect of temperature on tyre/road noise emission. Temperatures considered are tyre, road and ambient air temperatures.

The noise emission for which this document is applicable is measured by means of ISO 11819-2, or similar methods such as the on-board sound intensity (OBSI) method specified in Reference [1]. Measurement results obtained at a certain temperature, which may vary over a wide range, are normalized to a designated reference temperature (20 °C) using a correction procedure specified in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11819-2, *Acoustics — Measurement of the influence of road surfaces on traffic noise — Part 2: The close-proximity method*

ISO/TS 11819-3, *Acoustics — Measurement of the influence of road surfaces on traffic noise — Part 3: Reference tyres*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Acoustics

3.1.1
tyre/road noise
noise generated by the tyre/road interaction

3.1.2
CPX method
close-proximity method
measurement procedure designed to evaluate the influence of road pavement characteristics on vehicle and traffic noise under conditions when *tyre/road noise* (3.1.1) dominates and power unit noise is not very important

Note 1 to entry: The method is specified in ISO 11819-2.

Note 2 to entry: The measurements are made using microphones located close to one or more test tyres which are mounted on a special test vehicle.

3.1.3
CPX level
close-proximity level
L_{CPX}
time-averaged A-weighted sound pressure level (SPL) of the *tyre/road noise* (3.1.1) as determined by the *CPX method* (3.1.2), either broadband or spectral bands, as required

Note 1 to entry: The CPX level is expressed in decibels. In order to provide more information, additional suffixes are used; see ISO 11819-2 where the CPX method is described.

3.2 Tyres and road surfaces

3.2.1
reference tyre
test tyre specified for the purpose of representing certain features in tyre/road sound emission, designed and constructed for use in the *CPX method* (3.1.2) with specified and reproducible standard properties

Note 1 to entry: The reference tyres are specified in ISO/TS 11819-3.

3.2.2
road surface
surface course
upper course of the pavement, which is in contact with the tyres

Note 1 to entry: Various main types of road surfaces are described in Annex B.

3.3 Temperatures

3.3.1
air temperature
ambient air temperature
temperature of the air surrounding the tyres under test, but measured in such a way that the sensor is exposed to the airflow and protected from direct solar radiation

Note 1 to entry: The air temperature is expressed in degree Celsius.

3.3.2
road temperature
road surface temperature
static temperature of the part of the road that is in contact with the tyre(s) rolling on the road, where static means that it is the temperature that changes only with pavement convection, sun radiation and meteorological conditions

Note 1 to entry: The road temperature is expressed in degree Celsius.

3.3.3
tyre temperature
general term for the temperature of the *reference tyre* (3.2.1), which influences noise emission

Note 1 to entry: The tyre temperature is expressed in degree Celsius.

Note 2 to entry: Tyre temperature varies substantially between different parts of the tyre, as well as with the tyre operating conditions. In this document, distinction is not made between these different parts, but the tyre is seen as a unit with a temperature that influences noise emission in a particular way.

3.3.4
tyre tread temperature
temperature of the surface of the tread of the *reference tyre* (3.2.1)

Note 1 to entry: The tyre tread temperature is expressed in degree Celsius.

Note 2 to entry: In this document, this is considered the temperature of the centre one-third of the tread width.

3.3.5
reference temperature
T_{ref}
air temperature (3.3.1) of 20,0 °C representing a hypothetical, ideal measurement case, to which actual measurements are normalized

Note 1 to entry: The reference temperature is expressed in degree Celsius.

3.3.6
temperature correction term
$C_{T,\mathrm{t}}$
term used for correcting the *CPX level* (3.1.3) for temperature T for tyre t

Note 1 to entry: The temperature correction term is expressed in decibels.

3.3.7
temperature coefficient
γ_{t}
coefficient used for correcting the *CPX level* (3.1.3) for the effect of temperature for tyre t

Note 1 to entry: The temperature coefficient is expressed in decibels per degree Celsius.

4 Principles of the correction procedures

The general effect of temperature is an increase in sound levels with colder temperatures and a decrease in sound levels with warmer temperatures. Based on the empirically determined relationship between tyre/road noise and ambient air temperature, the aim is to normalize all CPX noise measurements to a reference temperature, from the actual air temperature during the measurement, within a temperature range where the relationship is reasonably linear.

The reference condition has been determined to be a hypothetical measurement of noise at an air temperature of 20,0 °C. The relationship between noise and temperature has been determined from a compilation of several published investigations, with distinction between the two reference tyres specified in ISO/TS 11819-3, and with speed as an influential factor. It has been found that the relationship depends on the main type of road surface, and somewhat different relationships are, therefore, necessary to apply based on the road surface type, and to some extent the condition of the surface (porosity).[2]

In this way, measured overall A-weighted levels as well as spectral levels, corrected for the difference between actually measured temperature and the reference temperature using formulae given in this document, are normalized to a common reference condition where air temperature would be 20 °C.

In general, it is advised that measurements be made as close as possible to the reference temperature, in order to avoid large corrections. In cases when one wants to compare, for example, a before–after measurement of some type, the lowest uncertainties will result if such before–after measurements are made at similar temperatures; in particular, if temperatures during measurements are relatively far from the reference temperature.

When using a semi-generic correction procedure, it shall be accepted that the use of an average temperature coefficient for tyres considered in this document, with a distinction between a few major road pavement categories, will lead to some over- and under-estimations of temperature corrections for individual pavements. However, the errors of such imperfect corrections are more than balanced by the correction itself as it normalizes the results to a common and comparable scale.

This procedure will reduce the uncertainty in CPX measurements due to varying temperature substantially. An analysis of uncertainty is included in this document.

Refer to Annex C for a discussion about the choice of temperature to use for normalization.

5 Temperature measurement equipment

The air and (optional) road and tyre temperature measuring instrument(s) shall have a maximum permissible error of ± 1 °C, as specified by the manufacturer. Meters utilizing the infrared technique shall not be used for air temperature measurements.

The equipment shall be calibrated in accordance with the manufacturer's specification, in most cases requiring a calibration annually by a laboratory authorized to perform calibrations traceable to appropriate standards.

The type of sensor used shall be reported.

6 Measurement methods

CAUTION — This document may involve hazardous operations when measurements are made on trafficked roads or streets. The personnel and the vehicles present on the measuring site shall be equipped with safety or warning devices in accordance with the regulations in force for work in the traffic flow (if any) on that particular site at that particular time. Otherwise, this document does not purport to address the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

6.1 General

The measurements shall comprise at least the first of the following operations.

— Measurement of air temperature representative of the ambient air surrounding the test tyre (mandatory).

— Measurement of road temperature representative of the road surface over which the tyres roll (optional).

— Measurement of tyre temperature (optional).

The temperature measurement shall have a duration of at least 15 s. The thermometer manufacturer's instructions shall be observed. The result is the reading rounded to the first decimal, in °C.

NOTE Regarding the various temperatures considered, a discussion follows in 6.2 to 6.4. See also the discussion in Annex C.

6.2 Measurement of air temperature

Locate the temperature sensor so that it is unobstructed and safe, and in such a way that it is exposed to the airflow and protected from direct solar radiation. The latter may be achieved by a shading screen. The sensor shall be positioned 0,5 m to 1,5 m above road surface level. The position of the sensor shall be reported.

NOTE If positioned closer to the road there can be an influence of road surface thermal radiation at low airflows.

6.3 Measurement of road surface temperature (optional)

Position the temperature sensor in order to measure where the temperature is representative of the temperature in the wheel tracks. Collect the measurements approximately simultaneously with the noise measurement. Where portions of the roadway are in full sun and other portions are shaded it is advised to collect the temperature values approximately over the same test section as noise is collected.

6.4 Measurement of tyre temperature (optional)

Position the temperature sensor in order that it measures the tyre tread surface temperature, without interfering with the noise measurement. In order to avoid dirt thrown from the tyre by centrifugal forces, the sensor should not be positioned in the tyre plane but a little outside the tyre plane. If tyre temperature is measured, the measuring position on the tyre shall be reported.

7 Temperature range

7.1 General

In order to reduce the uncertainty, it is recommended that noise measurements be made at air temperatures as close as practical to the reference air temperature (20,0 °C).

7.2 Temperature range within which the correction procedure is valid

The correction procedures in this document shall be applied only if air temperatures are within 5 °C and 35 °C.

NOTE The allowed temperature range is related to local road materials. In the warmer zones, high temperatures are common and bitumen viscosity is adjusted to it, while the same temperature in a cooler climate can cause bleeding of the bituminous mixture. This is known to cause extra stick-snap sound from the rolling tyre.[3]

8 Temperature correction procedure

8.1 Correction to CPX levels, L_{CPX}

Temperature correction shall be applied as follows. Each measured CPX level, L_{CPX}, determined according to ISO 11819-2, shall be corrected by the term $C_{T,t}$, using Formula (1):

$$C_{T,t} = -\gamma_t \left(T - T_{ref} \right) \tag{1}$$

where

$C_{T,\mathrm{t}}$ is the CPX level correction for temperature (T) for tyre t, in dB, to be added to the measured noise level;

γ_t is the temperature coefficient for tyre t (either P1 or H1), in dB/°C;

T is the air temperature (T) during the CPX measurement, in °C;

T_ref is the reference air temperature = 20,0 °C.

The γ_t values are indicated in 8.2 below.

NOTE The method for applying this correction coefficient is described in ISO 11819-2.

8.2 Temperature coefficient

For tyres P1 and H1 in ISO/TS 11819-3, it has been found that the temperature coefficients are approximately equal.[4],[5],[6],[7] It has also been found that they depend somewhat on speed[8],[5],[9] and that the relation to speed can be described by a simple linear formula. The γ_t values are then as follows.

For dense asphaltic surfaces (such as DAC, SMA, TAL with air voids typically below 18 %, and surface dressings, the latter also known as chip seals; see Annex B), as shown by Formula (2):

$$\gamma_{\mathrm{P1}} = \gamma_{\mathrm{H1}} = -0,14 + 0,000\,6\,v \qquad (2)$$

For cement concrete surfaces of all types (see Annex B), as shown by Formula (3):

$$\gamma_{\mathrm{P1}} = \gamma_{\mathrm{H1}} = -0,10 + 0,000\,4\,v \qquad (3)$$

For porous asphalt surfaces and high-porosity TAL (not seriously clogged; see Annex B), as shown by Formula (4):

$$\gamma_{\mathrm{P1}} = \gamma_{\mathrm{H1}} = -0,08 + 0,000\,4\,v \qquad (4)$$

where

γ_{P1} is the numerical value of the temperature coefficient for tyre P1, expressed in dB/°C;

γ_{H1} is the numerical value of the temperature coefficient for tyre H1, expressed in dB/°C;

v is the numerical value of the preferred speed (similar to v_ref in ISO 11819-2), expressed in km/h.

NOTE 1 Note that the formulae in no way represent a physical relationship; they are just a mathematical expression that rather closely fit relationships found for a number of speeds; see Annex A. It is practical to use the formulae here as they are easy to implement in software.

NOTE 2 For road surfaces not fitting any of the categories of Formulae (2), (3) and (4), determine a surface-specific coefficient by experiments, or use the coefficient for the category which is judged to be the most similar, for example as described in Reference [4]. See Annex B.

NOTE 3 The generic road surface type designated DAC is dense asphalt concrete, SMA is stone mastic asphalt and TAL is thin asphalt layer.

NOTE 4 Although the temperature effects have been studied for the tyres P1 and H1 separately, the results indicated no substantial differences between them; thus the values in the formulae are valid for both tyres.

NOTE 5 This correction does not include the potential effect of air density, which can be an issue in the OBSI method,[1] but not in the CPX method.

8.3 Spectral correction

It is known that the correction should ideally be made based on spectra. Available data suggest that the temperature influence is the highest at low and high frequencies, while the peak frequency, which often appears around 800 Hz to 1250 Hz, is affected to a lesser degree.[8] However, collected data are not sufficiently consistent to allow a frequency-dependent temperature correction. In order to avoid a discrepancy between separately measured overall levels and the same calculated from spectra, the same correction shall be applied for all frequencies.

9 Measurement uncertainty assessment according to ISO/IEC Guide 98-3

9.1 General

The result of the application of the temperature correction procedure for CPX measurements described in this document is subject to several uncertainties. The cause and nature of these uncertainties are either known, but randomly distributed in an uncontrollable way, or are of a systematic nature, but affect the result in an unpredictable way.

In accordance with ISO/IEC Guide 98-3, the effects are evaluated based on their contribution to the combined standard uncertainty and then a coverage probability is defined, resulting in a coverage factor k by which the combined standard uncertainty is multiplied, yielding the expanded uncertainty.

9.2 Potential uncertainties

The potential uncertainties are as follows.

a) The road surface does not fit adequately into the selected road surface category.

b) The actual properties of the road surface are not entirely representative.

c) The selected temperature coefficient has been determined with a (systematic) uncertainty.

d) The selected temperature coefficient has been determined based on too few measurements or too small temperature range (random uncertainty).

e) Uncertainty in temperature measurement equipment.

9.3 Uncertainty estimation of temperature correction

The general expression for the true temperature correction $C_{T,\mathrm{t}}$, for a certain tyre (t), road surface type (rs), and speed (v), is given by Formula (5):

$$C_{T,\mathrm{t}} = -\gamma_\mathrm{t}\left(T - T_\mathrm{ref}\right) + \delta \tag{5}$$

where

$C_{T,\mathrm{t}}$ is the temperature correction, in dB; see Formula (1);

γ_t is the temperature coefficient for tyre t, for road surface type rs and speed v, including any uncertainty due to incorrect temperature coefficient or its relation to the parameters;

T is the measured air temperature, including any measurement uncertainty;

T_ref is the reference temperature (20 °C);

δ is an input quantity to allow for any uncertainty due to deviating road surface properties.

9.4 Sources of uncertainty

9.4.1 Temperature coefficients, γ_t

The temperature correction procedure assumes that the underlying data which were used to derive the presented correction factors were correctly obtained using a sufficient amount of empirical data for each road surface category. Temperature effects are difficult to measure and isolate; additional precautions regarding measurement set-up and procedure are therefore required to minimize the occurrence of parasitic phenomena and reduce the standard uncertainties when investigating temperature effects. Although quality criteria were applied when selecting the underlying data,[4],[8] the selected coefficients and their variation with speed are still subject to uncertainty.

9.4.2 Road surface category, δ

In some cases, for example in the case of semi-dense or partially clogged porous road surfaces, the user's selection of the appropriate road surface category may not be ideal, since the real temperature effects may be somewhere between those of dense and porous road surfaces. Also, within a specific road surface category, there are variations between the surface types that are neglected in this procedure (for example road surfaces with rough surface texture versus smooth surface texture). Furthermore, the procedure in this document is not absolutely clear on how to select the right category, but relies on a certain amount of subjective assessment and decision-making by the user.

9.4.3 Temperature measurements, T

The temperature correction procedure assumes that the temperature measurement equipment is accurate and that the temperature sensor for ambient air temperature is installed in a way that it is exposed to the relevant airflow and protected from direct solar radiation. Errors can occur whenever the sensor may be heated up due to solar radiation or due to its exposure to the heat from the test vehicle's engine.

9.5 Estimation of uncertainties

In the procedure in this document, the sources of uncertainty and the resulting contribution of each source is listed in Table 1. The indicated tyres are the reference tyres defined in ISO/TS 11819-3. For information about the interpretation of the probability distributions, refer to ISO/IEC Guide 98-3.

NOTE 1 Estimated uncertainty contributions are products of standard uncertainties and corresponding sensitivity coefficients rounded to the nearest multiple of 0,05.

The total spread in measurement results expected in this procedure leads to the expanded uncertainties listed in Table 2.

NOTE 2 It is estimated that the semi-generic temperature correction in this document will be effective in reducing temperature-related uncertainties in CPX measurements to less than half of those of non-corrected measurements.

Table 1 — Typical values of standard uncertainties after applying the temperature correction procedure

Sources of uncertainty	Estimate	Probability distribution	Sensitivity coefficient	Uncertainty contribution	
				Tyre P1	Tyre H1
Temperature coefficients (γ_t)	$\gamma_{t,estimated}$	normal	$T - T_{ref}$	0,15 dB	0,25 dB
Road surface category (δ)	0	normal	1	0,15 dB	0,15 dB
Temperature measurement (T)	$T_{estimated}$	normal	γ_t	0,1 dB	0,1 dB
Combined standard uncertainty				0,25 dB	0,3 dB

Table 2 — Typical values for the expanded uncertainty

Coverage probability	Coverage factor (k)	Expanded uncertainty	
		Tyre P1	Tyre H1
80 %	1,28	0,3 dB	0,4 dB
95 %	1,96	0,5 dB	0,6 dB

10 Test report

The test report related to temperature correction will normally be included in the test report related to measurements made with the CPX method; therefore, refer to the corresponding clause in ISO 11819-2.

The following information related to the temperature correction is important to include, most of which are already mentioned in ISO 11819-2.

— Weather conditions (for example, sunshine, cloudiness or sunshine with shadows).

— Time and date of measurement.

— Reference tyre used.

— Road surface main type; refer to the categories described in Annex B (include a special note in case of doubt about which category the measured test section belongs to).

— Average or range of air temperature during the measurement.

— Average or range of road surface temperature during the measurement, if measured (optional).

— Average or range of tyre temperature during the measurement, if measured (optional).

— Where tyre temperature was measured (mandatory if tyre temperature was measured).

— Position of air temperature sensor (mandatory).

— Location on the road surface where temperature is measured (optional).

Annex A
(informative)

Discrete temperature coefficient

The temperature coefficients given in this document are based on several research projects and published data in the open literature. Compilation and assessment of such data appear in publications such as References [4] and [5]. During these studies it became obvious that the measurement speed (*v*) was a parameter that affected the temperature coefficient to a significant extent.[8] As it is the aim of documents such as ISO 11819-2 to reduce all possible uncertainties as much as is practical, it was finally decided to add speed as a parameter in the temperature correction.

Simultaneously, it was noted that there was a lack of consistent evidence indicating that reference tyres P1 and H1 (see ISO/TS 11819-3) gave different temperature coefficients. Therefore, it was decided to use the same coefficients for both these tyres.

The result of the compilation of data gave average coefficients for three different road surface categories and for three different ranges of speeds; the latter centred around the reference speeds 50 km/h, 80 km/h and 100 km/h. These results were put together in a simple matrix in Table A.1. In this table, a column was added for a "standard case" where the speed parameter is neglected, leaving just an average coefficient for the entire speed (rightmost column in Table A.1). Obviously, the "standard case" sacrifices some precision, and the case including the speed is therefore designated as a "high-precision case".

This optional presentation of temperature coefficients is referred to as a discrete representation of the temperature coefficient, as opposed to the continuous representation in Formulae (2), (3) and (4).

The discrete representation of the temperature coefficient has the disadvantage that at the borders of the speed ranges, there is a discontinuity in temperature coefficient.

For all practical reasons, it does not matter whether the table values or values obtained from the formulae are used. However, for use with tyres P1 and H1, it has been decided to use the continuous representation offered by the Formulae (2), (3) and (4), mainly since it is easier to include in software for the CPX method.

Table A.1 — Values for the temperature coefficient γ_t (dB/°C) in the optional case of using a discrete representation of the coefficient

Road surface category	**Tyre (t): P1 and H1**			
	High-precision case			Standard case
	(40 to 64) km/h	(65 to 89) km/h	(90 to 110) km/h	(40 to 110) km/h
Dense asphaltic surfaces (such as DAC, SMA, surface dressings, see further 8.2)	−0,11	−0,09	−0,08	−0,10
Cement concrete surfaces of all types	−0,08	−0,07	−0,06	−0,07
Porous asphalt surfaces and high-porosity TAL (not seriously clogged)	−0,06	−0,05	−0,04	−0,05
NOTE Regarding the road surface categories, see Annex B.				

Annex B
(informative)

Information about road surface types

B.1 General

In Clause 8, the temperature coefficient is specified as formulae for three categories of road surfaces. The same distinction between road surface categories is made in Annex A. These three categories are as follows.

— Dense asphaltic surfaces (such as DAC, SMA, TAL with air voids typically below 18 %, and surface dressings, the latter also known as chip seals).

— Cement concrete surfaces of all types.

— Porous asphalt surfaces and high-porosity TAL (not seriously clogged).

More information about these categories is presented in B.2. It can also be useful to consult a road surface terminology dictionary, such as Reference [10].

B.2 Description of road surface categories

B.2.1 Dense asphalt surfaces

This category includes the following types.

— (Dense) asphalt concrete (DAC) as defined in EN 13108-1.

— Porous asphalt concrete (PAC) as defined in EN 13108-7, but in clogged condition; i.e. approximately 50 % or more of the pores are clogged by dirt and bitumen.

— Porous asphalt concrete (PAC) as defined in EN 13108-7, but with design air void content below 18 %, corresponding to void categories H to Z in EN 13108-7. These are often referred to as open-graded friction courses (OGFC) or open-graded asphalt concrete (OGAC).

— Stone mastic asphalt (SMA) as defined in EN 13108-5.

— Thin asphalt layers (TAL), which are asphaltic surface courses with a thickness of less than 30 mm, in which the aggregate particles are essentially gap-graded to form a stone to stone contact and to provide an open surface texture, in this case with air void content less than 18 %.

— DAC, SMA or TAL types to which a significant amount of rubber particles have been added (rubber up to 3 % by weight of the total mix); these are often referred to as “asphalt rubber” or “rubber asphalt”.

— All kinds of reclaimed asphalt with air void content below 18 % (see EN 13108-8).

— Surface dressings (also known as chip seals) as defined in EN 12271.

— High friction surface courses (HFSC or HFS); surface treatments which utilize alternative materials such small-sized polish- and wear-resistant aggregates (often bauxite), bonded to the pavement surface using proprietary resin binders.

— Surface specified in ISO 10844.

B.2.2 Cement concrete surfaces

This category includes all kinds of road surfaces where the binder is cement, as defined in EN 13877-1; both with low and high porosity.

B.2.3 Porous asphalt surfaces

This category includes the following types.

— Porous asphalt concrete (PAC) as defined in EN 13108-7, but with design air void content of 18 % or higher, corresponding to void categories A to G in EN 13108-7, and not deteriorated into clogged condition.

— The same as above, but in partly clogged condition; in this case less than approximately 50 % of the pores are clogged by dirt and bitumen.

— Thin asphalt layers (TAL), as mentioned above, but with design air void content 18 % or more; TAL with small maximum aggregate sizes (4 mm to 6 mm) should be classified in the dense asphalt category for tyre H1 also for air void contents above 18 % (see EN 13108-2).

— PAC or TAL types to which a significant amount of rubber particles have been added (rubber up to 3 % by weight of the total mix); but having design air void content 18 % or more – these are often referred to as “open graded” types of “asphalt rubber” or “rubber asphalt” (although it is not often that design air void content is 18 % or higher).

NOTE 1 “Void content” in this document refers to geometric determination according to EN 12697-6.

NOTE 2 In case it is impossible to judge whether the surface has an air void content above or below 18 % (for example, after consulting the road contractor or the road authority), consider the surface as belonging to the dense asphalt surface category.

NOTE 3 In case it is impossible to judge whether the pores in the surface are clogged to more or less than 50 %, consider the surface as belonging to the porous asphalt surface category.

Annex C
(informative)

Selection of temperature for normalization

C.1 Air, road and tyre temperatures

Although it is recognized that the most relevant temperature for the normalization is probably tyre temperature, the temperature selected for correction is only air temperature. Tyre temperature is influenced not only by energy losses inside the tyre, but also by the cooling of the air surrounding the tyre as well as by the cooling or warming by the road surface in the tyre/road contact.

Temperature of a stationary or a running tyre varies substantially with both position of the sensor and with time. There is no agreement so far regarding where on or in the tyre one can measure the most relevant temperature. Furthermore, during operation, or after operation, temperatures on or in the tyre are generally not stable but vary with time, and this variation can interact with position of the sensor. It follows that the measurement of the most relevant tyre temperature for its noise influence is a very complicated matter which is so far not resolved. Tyre temperatures have consequently shown poorer correlations with noise emission than air or road temperatures and are not presently suitable for the normalization in this procedure. Nevertheless, for the purpose of collecting more information about the issue, for possible future use, it is recommended in this document to measure also tyre temperature.

On a global scale, road surface temperatures are generally well correlated with air temperatures. Exceptions are intensive sunshine on dark surfaces and short-term fluctuations in air temperature due to shadows or air turbulence. When there is intensive and unobstructed sunshine, road temperatures can by far exceed the air temperatures, but at temperatures considerably lower than the reference temperature, road surface temperatures can sometimes be lower than air temperatures.[9],[5]

Road surface temperatures have generally appeared not to give more accurate noise-to-temperature relations than air temperatures, and they can also vary substantially with position on the road and possible shadows. Since air temperature in most cases is more stable and slightly easier to measure, air temperatures have been selected for the normalization in this document.

It has been noted that in special conditions such as in urban locations dominated by high-rise buildings and where the heat island effect can be significant, noise may be better correlated with road surface temperature than with air temperature, or with an average of the two temperatures.[20] An average of the two temperatures may also be preferred to just the air temperature under conditions where direct sun radiation is negligible, such as in tunnels, in laboratories or during night time.[9],[20]

C.2 Linearity of the noise-to-temperature relations

The relations between noise and temperature are assumed in this document to be linear. This is because there is no firm evidence of a nonlinear behaviour. If the true relations are nonlinear, these nonlinearities have been too small in relation to measuring errors to be clearly detected so far.[5],[4]

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