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ISO 13473-5

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Characterization of pavement texture by use of surface profiles —

Part 5:
Determination of megatexture

Caractérisation de la texture d'un revêtement de chaussée à partir de relevés de profils de la surface —

Partie 5: Détermination de la mégatexture

Reference number
ISO 13473-5:2009(E)

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13473-5 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 13473 consists of the following parts, under the general title *Characterization of pavement texture by use of surface profiles*:

— *Part 1: Determination of Mean Profile Depth*

— *Part 2: Terminology and basic requirements related to pavement texture profile analysis*

— *Part 3: Specification and classification of profilometers*

— *Part 4: Spectral analysis of surface profiles* [Technical Specification]

— *Part 5: Determination of megatexture*

Introduction

Pavement surface texture largely influences factors such as noise emission caused by tyre/road interaction (Reference [7]), tyre/pavement friction (Reference [8]), and comfort, as well as rolling resistance and wear of tyres. Reliable methods of texture measurement are therefore essential.

Texture is subdivided into micro-, macro- and megatexture according to ISO 13473-2. A method for measurement and calculation of a macrotexture indicator based on a profile measurement is specified in ISO 13473-1. A procedure for measuring macrotexture by the volumetric patch method is described in ISO 10844:1994[2], Annex A. Currently, no reliable and practical method of measuring pavement microtexture *in situ* is available. This part of ISO 13473 aims to provide means of measuring and calculating megatexture indicators useful for pavement surface characterization.

Megatexture is an important texture range lying between macrotexture and unevenness. This type of texture has wavelengths of the same order of magnitude as a tyre/road interface and is often a result of potholes or 'washboarding'. Some common types of singularities, such as a single depressed or protruding spot on the pavement, will also show up in a texture profile spectrum as megatexture. Although some pavements, such as paving stones, possess an intrinsic megatexture, it is usually an unwanted characteristic resulting from defects in the surface.

The scope of ISO 13473 (all parts) does not include profile analysis of road unevenness, which is dealt with in ISO 8608[1].

Characterization of pavement texture by use of surface profiles —

Part 5: Determination of megatexture

1 Scope

This part of ISO 13473 specifies procedures for determining the average depth or level of pavement surface megatexture by measuring the profile curve of a surface and calculating megatexture descriptors from this profile. The technique is designed to give meaningful and accurate measurements and descriptions of pavement megatexture characteristics for various purposes.

Since there is an overlap between megatexture and the surrounding ranges, the megatexture descriptors unavoidably have a certain correlation with corresponding measures in those ranges. This part of ISO 13473 specifies measurements and procedures which are in relevant parts compatible with those in ISO 13473-1, ISO 8608[1] and EN 13036-5[6].

2 Normative references

The following referenced documents are indispensable for the application 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 13473-2:2002, *Characterization of pavement texture by use of surface profiles — Part 2: Terminology and basic requirements related to pavement texture profile analysis*

ISO 13473-3:2002, *Characterization of pavement texture by use of surface profiles — Part 3: Specification and classification of profilometers*

ISO/TS 13473-4:2008, *Characterization of pavement texture by use of surface profiles — Part 4: Spectral analysis of surface profiles*

ISO/IEC NP Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

3 Terms and definitions

For the purposes of this part of ISO 13473, the terms and definitions in ISO 13473-2, especially the following, apply.

3.1 General terms

3.1.1
pavement texture
texture
deviation of a pavement surface from a true planar surface, with a texture wavelength less than 0,5 m

NOTE It is divided into micro-, macro- and megatexture according to 3.2.

[ISO 13473-2:2002]

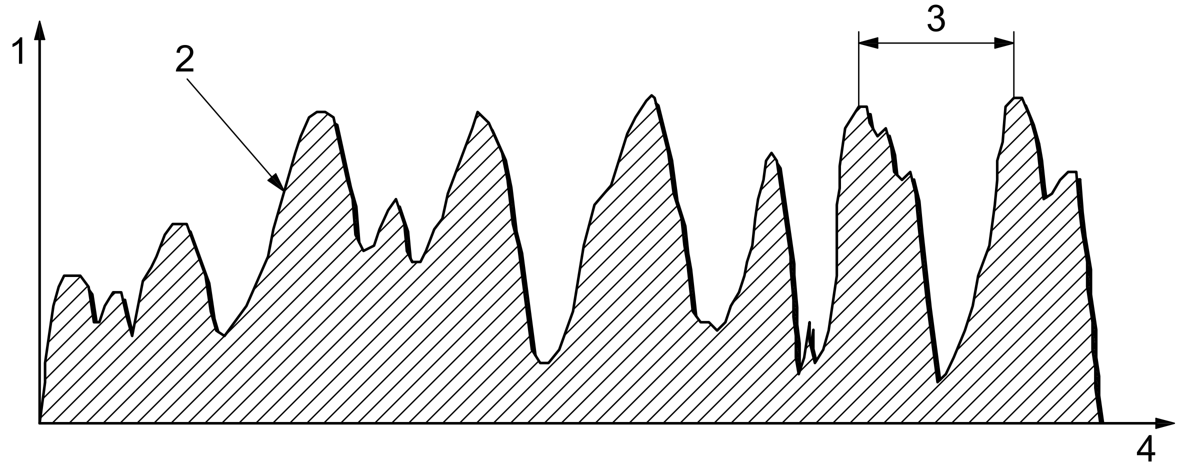
3.1.2
surface profile
texture profile
two-dimensional sample of the pavement surface generated if a sensor, such as the tip of a needle or a laser spot, continuously touches or shines on the pavement surface while it is moved along a line on the surface

NOTE 1 The profile of the surface is described by two coordinates: one in the surface plane, called “distance” (the abscissa), and the other in a direction normal to the surface plane, called “vertical displacement” (the ordinate). An example is illustrated in Figure 1. The distance may be in the longitudinal or lateral (transverse) directions in relation to the travel direction on a pavement, or any direction between these.

NOTE 2 Adapted from ISO 13473-2:2002.

NOTE 3 Texture profile is similar to surface profile but limited to the texture range.

NOTE 4 “Texture wavelength” is a descriptor of the wavelength components of the profile and is related to the concept of the Fourier transform of a time series. However, mathematically the correspondence is not exact. Note that vertical displacement (height) has an arbitrary reference.



Key

1 vertical displacement
2 profile
3 texture wavelength
4 distance

Figure 1 — Illustration of some basic terms describing pavement surface texture

3.1.3
profilometer
device used for measuring the profile of pavement surface

NOTE 1 Current designs of profilometers used in pavement engineering include, but are not limited to, sensors based on laser, light sectioning, needle tracer and ultrasonics technologies.

[ISO 13473-2:2002]

NOTE 2 Specifications for profilometers are dealt with in ISO 13473-3.

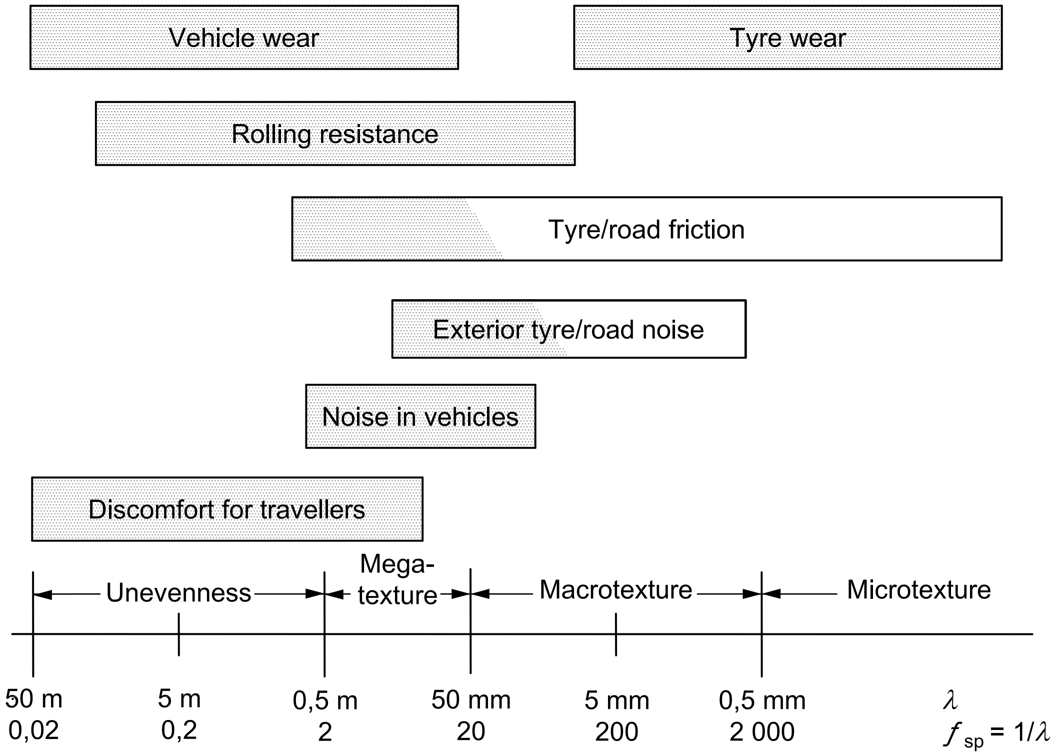
3.2 Ranges of texture

3.2.1
microtexture
pavement microtexture
deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of less than 0,5 mm, corresponding to texture wavelengths up to 0,5 mm expressed as one-third-octave centre wavelengths

NOTE 1 Peak-to-peak amplitudes normally vary in the range 0,001 mm to 0,5 mm. This type of texture is the texture which makes the surface feel more or less harsh but which is usually too small to be observed by the eye. It is produced by the surface properties (sharpness and harshness) of the individual chippings or other particles of the surface which come in direct contact with the tyres.

NOTE 2 Figure 2 illustrates the different texture ranges, with approximate limits regarding their effects on vehicle-pavement interactions.

[ISO 13473-2:2002]



Key

λ texture wavelength

f_{sp} spatial frequency, cycles/m

NOTE A lighter shade indicates a favourable effect of texture over this range, and a darker shade indicates an unfavourable effect.

Figure 2 — Ranges in terms of texture wavelength and spatial frequency of texture and unevenness and their most significant, anticipated effects

3.2.2
macrotexture
pavement macrotexture
deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 0,5 mm to 50 mm, corresponding to texture wavelengths with one-third-octave bands including the range 0,63 mm to 50 mm of centre wavelengths

NOTE 1 Peak-to-peak amplitudes may normally vary in the range 0,1 mm to 20 mm. This type of texture is the texture which has wavelengths of the same order of size as tyre tread elements in the tyre/road interface. Surfaces are normally designed with a sufficient macrotexture to obtain a suitable water drainage in the tyre/road interface. The macrotexture is obtained by suitable proportioning of the aggregate and mortar of the mix or by surface finishing techniques.

NOTE 2 Based on physical relations between texture and friction/noise, etc., the World Road Association (PIARC), originally defined the ranges of micro-, macro- and megatexture (Reference [9]). Figure 2, which is a modified version of the original PIARC figure, illustrates how these definitions cover certain ranges of surface texture wavelength and spatial frequency. Note that ride discomfort includes effects experienced in and on motorized road vehicles and bicycles, as well as wheelchairs and other vehicles used by disabled people.

NOTE 3 Adapted from ISO 13473-2:2002.

3.2.3
megatexture
pavement megatexture
deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 50 mm to 500 mm, corresponding to texture wavelengths with one-third-octave bands including the range 63 mm to 500 mm of centre wavelengths

[ISO 13473-2:2002]

NOTE Peak-to-peak amplitudes normally vary in the range 0,1 mm to 50 mm. This type of texture is composed of wavelengths with the same order of size as a typical tyre/road interface and is often created by potholes or ripples in the surface. It is usually an unwanted characteristic resulting from defects in the surface. Surface roughness with longer wavelengths than megatexture is referred to as unevenness and typically takes the form of undulations in the surface.

3.2.4
unevenness
pavement unevenness
deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 0,5 m to 50 m, corresponding to wavelengths with one-third-octave bands including the range 0,63 m to 50 m of centre wavelengths

NOTE 1 Pavement characteristics at wavelengths longer than 0,5 m are considered to be above that of texture and are referred to here as “unevenness”. For airfield applications, even wavelengths longer than 50 m would be considered.

[ISO 13473-2:2002]

NOTE 2 Longitudinal unevenness is a type of surface roughness which, through vibrations, affects ride comfort in, and road holding of, vehicles. Transverse unevenness, e.g. due to the presence of ruts, affects safety through lateral instability and water accumulation. It is not the intention of this part of ISO 13473 to include terms which are specifically related to unevenness. Such terms are defined in ISO 8608[1], ISO 16063-1[3], ASTM E 950-98[4], and EN 13036-5[6].

3.3 Megatexture measurement method

3.3.1
profilometer method
method in which the profile of a pavement surface is measured and the data used for calculation of certain mathematically defined measures

NOTE In most cases, the profile is recorded for subsequent analysis, in some cases it may be used only in real-time calculations.

[ISO 13473-2:2002]

3.4 Terms and parameters related to spectrum analysis of texture profiles

NOTE These terms and their applications are further described in ISO/TS 13473-4.

3.4.1
texture spectrum
spectrum obtained when a profile curve has been analysed by either digital or analog filtering techniques in order to determine the magnitude of its spectral components at different **texture wavelengths** (see 3.4.2) or **spatial frequencies** (see 3.4.3)

NOTE 1 A texture spectrum presents the magnitude of each spectral component as a function of either texture wavelength or spatial frequency.

NOTE 2 Adapted from ISO 13473-2:2002.

3.4.2
texture wavelength
λ
quantity describing the horizontal dimension of the irregularities of a texture profile

[ISO 13473-2:2002]

NOTE 1 Texture wavelength is normally expressed in metres or millimetres.

NOTE 2 Wavelength is a concept commonly used and accepted in electrotechnical and signal-processing vocabularies. Since many users of this part of ISO 13473 may not be accustomed to using the term wavelength in pavement applications, and because electrical signals are often used in the analyses of road surface profiles, there is the possibility of confusion. Hence the expression 'texture wavelength' is preferred here to make a clear distinction in relation to other applications.

NOTE 3 The profile may be considered as a stationary, random function of the distance along the surface. By means of a Fourier analysis, such a function may be mathematically represented as an infinite series of sinusoidal components of various frequencies (and wavelengths), each having a given amplitude and initial phase. For typical and continuous surface profiles, a profile analysed by its Fourier components contains a continuous distribution of wavelengths. The texture wavelength in ISO 13473 (all parts) is the reciprocal of the spatial frequency, the unit of which is reciprocal metre, equivalent to cycles per metre. See also 3.4.3.

NOTE 4 The wavelengths may be represented physically as the various lengths of periodically repeated parts of the profile; see Figure 1.

3.4.3
spatial frequency
f_{sp}
inverse of **texture wavelength** (3.4.2)

NOTE 1 Spatial frequency is normally expressed in reciprocal metres, see also 3.4.2, Note 3.

NOTE 2 The term “frequency” used in the time domain (more precisely “temporal frequency”), corresponds to “spatial frequency” in the space domain.

NOTE 3 Adapted from ISO 13473-2:2002.

3.5 Terms and parameters related to texture profile level

3.5.1
texture profile level
$L_{tx,\lambda}$
$L_{TX,\lambda}$
logarithmic transformation of an amplitude representation of a profile curve, $Z(x)$, the latter expressed as a root mean square value

NOTE 1 To distinguish between octave and one-third-octave bands, the subscript for L is written in capital letters when it relates to octave bands, $L_{TX,\lambda}$, and in lower case letters when it refers to one-third-octave bands, $L_{tx,\lambda}$.

NOTE 2 The texture profile level, in decibels, relative to a reference value of 10^{-6} m in one-third-octave bands having centre texture wavelength, λ, $L_{tx,\lambda}$, or the texture profile level, in decibels, relative to a reference value of 10^{-6} m in octave bands having centre texture wavelength, λ, $L_{TX,\lambda}$, can be expressed by Equation (1):

$$\left.\begin{aligned} L_{TX,\lambda} &= 10 \lg \frac{a_\lambda^2}{a_{ref}^2} \text{ dB} = 20 \lg \frac{a_\lambda}{a_{ref}} \text{ dB} \\ L_{tx,\lambda} &= 10 \lg \frac{a_\lambda^2}{a_{ref}^2} \text{ dB} = 20 \lg \frac{a_\lambda}{a_{ref}} \text{ dB} \end{aligned}\right\} \quad (1)$$

where

a_λ is the root mean square (r.m.s) value of the vertical displacement, in metres, of the surface profile;

a_{ref} is the reference value, i.e. 10^{-6} m.

NOTE 3 Octave-band and one-third-octave band filters are specified in ISO 13473-2:2002, 4.4.

EXAMPLE L_{tx80} denotes the texture profile level for the one-third-octave band having a centre texture wavelength of 80 mm, see ISO 13473-2:2002, Table 1.

NOTE 4 Texture amplitudes expressed as r.m.s. values, whether filtered or not, can have a range of several magnitudes; typically 10^{-5} m to 10^{-2} m. Spectral characterization of signals is used frequently in studies of acoustics, vibrations, and electrotechnical engineering. In all those fields it is most common to use logarithmic amplitude scales. The same approach is preferred in this part of ISO 13473.

NOTE 5 Texture profile levels in practical pavement engineering typically range from 20 dB to 80 dB with these definitions.

NOTE 6 Adapted from ISO 13473-2:2002.

3.5.2
megatexture level
L_{Me}
special case of texture profile level with the profile passing through a bandpass filter encompassing all one-third-octave bands within the megatexture range according to 3.2.3

[ISO 13473-2:2002]

3.6 Terms related to profilometer performance

3.6.1
evaluation length
l
length of a sample from a profile which has been or is to be analysed

NOTE Evaluation length is normally expressed in metres or millimetres.

[ISO 13473-2:2002]

4 Significance and use of the megatexture indicators

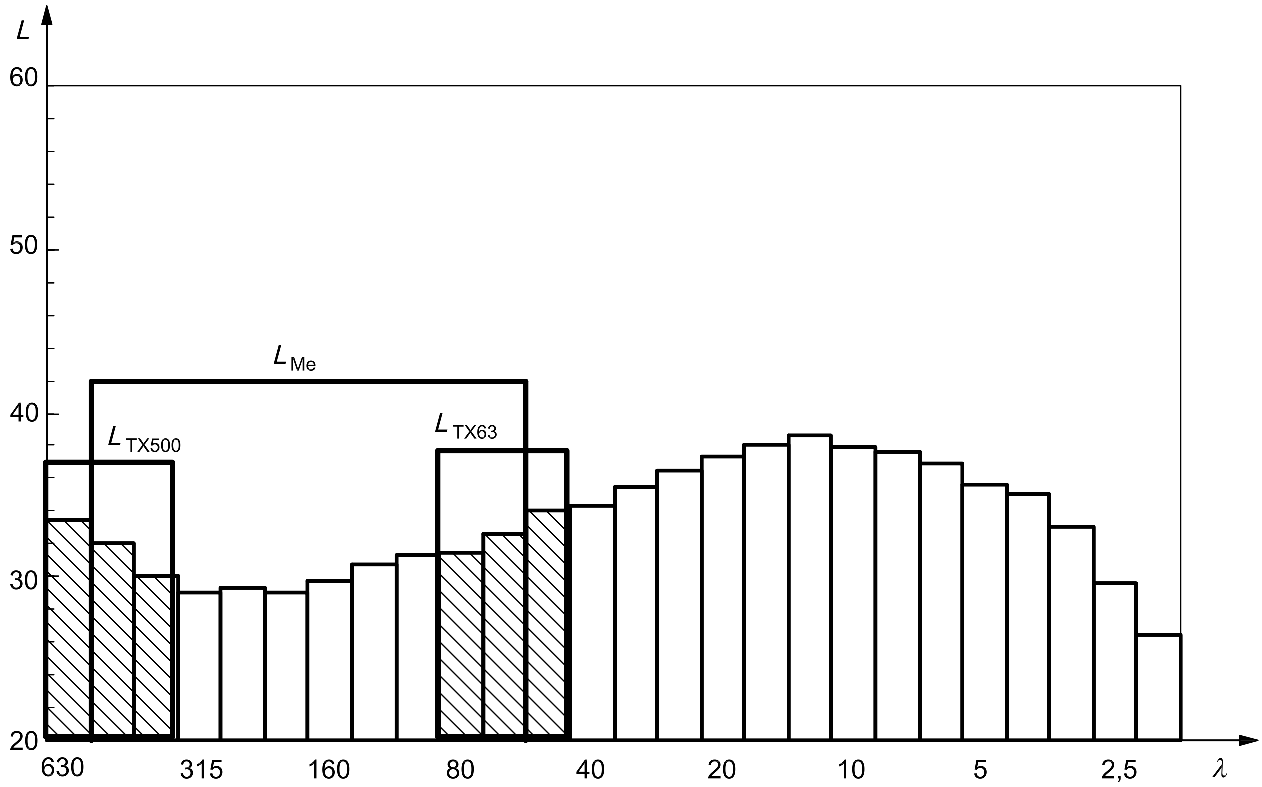
4.1 General

The indicator L_{Me} shall always be calculated and reported to ensure comparability between measurements. Depending on the aim of the study in question and information already obtained (e.g. unevenness or macrotexture measures), any or all of the three other indicators mentioned below may also be reported.

The profilometric method described in this part of ISO 13473 enables the indicators (see 4.2 to 4.5) characterizing the megatexture of a pavement surface to be determined.

4.2 Megatexture spectrum

This is a one-third-octave band texture spectrum covering the megatexture range and/or the adjacent ranges. A megatexture spectrum gives a relatively complete description of the megatexture characteristics and is used when a detailed description is needed. A spectrum covering the entire megatexture and most of the macrotexture range is shown in Figure 3 as an example.



Key

λ texture wavelength, in millimetres

L texture profile level, in decibels, relative to a reference value of 10^{-6} m

L_{Me} megatexture level

L_{TX63} texture profile level in octave bands having centre texture wavelength 63 mm

L_{TX500} texture profile level in octave bands having centre texture wavelength 500 mm

Figure 3 — Example of texture spectrum with indication of which bands are included in the L_{TX500} and L_{TX63} texture levels

4.3 Megatexture level

This indicator, L_{Me}, represents an overall description of defects existing in the deviation between the pavement surface and a true planar surface. Its characteristic dimensions range between 50 mm and 500 mm along the surface (this deviation corresponds to texture wavelengths analysed in one-third-octave bands, which include centre texture wavelengths from 63 mm to 500 mm). This indicator is used when there is a requirement to characterize megatexture by a single measure. It covers the range of the horizontal double headed arrow in Figure 3. For example, this parameter would be the most appropriate to identify potholes and other irregularities (Reference [11]).

4.4 Texture profile level relative to a reference value of 10^{-6} m in octave bands having centre texture wavelength 63 mm

This indicator, L_{TX63}, is one of the band levels derived from the above-mentioned spectral analysis. It represents a description of the pavement defects having the shortest dimensions within the megatexture range (deviation between the real surface and a true planar surface corresponding to texture wavelengths analysed in one-third-octave bands which include centre texture wavelengths from 50 mm to 80 mm, being equivalent to an octave band with a centre texture wavelength of 63 mm). This indicator facilitates the characterization of defects which correspond approximately to the length of a normal tyre/pavement contact patch and which, for this reason, play a direct role in the generation of tyre/road noise (Reference [7]). See the rectangle in Figure 3 labelled L_{TX63}.

4.5 Texture profile level relative to a reference value of 10^{-6} m in octave bands having centre texture wavelength 500 mm

This indicator, L_{TX500}, is similar to L_{TX63} but represents a longer wavelength within the megatexture range. It represents a description of the pavement defects having the longest dimensions within the megatexture range (deviation between the real surface and a true planar surface corresponding to texture wavelengths analysed in one-third-octave bands which include centre texture wavelengths from 400 mm to 630 mm, being equivalent to an octave band with a centre texture wavelength of 500 mm). This indicator enables the characterization of defects which can lead to tyres losing contact with the surface and therefore reduce safety (increase in stopping distances, loss of steering control in bends, etc.), and the comfort of the driver and passengers. This indicator is complementary to the information obtained by unevenness measurements at short unevenness wavelengths (0,7 m to 1,3 m). See the rectangle in Figure 3 labelled L_{TX500}.

NOTE Both octave-band levels L_{TX500} and L_{TX63} overlap into the adjacent ranges, although two of the three one-third-octave bands of these indicators are within the megatexture range. This is because the original definition of macrotexture and megatexture did not consider octave and one-third-octave bands; instead “even” numbers such as 500 mm and 50 mm were chosen as the limits. Technically, this overlap is unimportant.

The values obtained by processing of the profile curve when applying this part of ISO 13473 are insensitive to any asymmetry in the profile curve; so-called “positive” and “negative” texture. In principle, a megatexture feature having high but narrow peaks in the positive direction can have an influence on the tyre/road interaction which is quite different from a similar profile having inverse characteristics (the peak in the negative direction). Such profiles, one being the inverse of the other, give the same result in terms of the megatexture values obtained when applying this part of ISO 13473. The user is advised to observe some caution due to this when interpreting measurement results. However, so far, very little influence of this effect *in practice* has been reported and no accepted procedures to mitigate it are available. It is possible that, in any future revision of this part of ISO 13473, such effects will be taken into account; e.g. by applying some procedure simulating the enveloping of the texture by tyres. In the meantime, a user who wishes to consider this effect is recommended to apply the skewness parameter as defined in ISO 13473-2:2002, 3.7.5 as a measure supplementary to the ones in this part of ISO 13473. A type of pavement which potentially would give a high skewness is paving stones. For such a surface and similar types, the megatexture values would need to be used with caution.

5 Measurement and data processing principles

A vehicle-based non-contact system carries out the following operations:

a) measurement of the pavement surface profile curve;

b) preprocessing the measured profile to make it suitable for spectral analysis;

c) calculation of the texture spectrum of the profile of the longitudinal section within the megatexture wavelength range (not mandatory if L_{Me} is measured and calculated based on bandpass filtering);

d) from the spectrum, the indicator L_{Me} is calculated; alternatively L_{Me} is measured by means of a bandpass filter having suitable upper and lower limiting frequencies;

e) from the spectrum, the indicators L_{TX63} and L_{TX500} may be calculated (optional).

NOTE Calculations are normally carried out in real time, although post-processing is an option.

6 Test surface considerations

6.1 General

The measurements shall not be taken in rain or snow. The surface shall be dry during measurements, unless it has been established that the equipment used works equally well on a wet or dry surface. In addition, the surface shall be clean and free of all elements which could disturb the measurements.

NOTE Measurements with an optical system are not necessarily very reliable for asphalt surfaces which have recently been paved, since these are usually exceptionally dark and shiny. If megatexture tests are carried out during or rather soon after laying of asphalt, distortions due to temperature gradients in the air above the test surface can influence the measurement results.

For roads open to traffic, texture normally varies over a cross-section. In this case, the lateral position of the measurements should be in accordance with the planned use of the results.

6.2 Test lengths

It is recommended that measurements and calculations be made along the entire test section; i.e. if a profile is recorded longitudinally along the test section, 100 % of the measured line should be utilized, if possible.

Although a continuous measurement is the ideal, the measured length shall include no less than five evenly distributed profiles per 100 m test section. The evaluation length of each profile shall normally be 10 m. However, in cases where stationary profilometers are used, shorter lengths may be used. The minimum evaluation length is then 3 m for octave band analysis as well as for determination of L_{Me}, or 9 m for one-third-octave band analysis.

To determine the variability in longitudinal direction, represented by longitudinal standard deviation, a number of surface profiles, each the length of one evaluation length (refer to the previous paragraph), shall be measured (see also 9.4).

When characterizing a long test section with relatively short sample lengths, ensure that the texture within the sample length(s) is sufficiently representative of the total length. It is necessary to determine the minimum number of samples necessary to minimize the effect of any suspected non-homogeneities.

7 Measuring equipment

7.1 General

Use a profilometer system which produces an electrical signal that is proportional to the distance between a sensor reference plane and a given surface sample point. Typically, the sensor would normally be an electro-optical device or a video camera, but other devices that comply with the requirements of ISO 13473-3 may be used. The final output shall be linearly related to the texture profile and linearity may be obtained either in hardware or software.

The profilometer system shall also provide means of moving the sensor along or across the surface at an elevation (vertically) which is essentially constant over at least one full wavelength. However, this is not applicable when the profile is produced by a technique such as light sectioning where the profile and its reference line or plane are recorded instantaneously.

The profilometer system shall meet the following specifications according to ISO 13473-3:

Mobility class: Mobile, Fast or Slow

Texture wavelength: Class EF (63 mm to 500 mm) or wider

Minimum vertical measuring range: 60 mm

Minimum horizontal uninterrupted measuring (evaluation) range: 3 m (when using octave bands) or 9 m (when using one-third octave bands)

Vertical resolution: 0,04 mm or better

Horizontal resolution: 20 mm or better

Maximum sampling interval: 20 mm (10 mm or better recommended)

Texture wavelength range of sensor and recording system: The frequency response of the entire measuring and data collection system shall be within ±1 dB over the entire megatexture range

Background noise: Maximum r.m.s. value: 0,05 mm (see further in ISO 13473-3:2002, Table 7)

Alignment of sensor and local slope limitation: Refer to ISO 13473-3:2002, 6.10

7.2 Sensitivity to ambient light

The output profile signal shall not change by more than 0,1 mm when changing between dark and bright surroundings.

7.3 Sensitivity to surface optical properties

The output profile signal shall not change by more than 0,1 mm when moving the sensor between very dark and very bright materials. It is recommended that checks be made on the system by moving the sensor over a smooth surface having transitions from white to black to white.

NOTE Newly laid surfaces, at least if bituminous, generally have glossy and extremely dark appearances. Profilometers relying on optical beams usually have problems with such surfaces because too little light is diffused in the direction of the receiving element. Drop-out rates become high and there may be transients at extreme transitions between dark and bright surfaces. The same applies to surfaces that are dark due to moisture.

7.4 Sensitivity to dampness/wetness of surface

Report whether the output profile is sensitive to the degree of moisture on the pavement, and any type or quantity of wetness or dampness considered acceptable.

8 Measurement method

8.1 General

The measurements shall comprise the following operations:

a) testing of the sensitivity to vertical motion of the vehicle (only at certain intervals, see 8.4);

b) calibration of the profilometer system (see 8.2);

c) running the profilometer over the test section and measuring the pavement surface profile (see 8.3), using a suitable test speed as specified in 8.3;

d) preprocessing of the profile to make it suitable for spectral analysis (see 8.5 and 8.6).

8.2 Calibration

Calibration shall be carried out by running the sensor over a special calibration surface utilizing a well-defined profile. The vertical deviation of the calibration surface, in relation to its theoretical profile, shall not exceed 1 % of its peak-to-peak amplitude; roughly corresponding to 0,1 dB.

Calibration procedures are not further specified here. They shall be designed such that the extra standard uncertainty introduced by the procedure (in addition to the calibration surface, see above) is no worse than 0,1 dB.

Report the type of calibration used.

NOTE For calibration procedure and examples of calibration surfaces, refer to the principles explained in ISO 13473-3:2002, Annex A. Consider the possibility of an adaptation to the appropriate wavelength range for megatexture, although a calibration surface intended for the macrotexture range can be used also for megatexture if the fundamental wavelength is at least 10 mm.

8.3 Measuring speed

Variations in the measuring speed affect the accuracy of the measured profile; see also ISO/TS 13473-4:2008, 6.1. This clause also provides requirements for a distance-based measuring system. The speed with which the profile is traced shall be such that the requirements on sampling and bandwidth are met.

NOTE 1 The measuring speed may affect the frequency scale of any spectral analysis. The temporal frequency, f, is given by

$$f = v f_{sp}$$

where

v is the speed;

f_{sp} is the spatial frequency (reciprocal wavelength).

NOTE 2 According to the sampling method and the existence of any low-pass filter, the speed can influence the minimum wavelength limit.

8.4 Sensitivity to vertical motion of the vehicle

Ensure that the sensor is stable in its vertical position at least during the measurement of a full evaluation length and for all operating speeds, or that it has some means of compensation for vertical motions. This requires that vertical motions, e.g. those occurring at the natural suspension frequency of the sensor and/or its carrier, shall have negligible influence, i.e. shall not violate the background noise requirements specified in 7.1.

A suitable test is to run the test vehicle (carrying the measuring device) on a smooth and even surface so that the tyres roll over an object, having a height of 20 mm to 25 mm, a width of 200 mm and a length of 100 mm to 150 mm, placed on the surface. Rolling over the object will excite vertical motions in the vehicle. The difference in recorded profile with and without the object is an indication of the influence of vertical motion of the vehicles.

The testing described in this clause is necessary when the performance of the measuring system is checked the first time, as well as at later intervals when the vehicle suspension system performance may have changed.

8.5 Preprocessing: Indication of invalid readings and measures to avoid their influence

The profilometer system shall have means of ensuring that invalid readings do not significantly influence the measured results. For example when the signal becomes invalid, it may be held at the previous correct level, or a linear interpolation may be made between the previous and following correct levels. The linear interpolation procedure is preferred. See also ISO 13473-3.

8.6 Preprocessing: Drop-out rate and validity of measurements

The measurements on a particular pavement are considered valid only if the drop-out rate for the evaluation length in question meets one of the following criteria (Reference [10]):

a) if linear interpolation is used, a drop-out rate of up to 10 % is acceptable;

b) if linear interpolation is not used, the last valid reading before the drop-out shall be considered as a substitute for the drop-out value(s), and in such a case the drop-out rate shall not exceed 5 %.

NOTE Drop-outs can occur. They are mainly due to specific photometrical properties in the test surface or to the absorption of the light in deep profile depressions. In addition, laser diodes (if used) lose their strength little by little when in use, which can eventually lead to an excessive frequency of drop-outs. Means of checking on a regular basis the intensity of the light-emitting device are necessary.

9 Data processing

9.1 General

The measurements and calculations shall comprise the following operations:

a) calculation of the texture spectrum (in one-third octaves) of the longitudinal section of the pavement within the megatexture wavelength range;

b) calculation of the indicator L_{Me} from the spectrum.

Alternatively, the indicator L_{Me} can be measured directly by using a suitable bandpass filter having a passband coinciding with the limiting frequencies of the 500 mm and 63 mm one-third-octave bands; in which case it is not necessary to calculate the full spectrum.

Optionally, the following calculations may be made:

— from the spectrum, the indicators L_{TX63} and L_{TX500} may be calculated;

— the longitudinal standard deviation, s, representing the variability of L_{Me}, L_{TX63} and L_{TX500} between 10 m sections of the profile, may be useful as a measure of homogeneity of a surface.

NOTE Calculations are normally carried out in real time, although in principle this is only optional.

9.2 Texture spectrum

9.2.1 General

This clause specifies requirements and makes recommendations applying to spectral analyses of texture profile signals. The intention is to aid in selection of suitable types of spectra and to make presentations of texture spectra and scales of diagrams more uniform.

More detailed technical specifications for spectral analysis are given in ISO/TS 13473-4.

9.2.2 Presentation of texture spectrum

A texture spectrum shall be presented with the logarithmic value of texture wavelength and/or spatial frequency on the abscissa. The order of values from left to right is preferred to be decreasing wavelength and/or increasing spatial frequency. The ordinate of the texture spectrum shall be the texture profile level, $L_{\mathrm{tx},\lambda}$ or $L_{\mathrm{TX},\lambda}$.

The use of a logarithmic measure does not preclude the use of a linear value; i.e. the r.m.s. value. Wherever it is practical, it is recommended to use the linear value as a supplement to the logarithmic one. This can be accomplished, e.g. by providing a scale for texture profile level on the left vertical axis of a spectral diagram and profile r.m.s. value on the right vertical axis.

NOTE The requirement above makes measured spectral shapes similar regardless of whether texture wavelength or spatial frequency is used. Parallel presentation in the same diagram is also possible; e.g. see the dual labelling of the abscissa in Figure 2.

9.2.3 Spectral bandwidth

Within the scope of this part of ISO 13473, performance of spectral analysis using octave- or especially one-third-octave bandwidths is preferred. Constant-bandwidth, twelfth-octave or narrow-band spectra are not recommended in this case, since these usually give data with finer spectral resolution than warranted by the measurements and by the sample, and thus collect too much data of limited use.

NOTE 1 Spectral analysis can be made with different bandwidths of the texture wavelength or spatial frequency scale. The bandwidth is the range of texture wavelength or spatial frequency which the spectral amplitude or level covers, and is defined as the width of the band between the points where the signal is attenuated by 3 dB.

NOTE 2 It is possible to use the narrower bands specified here to calculate wider bands.

9.2.4 Centre frequencies of spectral bands

Octave or one-third-octave bands shall have centre texture wavelengths and centre spatial frequencies according to Table 1, which is established so as to numerically correspond to the bands specified in IEC 61260. The upper and lower cut-off (–3 dB) limits of each band, as well as the shape of the filter frequency response should conform to IEC 61260 (see also ISO/TS 13473-4).

NOTE The range shown in Table 1 covers the range over which most profilometers currently operate. This range may be extended at both ends by extrapolating the numerical series, should the measuring instruments permit this.

Table 1 — Centre texture wavelengths and spatial frequencies

Octave bands		One-third-octave bands		Range
Texture wavelength λ mm	Spatial frequency f_{sp} m^{-1}	Texture wavelength λ mm	Spatial frequency f_{sp} m^{-1}	
		....	1,60	unevenness
		630		↓
500	2,00	500	2,00	↑
		400	2,50	
		315	3,15	
250	4,00	250	4,00	
		200	5,00	megatexture
		160	6,30	
125	8,00	125	8,00	
		100	10,0	
		80,0	12,5	
63,0	16,0	63,0	16,0	↓
		50,0	20,0	↑
		....		macrotexture

9.3 Single number indicators

Calculate L_{Me} based on the definition in 3.5.2. As a basis for this, use one-third-octave band levels or r.m.s. values of vertical displacement according to 3.5.1. The calculations are made as follows.

For each one-third-octave band, use the linear value a_λ of the profile (see 3.5.1). If the measuring device delivers a level $L_{\text{tx},\lambda}$ instead of the r.m.s. value, calculate the r.m.s. value by applying the antilog equation:

$$a_\lambda^2 = a_{\text{ref}}^2 \, 10^{(L_{\text{tx},\lambda}/10)}$$

Calculate the summation of all relevant third-octave-band values to arrive at a value representing the full megatexture range and denoted a_{Me}^2 from the expression:

$$a_{\text{Me}}^2 = a_{63}^2 + a_{80}^2 + a_{100}^2 + a_{125}^2 + a_{160}^2 + a_{200}^2 + a_{250}^2 + a_{315}^2 + a_{400}^2 + a_{500}^2$$

Calculate the corresponding megatexture level (see 3.5.2), L_{Me}, as follows:

$$L_{\text{Me}} = 10 \lg \left(\frac{a_{\text{Me}}}{a_{\text{ref}}} \right)^2 \text{ dB}$$

where a_{ref} is the reference value, 10^{-6} m.

Calculate (optionally) the texture profile level (3.5.1), L_{TX63} or L_{TX500}, using the same principle as for L_{Me}, but using

$$a_{\text{TX63}} = a_{50}^2 + a_{63}^2 + a_{80}^2$$

$$a_{\text{TX500}}^2 = a_{400}^2 + a_{500}^2 + a_{630}^2$$

Alternatively, the L_{Me} can be obtained by measuring the signal output from a bandpass filter that has its lower limiting frequency corresponding to a texture wavelength of 562 mm and its higher limiting frequency corresponding to a texture wavelength of 56 mm (with the same cut-off rate as that of one-third-octave bands according to IEC 61260).

The result(s) shall be reported, in decibels, as levels relative to 10^{-6} m. As an option, the results can, moreover, be reported in millimetres. To convert from logarithmic values, $L_{\text{tx},\lambda}$, in decibels, to linear, a_λ, in millimetres, use the following equation:

$$a_\lambda = 10^3 a_{\text{ref}} 10^{(L_{\text{tx},\lambda}/20)}$$

9.4 Longitudinal standard deviation

The longitudinal standard deviation, s, is the standard deviation for either L_{Me}, L_{TX63} or L_{TX500}, between all the levels measured on consecutive sections of the profile within the full test length:

$$s = \sqrt{\frac{\sum_{i=1}^{n} \left(L_i - \overline{L} \right)^2}{n-1}}$$

where

n is the number of samples (evaluation lengths) within the test length;

L_i is the texture profile level of an individual evaluation length (see 6.2);

$\overline{L}$ is the arithmetic mean of all texture profile levels over the full test length.

To distinguish between the standard deviations referring to L_{Me}, L_{TX63} or L_{TX500}, respectively, subscripts are used as follows:

s_{Me} is the longitudinal standard deviation of L_{Me};

s_{TX63} is the longitudinal standard deviation of L_{TX63};

s_{TX500} is the longitudinal standard deviation of L_{TX500}.

9.5 Singularities

A singularity is a roughness feature of the surface that does not repeat itself from one evaluation length to another within a 100 m distance. Examples of singularities are:

a) potholes, if not repeated or continued over a distance longer than 10 m;

b) sunken manholes;

c) bridge joints;

d) damaged joints between concrete slabs (although the joints themselves are usually repeated regularly and shall not be considered as singularities);

e) severe loss of chippings at a single place;

f) level changes on a pavement where a section has been ground away temporarily or between two types of wearing courses;

g) markings at pedestrian crossings;

h) depressions due to mechanical damage to the pavement.

To represent the megatexture level of a singularity, process the measured profile as follows:

Calculate the L_{Me} over a 10 m evaluation length within which the singularity is located and use this level as a typical value representing the singularity. The symbol for this measure is L_{sg}.

A high value of L_{Me} is not sufficient to define a singularity; a visual observation that supports it is also required.

NOTE Further information on the subject can be found in Reference [12].

10 Measurement uncertainty

The uncertainty of results obtained from measurements according to this part of ISO 13473 shall be evaluated, preferably in compliance with ISO/IEC NP Guide 98-3. If reported, the expanded uncertainty together with the corresponding coverage factor for a stated coverage probability of 95 % as defined in ISO/IEC NP Guide 98-3 shall be given. Guidance on the determination of the expanded uncertainty is given in Annex B.

11 Safety considerations during measurements

WARNING — This part of ISO 13473 may involve hazardous operations when measurements are made on trafficked pavements. 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 part of ISO 13473 does not purport to address the safety problems associated with its use. It is the responsibility of the user of this part of ISO 13473 to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

12 Test report

Present the results in a form comprising at least the following items

a) references:

1) identification of the organization carrying out the test,

2) description and identification of the measuring system,

3) name of the organization requesting the tests (optional),

4) identification of the measuring team (optional),

5) date at which the measuring device was checked and/or calibrated by an authorized agency as well as the name of the organization that performed this service;

b) identification of the site:

1) road number or street name,

2) measured section, preferably indicating both beginning and end (e.g. including kilometre markings),

3) class of road including number of lanes (optional), as well as the history of the site, e.g. the date of paving and any substantial and identifiable damage (optional),

4) lane and driving direction of the measurements,

5) measured track (e.g. left wheel track, right wheel track or between wheel tracks);

c) test surface description:

1) type of pavement,

2) maximum chipping size and gradation if available,

3) origin of the materials (optional),

4) condition of the surface (optional),

5) particular features of the paving technique used (optional);

d) special characteristics of the test area and the test:

1) date of measurement,

2) weather conditions (optional),

3) particular test conditions, e.g. any presence of dirt on the pavement or precipitation (optional);

e) presentation of results comprising:

1) evaluation length and measured test length,

2) measured L_{Me}, including the arithmetic mean as well as its standard deviation, s_{Me},

3) measurement identification number (optional),

4) longitudinal location of each measurement (optional),

5) measured one-third-octave-band spectrum (optional),

6) measured L_{TX63} (optional), including the arithmetic mean and standard deviation, s_{TX63},

7) measured L_{TX500} (optional), including the arithmetic mean and standard deviation, s_{TX500},

8) value, L_{sg}, of any prominent singularity,

9) histogram of the values obtained on the tested section (optional),

10) expanded measurement uncertainty.

Annex A contains an example of a test report.

Annex A
(informative)

Example of test report and graphical presentations

A.1 Form suitable as a test report

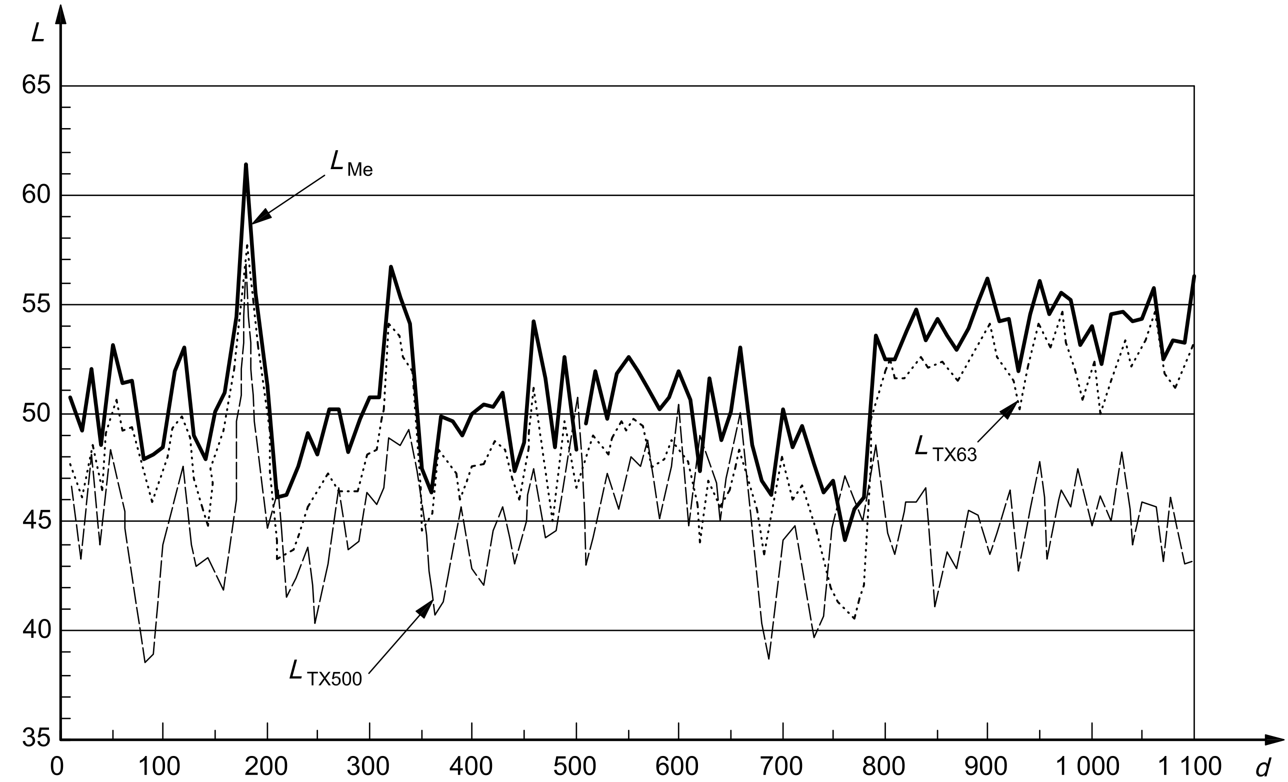
The form on the following page is an example of how a test report may be designed. The user of this standard is allowed to copy this form.

It is recommended that the test report be supplemented with graphical presentations as shown in Figures A.1, A.2 and A.3.

A.2 Graphical presentations

A.2.1 Amplitude versus distance and histogram

For a measurement representing a certain road test section, it is appropriate to show the measured single number indicators. Figure A.1 shows such a measurement running over an 1 100 m test section. Note that if the test section is much longer than 1 km, it is advisable for synchronization purposes to include in the measurement data, as well as in the presented diagram, kilometre markers made by the measurement operator or by some automatic means. Figure A.2 shows the same data but in a histogram illustrating the frequency of occurrence of each level.

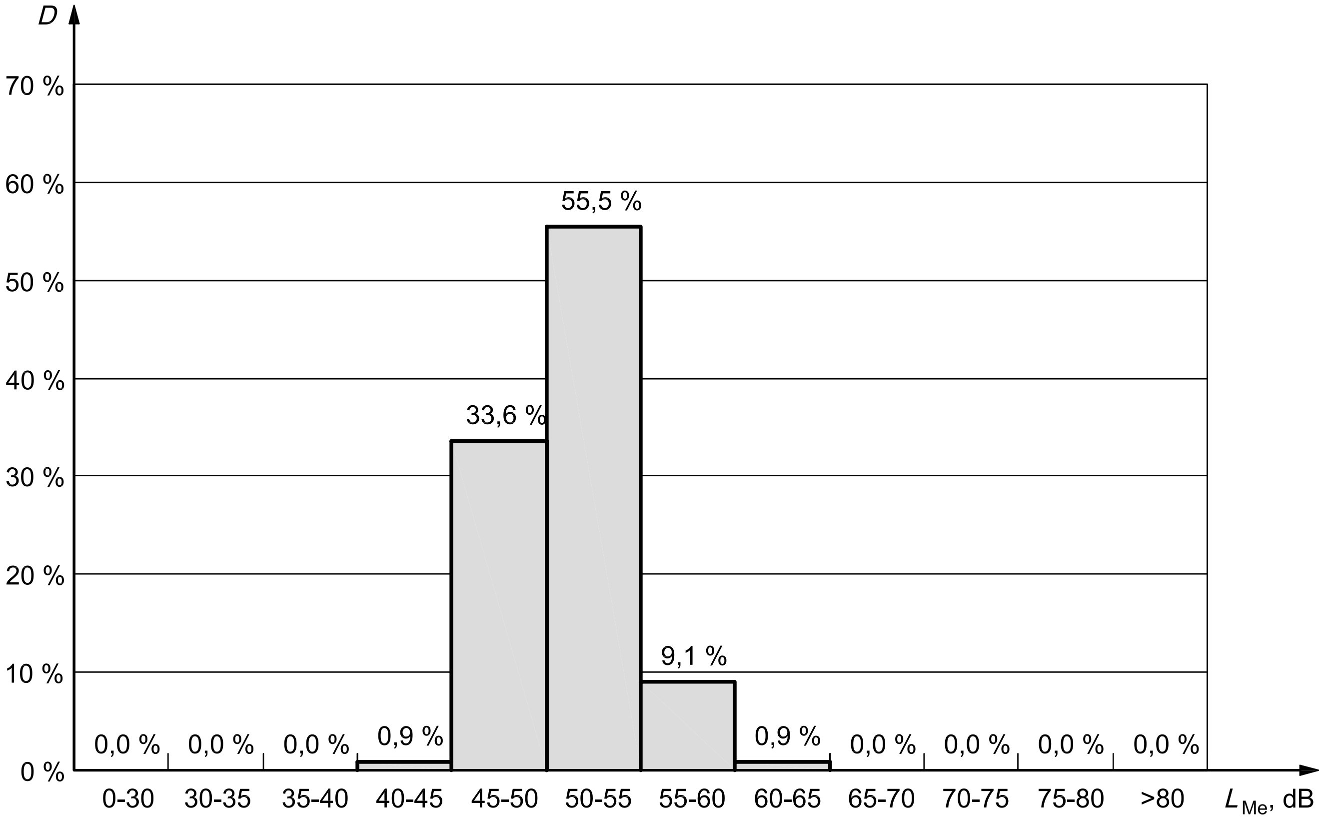


Key

d	distance along test section, in metres
L	texture profile level relative to a reference value of 10^{-6} m, in decibels
L_{Me}	megatexture level
L_{TX63}	texture profile level in octave bands having centre texture wavelength 63 mm
L_{TX500}	texture profile level in octave bands having centre texture wavelength 500 mm

NOTE Evaluation length was 10 m.

Figure A.1 — Example of measured texture profile levels, expressed as L_{Me}, L_{TX500} and L_{TX63}, over a test section 1 100 m long



Key

D frequency of occurrence of observed values of L_{Me}

L_{Me} megatexture level

Figure A.2 — Example of histograms of measured texture profile levels, in the special case of megatexture level, L_{Me}

Table A.1 — Measurement of megatexture — Test report

<table>
<tr><th colspan="4">References</th></tr>
<tr><td colspan="2">Testing organization:</td><td colspan="2">Ordering organization (optional):</td></tr>
<tr><td colspan="2">Measuring system:</td><td colspan="2">Measuring team (optional):</td></tr>
<tr><td colspan="4">Measuring system check/calibration by authorized agency (date and document):</td></tr>
<tr><th colspan="4">Site identification</th></tr>
<tr><td colspan="2">Road/street number:</td><td colspan="2">Measured test section (location, start & finish):</td></tr>
<tr><td colspan="2">Lane and driving direction:</td><td colspan="2">Measured track (right/left/between/etc. wheel track):</td></tr>
<tr><td colspan="4">Category of road, paving & condition history (optional):</td></tr>
<tr><th colspan="4">Test surface description</th></tr>
<tr><td colspan="2">Type of pavement (e.g. formal designation):</td><td colspan="2">Maximum chipping size and/or gradation (if available):</td></tr>
<tr><td colspan="2">The origin of the road material (optional):</td><td colspan="2">Particular features of the paving technique (optional):</td></tr>
<tr><td colspan="4">Condition of the surface, including any indications of predominance of “positive” or “negative” texture (optional):</td></tr>
<tr><th colspan="4">Special characteristics of test area and the test</th></tr>
<tr><td colspan="2">Date of measurement:</td><td colspan="2">Weather conditions (optional):</td></tr>
<tr><td colspan="4">Particular test conditions; e.g. existence of dirt on the surface or any precipitation (optional):</td></tr>
<tr><th colspan="4">Test results</th></tr>
<tr><td colspan="2">Measured test length:</td><td colspan="2">Evaluation length:</td></tr>
<tr><td colspan="2">Measurement identification number:</td><td colspan="2">Location of this measurement within the test section (if applicable):</td></tr>
<tr><td colspan="2">Road profile diagram enclosed (e.g. Figure A.1)?</td><td colspan="2">Histogram enclosed (e.g. Figure A.2)?</td></tr>
<tr><td colspan="4">One-third-octave spectrum enclosed (e.g. Figure A.3)?</td></tr>
<tr><td>Mean L_{Me}:</td><td colspan="2">Standard deviation s_{Me}:</td><td>Expanded uncertainty (95 %) U_{tot}:</td></tr>
<tr><td>Mean L_{TX63}:</td><td colspan="2">Standard deviation s_{TX63}:</td><td>Expanded uncertainty (95 %) U_{tot}:</td></tr>
<tr><td>Mean L_{TX500}:</td><td colspan="2">Standard deviation s_{TX500}:</td><td>Expanded uncertainty (95 %) U_{tot}:</td></tr>
<tr><td colspan="4">Values of L_{sg} of any prominent singularities:</td></tr>
</table>

A.2.2 Spectral diagrams

Several means of graphically presenting texture spectra are possible; although the ordinate is always some amplitude- or level-related value, and the abscissa is always either spatial frequency or texture wavelength. In the pavement texture field, it is common for the ordinate to be expressed in decibels per one-third-octave band and the abscissa in one-third-octave band centre frequency.

The megatexture band includes 10 one-third-octave bands, the centre spatial frequencies, $f_{sp,c}$, of which vary between 1,6 m^{-1} (0,63 m) and 16 m^{-1} (0,063 m). Each of these bands has an upper limit, F_{up}, and a lower limit, F_{lo}, set by the following relations:

$$F_{up} = 10^{1/20} f_{sp,c}$$

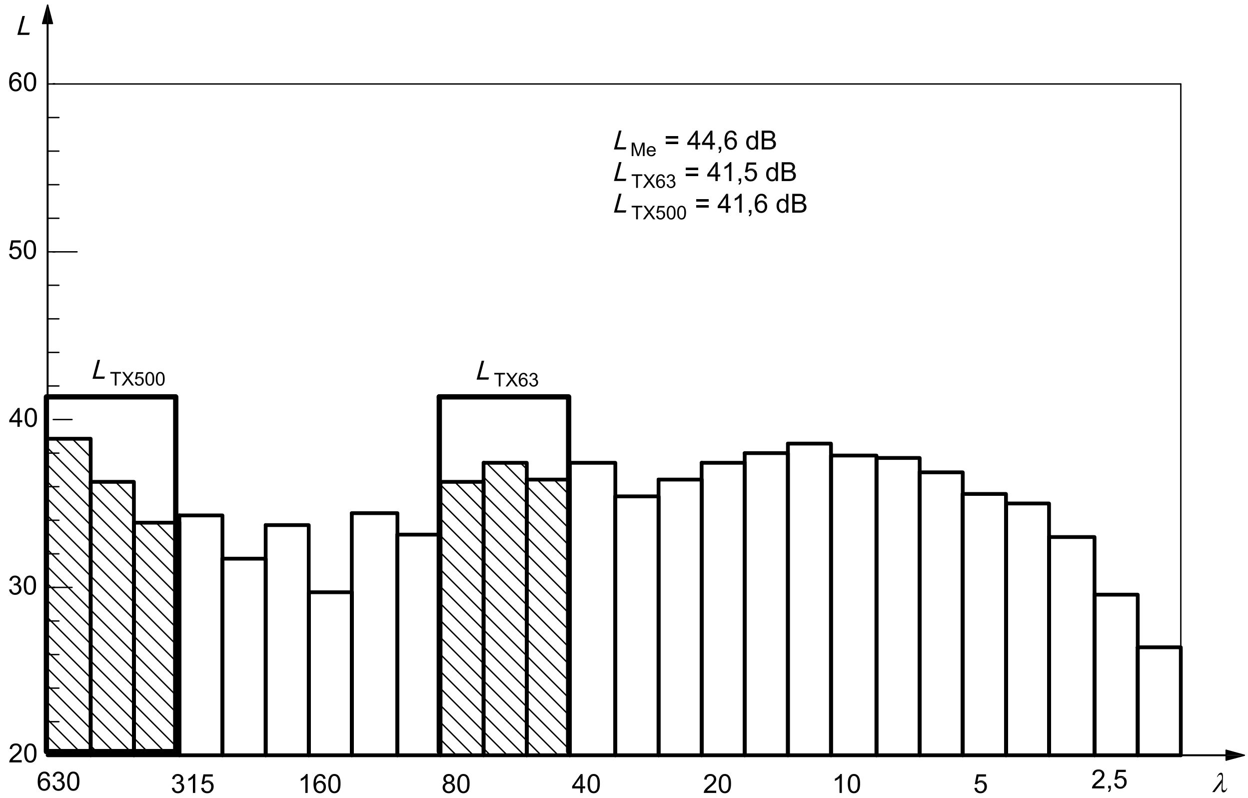
$$F_{lo} = 10^{-1/20} f_{sp,c}$$

Centre spatial frequency values in Table 1 are derived using these relations.

In the fields of vibration and acoustical engineering, it is common to calculate an average power spectral density (PSD) per band, which leads to the accumulated power being divided by the bandwidth (applied to texture, the result should be expressed in cubic metres). However, according to this part of ISO 13473, it is preferred to present the power per one-third-octave band rather than its PSD.

An example of a suitable presentation of a texture spectrum is shown in Figure A.3. This is an average spectrum (power-based) over the entire measured test length. Note that instead of presenting bars, one may use just points at each centre texture wavelength and connect these with lines. Note also that the abscissa runs from long wavelengths to the left to short wavelengths to the right. This is because the spectrum is based on a spatial frequency scale, in analogy with a frequency scale in vibration and acoustical engineering. This is also the common scale when presenting spectra in the pavement unevenness range.

NOTE The spectrum in Figure A.3 covers not only megatexture but also the main part of the macrotexture range. Of course, for the purposes of this part of ISO 13473 it is necessary to include only the megatexture range. However, it is common that the mega- and macrotexture ranges are treated together. It is left to the discretion of the user to decide whether to combine the megatexture and macrotexture spectra in one graph or just display megatexture.



Key

λ texture wavelength, in millimetres

L texture profile level, in decibels, relative to a reference value of 10^{-6} m

NOTE The level of each octave band is indicated by the level of the top line of each rectangle. The spectrum presented represents a pavement having a relatively low megatexture (a dense asphalt concrete with maximum 10 mm chippings in near new condition).

Figure A.3 — Example of one-third-octave band texture spectrum with indication also of the texture levels of the octave bands, L_{TX500} and L_{TX63}

A.3 Example of measured values

Table A.2 shows typical examples of measured values on various pavements expressed as L_{Me} (Reference [13]). Note that these are just examples. There may be large differences in values measured on similar surfaces at other places.

Table A.2 — Typical examples of measured values expressed as L_{Me}

Pavement type	Typical L_{Me} value dB
Pure resin (test track sealed by epoxy)	39
Dense asphalt concrete 0/10	44
Very thin asphalt concrete 0/10	52
Surface dressing 2/3	52
Surface dressing 10/14 (old and worn)	54
Porous asphalt concrete 0/14	56
Exposed aggregate cement concrete (new)	57
Surface dressing on cement concrete	60
Surface dressing 10/14 (new condition)	63
Paving stones (old cobblestone street)	66

Annex B
(informative)

Measurement uncertainty

B.1 General information

Uncertainties can principally be expressed as standard uncertainties or expanded uncertainties. In summary, standard uncertainties are expressed as the standard deviations of a given measure around the estimated average value, whereas the expanded uncertainty multiplies the standard uncertainty with a coverage factor that, under the assumption of a normal distribution, is taken as 2 for a coverage probability of 95 %.

The expanded uncertainty rather than the standard uncertainty should be reported since the former provides a better coverage probability; i.e. a "safer" estimate of the uncertainty.

The general expression for the calculation of the megatexture level, L_{Me}, is Equation (B.1):

$$L_{\mathrm{Me}} = \overline{L}_{\mathrm{Me}} + \delta_{\mathrm{hom}} + \delta_{\mathrm{cal}} + \delta_{\mathrm{prof}} \qquad \text{(B.1)}$$

where

$\overline{L}_{\mathrm{Me}}$ is the expectation (mean) value of the band level derived from 9.3;

δ_{cal}, δ_{hom}, δ_{prof} are uncertainties (see Clause B.2).

For any other band level determined according to this part of ISO 13473, the same principle and equation applies, with the symbol for the band level changed as appropriate.

NOTE Lack of homogeneity of the test object and the associated lack of representativity of the chosen sample give rise to δ_{hom}, while δ_{cal} and δ_{prof} are due to imperfections in the method and the equipment.

B.2 Contributions to measurement uncertainty

B.2.1 General

The uncertainty of the results of megatexture measurements based on pavement surface profiles is determined by contributions from the major sources listed in B.2.2 to B.2.4.

NOTE 1 The expectation value of all the uncertainties, δ, is zero.

NOTE 2 The uncertainties caused by drop-outs can be neglected in the megatexture range, provided the requirements on drop-out rate are observed.

NOTE 3 The spectrum analysis uncertainty contribution, δ_{spectr}, is treated in ISO/TS 13473-4:2008, Annex A and is not part of measurement uncertainty. As such it does not appear in this part of ISO 13473. Note that the measurement uncertainty discussed here does form a part of spectrum analysis uncertainty should the practitioner use spectral analysis (see ISO/TS 13473-4:2008, Annex A).

NOTE 4 For octave and one-third-octave band levels, which indicate use of spectral analysis, the uncertainty here should be included in the analysis as described in ISO/TS 13473-4:2008, Annex A. The values here only represent the measurement uncertainties.

B.2.2 Uncertainty due to calibration

This is the contribution to the uncertainty budget due to calibration errors, denoted δ_{cal}. It depends on precision in manufacturing of calibration surfaces as well as uncertainty in the calibration procedure; see 8.2 and ISO 13473-3, Annex A. The suggested value of 0,1 dB for the standard uncertainty assumes reasonably high quality surfaces but yet includes an acceptable margin of safety.

B.2.3 Uncertainty due to surface inhomogeneity

This arises out of not measuring the entire test length (of 100 m), and is denoted δ_{hom}. Evaluation of the profile at shorter test lengths will introduce an uncertainty to the budget due to the fact that the measured length may not represent the entire length completely. Its value can be measured by recording the standard deviation of the profile measured at a number of lengths, e.g. 5 measurements at 3 m length each.

NOTE In addition, the uncertainty in measurement is due to lateral variability of the pavement megatexture. However, this is a product variation which is not considered here.

B.2.4 Uncertainty due to profilometer

This type of uncertainty, denoted δ_{prof}, contains two contributions: δ_{bkgr} and δ_{lin}.

The influence of background (electronic) noise, δ_{bkgr}, is highest when measuring on very smooth megatextures, but will be lower when measuring rougher megatextures.

In this part of ISO 13473, the influence of profilometer vertical non-linearity, δ_{lin}, is assumed to take a standard uncertainty value of 1 % (see ISO 13473-3), but the exact value for specific equipment should be obtained from the manufacturer.

The square root of the sum of the squares of the two contributions gives δ_{prof}, as in Equation (B.2):

$$\delta_{prof} = \sqrt{\delta_{bkgr}^2 + \delta_{lin}^2} \tag{B.2}$$

The estimated contribution of the combined background noise and non-linearity standard uncertainties to the budget is 0,25 dB. This value assumes a very smooth megatexture (L_{Me} = 43 dB to 48 dB); higher values normally give lower uncertainties. See also ISO 13473-3.

In addition to the non-linearity expressed by δ_{lin}, which is due to the profilometer sensor, there might for certain profilometers be another type of nonlinearity that is caused by secondary light (laser) spot reflections on adjacent slopes of the profile curve. If this occurs, it should be included in δ_{lin}.

B.2.5 Example of uncertainty budget

Table B.1 presents a "budget" for standard uncertainty. This assumes that measurements are made by application of this part of ISO 13473, as well as ISO 13473-3:2002, e.g. Table 7. The values in Table B.1 are examples based on the experience of a number of users taking part in the development of this part of ISO 13473, and are not necessarily valid for any other user.

Table B.1 — Example of uncertainty budget (standard uncertainty) for L_{Me}, L_{TX63} and L_{TX500}

Quantity	Estimate dB	Standard uncertainty u_i dB	Probability distribution	Sensitivity coefficient c_i	Uncertainty contribution $c_i u_i$
δ_{hom}	0	To be determined	Normal	1	To be determined
δ_{cal}	0	0,1	Normal	1	0,1
δ_{prof}	0	0,25	Normal	1	0,25

B.3 Combined and expanded uncertainty

The sources of uncertainty in Table B.1 are considered to be uncorrelated. Therefore, the estimated combined standard uncertainty, u_{comb}, is given by the square root of the sum of squares of the individual uncertainties contained in Table B.1 as follows:

$$u_{\text{comb}} = \sqrt{u_{\text{hom}}^2 + u_{\text{cal}}^2 + u_{\text{prof}}^2 + u_{\text{spectr}}^2} \tag{B.3}$$

The individual standard uncertainties should be multiplied by their respective sensitivity coefficients prior to squaring. However, in this case, the sensitivity coefficients are all assumed to be equal to 1; thereby simplifying the equation. The expanded uncertainty, U_{exp}, for a coverage factor of 2, corresponding to a coverage probability of 95 % in accordance with the guidelines given in ISO/IEC NP Guide 98-3, is given by Equation (B.4):

$$U_{\text{exp}} = 2u_{\text{comb}} \tag{B.4}$$

The expanded uncertainty for L_{Me} based on the combined standard uncertainties derived from Table B.1 is 0,5 dB. Note that the u_{hom} contribution is not taken into account here, which would be valid for cases where one measures the full test section. Even when measuring the minimum test length, this uncertainty adds a rather small contribution to u_{comb} for surfaces in “normal condition”, but may be significant for very inhomogeneous surfaces.

Table B.2 presents the expanded uncertainties based on an actual validation experiment (Reference [13]) performed by one of the organizations taking part in the development of this part of ISO 13473. These uncertainties include the u_{hom} contribution as well as the spectral analysis uncertainties. However, it should be noted that u_{hom} may vary over a wide range depending on the type of surface and how large are the parts of it that are measured.

Table B.2 — Expanded uncertainties (95 % coverage probability assumed) based on an actual experiment (Reference [13])

	L_{Me}	L_{TX63}	L_{TX500}	One-third-octave band levels
Expanded uncertainty, dB	0,8	0,9	1,2	

NOTE The expanded uncertainty obtained in this way is the same as the 95 % confidence interval (single-sided) provided the values are normally distributed. For detailed explanations, see ISO/IEC NP Guide 98-3. For a summary refer to ISO 16063-1:1998, Annex A.

Experimenters are encouraged to determine their own uncertainty values, based on special measurements and experience using the device which is used. However, in cases where these data are not available, the values given in Table B.2 may be used for temporary guidance.

The following advice for performing uncertainty studies may be useful: the values of the above mentioned standard uncertainties (per each type) should preferably be evaluated for actual parameter values and conditions that apply to a specific measurement and analysis case. This evaluation may be done by executing comparative measurements and analyses of representative or typical pavement sections for different values of one of the parameters influencing the uncertainty, while all other parameters remain unchanged.

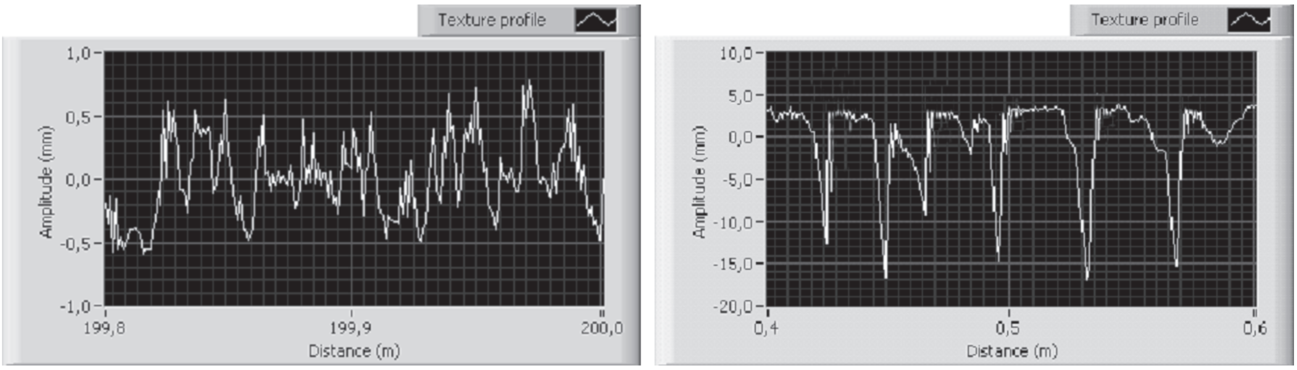
Annex C
(informative)

Profile asymmetry issues

The spectral analysis used in this part of ISO 13473, in a statistical sense a second moment analysis, cannot reveal all relevant characterizations of the pavement surface profile. The mathematical operations involved in the discrete Fourier transform and the determination of the PSD disregard any asymmetry of the signal under analysis.

Therefore the user of this method should be aware that some relevant information contained in the profile may be lost during the process of spectral analysis. In particular, a possible asymmetry of the profile, resulting in a “positive” or “negative” texture will not be expressed in the results of the analysis. It would require an analysis of the skewness; i.e. the third statistical moment of the quantity, to reveal this aspect of the profile.

Nevertheless, a “positive” texture (exhibiting protrusions) may show a significantly different behaviour in functional qualities, like skid resistance or noise generation, than a negative texture (exhibiting depressions). This would appear mainly in the macrotexture range and not so much in the megatexture range. Furthermore, there would be a few examples of positive or negative textures also in the megatexture range which may have some influence. See Figure C.1.



a) b)

Figure C.1 — Examples of surface profiles of: a) positive macrotexture; and b) negative macrotexture

Although the method of spectral analysis does have these shortcomings it is considered to be sufficiently relevant as a method of characterization of road surfaces and is therefore elaborated in this part of ISO 13473 with the aim of standardizing the method and improving the uniformity of the determination of road surface characteristics.

Possible methods to deal with the asymmetry problem are under consideration and are likely to be investigated during the years immediately following the publication of this part of ISO 13473. Such methods may be:

a) the application of a weighting factor to the spectral values that is proportional to the quotient of the mean profile depth to the root mean square of the profile — the value of this quotient should be reasonably well correlated with the skewness or asymmetry of the profile;

b) the development of a method of spectral analysis on the third moment of the profile (skew) instead of on the unprocessed profile;

c) the application of a tyre-enveloping function to the profile before spectral analysis is applied — a consequence of this approach would be that the enveloping behaviour of a tyre would have to be defined and standardized.

At the time of publication of this part of ISO 13473 the conclusion is that no solution for a more comprehensive spectral description of road surface profiles is ready for standardization. If a method becomes available during the next few years, ISO/TS 13473-4 may be the appropriate place to incorporate such a method.

Bibliography

[1] ISO 8608, *Mechanical vibration — Road surface profiles — Reporting of measured data*

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[3] ISO 16063-1:1998, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts*

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