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Characterization of pavement texture by use of surface profiles —

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

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

Partie 2: Terminologie et exigences de base relatives à l'analyse de profils de texture d'une surface de chaussée

Reference number
ISO 13473-2:2002(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 13473 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13473-2 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*

Introduction

The terminology related to surface texture analysis by profiling techniques used in International Standards for applications other than pavements is often not appropriate for pavement analysis. Although many basic measurement and analysis procedures in these other applications are similar to those used in pavement analysis, the terminology has by tradition developed very differently. It is therefore necessary to issue this terminology standard for **pavement** applications, although attempts have been made to be consistent with the other terminology standards where suitable.

Characterization of pavement texture by use of surface profiles —

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

1 Scope

This part of ISO 13473 defines terms, expressions and parameters that are related to the analysis of pavement texture, on roads as well as on airport runways and taxiways. In particular, it defines terms and expressions related to profile representations of texture, which are anticipated to be useful in the modelling of pavement characteristics such as tyre/road noise emission, tyre/road friction, tyre rolling resistance and tyre wear. In addition, some brief general information on pavement surface characteristics and their effects is presented.

This part of ISO 13473 also contains some basic requirements in connection with the use of the terms, expressions and parameters.

Profile analysis of machined surfaces is not included, since this subject is dealt with in other International Standards, for example ISO 3274, ISO 4287, ISO 4288, ISO 5436-1 and ISO 12085. Profile analysis of road unevenness, which is dealt with in ISO 8608, is also excluded.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of ISO 13473. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 13473 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

3 Terms and definitions

For the purposes of ISO 13473 (all parts), the following terms and definitions 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.

3.1.2
surface profile
texture profile
two-dimensional sample of the pavement texture 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 The profile of the surface is described by two coordinates: one along the surface plane, called “distance” (the abscissa), and the other in a direction normal to the surface plane, called “amplitude” (the ordinate); refer to the example illustrated in Figure 1. The distance may be in a longitudinal or lateral (transverse) direction in relation to the travel direction on a pavement, or any direction between these.

3.1.3
texture wavelength
quantity describing the horizontal dimension of the irregularities of a texture profile

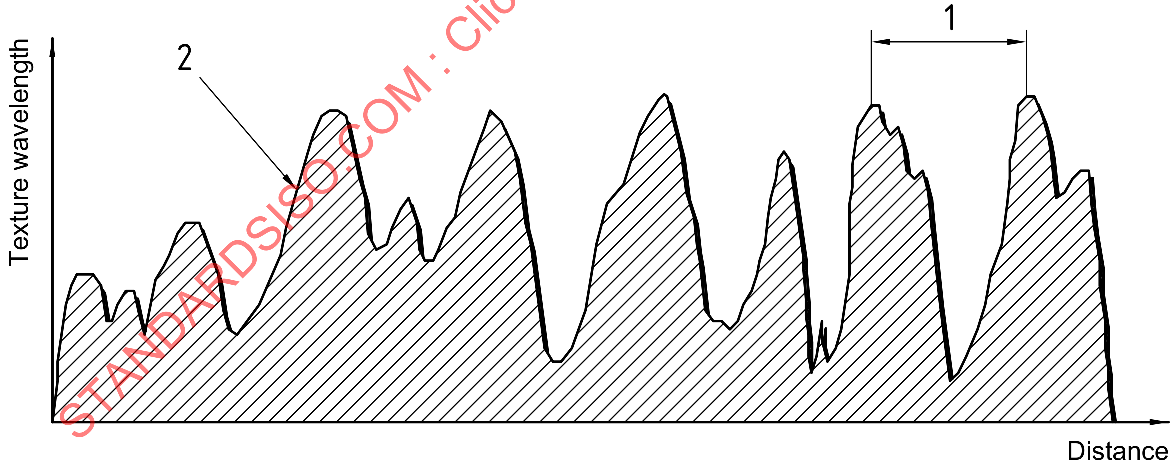
NOTE 1 Texture wavelength is normally expressed in metres (m) or millimetres (mm).

NOTE 2 Wavelength is a concept commonly used and accepted in electrotechnical and signal-processing vocabularies. 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 can 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 is the inverse of the spatial frequency, the unit of which is m^{-1} [equivalent to cycles per metre (cycles/m)]. Refer also to 3.8.2.

NOTE 3 The wavelengths can be represented physically as the various lengths of periodically repeated parts of the profile, see Figure 1.

3.1.4
profilometer
device used for measuring the profile of pavement texture

NOTE 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.



Key

1 Amplitude
2 Profile

NOTE “Texture wavelength” is an illustration of a component of the profile related to the wavelength concept but is not correct from a strictly mathematical point of view. Also note that amplitude (height) has an arbitrary reference.

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

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.

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 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 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 relationships between texture and friction/noise, etc., the World Road Association (PIARC) originally defined the ranges of micro-, macro- and megatexture (see reference [14]). Figure 2 illustrates how these definitions cover certain ranges of surface texture wavelength and spatial frequeny.

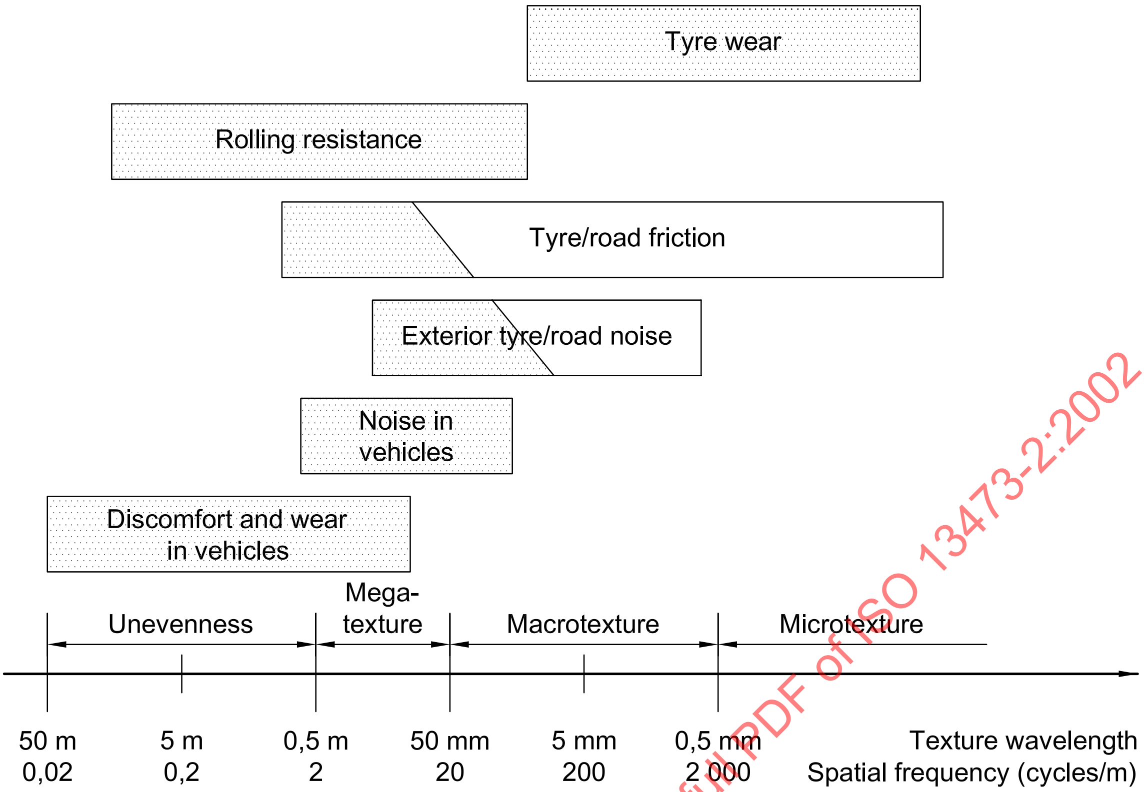
3.2.3
megatexture
pavement megatexture
deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 50 mm to 500 mm, corresponding to texture wavelengths with one-third-octave bands including the range 63 mm to 500 mm of centre wavelengths

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

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.

NOTE 2 Longitudinal unevenness is a type of surface roughness which, through vibrations, affects ride comfort in and road holding of vehicles. Transverse unevenness due to, for example, rutting, 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, prEN 13036-5 and prEN 13036-8.



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

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

3.3 Macrotexture depth measures

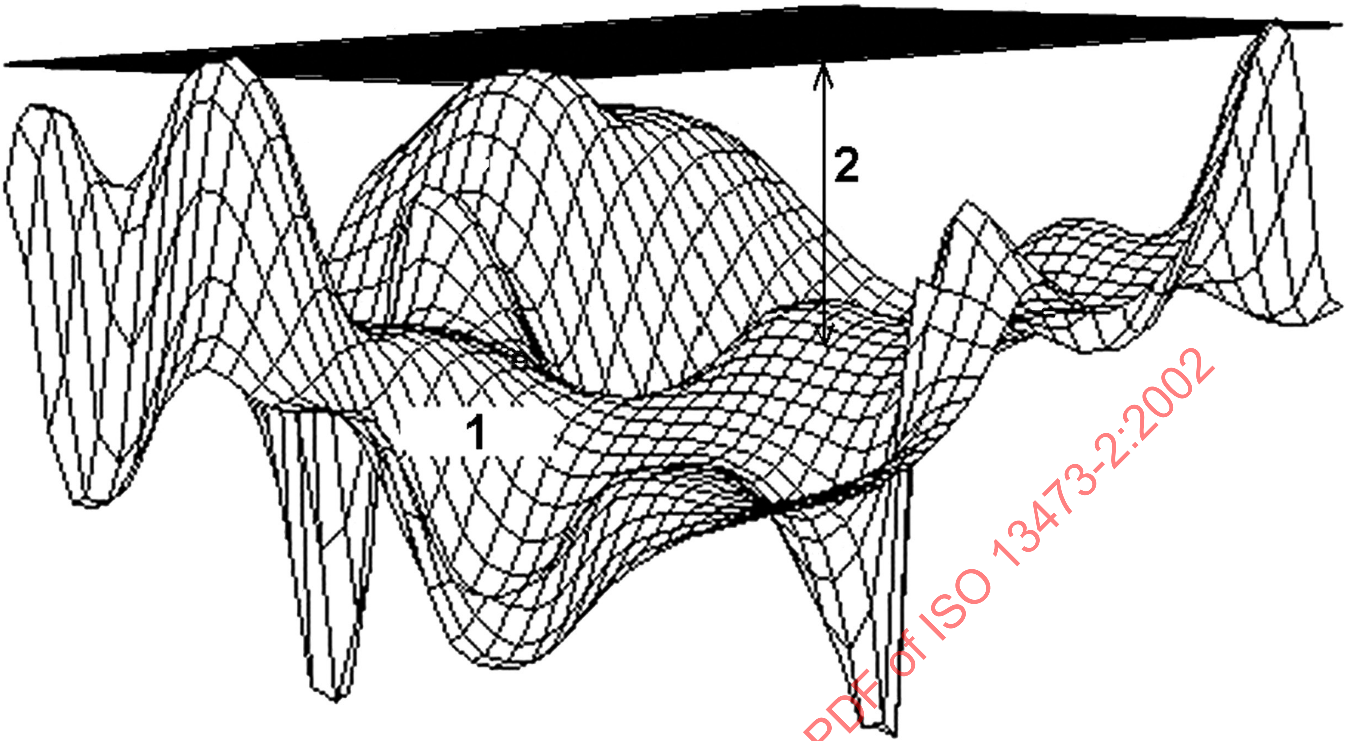
3.3.1
texture depth
distance between the textured surface and a plane through the peaks of the three highest particles within a surface area in the same order of a size as that of a tyre/pavement interface

See Figure 3.

NOTE 1 Texture depth is normally expressed in millimetres (mm).

NOTE 2 Texture depth refers to a three-dimensional case.

NOTE 3 Figure 3 illustrates the texture of a pavement in the three-dimensional case and the term “texture depth”, which is the distance between an arbitrary point of the plane down to the surface perpendicular to the plane. The plane is defined by the three highest peaks of the surface. The texture depth according to this definition depends on the size and position of the reference plane.



Key

1 Surface

2 Texture depth

Figure 3 — Illustration of the terms surface and texture depth

3.3.2
Mean Texture Depth
MTD
quotient of a given volume of standardized material and the area of that material spread in a circular patch on the surface being tested

NOTE 1 Mean Texture Depth is normally expressed in millimetres (mm).

NOTE 2 A method based on measurement and calculation of MTD is standardized as the “volumetric patch method”, see ISO 10844:1994, annex A, and EN 13036-1. The reference “plane” described in 3.3.1 is then in practice determined by the contact between a rubber pad and the surface, when this pad is rubbed over the area in order to spread out the material in a circular patch. Therefore, the texture depth obtained in this case is not based on a “plane”, but on a somewhat curved surface that attempts to simulate the tyre/road contact.

3.3.3
profile depth
height difference between the profile and a horizontal line through the highest peak (the peak level) within a distance along the surface of the same order of length as a tyre pavement interface,

See Figure 4.

NOTE 1 Profile depth is normally expressed in millimetres (mm).

NOTE 2 Whereas texture depth and mean texture depth both refer to a three-dimensional case, the term “profile depth” refers to a two-dimensional case, i.e. when studying a profile.

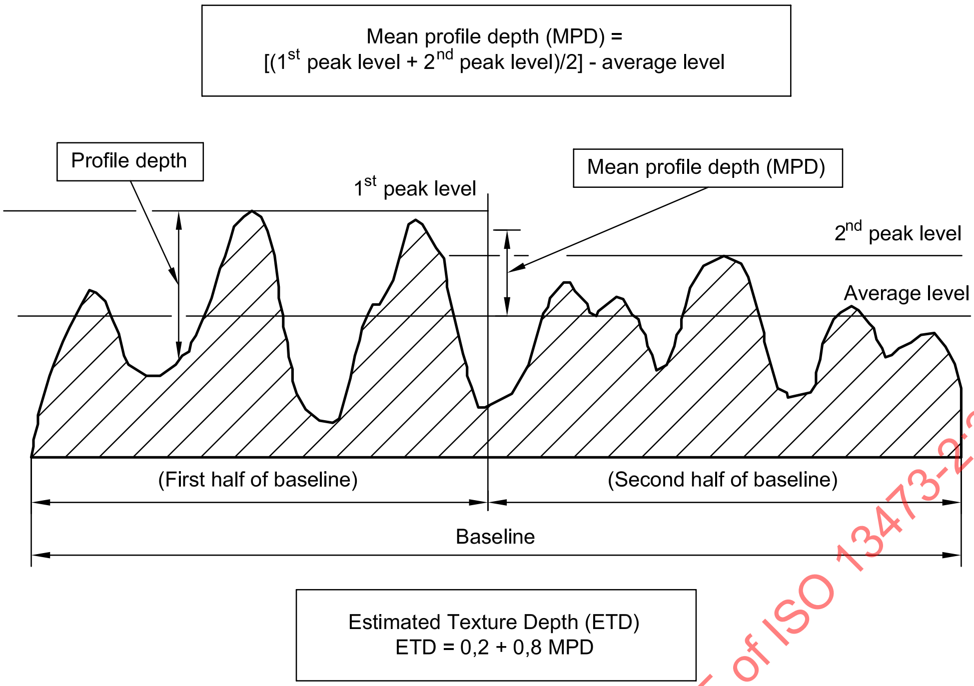


Figure 4 — Illustration of the terms baseline, average level, peak level, profile depth, MPD and ETD

3.3.4
Mean Profile Depth
MPD
average value of the profile depth over a 100 mm long baseline

NOTE 1 Mean Profile Depth is normally expressed in millimetres (mm).

NOTE 2 An illustration of the terms and their determination is given in Figure 4.

NOTE 3 Measurement of the Mean Profile Depth is specified in ISO 13473-1 and ASTM E1845. For practical reasons, MPD is calculated as the difference between the arithmetic mean of the peak levels of the two baseline halves and the average level over the full baseline (see Figure 4). In ISO 13473-1 the average level always becomes zero, since it is equal to the (horizontal) profile reference line obtained after slope and offset suppressions (see 3.7.1) have been applied.

NOTE 4 Note that averaging the profile depth over a longer continuous profile than the specified baseline will generally not give the same value as when averaging the MPD over the same length.

3.3.5
Estimated Texture Depth
ETD
estimate of the Mean Texture Depth (MTD) from a measurement of Mean Profile Depth (MPD), by means of a transformation equation:

$$ETD = 0,2 + 0,8\ MPD \quad (1)$$

where ETD and MPD are expressed in millimetres (mm)

NOTE Calculation of the Mean Profile Depth is specified in ISO 13473-1. Equation (1) is taken from this standard.

3.4 Macrotexture measurement methods

3.4.1
volumetric patch method
method for the measurement of Mean Texture Depth, based on a given volume of fine-grained material which is spread out on a surface with a rubber pad to form an approximately circular patch, the average diameter of which is measured to obtain, by dividing the volume of the material by the area covered, the average depth of the layer, i.e. the Mean Texture Depth (MTD)

NOTE 1 The volumetric patch method is standardized in ISO 10844:1994, annex A, EN 13036-1 and ASTM E965. This method is based on the use of glass spheres of a specified size range as the material to be spread out on the pavement.

NOTE 2 An alternative material that has been used instead of the now standardized glass spheres is sand. The “sand patch test” was the traditional term used to describe this method which has been in worldwide use for many decades. Sand is no longer preferred since glass spheres give better reproducibility. Although less common, other materials have been used, for example putty or grease.

3.4.2
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 1 In most cases, the profile is recorded for subsequent analysis; in some cases it is used only in real-time calculations.

NOTE 2 A standard for measurement of the Mean Profile Depth (MPD) with the profilometer method is specified in ISO 13473-1.

NOTE 3 The above-mentioned measures and methods are primarily applicable to macrotexture studies but some of them may have potential application to micro- and megatexture as well.

3.5 Terms related to spatial variation of texture

3.5.1
periodic texture
surface texture which exhibits a repeated characteristic pattern or waveform, with a periodicity which may or may not be directional

See Figure 5.

3.5.2
random texture
texture which does not exhibit a noticeable periodicity

See Figure 5.

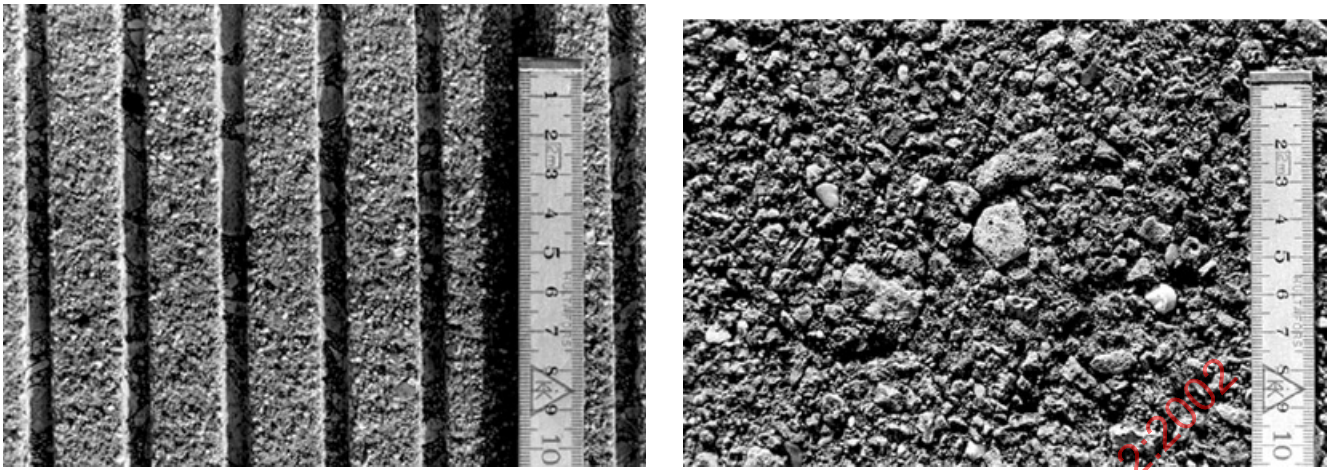
NOTE The definitions of periodic and random textures here are intended for the layman. For mathematically correct definitions of random and periodic signals, refer to text books on random signal processing.

3.5.3
isotropic texture
texture which exhibits similar texture characteristics in all directions within the plane of the surface

See Figure 5.

3.5.4
anisotropic texture
texture which exhibits some directional characteristics, such as, but not limited to, transversal and longitudinal grooves

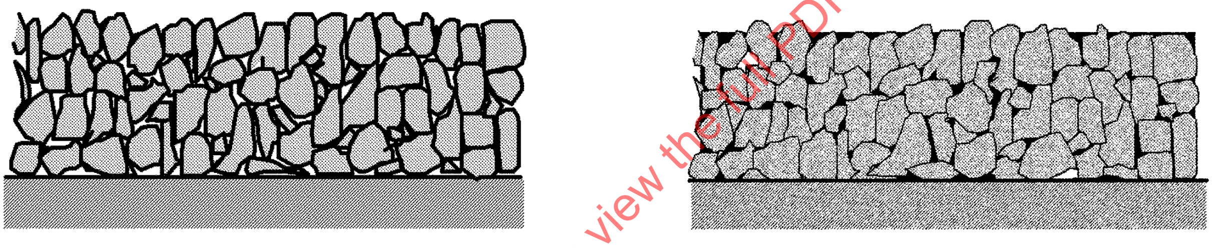
See Figure 5.



a) **Periodic anisotropic texture**

b) **Random isotropic texture**

Figure 5 — Examples of periodic anisotropic texture and random isotropic texture



a) **Porous surface layer**

b) **Layer with closed texture**

Figure 6 — Illustration of a porous surface layer with many interconnected voids, and a closed texture (dense-graded aggregate distribution) in which a binder and smaller aggregate fill most of the voids

3.5.5
porous surface layer
surface layer in which there is a significant number of connected cavities

See Figure 6.

NOTE Such pavement types are often called “drainage”, “porous” or “pervious” pavements. This definition of a porous surface layer does not characterize its efficiency for acoustical or other purposes.

3.5.6
open texture
surface under which there are re-entrant cavities open to the surface

3.5.7
closed texture
surface in which the number of cavities is small and in which the cavities are rarely connected

See Figure 6.

NOTE 1 Such pavement types are made using a “dense-graded” aggregate which results in a “dense layer” intended to be impervious to water and air; “closed texture” is the prefered term to characterize the top of the layer.

NOTE 2 Porous surface layers are designed with a narrow selection of the size distribution of the aggregate; i.e. a grading curve for the aggregate which includes only small (if any) proportions of some medium- or small-sized particles. Such aggregate mixes are referred to as “open-graded” or “gap-graded”. An open-graded or gap-graded surface often results in a relatively rough texture with a lot of voids between the particles in the top section of the layer, but does not necessarily result in a porous surface. Aggregate mixes with a continuous and rather smooth grading curve are referred to as “dense-graded”, the texture of which is “closed-textured” (often also called “dense-textured”).

3.6 Terms related to profilometer performance

3.6.1
measuring speed
speed at which the profilometer sensor traverses the surface to be measured

NOTE Measuring speed is normally expressed in kilometres per hour (km/h) or metres per second (m/s).

3.6.2
profile sampling interval
distance between two adjacent data points on the surface, which is equal to the measuring speed divided by the sampling frequency of the sensor

NOTE Profile sampling interval is normally expressed in millimetres (mm).

3.6.3
profile measurement length
length of an uninterrupted profile measurement

NOTE Profile measurement length is normally expressed in metres (m) or millimetres (mm).

3.6.4
repetition interval
distance between the beginning of two consecutive profile measurement lengths (3.6.3)

NOTE Repetition interval is normally expressed in metres (m).

3.6.5
evaluation length
l
length of a sample from a profile which has been or is to be analysed

NOTE 1 This may or may not be equal to the profile measurement length (but is never greater).

NOTE 2 Evaluation length is normally expressed in metres (m) or millimetres (mm).

NOTE 3 The evaluation length may or may not be equal to the length of the baseline (see 3.6.6) which is also defined in ISO 13473-1.

3.6.6
baseline
particular evaluation length used in the method for determination of Mean Profile Depth specified in ISO 13473-1

See Figure 4.

NOTE Baseline is normally expressed in metres (m) or millimetres (mm).

3.6.7
measuring range
maximum vertical variation of the profile which the system can measure

NOTE Measuring range is normally expressed in millimetres (mm).

3.6.8
vertical resolution
minimum vertical variation that can be detected

NOTE Vertical resolution is normally expressed in millimetres (mm) or micrometres (μm).

3.6.9
horizontal resolution
shortest distance in the direction that the sensor is moved, over which a variation in vertical level can be detected

NOTE Horizontal resolution is normally expressed in millimetres (mm) or micrometres (μm).

3.6.10
background noise
that part of the signal output which is uncorrelated with the profile

NOTE 1 This may be of two kinds:

— static background noise: noise when the profilometer sensor is operating at rest;

— dynamic background noise: noise when the profilometer sensor is moving at normal measuring speed (this will also include static background noise).

NOTE 2 Dynamic background noise can be caused by, for example, unintentional sensor movements, vehicle vibrations, ambient light variations and surface reflectivity variations; in addition to the static contribution. It is generally very difficult to measure. One possibility is to run a test on an ideal, extremely smooth-textured surface. Preferably, for contactless devices, the smooth-textured surface should also have normal reflectivity variations.

3.6.11
non-linearity
peak deviation of a line expressing the actual relationship between the output signal and the profile depth, and a least-squares, best-fit straight line through this relationship

NOTE Non-linearity is expressed as a percentage of the measuring range.

3.6.12
minimum texture wavelength
shortest texture wavelength at which the response of the total profilometer system is attenuated by no more than 3 dB (approximately 30 %) with respect to the true value

NOTE See also 3.1.3.

3.6.13
maximum texture wavelength
longest texture wavelength at which the response of the total profilometer system is attenuated by no more than 3 dB (approximately 30 %) with respect to the true value

NOTE See also 3.1.3.

3.6.14
stand-off distance
distance between the surface and the sensor when the measuring point is in the middle of the measuring range

3.6.15
local slope angle
angle between the tangent to the profile and the normal of the bulk surface at a particular point, e.g. on the edges of a chipping or a groove

NOTE Usually sensors are only able to follow a maximum local slope of the profile without significant distortion. For an electro-optical sensor, this maximum local slope would be approximately equal to the angle between the optical axes of the transmitter and receiver.

3.6.16
drop-out
measured point (sample) on the profile which is recognized as invalid, and which is usually discarded in the subsequent data processing

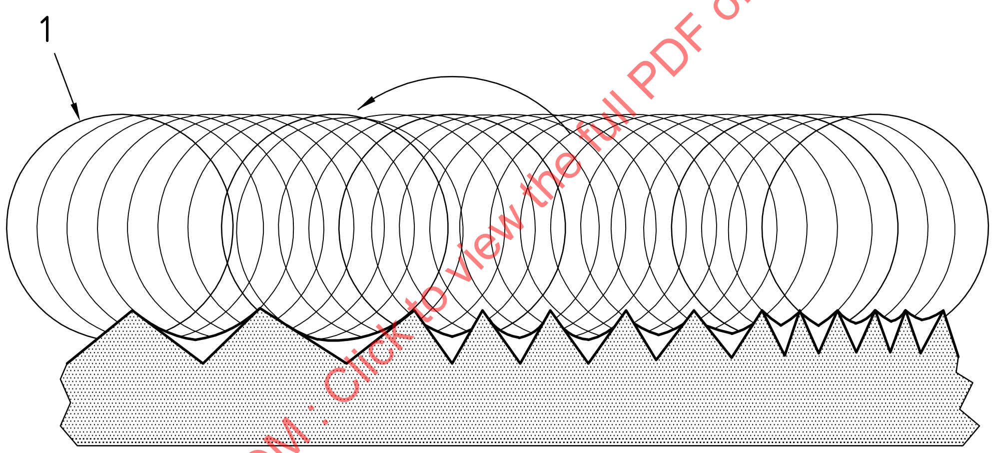
3.6.17
drop-out rate
percentage of measured points on the profile which are recognized as being invalid

3.6.18
profile envelope
two-dimensional approximation of the locus of the maximum penetration depth of the tyre tread when the tyre is rolling on the surface

See Figure 7.

NOTE 1 The tyre is said to envelop the surface, as described in reference [15].

NOTE 2 The profile envelope is intended to approximate the depth of a texture profile with which a rolling tyre is able to make contact. The definition here is only qualitative.



NOTE The profile envelope is the lower boundary of the light grey area.

Key

1 Rolling tyre

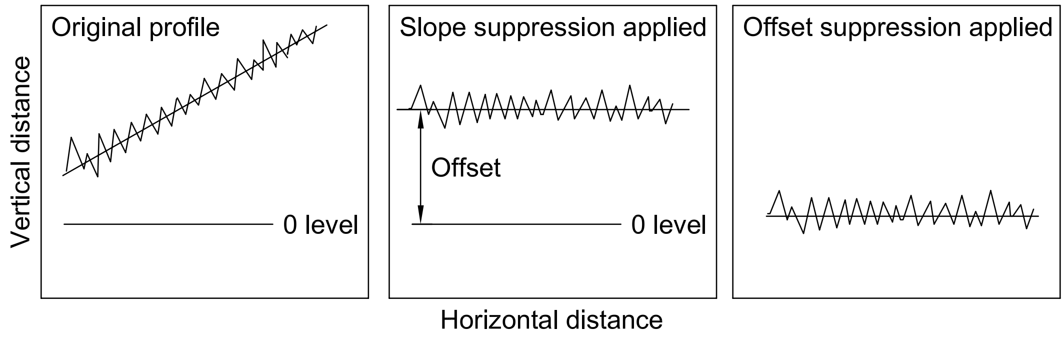
Figure 7 — Illustration of the profile envelope curve

3.7 Terms and parameters related to amplitude distribution

3.7.1
zero-mean, slope-suppressed profile curve
$Z(x)$
profile curve for which the mean level of the profile over the evaluation length has been brought to zero and for which long-wavelength trends have been removed

See Figure 8.

NOTE To obtain a profile curve useful for mathematical calculations, it is necessary to remove any slope or long-wavelength component (slope suppression) as well as to bring the mean level of the profile over the evaluation length to zero (offset suppression). This can be accomplished by either high-pass filtering or by subtracting a least-squares fit from the profile (see ISO 13473-1). The resulting mean line of the profile is then at zero level.



NOTE The features in this figure are exaggerated in order to make the illustration more clear. If subtracting a least-squares fit from the profile, the two steps from left to right in the figure are performed in one operation (which can be performed also by high-pass filtering). The “zero” line in the right third of the figure is equal to the “average level” in Figure 4 and Note 3 in 3.3.4.

Figure 8 — Illustration of slope and offset suppressions

3.7.2
profile amplitude distribution

p(*Z*)

sample probability density function of the ordinate values $Z(x)$, within the evaluation length, l, in the x-direction

See Figure 9.

3.7.3
mean absolute deviation of the profile

Ra

average absolute value of the ordinate values $Z(x)$ within an evaluation length l:

$$Ra = \frac{1}{l}\int_0^l \left| Z(x) \right| \mathrm{d}x \qquad (2)$$

NOTE 1 It is a result of calculations based on the offset- and slope-suppressed profile, with ordinate values $Z(x)$.

NOTE 2 *Ra* is normally expressed in millimetres (mm).

NOTE 3 Historically, *Ra* comes from “rugosité arithmétique” in the French language. In English, the term “rectified average” is sometimes used.

3.7.4
root mean square deviation of the profile

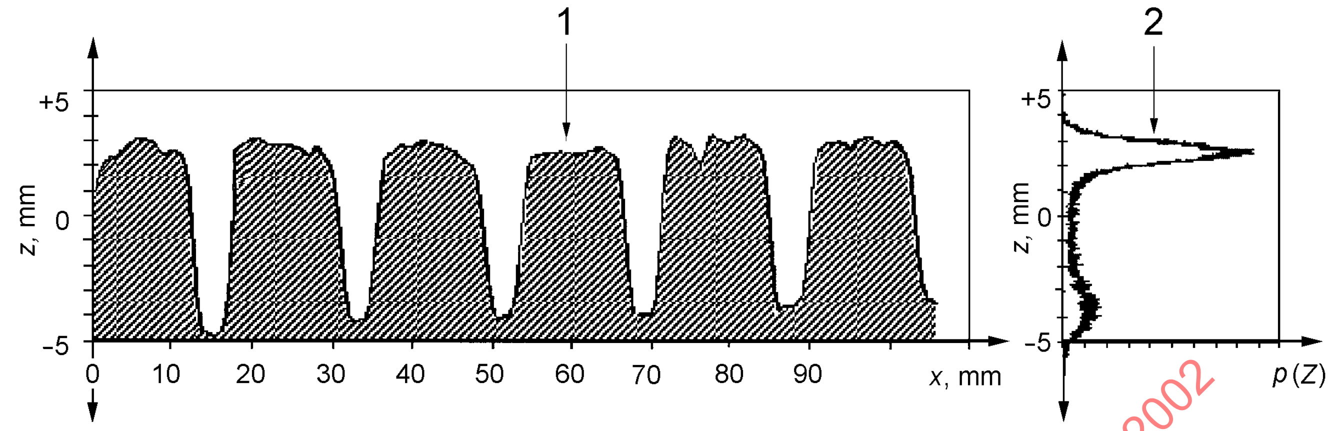
Rms

root mean square value of the ordinate values $Z(x)$ within an evaluation length l:

$$Rms = \sqrt{\frac{1}{l}\int_0^l Z^2(x)\,\mathrm{d}x} \qquad (3)$$

NOTE 1 *Rms* is normally expressed in millimetres (mm) in this application.

NOTE 2 *Rms* is denoted *Rq* (from “rugosité quadratique” in French) in ISO 4287. However, when dealing with pavements, *Rms* is preferred, since it is already one of the most commonly used terms in pavement analysis. Furthermore, there is a risk of mixing of the terms *Rq* and *Rku* which are pronounced similarly.



Key

1 Profile curve $Z(x)$

2 Probability density

NOTE Most often, however, the amplitude distribution diagram is turned 90° counterclockwise when displayed.

Figure 9 — Sample profile of an actual grooved cement concrete pavement, and its profile amplitude distribution $p(Z)$ shown to the right

3.7.5
skewness of the profile
Rsk
quotient of the mean cube value of the ordinate values $Z(x)$ and the cube of Rms, within an evaluation length l:

$$Rsk = \frac{1}{Rms^3}\left[\frac{1}{l}\int_0^l Z^3(x)\,\mathrm{d}x\right] \tag{4}$$

NOTE 1 Skewness is dimensionless.

NOTE 2 Skewness or skew is a measure of the asymmetry of the amplitude distribution (in this case of the ordinate values). This indicates whether the profile curve exhibits a majority of peaks directed upwards (positive skew) or downwards (negative skew). The profile in Figure 9 is an example of a profile having a relatively high degree of negative skew. For a normal distribution Rsk is zero.

3.7.6
kurtosis of the profile
Rku
quotient of the mean quartic value of the ordinate values $Z(x)$ and the fourth power of Rms, within an evaluation length l:

$$Rku = \frac{1}{Rms^4}\left[\frac{1}{l}\int_0^l Z^4(x)\,\mathrm{d}x\right] \tag{5}$$

NOTE 1 Kurtosis is dimensionless.

NOTE 2 Kurtosis refers to the weighting of the tails of a distribution and is a measure of how “flat” or “sharp” it is in relation to a normal distribution. For example, a distribution with “long and thick tails” in the distribution will have a high kurtosis value.