INTERNATIONAL STANDARD

ISO 13473-1

Second edition
2019-02

Corrected version
2021-06

Characterization of pavement texture by use of surface profiles —

Part 1:
Determination of mean profile depth

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

Partie 1: Détermination de la profondeur moyenne du profil

Reference number
ISO 13473-1:2019(E)

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Foreword

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

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 13473-1:1997), which has been technically revised. The main changes compared to the previous edition are as follows:

— Some alternative calculation options such as the slope suppression for continuous data have been removed.

— A more precise definition of high-pass and low-pass filtering has been provided.

— Removal of spikes has been introduced in the profile.

— The MPD now refers only to the overall value obtained after averaging all *MSD*s where *MSD* means Mean Segment Depth (earlier, MPD was used as the term both for the mean segment depth and for mean profile depth, which might have been confusing).

A list of all parts in the ISO 13473 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This corrected version of ISO 13473-1:2019 incorporates the following corrections:

— The segment length was corrected to 100 mm throughout the document;

— in 7.3, at the end of the fourth paragraph, the following sentence was added: "If there are more invalid samples than 5 mm in the beginning or the end of a sampled profile the effected MSD value(s) should be discarded." and in the last paragraph, "Profiles" was replaced by "Segments" and "readings" replaced by "samples";

— in 7.6, the third paragraph was replaced by the following one: "If there are no data available before and after the section to be computed, one should extend the signal by mirroring the first and the last segments before filtering.";

- in 7.10, the first list element was rephrased;
- in Clause 10, the following text was deleted: "whether or not spike removal procedure was applied;", "type and order of filters used;" and "and type of interpolation used";
- in D.3.7, replace "7.10" by "7.9";
- in E.1, fifth paragraph, a third sentence was added as follows: "The spikes are first identified in forward and reverse direction before replacing them with the interpolated value.".
- Figure E.3 was corrected.

Introduction

Road surface texture determines factors such as noise emission from the tyre/pavement interface, acoustic comfort inside vehicles, friction between the tyre and road, rolling resistance and tyre wear. The main concept and the basic terms are illustrated for information in Annex A. Valid methods for measuring surface texture are therefore highly desirable.

The so-called “sand patch” method, or the more general “volumetric patch” method (see Clause 3), has been used worldwide for many years to give a single and very simple measurement describing surface texture. It relies on a given volume of sand or glass beads which is spread out on a surface. The material is distributed to form a circular patch, the diameter of which is measured. By dividing the volume of material spread out by the area covered, a value is obtained which represents the average depth of the sand or glass bead layer, known as “mean texture depth” (MTD). The method was originally standardized in ISO 10844:1994[1)], Annex A[5] in order to put limits concerning surface texture for a reference surface used for vehicle noise testing but was later adopted by CEN as EN 13036-1[13].

The volumetric patch method is operator-dependent and can be used only on surfaces which are partly or fully closed to traffic. Therefore, it is not practical for use in network surveys of roads, for example. Along with developments in contactless surface profiling techniques, it has become possible to replace the volumetric patch measurements with those derived from profile recordings, which are possible to make by mobile equipment in flowing traffic. However, several very different techniques have been used to calculate a “predicted mean texture depth”, many of them quite successfully. The values they give are not always comparable, although individually they generally offer good correlation coefficients with texture depth measured with the volumetric patch method.

It is, therefore, important to have a standardized method for measuring and evaluating the texture depth by a more modern, safe and economical technique than the traditional volumetric patch method, resulting in values which are directly compatible both with the patch-measured values and between different equipment.

1) Withdrawn and replaced by ISO 10844:2014.

Characterization of pavement texture by use of surface profiles —

Part 1: Determination of mean profile depth

1 Scope

This document describes a test method to determine the average depth of pavement surface macrotexture (see Clause 3) by measuring the profile of a surface and calculating the texture depth from this profile. The technique is designed to provide an average depth value of only the pavement macrotexture and is considered insensitive to pavement microtexture and unevenness characteristics.

The objective of this document is to make available an internationally accepted procedure for determination of pavement surface texture depth which is an alternative to the traditionally used volumetric patch technique (generally using sand or glass beads), giving comparable texture depth values. To this end, this document describes filtering procedures that are designed to give the best possible representation of texture depths determined with the volumetric patch method[13].

Modern profilometers in use are almost entirely of the contactless type (e.g. laser, light slit or light sheet, to mention a few) and this document is primarily intended for this type. However, this does not exclude application of parts of it for other types of profilometers.

This ISO 13473 series has been prepared as a result of a need identified when specifying a test surface for vehicle noise measurement (see ISO 10844:2014[6]). Macrotexture depth measurements according to this document are not generally adequate for specifying test conditions of vehicle or traffic noise measurements, but have limited applications as a supplement in conjunction with other ways of specifying a surfacing.

This test method is suitable for determining the mean profile depth (MPD) of a pavement surface. This MPD can be transformed to a quantity which estimates the macrotexture depth according to the volumetric patch method. It is applicable to field tests as well as laboratory tests on pavement samples. When used in conjunction with other physical tests, the macrotexture depth values derived from this test method are applicable to estimation of pavement skid resistance characteristics (see e.g. Reference [15]), estimation of noise characteristics and assessment of the suitability of paving materials or pavement finishing techniques.

The method, together with other measurements (where applicable), such as porosity or microtexture, can be used to assess the quality of pavements.

This document is adapted for pavement texture measurement and is not intended for other applications. Pavement aggregate particle shape, size and distribution are surface texture features not addressed in this procedure. The method is not meant to provide a complete assessment of pavement surface texture characteristics. In particular, it is known that there are problems in interpreting the result if the method is applied to porous surfaces or to grooved surfaces (see Annex B).

NOTE Other International Standards dealing with surface profiling methods include, for example, References [1], [2] and [3]. Although it is not clearly stated in these, they are mainly used for measuring surface finish (microtexture) of metal surfaces and are not intended to be applied to pavements.

2 Normative references

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

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

3 Terms and definitions

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

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

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

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

3.1
texture wavelength
λ
quantity describing the horizontal dimension of the irregularities of a *texture profile* (3.3)

Note 1 to entry: Texture wavelength is normally expressed in metres (m) or millimetres (mm).

Note 2 to entry: Texture wavelength is a descriptor of the wavelength components of the profile and is related to the concept of the Fourier Transform of a series regularly sampled measurement points along a spatial axis. Vertical displacement (height) has an arbitrary reference.

3.2
texture
pavement texture
deviation of a pavement surface from a true planar surface, with a *texture wavelength* (3.1) less than 0,5 m

3.3
surface profile
texture profile
upper contour of a vertical cross-section through a pavement

Note 1 to entry: Texture profile is similar to surface profile but limited to the texture range.

Note 2 to entry: 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 given in Figure A.1. The distance may be in the longitudinal or lateral (transverse) directions in relation to the travel direction on a pavement, or in a circle or any other direction between these extremes.

3.4
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* (3.1) with one-third-octave bands including the range 0,63 mm to 50 mm of centre wavelengths

Note 1 to entry: 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 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 to entry: Based on physical relations between texture and friction, noise, etc., the World Road Association (PIARC) originally defined the ranges of micro-, macro- and megatexture[16]. Figure A.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. In this figure, "discomfort for travellers" includes effects experienced in and on motorized road vehicles and bicycles, as well as wheelchairs and other vehicles used by disabled people.

3.5 Texture depth measurements

3.5.1
texture depth
TD
in the three-dimensional case, the distance between the surface and a plane through the top of the three highest peaks within a surface area in the same order of a size as that of a car tyre/pavement interface

Note 1 to entry: See Figure A.3.

3.5.2
mean texture depth
MTD
texture depth (3.5.1) obtained from the volumetric patch method

Note 1 to entry: In the application of the "volumetric patch method" (see below), the "plane" is in practice determined by the contact between a rubber pad and the surface when the pad is rubbed over the area. Therefore, the texture depth obtained in this case is not based on exactly a "plane", but rather an approximation which is a somewhat curved surface that is hard to define.

3.5.3
profile depth
PD
in the two-dimensional case, i.e. when studying a profile, the difference, within a certain longitudinal/lateral distance in the same order of length as that of a car tyre/pavement contact interface, between the profile and a horizontal line through the top of the highest peak within this profile

3.5.4
evaluation length
l
length of a portion of one or more profiles for which *MPD* (3.5.2) is to be calculated

3.5.5
segment
portion of the profile over a length of 100 mm

Note 1 to entry: See Figure A.4.

3.5.6
mean segment depth
MSD
average value of the *profile depth* (3.5.3) of a *segment* (3.5.5)

Note 1 to entry: See Figure A.4.

3.5.7
mean profile depth
d_{MPD}
MPD
average of the values of the *MSD* (3.5.6) of the tested section

3.5.8
estimated texture depth
d_{ETD}
ETD
term used when the *MPD* (3.5.7) is used to estimate the *MTD* (3.5.2) by means of a transformation formula

3.6
volumetric patch method
method relying on the spreading of a material, usually sand or graded glass beads, in a patch

Note 1 to entry: The material is distributed with a rubber pad to form an approximately circular patch, the average diameter of which is measured. By dividing the volume of material by the area covered, a value is obtained which represents the average depth of the layer, i.e. MTD. The volumetric patch method is described in EN 13036-1.

Note 2 to entry: The volumetric patch method is used not only with sand or glass beads as the patch material, but in some cases with putty or grease. However, such materials have certain disadvantages, and for international standardization, only glass beads have been recommended. The ETD measure is based on glass beads as the patch material.

3.7
drop-out
data in the measured profile indicated by the sensor as invalid

3.8
spike
unusually high and sharply defined peak in the measured profile, which is not part of the true profile and is not automatically detected as invalid by the system

Note 1 to entry: See Annex E for a quantitative definition of a spike.

4 Test surfaces

4.1 Condition of the surface

Measurements shall not be made during rain or snow fall. Unless it has been demonstrated that the equipment provides valid measurements on wet or damp surfaces, the surface shall be dry during the measurements. It shall also be clean and reasonably free of debris and foreign objects.

It is possible that optical-based measuring systems do not perform properly on newly laid asphalt surfaces which are glossy and dark. If the test is performed during the paving process, optical distortions due to temperature gradients in the air above the tested surface can produce invalid data.

For roads which have been in service, the texture can vary across the pavement. In this case, the transverse location of the measurement is normally determined by the intended use of the data.

4.2 Amount of data to be collected per field test section

4.2.1 Continuous measurements

Continuous measurements are made when a certain length of a road is measured with possible interruptions of a maximum of 10 % of the length. The minimum evaluation length over which MPD is calculated shall be 1,0 m. It is not meaningful to report MPD over shorter lengths.

It is recommended that measurements and calculations be made continuously along the entire test section.

4.2.2 Spot measurements

If a continuous measurement is not possible, as is the case for stationary devices, measurements may be made at certain spots which are appropriately distributed. The following minimum provisions apply:

— Each evaluation length shall include at least eight single measured segments of 100 mm length. This would normally be along a straight line, but may also be in a circular path or in parallel lines (in connection with 3D measurements). Each segment shall be measured continuously. The exception is when analysing round laboratory samples; see 4.3.

— The procedure in Annex C is recommended to select measurement positions and evaluation lengths in an unbiased manner.

— The minimum evaluation length shall be 1,0 m.

For surfaces with periodic textures (e.g. grooved or tined surfaces), the total profile length shall include at least 10 periods of the dominant texture frequency.

4.3 Amount of data to be collected on laboratory samples

Laboratory samples are generally either circular cores or rectangular slabs. They may be directly taken from a road or airfield, produced in a laboratory or replicated based on mouldings from an actual road or airfield site.

When measuring laboratory samples, care should be taken that edge effects of the samples do not affect the measurement.

In order for the measurements to give values reasonably representative of an actual field site, the following three requirements shall be met:

— Cores, slabs or mouldings intended for profile measurement shall be taken from at least four different places, evenly distributed longitudinally along the site.

— The measurements shall include at least 4 segments (per core), evenly distributed on the laboratory samples (see below), each profile measured over 100 mm length and not being part of another profile, except that one profile may cross another profile.

— The minimum evaluation length shall be 1,0 m.

It is recommended that cores have a minimum 150 mm diameter, although 100 mm diameter cores are acceptable. If the core diameter does not allow measurements to follow a straight line of the required length across the core, it is recommended to rotate the core underneath the sensor (or vice versa) and make the measurement along a circle around the core centre. Such circles should have a minimum circumference of 200 mm (corresponding to a diameter of 64 mm).

Rectangular samples often have dimensions which exceed typical core dimensions. On such samples, individual profile measurements should be distributed uniformly.

Measurements on laboratory samples can have many different purposes. This means that it is difficult to specify general minimum requirements. The specification here assumes that the purpose is to obtain values which are reasonably representative of pavements.

5 Measurement instruments

5.1 Instruments in general

A profilometer system shall be used which produces a signal output that is proportional to the distance between a sensor reference plane and the surface spot in question. Examples of sensors include acoustical, electro-optical type or a video camera. The final output shall be linearly related to the texture profile and this may be obtained either in hardware or software, as necessary. 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 profile length. This does not apply when the profile is produced by some techniques such as light sectioning.

5.2 Vertical resolution

The vertical resolution shall be 0,05 mm or better. The measuring range of the sensor should be a minimum of 20 mm. When measuring smoother surfaces, a smaller range is permissible. For a sensor mounted on a moving vehicle, a higher range is usually required to allow for vehicle motion.

NOTE 1 A laser sensor system having a measuring range of 200 mm and a 12-bit digital resolution has a vertical resolution of a little less than 0,05 mm.

NOTE 2 It has appeared that many of the laser profilometers have a noise floor which corresponds to 0,13 mm to 0,17 mm of MPD. A vertical resolution of 0,05 mm means that the vertical resolution does not contribute to the noise floor.

5.3 Horizontal resolution

In the case of a device utilizing a laser, other electro-optical sensor, or a sensor based on sound transmission, the spot of the radiation should be such that its average diameter on the road surface shall in no case be greater than 1 mm over the used vertical range. In this case, the effective spot is taken as that contained within an area limited by a contour line where the intensity of the spot is 1/e (approximately 37 %) of the maximum intensity within the spot.

In the case where a light-sectioning device is used, the projected light band or line shall be sufficiently sharp to give a light/dark transition within 1 mm. In this case, the effective line width is taken as that where the intensity of the line has reduced from 100 % to 1/e (approximately 37 %) of the maximum intensity within the line.

In the case where a contact device is used (e.g. utilizing a stylus sensor), the widest dimension of the contacting part (tip) shall have a diameter of no more than 1 mm up to 1 mm in height from the tip. Contact forces on the surface shall not be so high as to cause penetration or destruction of the surface texture. Such destruction is usually detectable as a clearly visible trace where contact was made.

The sampling interval shall not be more than 1,0 mm, and samples shall be taken at a fixed interval in the horizontal direction.

It shall be noted that the movement by the laser or light spot during the time of collecting each sample means that the spot is extended somewhat in the direction of measurement. This “stretching” of the spot due to the measurement speed can be calculated by dividing the measurement speed by the time for each sample collection and it should never result in a spot longer than 1 mm. It can mean a limitation of the measurement speed.

5.4 Measurement speed

The measurement speed is the speed with which the profile is traced by the profilometer, and shall be such that the requirements on sampling interval are met. This applies to stationary as well as mobile profilometers. The relation is:

$$v \leq f_s \cdot s / 1\,000 \quad (1)$$

where

v is the profilometer speed (m/s);

f_s is the sampling frequency of the sensor (Hz);

s is the sampling interval (mm).

In some devices, the speed influences the effect of the background noise, since the latter can be higher at higher frequencies. Depending on how sampling takes place and the low-pass filtering, the speed can influence the electronic frequency corresponding to the lower texture wavelength limit. See 5.2 regarding possible effect of sampling variations.

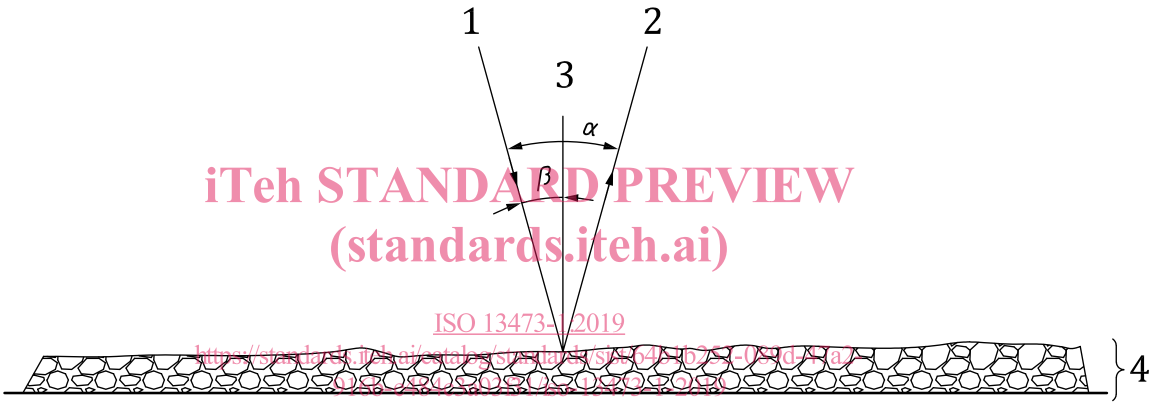
NOTE Low-pass refers to a filtering of the signal with the intention to attenuate the higher frequencies (either temporal or spatial).

5.5 Alignment of sensor

In case of reflected radiation, the angle between the optical or acoustical axis of the radiation toward the surface and the optical or acoustical axis of the detector (α) should not exceed 30°. See Figure 1. Larger angles underestimate very deep textures and cause higher drop-out rates. It is preferred that the β angle is as low as possible. This paragraph applies also to light-sectioning devices.

It is recommended that the sensor be moved in a direction perpendicular to the plane of the radiation; i.e. perpendicular to the plane of the figure.

For mechanical devices, α is not applicable and β shall be no more than 30°.



Key

1 emitting device
2 receiving device
3 surface normal
4 road surface

Figure 1 — Requirements regarding alignment of non-contact sensors above a road surface

5.6 Bandwidth of sensor and recording system

The bandwidth of the sensor and recording system shall meet at least the bandwidth induced by the filtering procedures described in 7.6.

NOTE 1 The bandwidth can be verified to be within the appropriate range by using surfaces machined to simulate textures with known profiles. For mobile devices, such surfaces (discs or drums) can be rotated underneath the sensing device. In this instance, the measurement device remains stationary.

NOTE 2 The lower and the higher texture wavelength limits given in 7.6 do not correspond to the definition of macrotexture according to 3.4. This is because:

— to some extent, this imitates the effect of the enveloping by rubber surfaces, such as a tyre,

— wavelengths smaller than 3 mm and higher than 140 mm do not play a major role in determination of MPD or ETD according to Figure 13 of Reference [15],

— many profilometers have poor performance in the range below 3 mm, and

