INTERNATIONAL STANDARD

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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 profil —

Partie 1: Détermination de la profondeur moyenne de la texture

Reference number
ISO 13473-1:1997(E)

Foreword

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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.

International Standard ISO 13473-1 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 related to pavement texture profile analysis*

— *Part 3: Specifications and classification of profilometers*

Annexes A to F of this part of ISO 13473 are for information only.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

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Introduction

Road surface texture determines factors such as noise emission from the tyre/pavement interface, friction between the tyre and road, rolling resistance and tyre wear. 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, Definitions) 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 spheres 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 sphere layer, i.e. a 'mean texture depth'. The method has been standardized in ISO 10844 in order to put limits as to surface texture for a reference surface used for vehicle noise testing.

The volumetric patch method is very crude; it 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. However, several very different techniques have been used to calculate 'predicted mean texture depths', 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 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.

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Characterization of pavement texture by use of surface profiles —

Part 1:
Determination of Mean Profile Depth

1 Scope

This part of ISO 13473 describes a test method to determine the average depth of pavement surface macrotexture (see clause 3, Definitions) by measuring the profile curve 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 part of ISO 13473 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 spheres), giving comparable texture values.

This ISO 13473 series has been prepared as a result of a need identified when specifying a test surface for vehicle noise measurement (ISO 10844). Macrotexture depth measurements according to this International Standard 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 of a pavement surface. This Mean Profile Depth 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 [1]), estimation of noise chacteristics (see e.g. ISO 10844), 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.

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, care should be exercised in interpreting the result if the method is applied to porous surfaces or to grooved surfaces (see annex B).

NOTE 1 - Other International Standards dealing with surface profiling methods include for example ISO 468, ISO 1878, ISO 1879, ISO 1880, ISO 3274, ISO 4287 and ISO 4288 (see annex F). Although it is not clearly stated in these, they are mainly used for measuring surface finish (microtexture) of metal surfaces and do not apply to pavements. This part of ISO 13473 is adapted for pavement texture measurement and is not intended for other applications.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 13473. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 13473 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 10844:1994, *Acoustics — Specification of test tracks for the purpose of measuring noise emitted by road vehicles*

3 Definitions

For the purposes of this part of ISO 13473, the following definitions apply.

3.1 pavement texture: The deviation of a pavement surface from a true planar surface, within the wavelength ranges defined in 3.4.

3.2 profile: A two-dimensional representation of a surface. The profile of a surface is generated if a sensor, like a tip of a needle or a laser spot, continuously touches or shines on the pavement surface while it is moved along the surface. See figure A.1 in annex A.

The profile of a surface is described by two coordinates: one along the surface plane, called *distance*, and the other in a direction normal to the surface plane, called *amplitude*. See figure A.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. In a Fourier analysis, the profile curve can be mathematically described by a series of Fourier coefficients combined with sinusoidal curves with certain frequencies and wavelengths.

3.3 texture wavelength: The (minimum) distance between periodically repeated parts of the curve. For normal surface profiles, a profile analysed by its Fourier components contains a continuous distribution of wavelengths.

In this part of ISO 13473, the term *texture wavelength* (unit: m or mm) is used to describe the wavelengths of a profile taken from a pavement (see figure A.1 in annex A).

NOTE 2 - The term wavelength has historically been used mostly in acoustics (with regard to sound waves) or in electrotechnics (with regard to electrical signals or electro-magnetic waves). Since people may not be accustomed to using the term wavelength in pavement applications, and also since electrical signals often are used in the analyses of road surface profiles, the term 'texture wavelength' is introduced here. The inverse of texture wavelength is called 'spatial frequency' (unit: m^{-1} or cycles/m), which is when multiplied by the factor 2π, called 'texture angular wavenumber' (unit: rad/m).

3.4 Ranges of texture

3.4.1 macrotexture: The 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 third-octave bands including the range 0,5 mm to 50 mm of centre wavelengths).

See figure A.2 in annex A for an illustration of the different texture ranges.

NOTE 3 - 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 in the same order of size as tyre tread elements in the tyre/road interface. Surfaces are normally designed with a certain macrotexture in order 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 surface or by certain surface finishing techniques.

3.4.2 microtexture: The 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 with third-octave bands with up to 0,4 mm of centre wavelengths).

NOTE 4 - 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 obtained by the surface properties (sharpness and harshness) of the individual chippings or other particles of the surfacing which come in direct contact with the tyres.

3.4.3 megatexture: The 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 third-octave bands including the range 63 mm to 500 mm of centre wavelengths).

NOTE 5 - 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. Pavement characteristics at longer wavelengths than 0,5 m are considered to be above that of texture and are referred to as unevenness.

3.4.4 unevenness: The 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 6 - Unevenness is a type of surface roughness which, through vibrations, affects ride comfort in and road holding of vehicles.

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 particles within a surface area in the same order of a size as that of a tyre/pavement interface. See figure A.3 in annex A.

3.5.2 Mean Texture Depth, MTD: The texture depth obtained in the case of the volumetric patch method.

NOTE 7 - 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 and hard-to-define surface.

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 tyre/pavement interface, between the profile and a horizontal line through the top of the highest particle within this profile. See figure A.4 in annex A.

3.5.4 Mean Profile Depth, MPD: The average value of the profile depth over a certain distance (baseline). See figure A.4 in annex A.

3.5.5 Estimated Texture Depth, ETD: Term used when the Mean Profile Depth (MPD) is used to estimate the Mean Texture Depth (MTD) by means of a transformation equation.

3.6 texture spectrum: Spectrum obtained when a profile curve has been analysed by either mathematical Fourier techniques or corresponding filtering processes in order to determine the amplitude of its spectral components (wavelengths or spatial frequencies).

3.7 volumetric patch method: Method relying on the spreading of a material, usually sand or glass spheres, in a patch. 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. a 'mean texture depth'.

The volumetric patch method is described in annex A of ISO 10844:1994. This method is based on the use of glass spheres.

NOTE 8 - The volumetric patch method is used not only with sand or glass spheres as the patch material, but in some cases with putty or grease. However, such materials have certain disadvantages, and for international standardization only glass spheres have been recommended. The ETD measure is based on glass spheres as the patch material.

3.8 profilometer method: Method in which the profile of a pavement surface is obtained for subsequent analysis. The data are used for calculation of certain mathematically defined measures. In some cases, the profile is recorded for subsequent analysis, in other cases it may be used only in real-time calculations.

4 Test surfaces

4.1 Condition of the surface

Measurements shall not be made during rain or snow fall. Unless it has been proven that the equipment works properly also on wet or damp surfaces, the surface shall be dry during the measurements. It shall also be clean and free of any foreign objects.

NOTE 9 - Optical-based measuring systems may not perform properly on newly laid asphalt surfaces which are glossy and dark. If the test is performed during the paving process, distortions due to temperature gradients in the air above the tested surface may produce faulty data.

NOTE 10 - For roads which have been in service, the texture will vary across the pavement. In this case the transverse location of the measurement will normally be determined by the intended use of the data.

4.2 Amount of data to be collected per field test section

Ideally, 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, as a minimum requirement, the measured length shall be as follows:

10 evenly distributed profiles per 100 m test section, each profile being at least 100 mm long.

However, for a uniform test section, it will be sufficient to have a total of 16 evenly distributed profiles, regardless of test section length.

When characterizing a long test section with relatively short sample lengths, it is important to ensure that the texture is sufficiently homogeneous to provide a representative measure. It is necessary for the user to use sound judgement to determine the minimum number of samples necessary to characterize a non-homogeneous pavement.

For surfaces with periodic textures, e.g. grooved or tyned surfaces, the total profile length shall include at least 10 periods of the texture, in addition to the requirements above.

NOTE 11 - If the profile curve is used also for spectrum analysis, the minimum tested lengths stated above are inadequate.

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 replicates 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 requirements shall be met.

The measurements shall include at least 10 profiles (in total), evenly distributed on laboratory samples (see below); each profile measured over at least 100 mm length and not being part of another profile.

Cores, slabs or mouldings shall be taken from at least four different places, evenly distributed longitudinally along the site. See also Note 11.

It is recommended that cores have a diameter of 150 mm or more, although 100 mm (approximate diameter) cores are acceptable. On each core, a measurement allowing calculations over the required baseline length shall be conducted. On cores which have a diameter of 150 mm or more, it is recommended to make up to four different measurements in different directions over the core. 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 at least 32 mm diameter (to obtain 100 mm per revolution).

Rectangular samples often have dimensions which exceed typical core dimensions. On such samples one should distribute individual profile measurements evenly.

NOTE 12 - Measurements on laboratory samples may 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 Measuring instruments

5.1 Instruments in general

A profilometer system shall be used which produces an electrical signal output which is proportional to the distance between a sensor reference plane and the surface spot in question. The sensor could be, for example, of a mechanical, acoustical or 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, if 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 another technique, for example light sectioning.

Vertical resolution shall be better than 0,05 mm and the measuring range should be at least 20 mm (on smoother surfaces a smaller range can be used). For a sensor mounted on a moving vehicle, a higher range is usually required to allow also for vehicle motion.

5.2 Horizontal resolution

In the case of a contactless method, using a laser or other electro-optical principle or a sensor based on sound transmission, the spot of the radiation shall be such that its average diameter on the road surface is no greater than 1 mm (half-power points).

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 the case where a contact method is used, e.g. utilizing a needle, the tip of the contacting part shall be such that the tip, in its widest direction, has a diameter of no more than 1 mm, up to 1 mm 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 mm.

If the profile curve is used for spectrum analysis, sampling interval fluctuation shall not be greater than ± 10 %. This would influence the requirement in 5.3 for maintaining constant measuring speed.

5.3 Speed of measurement

The speed with which the profile is traced shall be such that the requirements on sampling and bandwidth are met. This applies to stationary as well as mobile profilometers. However, it shall be observed that the speed could influence the frequency scale for any spectral analysis. The relation is:

$$f = v \cdot \lambda^{-1} \qquad (1)$$

where
f = frequency on the spectrum analyser scale (Hz)
v = profilometer speed (m/s)
λ = texture wavelength (m).

In some devices the speed may influence background noise, since the latter may be higher at higher frequencies. In addition, depending on how sampling takes place and whether there is lowpass filtering, the speed may influence the lower wavelength limit. See the last paragraph of 5.2 regarding possible effect of sampling variations.

5.4 Alignment of sensor

If a mechanical sensor is used, the angle of the needle shall be no more than 30° to the surface normal.

The angle between the optical or acoustical axis of the radiation toward the surface and the optical or acoustical axis of the detector (reflected radiation) may be maximum 30°. See figure 1. Larger angles will underestimate very deep textures. This paragraph applies also to light-sectioning devices.

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

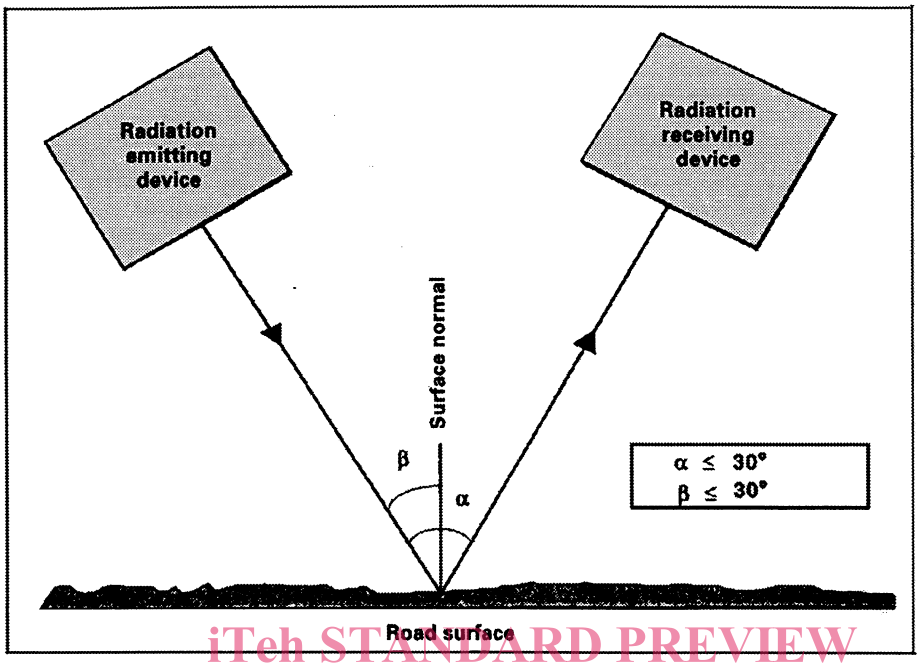

Figure 1 — Requirements regarding alignment of non-contact sensors

5.5 Bandwidth of sensor and recording system

The bandwidth of the entire data collection system shall meet the requirements in 7.3 and 7.4, i.e. the response shall be basically flat within 5 mm to 50 mm texture wavelength, and spectral components with wavelengths greater than 100 mm and lower than 2,5 mm shall be significantly reduced.

NOTE 13 - The bandwidth could 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) could be rotated underneath the sensing device, the latter of which is then stationary.

NOTE 14 - The low texture wavelength limit here does not correspond to the definition of macrotexture according to 3.4.1. This is by intention because (1) to some extent this imitates the effect of the enveloping by rubber surfaces, such as a tyre, (2) wavelengths smaller than 5 mm do not play a major role in determination of MPD or ETD, (3) many profilometers have poor performance in that range, and (4) with a 5 mm limit profilometers will give more uniform values less dependent on for example erroneous transients.

5.6 Calibration

Calibration shall be made by means of a special calibration surface, having a known profile. The maximum vertical deviation of the calibration from its theoretical profile shall be 0,05 mm.

The calibration procedure shall be designed so as to obtain a maximum standard uncertainty of the MPD value of 5 % or 0,1 mm, whichever is lower.

See annex D regarding various calibration surfaces and other suggestions.

NOTE 15 - One suitable profile is a surface machined to obtain a triangular profile with a peak-to-peak value of 5 mm to 20 mm and a texture wavelength of 10 mm to 50 mm. This gives an indication of not only amplitude but also of nonlinearity and the texture wavelength scale.

5.7 Indication of invalid readings

Invalid readings may occur, due to the special photometric properties of the surface or shadowing of the light in deep troughs of the profile. In addition, laser diodes will deteriorate with use which will eventually result in excessive invalid readings. For this reason, it is recommended that there be a means of monitoring the laser intensity at certain intervals.

If the signal from the profilometer can become significantly lower or higher than the true profile due to readings being invalid, the equipment shall identify all such potentially invalid readings in a special "invalid" signal output which can be used for correction of such readings.

The invalid signal shall meet the same minimum bandwidth and sampling requirements as the profile signal (see 5.2 and 5.5).

5.8 Sensitivity to vibrations

It shall be ensured that the sensor is stable in its vertical position at least during the measurement of a full baseline length and for all operating speeds, or that it has some means of compensation for vertical movements. It means that vibrations, for example those occurring at the natural suspension frequency of the sensor and/or its carrier, shall have negligible influence.

6 Measuring and data processing principle

The measuring and data processing procedures shall be as follows.

6.1 Calibration and measurement of profile
Calibrate the measuring system (when appropriate) and measure the profile of the surface.

6.2 Handling of invalid readings
Readings of this profile which are invalid (drop-outs) shall be eliminated or corrected for.

6.3 Highpass filtering
Unless slope suppression according to point 6.6 is used, highpass filtering shall be made. It consists of removing spatial frequency components which are below the passband specified in 5.5.

6.4 Lowpass filtering
Remove frequency components which are above the passband specified in 5.5. This can be made either by analog filtering, averaging of adjacent samples or can be automatically met by the performance of the sensor.

6.5 Baseline limiting
Pick out a part of the profile which has a baseline meeting the requirements of 7.5.

6.6 Slope suppression
The slope shall be suppressed by calculation of the regression line and following subtraction of this line. An alternative is to apply appropriate high-pass filtering (see point 6.3).

6.7 Peak determination
The peak levels of the profile over the two halves of the baseline length are detected.

6.8 MPD determination
The Mean Profile Depth (MPD) is calculated as the average of the two peaks according to 6.7 minus the profile average, the latter of which is normally zero as a result of highpass filtering or slope suppression.

6.9 ETD calculation
The MPD value is transformed to an Estimated Texture Depth (ETD) by applying a transformation equation.

6.10 Averaging of MPD and ETD values
Individual values measured on a site or a number of laboratory samples are averaged. This includes calculation of the standard deviation.

The following clause describes these steps one by one. See also figure E.1 in annex E.