Characterization of pavement texture by use of surface profiles —

Part 1: Determination of Mean Profile Depth

The European Standard EN ISO 13473-1:2004 has the status of a British Standard

ICS 17.140.30

British Standards

National foreword

This British Standard is the official English language version of EN ISO 13473-1:2004. It is identical with ISO 13473-1:1997.

The UK participation in its preparation was entrusted to Technical Committee B/510, Road materials, to Subcommittee B/510/5, Surface characteristics, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN ISO title page, the EN ISO foreword page, the ISO title page, pages ii and iii, a blank page, pages 1 to 19 and a back cover.

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English version

Characterization of pavement texture by use of surface profiles - Part 1: Determination of Mean Profile Depth (ISO 13473-1:1997)

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 (ISO 13473-1:1997)

Charakterisierung der Textur von Fahrbahnbelägen unter Verwendung von Oberflächenprofilen - Teil 1: Bestimmung der mittleren Profiltiefe (ISO 13473-1:1997)

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Foreword

The text of ISO 13473-1:1997 has been prepared by Technical Committee ISO/TC 43 "Acoustics" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 13473-1:2004 by Technical Committee CEN/TC 227 "Road materials", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2004, and conflicting national standards shall be withdrawn at the latest by October 2004.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 13473-1:1997 has been approved by CEN as EN ISO 13473-1:2004 without any modifications.

EN ISO 13473-1:2004

INTERNATIONAL STANDARD

ISO 13473-1

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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
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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.

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.

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°.

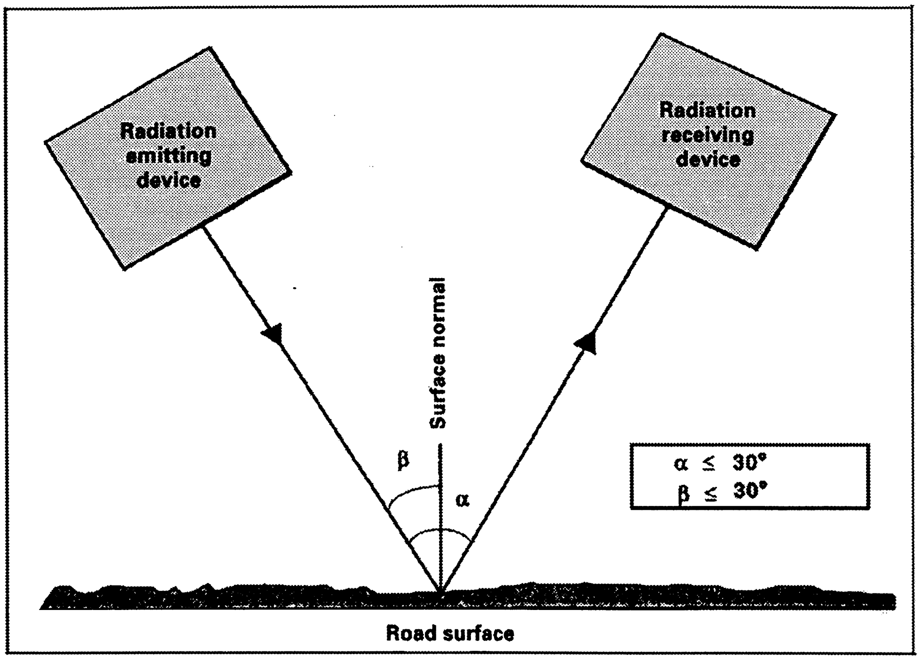


Figure 1 — Requirements regarding alignment of non-contact sensors

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.

7 Measuring and data processing procedure in detail

7.1 Calibration and measurement of profile

Calibration of the equipment shall be made in accordance with the manufacturer's recommendations using a known profile according to 5.6. However, calibration must not be less frequent than at the beginning and end of each measuring day.

The profile of the test surface shall be measured using equipment in accordance with clause 5 and meeting the requirements on sample length in clause 4.

7.2 Handling of invalid readings

Readings of the profile which are invalid, for example as a result of surface photometric properties or shadowing of light in deep surface troughs, shall not influence the final result significantly. For this reason, such readings, if their value is higher or lower than the range of the profile surrounding this location, shall not be part of the profile. Instead, the invalid part of the profile shall be either interpolated between the nearest previous and following valid values, or given any other value which is within the normal surface profile.

The maximum proportion of invalid readings in a profile shall not exceed 20 %. If it exceeds 10 %, caution should be used in interpretation of data. The proportion of invalid readings shall be reported.

7.3 Highpass filtering

Unless slope suppression according to 7.6 is used, highpass filtering of the profile curve shall be made no later than at this stage. It may be made either by digital filtering or an electronic filter. The process shall remove spatial frequency components which are below 10 m^{-1} (cycles/m), corresponding to a texture wavelength of 100 mm, but not affect spatial frequencies above 20 m^{-1}, corresponding to a wavelength of 50 mm (at least −3 dB at 100 mm and at most −1 dB at 50 mm with a slope of at least −12 dB/octave).

It is important to observe that if highpass filtering is applied, the measured profile must be sufficiently long to yield a useful filtered profile length corresponding with the minimum requirements of 4.2. The beginning and end of the filtered profile shall be discarded in order to remove the effect of transients in the filtering process.

NOTE 16 - For spectrum analysis, highpass filtering may not be desirable at all.

7.4 Lowpass filtering

In order to reduce the possible influence of noise and transients and to have a relatively uniform influence of narrow profile peaks, the profile shall be filtered in order to remove high-frequency components. The process shall remove spatial frequency components which are above 400 m^{-1} (cycles/m), corresponding to a texture wavelength of 2,5 mm, but not affect spatial frequencies below 200 m^{-1}, corresponding to a wavelength of 5 mm (at least −3 dB at 2,5 mm and at most −1 dB at 5 mm with a slope of at least −6 dB/octave). The filtering may be achieved with digital filtering, including for example averaging of adjacent samples, or with an electronic filter. All or part of the filtering effect may also be achieved by the finite size of the sensoring spot, line or tip. See further Note 17.

NOTE 17 - For spectrum analysis, lowpass filtering may not be desirable at all. Refer also to Note 16.

7.5 Baseline limiting

Each individual profile on which the following calculations are made shall have a baseline which is 100 mm ± 10 mm long). The term baseline is illustrated in figure A.4 in annex A.

7.6 Slope suppression

Unless high-pass filtering has been utilized (see 7.3), the slope of the profile curve with a baseline according to 7.5 shall be suppressed by calculating the regression line through all profile values and subtracting this line from the profile.

7.7 Peak determination

The peak level of the profile over each half of the baseline shall be identified. This requires that the baseline of 100 mm be divided into two equal parts and that the highest peak in each part be determined. The two peak levels shall be arithmetically averaged.

NOTE 18 - In some devices, the profile signal may have been inverted and it is important to observe that the peaks considered above are those asperities of the profile with the highest altitude.

7.8 Determination of MPD

The Mean Profile Depth (MPD) for each individual profile is determined as the arithmetically averaged two peak levels minus the average (profile) level.

NOTE 19 - The average level is zero as a result of the highpass filtering or slope suppression required above.

7.9 Calculation of ETD (optional)

The MPD value may be transformed to an Estimated Texture Depth (ETD) by applying the following transformation equation:

$$ETD = 0{,}2 \text{ mm} + 0{,}8 \cdot MPD \qquad (2)$$

where ETD and MPD are expressed in millimetres.

NOTE 20 - The use of this transformation equation, which has been derived in reference [1] (see annex F) should give ETD values which are as close as possible to MTD values measured with the volumetric patch method. The error in the transformation equation is estimated to be much less than the variation due to different operators and equipment of the volumetric patch method.

7.10 Averaging of MPD and ETD values

A number of MPD and (optionally) ETD values shall be measured and calculated to meet the requirements of 4.2 and 4.3. The finally reported values shall be:

- the arithmetic mean value for all relevant measurements (MPD and, optionally, ETD)
- the corresponding standard deviation
- the number of individual values on which the mean is based, including the number of measuring runs and the number of profile records in each run.

8 Preferred use of the MPD and ETD values

Mean Profile Depth (MPD) is preferred for use in all future cases. The only advantage of the ETD value is to make possible a nominal comparison of texture depth values obtained with the profilometer method with values obtained with the volumetric patch method. Transformation from MPD to ETD can always be made afterwards using equation (2) in 7.9. The reporting of an ETD value is therefore only optional.

9 Safety considerations

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

10 Test report

The test report for each pavement test surface shall contain data on the following items:

- date of measurement
- location and identification of test surface
- description of type of surface
- description of surface contamination, which could not be avoided by cleaning, including possible moisture
- remarks about possible prominent surface conditions such as the existence of joints, excessive cracking, potholes, etc.
- track on the test site in which the measurement was made
- identification of the measurement equipment and its operating agency
- measurement speed
- calculation length of the baseline of the algorithm
- type of calibration and when it was made
- rate of invalid measurement/interpolated values (drop-outs)
- number of measurements (including number of runs over the tested surface and number of profile records in each run)
- Mean Texture Depth (MPD), in millimetres, for the pavement test surface as a whole
- standard deviation of the individual MPD values, in millimetres
- optionally, ETD values can be reported along with the MPD values

Annex A
(informative)

Texture ranges

A typical profile recording of a pavement surface is illustrated in figure A.1 (vertical scale exaggerated), including the terms *profile*, *distance*, *amplitude* and *wavelength*. "Wavelength" in the figure is an illustration of a component of the profile related to the wavelength concept but it is not correct from a strictly mathematical point of view. Furthermore, it should be noted that the reference (bottom) line is arbitrary.

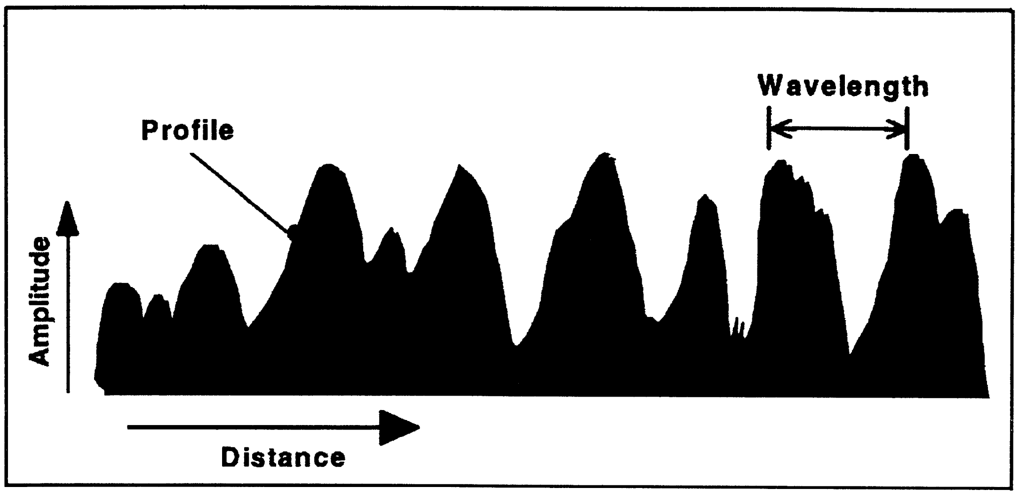
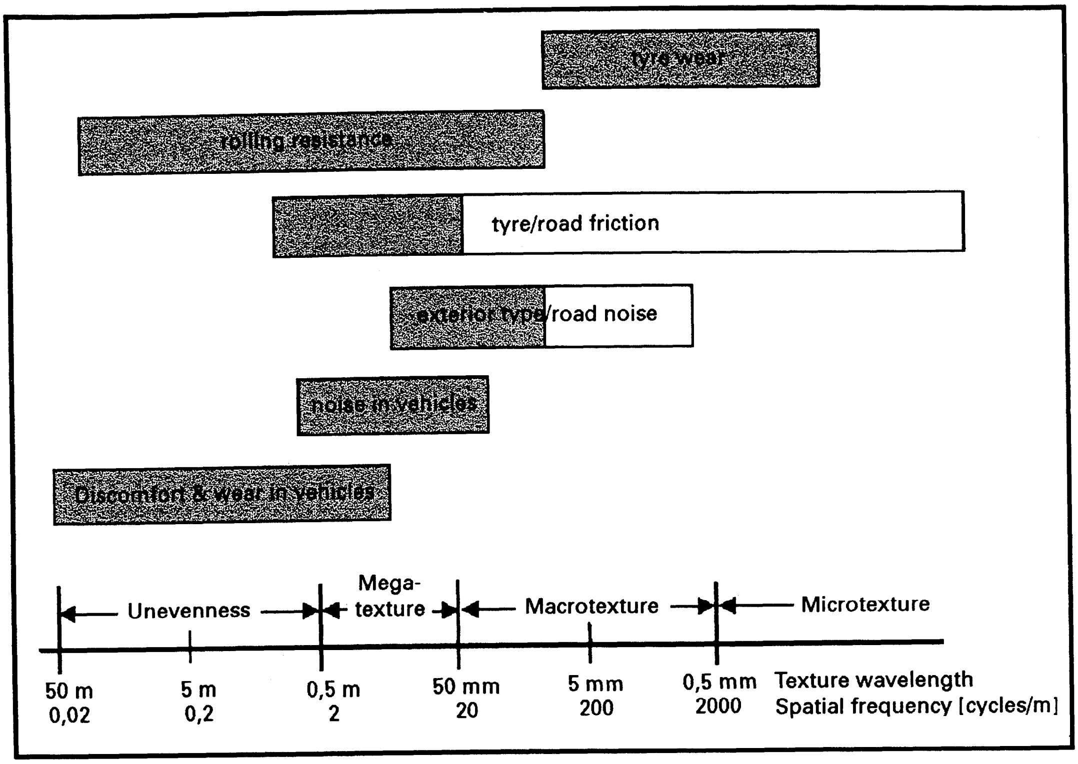


Figure A.1 — Illustration of some basic terms describing pavement surface characteristics

Based on physical relations between texture and friction/noise, etc., the World Road Association (PIARC) has defined the ranges of micro-, macro- and megatexture earlier; see reference [2] in annex F. Figure A.2 illustrates how these definitions cover certain ranges of surface texture wavelength and spatial frequency.

Figure A.3 attempts to illustrate the texture of a pavement in the three-dimensional case, especially the term *texture depth*, which is the distance between an arbitrary point of the plane down to the surface (at right angle relative to the plane). The plane is supposed to go through the three highest peaks of the surface.



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

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

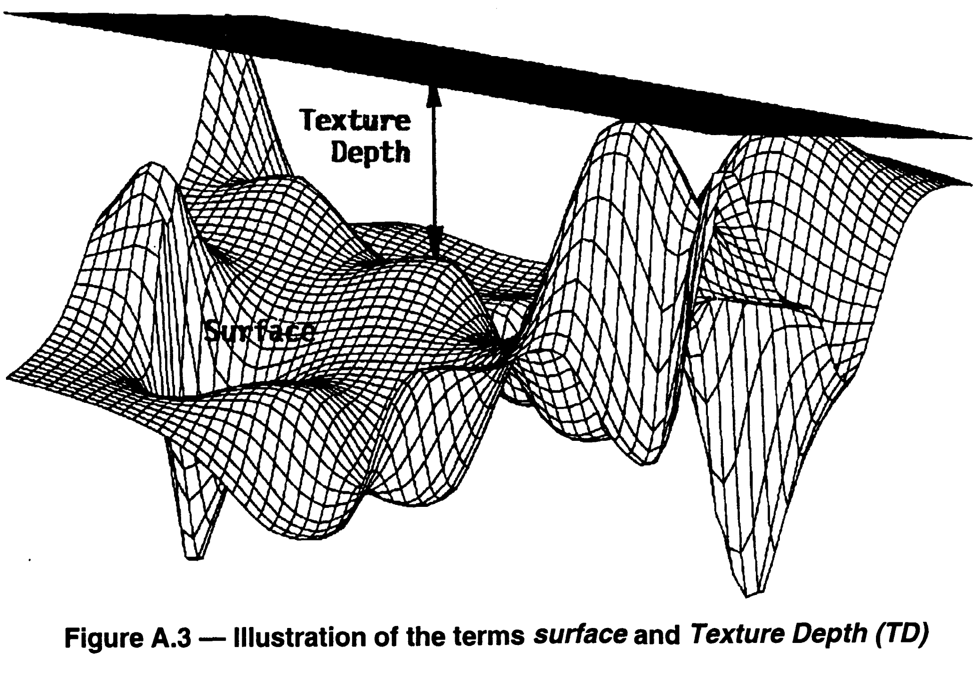


Figure A.3 — Illustration of the terms *surface* and *Texture Depth (TD)*

Finally, figure A.4 illustrates the definitions of *baseline*, *Profile Depth (PD)*, *Mean Profile Depth (MPD)* and *Estimated Texture Depth (ETD)*. The reference (bottom) line is arbitrary and just for illustration purposes here. The average level is normally set at "zero" level as a result of the highpass filtering or slope suppression procedures. The baseline is 100 mm long (see 7.5 and 7.7).

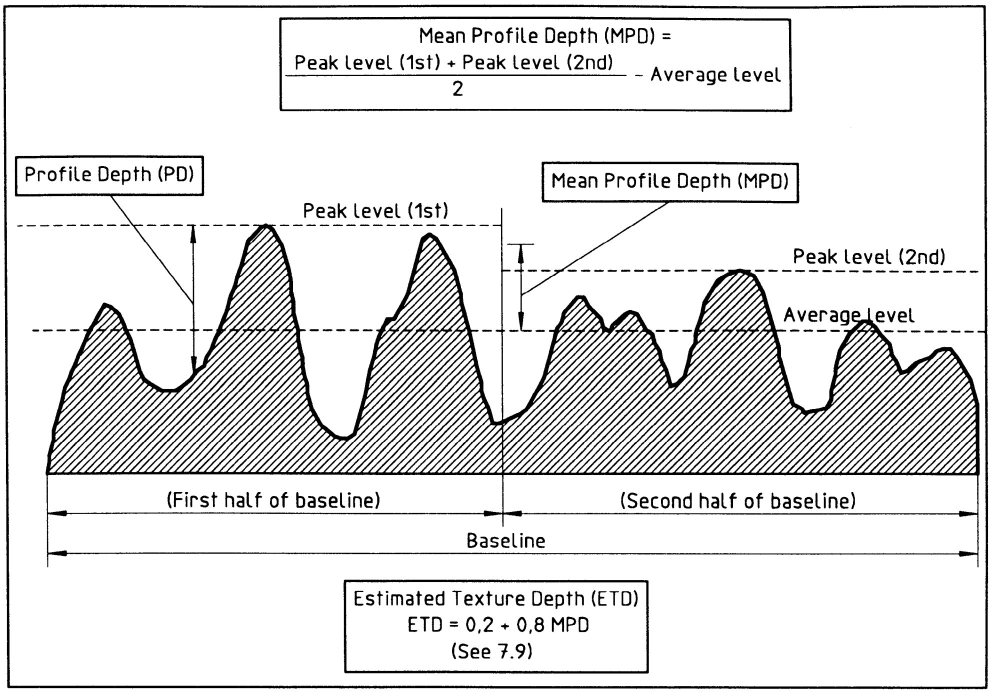


Figure A.4 — Illustration of the terms *baseline*, *Profile Depth (PD)*, *Mean Profile Depth (MPD)* and *Estimated Texture Depth (ETD)* (EDT and MPD are expressed in millimetres)

Annex B
(informative)

Problems experienced on special surfaces

B.1 Porous surfaces

On porous surfaces, in some cases the most essential property is the porosity, in some other cases it is not important at all. Friction and some noise characteristics rely on high porosity, while rolling resistance, tyre wear and some noise characteristics are not influenced by porosity, for example. Porosity is an effect which is created just underneath the surface and can clearly not be measured with a profiling technique. In the volumetric patch method, some material may pour down into the pores, but due to viscosity and particle size characteristics, the "true" porosity can never be measured in this way.

Consequently, neither the volumetric patch, nor the profiling method can measure the relevant characteristics covering all cases. Sometimes the patch method may give a more relevant result, while in other cases the profiling method may be preferred.

Experience has shown that the profiling method generally "underestimates" the texture depth on porous surfaces when compared to the values obtained with the volumetric patch method. This is true provided the profilometer works "correctly" on porous surfaces, i.e. without unacceptably high drop-out proportions and without any erroneous transients, which is not the case for all devices. On porous surfaces which have become clogged, experience has indicated that the profiling method gives values which correlate well with the volumetric patch method.

Before any texture depth values for porous surfaces are used, it must be ascertained that the profilometer works "correctly" on such surfaces. Secondly, even if it works "correctly", it must be kept in mind that the relevance of the measure for different purposes may be questionable.

B.2 Newly laid surfaces and humid/wet surfaces

Newly laid surfaces, at least if bituminous, generally have a glossy and extremely dark appearance. Profilometers relying on optical beams usually have problems with such surfaces because too little light is diffused in the direction towards the receiving element. Drop-out rates become high and there may be transients at extreme transitions to/from dark/bright surfaces. The same applies to surfaces which are dark due to wetness or humidity.

B.3 Surfaces with directional finish (grooved concrete, etc.)

Texture measurement of longitudinally grooved pavements causes problems, since, in most cases, mobile profilometers are unable to measure across such grooves other than at a very small angle. Stationary profilometers can be used appropriately if they are turned in the right direction. However, the problems of estimation of MPD or ETD are no worse than for transversely grooved surfaces (see below).

Regarding transversely grooved surfaces, in theory, the profiling method may somewhat underestimate the texture depth in relation to that measured with the volumetric patch method because most profilometers have problems in reproducing the very steep, almost vertical slopes in grooves. In practice, there are data which seem to support this but other data which show no particular effect of the directional grooves. It is concluded that if there is an effect at all, it is an underestimation for grooved surfaces and it is just a minor effect which can be neglected in most cases.

For measurement on directional textures, it is recommended that the sensor, profiling along a longitudinal line, should be directed in order that the optical plane is transverse to the direction of the grooves. For a light sectioning device, the direction of the section should be longitudinal for transverse grooving and transverse for longitudinal grooving.

B.4 Smooth surfaces

On pavements with very smooth textures, a measuring procedure used in some countries as an alternative or a supplement to the volumetric patch method is the "outflow method". A water container with a rubber ring at the bottom is placed on the spot to be measured. At the initiation of the test a valve is opened and the water flows out between the rubber ring and the surface. The time for the water to fall between two levels (the "outflow time") is taken as a measure of the smoothness of the surface.

The outflow method is not generally useful in connection with the profilometer method since the latter has no problem in measuring on smooth surfaces and thus needs no supplement.

Annex C
(informative)

Validity and accuracy of the method

Regarding validity of the method, limitations are discussed in annex B.

Regarding repeatability, reference [1] in annex F shows that for the minimum requirements of 4.2, ETD can be determined for a 150 m test section with a standard uncertainty of approximately 20 % of the average value. If more or longer runs over the same test section are made, the uncertainty decreases according to conventional statistical procedures when averaging random data.

The imperfections in repeatability are caused by sources such as:

1. equipment instability
2. software imperfections
3. operator influence
4. surface longitudinal inhomogeneity
5. surface lateral inhomogeneity (difficulty of measuring in the same lateral track each time).

Sources Nos. 4 and 5 generally dominate in this case.

The reproducibility, using two different systems and test crews, was found in the same experiment to be 0,15 mm, corresponding to 10 % of the average texture depth in the experiment (residual error in regression between two devices). However, it is important to note that these values included also the effect of repeatability, one device measuring approximately 4 m in total and the other 8 m in total per site (1,5 m per 150 m long site would be the minimum allowable measured length according to this part of ISO 13473).

Annex D
(informative)

Calibration procedure

Calibration surfaces according to table D.1 have been found to be practical.

Table D.1 — Useful calibration surfaces

Type of profile	Suitable for following type of profilometers	Amplitude calibration?	Wavelength calibration?
Triangular (e.g. 10 mm peak-bottom and 20 mm wavelength)	Rotating at edge of disc: All mobile lasers Straight: Mobile light sectioning and all stationary devices	RMS value of triangle wave (for spectrum: RMS of fundamental)	Fundamental and harmonics
Rectangular (e.g. 10 mm peak-bottom, each level ≥ 10 mm long)	Rotating at edge of disc: All mobile lasers Straight: Mobile light sectioning and all stationary devices	On flat top and bottom parts	Only if profile can be correctly measured (difficult)
Staircase (e.g. 10 mm long steps, each 1 mm high)	Rotating at edge of disc: All mobile lasers Straight: Mobile light sectioning and all stationary devices	On flat parts. Linearity can be checked	Not recommended using this profile

Calibration surfaces according to table D.1 can be machined by a qualified workshop to a high degree of mechanical accuracy. For optical profilometers it is recommended that the surfaces are blasted and/or painted with a matte finish to obtain a diffuse appearance, spreading the reflected light uniformly. The relative error in the machining and mechanical measurement can be reduced to negligible values if dimensions of the size suggested in table D.1 are used. Smaller profiles will have higher relative errors. If possible, the calibration should be made with a speed between surface and profilometer which is the same as normally used during measurement (dynamic calibration). For the rotating calibration surfaces, this can be obtained with a rotation speed giving the appropriate profile movement underneath the sensor (the latter of which is not moving).

Note that for a triangular wave it is not recommended to calibrate on the extreme peaks and valleys of the profile since they might be poorly reproduced by the profilometer. It is better to use the RMS value which is not much influenced by poor reproduction of the peak and valleys of the profile.

Calibration may easily be made if the calibration profile is mounted on a dynamometer roll, over which the sensor is placed, and running the dynamometer at a rotational speed giving a circumferential speed equal to the normal profilometer operating speed.

NOTE 21 - When slope suppression is applied to a calibration surface with relatively long texture wavelength, the slope may be influenced somewhat by the starting and finishing points of the profile. Three alternative ways to avoid this problem are as follows.

a) Base the calibration on the RMS value of the calibration profile. Use texture wavelength no longer than 20 mm and a sample length long enough to cover at least 20 periods, or use a sample length such that the start and finishing profile segments are symmetrical.

b) Adapt the measurement procedure for calibration surfaces so that the slope is negligible and do then **not** apply the slope suppression.

c) If slope suppression is necessary, use texture wavelength no longer than 20 mm for the calibration and a sample length long enough to cover at least 20 periods, or use a sample length such that the start and finishing profile segments are symmetrical.

Annex E
(informative)

Flow chart for determination of MPD and ETD

Figure E.1 illustrates the measuring and data processing procedure described in clauses 6 and 7.

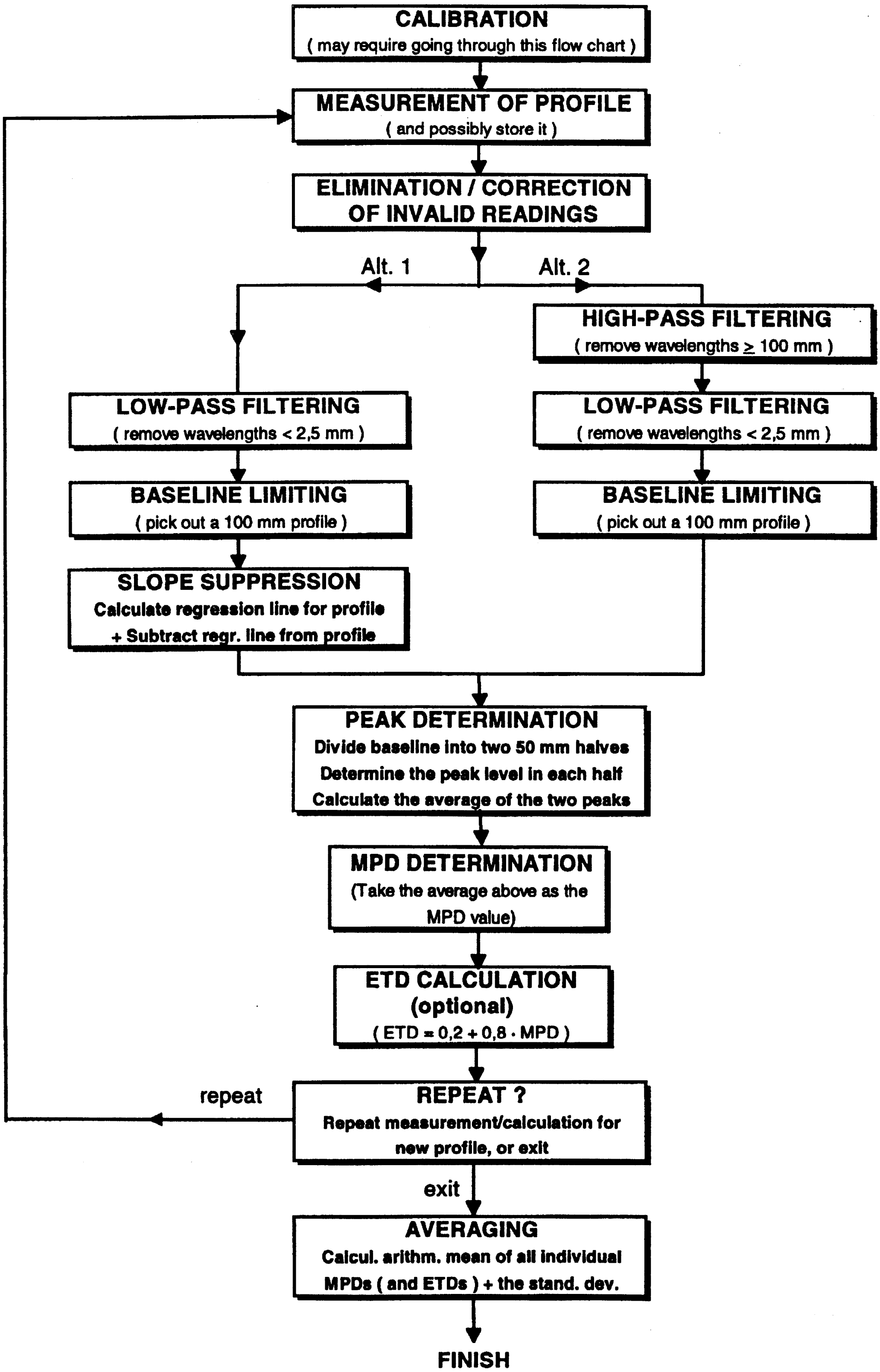


Figure E.1 — Illustration of the measuring and data processing procedure

Annex F
(informative)

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[2] PIARC (1987): "Optimization of Surface Characteristics". Report to the XVIIIth World Road Congress 1987 in Brussels, Belgium, from the Technical Committee on Surface Characteristics, World Road Association (PIARC), Paris.

[3] ISO 468:1982, *Surface roughness — Parameters, their values and general rules for specifying requirements.*

[4] ISO 1878:1983, *Classification of instruments and devices for measurement and evaluation of the geometrical parameters of surface finish.*

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[6] ISO 1880:1979, *Instruments for the measurement of surface roughness by the profile method — Contact (stylus) instruments of progressive profile transformation — Profile recording instruments.*

[7] ISO 3274:1975, *Instruments for the measurement of surface roughness by the profile method - Contact (stylus) instruments of consecutive profile transformation — Contact profile meters, system M.*

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[9] ISO 4287-2:1984, *Surface roughness — Terminology — Part 2: Measurement of surface roughness parameters.*

[10] ISO 4288:1996, *Rules and procedures for the measurement of surface roughness using stylus instruments.*

[11] ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions.*

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