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Characterization of pavement texture by use of surface profiles —

Part 3: Specification and classification of profilometers

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

Partie 3: Spécification et classification des appareils de mesure de profil

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.

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

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

Attention is drawn to the possibility that some of the elements of this part of ISO 13473 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 13473-3 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

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

— *Part 1: Determination of Mean Profile Depth*

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

— *Part 3: Specification and classification of profilometers*

Annex A of this part of ISO 13473 is for information only.

Introduction

Profilometers have been used in research on surface characteristics of pavements on roads and airfields since the 60's and have recently also been applied to general pavement surveys. Although most of the designs have been based on laser sensor technology, the principles of operation, measurement and analyses have been and are very different. This part of ISO 13473 is an attempt to facilitate the comparison of different profilometers and to specify requirements needed when they are applied to pavement engineering.

Characterization of pavement texture by use of surface profiles —

Part 3:
Specification and classification of profilometers

1 Scope

This part of ISO 13473 specifies requirements for profilometers used in pavement engineering in order to give meaningful and accurate measurement of pavement micro-, macro- and megatexture characteristics of paved road and airfield surfaces. It also includes schemes for the classification of such profilometers with respect to their use and overall accuracy. The profilometers may be of any operational type.

The scope of this part of ISO 13473 does not include profile analysis of machined surfaces. Also excluded from the scope is the profile analysis of road unevenness.

NOTE 1 Profile analysis of machined surfaces is dealt with in other standards, for example ISO 3274, ISO 4287, ISO 4288, ISO 5436-1, ISO 5436-2 and ISO 12085.

NOTE 2 Profile analysis of road unevenness is dealt with in ISO 8608.

NOTE 3 Throughout this part of ISO 13473, the use of the term "pavement" means "paved road or airfield surface".

2 Normative reference

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

ISO 13473-2:2002, *Characterization of pavement texture by use of surface profiles — Part 2: Terminology and basic requirements related to pavement texture profile analysis*

3 Terms and definitions

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

4 General classes of profilometers for texture measurement

4.1 Mobility

The classes of profilometers with respect to mobility are as follows (see also Table 1).

a) **Mobile, high speed**: Profilometers of this class are mounted on a vehicle and used at a driving speed of 60 km/h or more. Such profilometers do not normally disturb other traffic.

b) **Mobile, low speed**: Profilometers of this class are mounted on a vehicle and used at a driving speed of less than 60 km/h. Although such profilometers are truly mobile, on high-speed roads they are often a nuisance to other traffic.

c) **Stationary, fast**: Profilometers of this class are placed on the pavement each time a measurement is carried out, but are able to move fast enough in order not to require that the pavement section be closed for a short time. An example is a profilometer mounted on a trailer or other vehicle which must be stopped during measurement but which, after some seconds, can move on to the next measuring location. Another example is a profilometer operating at walking speed.

d) **Stationary, slow**: Profilometers of this class are placed on the pavement each time a measurement is carried out, but operate so slowly that the pavement section must be closed to other traffic.

Table 1 — Classes of profilometers with respect to mobility

	Fast	Slow
Mobile	operating speed: $\geqslant$ 60 km/h	operating speed: $<$ 60 km/h
Stationary	time on lane per single measurement: $<$ 1 min	time on lane per single measurement: $\geqslant$ 1 min

4.2 Texture wavelength range

The classes of profilometers with respect to wavelength range classes are given in Table 2. The wavelengths are expressed as one-third-octave-band centre wavelengths and the performance shall pertain to the entire band in question.

Table 2 — Classes according to texture wavelength range

Values in millimetres

	Wavelength range class					
	A	B	C	D	E	F
Texture wavelength range covered	0,05 to 0,16	0,20 to 0,50	0,63 to 2,0	2,5 to 50	63 to 200	250 to 500
One-third-octave bands covered (centre wavelengths)	0,05; 0,063; 0,08; 0,10; 0,125; 0,16	0,20; 0,25; 0,315; 0,40; 0,50	0,63; 0,80; 1,0; 1,25; 1,6; 2,0	2,5; 3,15; 4; 5; 6,3; 8; 10; 12,5; 16; 20; 25; 31,5; 40; 50	63; 80; 100; 125; 160; 200	250; 315; 400; 500

NOTE If, for example, a profilometer covers the range 0,3 mm to 100 mm, the range specification is written as wavelength range class CD; if it covers the range 0,2 mm to 500 mm, it is a wavelength range class BF profilometer.

4.3 Pavement contact

Profilometers may be of two types depending on whether or not the sensor contacts the pavement.

a) **Contact devices**: The sensor makes contact with the measured surface.

b) **Contactless devices**: The sensor makes no contact with the measured surface.

4.4 Principle of operation

Profilometers may be based on different principles of operation, mainly pertaining to the type of sensor. The following list may not be complete, but it indicates the preferred terms for the most common principles in current use.

a) **Laser profilometer**: A device utilizing an electro-optical sensor in which a laser beam is reflected against the pavement, the spot of which is projected via optical lenses on a position-sensitive semiconductor transducer. The sensor is moved along the surface to be measured, resulting in an electrical output signal proportional to the height (elevation) of the laser spot on the surface as a function of distance.

b) **Light-sectioning profilometer**: A device utilizing either a narrow or an extended beam of light, creating on the pavement a thin line or an intensively illuminated band with sharp light edges. The light may be flashed with a very short exposure time or may shine continuously. A video camera monitors this light line or light edge from an angle in relation to the light beam. In the x-y output of the camera sensor, the profile is distinguishable as the transition between the light edges and the background. This device must not be moved during the time when the profile is sampled, because the profile trace will then be blurred.

c) **Stylus profilometer**: A device using a stylus (needle) which touches the pavement and which is mechanically connected to a displacement transducer. The latter may be of many different principles, but linear potentiometers or linear variable differential transformers (LVDT) are the most common. The sensor is moved or stepped along the surface to be measured, resulting in an electrical output signal proportional to the height (elevation) of the contact spot on the surface as a function of distance.

d) **Ultrasonic profilometer**: A device utilizing an electro-acoustical sensor in which a beam of ultrasonic sound is transmitted to the pavement and reflected from it. A microphone picks up the reflected sound, and the time between the transmitted and received ultrasound is calculated and transformed into a corresponding distance. The sensor is moved along the surface to be measured, resulting in an electrical output signal proportional to the height (elevation) of the ultrasound-exposed spot on the surface as a function of distance.

5 Types of measurements

Examples of the most common types of measurements and analyses that are made with profilometers are the following.

a) **General recording of profile curves**: This can be made for simple illustration purposes or for qualitative assessment of the texture.

b) **Measurement of mean profile depth (MPD)**: A method for the measurement of MPD is described in ISO 13473-1. The MPD is used to assess the skid resistance speed gradient characteristics (see reference [1] in the Bibliography).

c) **Measurement of profile amplitude distributions**: See ISO 13473-2 for definitions.

d) **Other amplitude-related measurements from profile curves**: Some profilometers provide r.m.s. values as an output. It is also possible to present skewness and kurtosis. See ISO 13473-2 for definitions.

e) **Texture spectrum measurement**: Profile curves are often analysed in terms of their spectral content; this is most often expressed as octave or one-third-octave band texture spectra. See ISO 13473-2 for definitions.

This part of ISO 13473 does not specify how measurements with profilometers shall be used or applied in special cases. However, the above list gives some guidelines for further study. In particular, ISO 13473-2 specifies and harmonizes terms and measures useful in pavement engineering.

6 Specific performance requirements

6.1 General

A profilometer system which produces an electrical signal that is proportional to the distance between a sensor reference plane and the surface spot in question shall be used. The sensor may be a mechanical, acoustical or electro-optical type of sensor or a video camera. The final output shall be linearly related to the texture profile and linearity may be obtained either in hardware or software.

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

6.2 Vertical measuring range

The capability of the system to measure vertical displacement (profile and the vertical motion of the sensor as well) shall meet the minimum requirements given in Table 3.

If the system has a range-tracking capability, i.e. the sensor carrier is displaced by a servo-mechanism to approximately follow the longer wavelengths of the profile, the requirements of the sensor of mobile systems may be relaxed to be the same as for stationary devices.

Table 3 — Minimum vertical measuring range

Values in millimetres

	Wavelength range class			
	A	B	C	D, E and F
Texture wavelength range covered	0,05 to 0,16	0,20 to 0,50	0,63 to 2,0	2,5 to 500
Mobile, high speed	N.A.	N.A.	50	60
Mobile, low speed	N.A.	40	50	60
Stationary, fast	N.A.	20	20	20
Stationary, slow	10	10	10	20
The indication N.A. (not applicable) means that there are no devices that reasonably will meet such requirements at the time of publication of this part of ISO 13473.				

NOTE The requirements given in Table 3 are a compromise that attempts to satisfy conflicting requirements for vertical resolution and the risk of out-of-range measurements. They are expected to satisfy most texture measuring needs on pavements normally used on streets, roads and airfields. A single and unusually large irregularity may nevertheless drive the sensor out-of-range, which may be acceptable if it does not occur too often (see 6.13). However, in cases where there is abnormally high unevenness or megatexture, wider ranges may be needed.

6.3 Horizontal evaluation length

The horizontal evaluation length shall meet the minimum requirements given in Table 4. Over the “evaluation length” the profile shall be continuously measured (dropouts accepted according to 6.13).

Table 4 — Minimum “uninterrupted” horizontal evaluation length

Values in millimetres

	Wavelength range class					
	A	B	C	D	E	F
Texture wavelength range covered	0,05 to 0,16	0,20 to 0,50	0,63 to 2,0	2,5 to 50	63 to 200	250 to 500
Mobile, high speed	N.A.	N.A.	20	200	1 000	2 000
Mobile, low speed	N.A.	5	20	200	1 000	2 000
Stationary, fast	N.A.	5	20	200	500	1 000
Stationary, slow	5	5	20	200	500	1 000
Note that in order to get the appropriate statistical representativity, several such evaluation lengths may be required. The indication N.A. (not applicable) means that there are no devices that reasonably will meet such requirements at the time of publishing of this part of ISO 13473.						

Furthermore, over a distance up to the maximum wavelength, the level of the profilometer reference plane or line shall not change significantly. This effect shall be included in the requirements for background noise. For example, if a road vehicle carries the sensor, the vehicle shall not change its vertical position over this distance.

NOTE 1 The requirements given in Table 4 are a compromise between practicability and accuracy.

NOTE 2 One way to avoid the problem of vertical vehicle motion is to employ a so-called “Accelerometer-established inertial profiling reference” which is achieved by mounting an accelerometer system to the vehicle body and integrating the acceleration twice to obtain vehicle body displacement (see reference [2]).

NOTE 3 At the time of publication of this part of ISO 13473, work is underway to develop a Technical Specification describing procedures for spectral analysis in more detail. In this work it is considered to increase the evaluation length requirement for class F for mobile devices from 2 m to 3 m.

6.4 Vertical resolution

Profilometer sensors in systems measuring and presenting only profile curves, and those presenting only overall values like MPD and ETD (as in ISO 13473-1), shall have a vertical resolution of 0,05 mm or better. If, however, detailed parts of profiles are to be analysed, by zooming or similar techniques, the vertical resolution shall meet the minimum requirements of Table 5.

Table 5 — Minimum vertical resolution

Values in millimetres

	Wavelength range class					
	A	B	C	D	E	F
Texture wavelength range covered	0,05 to 0,16	0,20 to 0,50	0,63 to 2,0	2,5 to 50	63 to 200	250 to 500
Minimum vertical resolution	0,001	0,003	0,01	0,03	0,04	0,05
NOTE For profilometer systems which rely on a digitized profile, the resolution is often (but not necessarily) equal to the quantity represented by the least significant bit (LSB).						

For profilometers used for texture spectrum analysis, vertical resolution shall meet the minimum requirements of Table 5.

6.5 Nonlinearity

Vertical nonlinearity after the final signal processing shall be no greater than 2 % of the range for wavelength range classes D, E and F, and 5 % for classes B and C. The performance for Class A is yet to be determined.

6.6 Horizontal resolution

The horizontal resolution, Δx, shall meet the requirements of Table 6 over the entire vertical measuring range. Horizontal resolution is determined in practice by the following characteristics according to type of device.

a) In the case of a contactless device, utilizing 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 shall be no greater than Δx. 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 %)[1] of the maximum intensity within the spot.

b) 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 Δx. 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.

c) In the case where a contact device is used (e.g. utilizing a stylus sensor), the tip of the contacting part shall be such that the tip, at its widest dimension, has a diameter of no more than Δx, up to Δx in height from the tip.

NOTE 1 Ideally, the horizontal resolution would be measured as the ability to reproduce small objects or changes horizontally. However, it is not yet possible to specify such a method which is technically and practically acceptable. In the interim, the above procedures can be used to estimate the resolution. For contactless devices, spot size or line width are reasonable indicators of horizontal resolution, but spatial properties of the detector are equally important. With the designs and products available at the time of production of this part of ISO 13473, the spot size and line width are the major determining factors for horizontal resolution, and thus can be used as specified above.

NOTE 2 The shape of the stylus tip can influence the response at extremely short wavelengths. The distribution of intensity within a laser spot of the laser profilometers in use when this part of ISO 13473 was produced is approximately Gaussian. In order to resemble such a spot, the stylus tip should be rounded.

1) "e" is the base of the natural system of logarithms (2,718 281 8...).