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BSI Standards Publication

Road and airfield surface characteristics

Part 15: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal controlled slip (LFCl): The IMAG

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Road and airfield surface characteristics - Part 15: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal controlled slip (LFCI): The IMAG

Caractéristiques de surface des routes et aéroports - Partie 15: Mode opératoire de détermination de l'adhérence d'un revêtement de chaussée à l'aide d'un dispositif à glissement longitudinal contrôlé (CFLI): IMAG

Oberflächeneigenschaften von Straßen und Flugplätzen - Teil 15: Verfahren zur Bestimmung der Griffigkeit von Fahrbahndecken durch Verwendung eines Geräts mit geregeltem Schlupf in Längsrichtung (LFCE): Das IMAG-Gerät

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Foreword

This document (CEN/TS 15901-15:2014) has been prepared by Technical Committee CEN/TC 227 "Road materials", the secretariat of which is held by DIN.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. CEN [and/or] CENELEC shall not be held responsible for identifying any or all such patent rights.

CEN/TS 15901, *Road and airfield surface characteristics*, is composed with the following parts:

— *Part 1: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal fixed slip ratio (LFCS): RoadSTAR*;

— *Part 2: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal controlled slip (LFCRNL): ROAR (Road Analyser and Recorder of Norsemeter)*;

— *Part 3: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal controlled slip (LFCA): The ADHERA*;

— *Part 4: Procedure for determining the skid resistance of pavements using a device with longitudinal controlled slip (LFCT): Tatra Runway Tester (TRT)*;

— *Part 5: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal controlled slip (LFCRDK): ROAR (Road Analyser and Recorder of Norsemeter)*;

— *Part 6: Procedure for determining the skid resistance of a pavement surface by measurement of the sideway force coefficient (SFCS): SCRIM®*;

— *Part 7: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal fixed slip ratio (LFCG): the GripTester®*;

— *Part 8: Procedure for determining the skid resistance of a pavement surface by measurement of the sideway-force coefficient (SFCD): SKM*;

— *Part 9: Procedure for determining the skid resistance of a pavement surface by measurement of the longitudinal friction coefficient (LFCD): DWWNL skid resistance trailer*;

— *Part 10: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal block measurement (LFCSK): the Skiddometer BV-8*;

— *Part 11: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal block measurement (LFCSR): the SRM*;

— *Part 12: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal controlled slip: the BV 11 and Saab friction tester (SFT)*;

— *Part 13: Procedure for determining the skid resistance of a pavement surface by measurement of a sideway force coefficient (SFCO): the Odoliograph*;

— *Part 15: Procedure for determining the skid resistance of a pavement surface using a device with longitudinal controlled slip (LFCI): The IMAG* [the present document].

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This Technical Specification describes a method only used on airports for determining the skid resistance of pavements by measurement of the longitudinal friction coefficient LFCI.

The method provides a measure of the wet skid resistance properties of a bound surface by measurement of the longitudinal friction coefficient using a trailer with a standard slip ratio of 15 %. The slip ratio can be chosen between 0 % and 100 % for research application.

The test tyre is dragged over a pre-wetted pavement under vertical force and constant speed conditions while the test tyre is parallel to the direction of motion.

This Technical Specification covers the operation of the IMAG device.

The skid resistance of a pavement is determined by friction measurements at different speeds. Tests can be performed between 40 km/h and 120 km/h but standard test speeds are 40 km/h, 65 km/h and 95 km/h. Low speed measurements asses the microtexture while high speed measurements asses the macrotexture. The skid resistance is reported as friction measurements at these speeds and by comparison with the minimum friction level.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ASTM E670-09, *Standard Test Method for Side Force Friction on Paved Surfaces Using the Mu-Meter*

ASTM E2100-04, *Standard Practice for Calculating the International Runway Friction Index*

PIARC Technical Document. *Specification for a standard test tyre for friction coefficient measurement of a pavement surface: Smooth test tyre* (2004-03)

3 Recommended uses

The IMAG is used in the following fields of application:

— monitoring of airport pavements (Pavement Management) according to ICAO Annex 14 Attachment A 7,

— approval of new surfacing according to ICAO Annex 14 Attachment A 7,

— investigation of surface skid resistance,

— measurements on project-level compliance,

— comparative measurements among different devices,

— measurements on contaminated (ice or snow covered) airport pavements (not covered by this Technical Specification) according to ICAO Annex 14 Attachment A 6,

— research measurements.

4 Terms and definitions

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

4.1
contact area
overall area of the road surface instantaneously in contact with a tyre

Note 1 to entry: This term describes the overall area generally covered by the tyre. Due to the effects of surface texture or any tyre tread pattern, not all of the tyre or road surface in the contact area may be in contact at any instant.

4.2
friction
resistance to relative motion between two bodies in contact, the frictional force being the force which acts tangentially in the contact area

4.3
vertical force (load)
force applied by the wheel assembly on the contact area

Note 1 to entry: Some devices use an assumed load based on the static load.

4.4
horizontal force (drag)
horizontal force acting tangentially on the test wheel in line with the direction of travel

4.5
slip ratio
slip speed divided by the operating speed

4.6
longitudinal friction coefficient
LFC
ratio between horizontal force (drag) and vertical force (load) for a braked wheel in controlled conditions, which is normally a decimal number quoted to two significant figures

Note 1 to entry: LFC varies depending on the slip ratio of the device and the operational speed.

4.7
skid resistance
characterisation of the friction of a road surface when measured in accordance with a standardized method

4.8
wet skid resistance
property of a trafficked surface that limits relative movement between the surface and the part of a vehicle tyre in contact with the surface, when lubricated with a film of water

Note 1 to entry: Factors that contribute to skid resistance include the tyre pressure, contact area, tread pattern, and rubber composition; the alignment, texture, surface pollution, and characteristics of the road surface; the vehicle speed; and the weather conditions.

The change in skid resistance of a surface in service is affected by the volume of traffic and the composition of the traffic, as the tyres of these vehicles polish and/or wear away the surfacing material in different ways. Rubber debris especially affects wet skid resistance.

Where the surface contains aggregate with a coating of binder, e.g. bitumen, resin or Portland cement, the skid resistance will change as the coating is worn away by tyres.

4.9
fixed slip
condition in which a braking system forces the test wheel to roll at a fixed reduction of its operating speed

4.10
fixed slip friction
friction between a test tyre and a airfield surface when the wheel is controlled to move at a fixed proportion of its natural speed

4.11
longitudinal friction coefficient IMAG
LFCI
ratio between the horizontal force in the direction of the motion that can be activated between the test wheel and the wet pavement and the vertical wheel force accomplished under controlled slipping conditions

Note 1 to entry: The controlled slipping condition of the test wheel is achieved by a hydraulic pump and a hydraulic servo-valve enslaved by the sensors of the IMAG.

4.12
sampling length or sampling interval
distance over which responses of the sensors are sampled to determine a single measurement of the recorded variables

Note 1 to entry: The sampling length depends upon the detailed operation of device and its recording system; a number of samples may be combined to determine a measurement for a subsection.

Note 2 to entry: This should not be confused with horizontal resolution which is the shortest distance over which a change in the measured parameter can be detected.

4.13
microtexture
deviation of a pavement from a true planar pavement with characteristic dimensions along the pavement of less than 0,5 mm, corresponding to texture wavelengths with one-third-octave bands and up to 0,5 mm centre wavelengths

Note 1 to entry: Peak to peak amplitudes normally vary in the range 0,001 mm to 0,5 mm.

Note 2 to entry: Microtexture is a primary component in skid resistance at low speeds. Those devices that utilize a relatively low slip speed primarily measure the component of friction affected by microtexture.

4.14
macrotexture
deviation of a pavement from a true planar pavement with characteristic dimensions along the pavement of 0,5 mm to 50 mm, corresponding to texture wavelengths with one-third-octave bands including the range 0,63 mm to 50 mm centre wavelengths

Note 1 to entry: Peak to peak amplitudes normally vary in the range 0,1 mm to 20 mm.

Note 2 to entry: Macrotexture is a major factor influencing skid resistance at high speeds but it also has an effect at low speeds.

4.15
mean profile depth
descriptor of macrotexture, obtained from a texture profile measurement as defined in EN ISO 13473-1 and ISO 13473-2

4.16
calibration
periodic adjustment of the offset, the gain and the linearity of the output of a measurement method so that all the calibrated devices of a particular type deliver the same value within a known and accepted range of uncertainty, when measuring under identical conditions within given boundaries or parameters

Note 1 to entry: The calibration method for IMAG is given in Clause 10.

4.17
repeatability
r
maximum difference expected between two measurements made by the same machine, with the same tyre, operated by the same crew on the same section of road in a short space of time, with a probability of 95 %

4.18
reproducibility
R
maximum difference expected between two measurements made by different machines with different tyres using different crews on the same section of road in a short space of time, with a probability of 95 %

4.19
IMAG
acronym applying to a device, developed by the “Service Technique des Bases Aériennes” in France in cooperation with the “Aéroports de Paris”, to perform routine, continuous measurements of friction for airport pavement

Note 1 to entry: A device conforming to the general characteristics of the IMAG and the specific provisions of this Technical Specification should be used for the tests.

4.20
operating speed
speed at which the device traverses the test surface, with the IMAG normally working to test speeds between 40 km/h to 120 km/h

4.21
slip speed
relative speed between the tyre and the travelled surface in the contact area

4.22
wheel path
parts of the pavement surface where the majority of wheel passes are concentrated

Note 1 to entry: The wheel path is not a fixed location on a pavement surface. It should correspond to the most circulated area and is usually comprised between 3 m and 7 m from the centre line of the runway.

For special circumstances such as acceptance tests, a particular path may be defined.

4.23
water delivery system
system for depositing a given amount of water in front of the test tyre so that it then passes between the tyre and the surface being measured

4.24
water flow rate
rate (litres/second) at which water is deposited on the surface to be measured in front of the test tyre

4.25
theoretical water film thickness
theoretical thickness of a water film deposited on the surface in front of the test tyre, assuming the surface has zero texture depth

4.26
subsection
defined length of surface for which one set of the measured variables is reported by the device

Note 1 to entry: Different subsections can be used, but skid resistance parameters are generally reported each 100 m, each third of the runway, and for the whole runway.

4.27
test section
length of runway between defined points (e.g. location references, specific features or measured distances) comprising a number of subsections over which a continuous sequence of measurements is made

4.28
reference device
particular measurement device selected as a reference for the correlation of other friction measuring device and described in ASTM E2100-04

5 Safety

Safety measures shall maintain safe working conditions in accordance with current regulations, to ensure the safety of test operators and other users (including measures to control traffic).

When measuring skid resistance on runways, test operator shall ensure traffic is stopped and start measures against the direction of traffic movement.

Tests that involve water deposition should not be carried out if there is a risk of water freezing on the pavement.

6 Essential characteristics

6.1 Principle of measurements

Devices complying with this Technical Specification operate on the principle that the test wheel allows the simulation and investigation of a real braking situation. The test wheel is loaded and towed at a constant speed and then brake at a fix slip ratio. Friction at tyre/pavement interface is created through partial slipping of the test tyre.

The runway is pre-wetted with a theoretical defined water film thickness of 1 mm in front of the test wheel.

6.2 Description of IMAG

The device is a trailer and consists of a principal frame with two wheels fitted on articulated arms. This frame supports an articulated measuring frame equipped with loaded test wheel and a hydraulically controlled braking system (ASTM E2100-04). A typical device is illustrated in Figure 1. The IMAG is equipped with:

— two distance transducers (CO1 and CO_2) for distance and speed measurement,

— three force transducers (T1, T2 and Fv) for horizontal and vertical force measurements,

— one torque transducer (CC, not used for maintenance purpose but for winter measurements and research), and

— one speed transducer (GT) for measurement of test wheel speed.

The vertical force is set at a nominal level and applied to test tyre by a system with shock absorber.

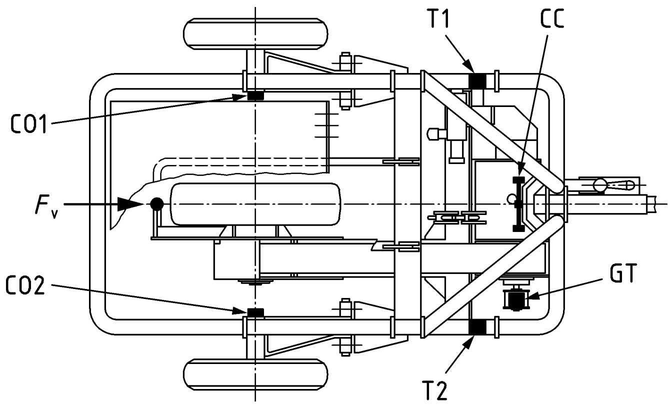

Figure 1 — Overview of the IMAG

Figure 2 — Skid resistance trailer

For skid resistance measurements the IMAG is working at a fix slip ratio of 15 % only (calculated from measurements of CO1, CO_2 and GT). The test wheel is loaded with a mass adjustable from 1 700 N to 2 000 N. To increase the accuracy of the measurements, the IMAG dynamic vertical force (F_V) on the test wheel is measured and recorded during the test.

Friction measurements are performed at a constant speed of 40 km/h, 65 km/h and 95 km/h (measured by CO1 and CO_2).

The IMAG is used with a theoretical defined water film thickness equal to 1 mm. The trailer vehicle is equipped with a water delivery system. At the back of the vehicle, the water flow meter records the water flow rate against the test speed. The amount of water required is adjusted depending on the specified test speed. A hydraulic servo-valve controls the water flow rate and ensures the 1 mm theoretical water film thickness. Water is poured in front of the test wheel through a nozzle designed and set in accordance with the ASTM

Standard ASTM E670-09. The horizontal distance between the nozzle and the centre of the test wheel is 410 mm.

7 Key characteristics

7.1 General

Below, the minimum requirements to ensure a good repeatability and reproducibility of the devices results are listed.

7.2 Test speed

During tests the towing vehicle is capable of maintaining speeds of 40 km/h to 120 km/h, ± 2 km/h. The tachometer provides speed resolution and accuracy of 0,1 km/h The output is directly displayed to the driver and simultaneously recorded.

7.3 Braking system

The controlled slipping condition of the test wheel is achieved by a hydraulic pump through a servo valve enslaved by an electronic controller which compares signals given by reference wheels (rotational pulse generator) and test wheel (tachimeter). This system allows common measurements between 10 % and 20 % slip ratio. The IMAG is generally used at a 15 % slip ratio. Value of slip ratio is recorded.

7.4 Static wheel load

The apparatus is designed to provide an equal static load adjustable from 1 700 N to 2 000 N to the test wheel.

7.5 Dynamic wheel load

During the test the IMAG is able to measure the vertical force with an accuracy of ± 0,05 % and a resolution of ± 0,1 % at the same time as the other measurements are done.

7.6 Test wheel arrangement

The brake system of the test wheel on the trailer is connected to a torque-sensor. During measurement, the braking effort, which is proportional to the friction coefficient, is recorded in order to calculate the LFCI. An incremental encoder records the speed of the test wheel.

7.7 Test tyre

For standard friction measurements with the IMAG, a smooth PIARC tyre, conforming to the PIARC Technical Document: “Specification for a standard test tyre for friction coefficient measurement of a pavement surface: Smooth test tyre” (2004-03) is used.

It is inflated to the pressure of 150 (±10) kPa at 20 °C.

Tyres should be stored in a cool dry environment away from direct sunlight, in such a way that they are not damaged or distorted.

The tyre shall be replaced if it is damaged or worn beyond the wear line given by the wear indicators, as specified in the PIARC Technical Document.

7.8 Tyre and rim

The test tyre for standard measurements is a smooth PIARC tyre. The tyres are mounted on a suitable rim.

Since some rims do not have the same offset from the hub, it shall be ensured, that replacement rims have the same offset to ensure consistent alignment of the tyre with the water path.

7.9 Force-measuring transducer

The IMAG is able to measure horizontal dragging force with an accuracy of ± 0,05 % and a resolution of ± 0,1 %.

7.10 Pavement wetting system, water film thickness

The pavement wetting system consists of a special nozzle designed and set in accordance with the ASTM Standard ASTM E670-09. It is 115 mm wide and 75 mm high. It is set up at 300 mm from the surface of the pavement. The nozzle angle with the pavement surface shall be set at an angle of (25 ± 2)°.

The water flow is controlled by an automatic adjustable control valve to apply the water to the pavement in front of the test tyre. The quantity of water for pavement wetting is regulated for each operating speed to a constant theoretical water film thickness of 1 mm (± 10 %). Water flow value is recorded.

NOTE The water film thickness is called “theoretical” because it means the thickness on a perfectly dense, smooth and horizontal pavement. The real water film thickness depends on the pavement on which it is applied. For example on porous pavements the water depth is depending on the real porosity of the pavement.

The water used for testing shall be reasonably clean, free of suspended solids, oil and salt and have no added chemicals such as wetting agents or detergents.

7.11 Minimum sampling interval

The sampling frequency is 6 250 Hz. The minimum sampling interval is thus 1,8 mm at 40 km/h, 3 mm at 65 km/h and 4 mm at 95 km/h.

For the parameters described above and for longitudinal friction coefficient IMAG, the software allows recording average values calculated for 0,2 m to 1,0 m step length.

7.12 General requirements for measuring system

The instrumentation system conforms to the following overall requirements at air temperatures between 5 °C and 50 °C.

The exposed components of the system tolerate 100 % relative humidity (rain or spray) and all other adverse conditions, such as dust, shocks and vibrations, which may be encountered in test operations.

8 Test Procedure

8.1 Standard test conditions

The standard test conditions with the IMAG are (see Table 1):

Table 1 — Standard test conditions for IMAG measurements

Air temperature	> 5 °C
	< 50 °C
Pavement temperature	> 5 °C (testing season: April until November)
	< 50 °C
Test wheel	smooth PIARC-tyre
Method	braked wheel (slip ratio, 15 %)
Static wheel load	adjustable from 1 700 N to 2 000 N
Operating speed	40 km/h to 120 km/h
Theoretical water film thickness	1 mm
Length for the mean value	1 m
Measured wheel path	most trafficked area (between 3 m and 7 m from the central axis of the runway)

8.2 Prior to testing

Prior to testing the device shall be checked for the following:

— the test tyre for pressure at the air temperature;

— the test tyre for wear using the depth of wear indicators on the smooth test tyre;

— the test tyres for flat spots, damage or other irregularities that may affect test results;

— the operation of the water flow system, including the nozzle position.

Prior to testing the pavement shall be checked for any trace of moisture and for temperature requirements. Air temperature shall also be checked prior to testing.

8.3 Testing

Adjust the vehicle speed and the water flow to the specified value and start the recorder. Continue with the test maintaining the specified test speed and record the curviline abscissa of the measuring section. At the beginning of the measurement phase, start the following operations:

— braking the test wheel (during this phase the LFCI is recorded);

— unbraking the test wheel;

— stopping the wetting operation.

The path taken by the test wheel should follow the most trafficked area (usually between 3 m and 7 m from the central axis of the runway). During the test the operator should monitor speed, test line and recorded values. The operator can also invalidate the measurement for different reasons: deviation from the test line, incorrect test speed, invalidate water flow or other conditions that could affect the validity of the measurements.

The beginning and the end of the section shall be marked with kilometric points or with well-defined locations near the runway. On completion of the test length, after the final reference point, stop the recorder.

The number of test runs depends on the runway width. Tests shall be performed symmetrically on both right and left side of the centre axle of the runway.

Maintenance friction measurements of airport pavement should only be taken on dry pavement without any rain or moisture. Runway temperature should be above 5 °C.

9 Data recording

The braking force, the vertical force, the water flow, the speed and travelled distance are recorded continuously for each shot. Friction coefficient is calculated in real time by dividing the drag force (from T1 and T2 on Figure 1) to the vertical force (Fv on Figure 1).

After this online calculation, longitudinal friction coefficient IMAG (LCFI) is averaged over a significant portion.

NOTE 100 m is usually considered to be a significant portion.

10 Calibration

10.1 General

Static vertical force and static braking force are calibrated before and after every test campaign. The distance recorder is calibrated periodically and check each time necessary. The wetting system is calibrated at least every two years.

10.2 Calibration of the static vertical test wheel force

For a full calibration of the static wheel load, the IMAG is positioned on a plane pavement in such a way that the wheel can be lowered and put on an electrical load cell. The load cell should be positioned in such a way, that the wheel is at the same level as it would normally be when in contact with the pavement. The related effort is shown on the load cell.

10.3 Calibration of the static braking force

For a full calibration of the braking force, the IMAG is positioned on a plane pavement. The test wheel is put on a special system which is able to drag the test wheel with a known force shown on a special load cell. This load is compared to the one given by the IMAG measuring chain.

NOTE This procedure requires purpose-made equipment. Suitable equipment that complies with this principle is normally supplied by the IMAG manufacturer.

10.4 Dynamic calibration of the travelled distance sensor

The distance recorder is periodically calibrated through runs on a known distance.

10.5 Calibration of the water delivery system

The water sensor used on the water delivery system is calibrated every 2 years at least. There are two solutions to ensure the traceability of the system location:

— Water flow rate is recorded and the measurement is compared with the theoretical and needed flow according to the actual speed.

— The speed signal from the IMAG is simulated to release the water flow. The signal flow sensor is compared to that of a reference sensor.

10.6 Dynamic comparison of friction devices

All the friction devices used in France for maintenance measurement of airfield pavement are certified by the State. As part of the process of certification, all devices are used together on the same test tracks. Repeatability and reproducibility of each device is studied and results are compared with a reference device (ASTM E2100-04). If one device does not reach the criteria for certification, it shall be controlled to find the reasons (test tyre, water flow, load on the test wheel…).

When a device is approved by tests, it is given a certificate. This certificate is available for 2 years.

11 Precision

For determining the precision of the friction measurements the repeatability and reproducibility are used. These two values have been calculated from comparative measurements performed in March 2008, on 11 surfaces. Three IMAG participated at the comparative measurements. Test surfaces were from 50 m to 150 m long. Repeatability and reproducibility were calculated from mean LFCI on each surface.

Table 2 — Precision of measurement (ISO 5725-2)

Repeatability (r)	0,03
Reproducibility (R)	0,11

12 Test report

The test report contains the following information in each measuring file:

a) name of the organization;

b) names of test report writer;

c) date of test;

d) filename (with name of the test section);

e) test length description;

f) test section location;

g) specification of the driving direction;

h) specification of the lane;

i) starting point (specification of the station);

j) final point (specification of the station);

k) air and pavement temperature;

l) pavement state (dry/damp);

m) measuring program;

n) average determination of the friction results;

o) name of the test tyre;

p) friction values;

q) average friction coefficient IMAG for each test speed;

r) test speeds;

s) comments.

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[1] EN ISO 13473-1, *Characterization of pavement texture by use of surface profiles — Part 1: Determination of Mean Profile Depth (ISO 13473-1)*

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

[3] ICAO Annex 14 to Aerodrome Design and Operations, Attachment A 6, *Determining and expressing the friction characteristics of snow- and ice-covered paved surfaces*

[4] ICAO Annex 14 relative to Aerodrome Design and Operations, Attachment A 7, *Determination of friction characteristics of wet paved runways*

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