INTERNATIONAL STANDARD

ISO 8349

First edition
2002-04-01

Road vehicles — Measurement of road surface friction

Véhicules routiers — Mesurage du coefficient d'adhérance

Reference number
ISO 8349:2002(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

Contents

Page

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.

The main task of technical committees is to prepare International Standards. 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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 8349 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

This first edition cancels and replaces the first edition of ISO/TR 8349:1986, which has been technically revised.

Annex A and B form a normative part of this International Standard. Annex C is for information only.

Introduction

During its work to establish vehicle-handling test methods, ISO/TC 22/SC 9 found it necessary to establish test methods for evaluating the friction characteristics of a test surface for handling and braking tests with non-locked wheels that considered the peak friction rather than the locked-wheel friction — until now the most commonly used measure of tyre-road friction.

The reason for this was that the tyre-road friction determining the limits of braking and handling performance is the friction obtained with wheels rolling at a longitudinal slip below 20 % and side slip angles below 20°. The maximum or peak-friction values are normally found within these ranges. Furthermore, research has shown that there is a strong correlation between these longitudinal and lateral peak values but not between such values and locked-wheel friction.

Both longitudinal and lateral friction test procedures and test equipment exist and are widely used. Different countries tend to favour either longitudinal or lateral procedures.

Because of these difficulties, the work of ISO/TC 22/SC 9 first resulted in Technical Report ISO/TR 8349, in which two basic measuring methods with four optional reference tyres were proposed for evaluation. The two measuring methods were a longitudinal friction measurement with a constant slip of 15 % and a lateral friction measurement at a constant side slip angle of 20°. Both methods are well established and traditionally used by road and airport authorities for obtaining reference friction values. As they are continuous measurements, the uniformity of the friction along the track as well as a mean value over the length of track used for the vehicle test is obtained in a single test run. For braking tests, the speed sensitivity of the friction is of interest. This can be obtained by testing at two or more speeds depending on the precision needed. In most cases two speeds will be sufficient.

In the field of automotive handling and brake testing, the use of special test vehicles has been very limited and primarily restricted to locked-wheel test trailers of ASTM (American Society for Testing and Materials) conformance, since the US Federal Motor Vehicle Safety Standard (FMVSS) referred to locked-wheel friction according to the ASTM standard.

The United Nations Economic Commission for Europe (UNECE) has established in its braking Regulation No. 13 a method for measuring the maximum friction coefficient of the test surface using the tested vehicle itself, prepared for single-axle braking. The tyres of the test vehicle are used as reference tyres. The maximum constant braking force that can be used without wheel lock is the UNECE definition of a reference friction called the peak adhesion coefficient, K. It represents the minimum peak value on the track surface in the speed interval from 40 km/h to 20 km/h.

The UNECE method is based on the assumption of a surface with uniform friction without speed sensitivity and a test vehicle whose brake force at constant brake pressure is constant. As this is normally not the case, the method provides a reference friction value lower than the actual mean peak friction along the tested track. How much lower depends on the magnitude of the speed sensitivity of the tyre–road friction and vehicle brake factor as well as the non-uniformity of the friction and its distribution along the test track.

Despite objective reasons for adopting one of the continuous-friction measuring methods proposed in ISO/TR 8349, the USA, in its latest proposed rule (FMVSS 135) for passenger car brakes, has chosen the ASTM standard E 1337-90 for determining longitudinal peak-friction measurement. This is based on the same equipment used for locked wheel friction according to ASTM standard E 274-90 but using a new standard reference test tyre, ASTM E 1136. US car manufacturers already use this method.

The UNECE has not adopted the new ASTM peak-friction measurement standard nor any of the options in ISO/TR 8349, but is striving to improve the existing UNECE K value method.

ISO/TR 8349 has been criticized in the USA and by some other SC 9 members for having too many options and for being insufficiently clear concerning the correlation between the different options.

With this background, ISO/TC 22/SC 9 decided to reconsider the approach taken by ISO/TR 8349. It was decided not to include the UNECE method, due to the above mentioned drawbacks. It was also considered too elaborate to measure both longitudinal and lateral friction and that the correlation between the two was high enough to justify measuring only one. Longitudinal friction was favoured as being the better-established in automotive legislation and for approval of original equipment tyres by automotive manufacturers.

As a result, this International Standard defines three options for measuring longitudinal friction, the choice of which depends on the available means and the application. Only two types of standard reference test tyres are used: one of passenger-car size and the other a small test tyre for low-cost equipment.

Road vehicles — Measurement of road surface friction

1 Scope

This International Standard specifies test methods for determining the characteristic longitudinal friction force values of paved surfaces using either a standard reference test tyre or the tyre of a vehicle under test. General test procedures and their validity are presented for determining peak- and slide-braking coefficients on actual test surfaces, where the surface conditions are determined and controlled by the user at the time of testing. Test and test-surface condition documentation procedures and details are also specified.

The purpose of this International Standard is to provide for the harmonization of results of testing on different test tracks. The values measured with standard reference test tyres (SRTT) are intended to form standard reference numbers indicating the friction properties of test tracks and road surfaces that are representative for passenger car tyres.

Certain of the methods may also be suitable for measuring the friction properties for a specific test car tyre on the test track.

The values quantify the peak-, near-peak or slide-braking coefficients at the time of test and do not necessarily represent fixed values.

The values measured with reference tyres are intended as reference numbers indicating certain friction properties of test tracks and road surfaces.

This International Standard does not purport to address all the safety problems associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE 1 Friction is affected by many variables such as environmental conditions, usage, age and surface contamination. Measured values will change when any of these conditions significantly changes.

NOTE 2 The measured braking coefficient values obtained with the procedures stated in this International Standard may not necessarily agree or correlate directly with those obtained by other surface coefficient measuring methods.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents 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 8855:1991, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ASTM E178-94, *Standard Practice for Dealing With Outlying Observations*

ASTM E274-97, *Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire*

ASTM E556-95 (2000), *Standard Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)*

ASTM E867-97, *Terminology Relating to Vehicle-Pavement Systems*

ASTM E1136-93 (1998), *Standard Specification for A Radial Standard Reference Test Tire*

ASTM F377-94a (1999), *Standard Practice for Calibration of Braking/Tractive Measuring Devices for Testing Tires*

ASTM E1551-93a (1998), *Standard Specification for Special Purpose, Smooth-Tread Tire, Operated on Fixed Braking Slip Continuous Friction Measuring Equipment*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 8855 and ASTM E867 and the following apply.

3.1
chirp test
the progressive application of brake torque required to produce the maximum value of longitudinal braking force that will occur prior to wheel lockup, with subsequent brake release to prevent tyre wear due to wheel lockup (tyre slide)

4 Summary of test methods

4.1 General

This International Standard specifies the following alternative methods for measuring longitudinal friction measurement.

— A constant-speed, transient braking force method for measuring peak and slide friction using the ASTM E1136 or, for special purposes, other passenger-car size tyres. This method provides mean values based on spot measurements of the peak and slide friction.

— A constant-speed, constant-braking slip method for measuring peak and slide friction using the ASTM E1136 or, for special purposes, other passenger-car size tyres. This method provides a rapid uniformity and reference peak-friction check of the test surface based on continuous measurement along the entire track length of interest and mean values for slide friction based on spot measurements.

— A constant-speed, fixed-braking slip method for measuring a characteristic friction value close to the actual peak friction using a small SRTT: either an ISO-specified, patterned tread or ASTM E1551 smooth-treaded tyre. This is a rapid and economical method of obtaining a reference friction and uniformity check of the test track or road surface.

4.2 Constant-speed, transient braking force method

This test method provides mean values of the peak and slide friction based on spot measurements.

The test apparatus is normally brought to a test speed of 65 km/h. The brake is progressively applied until sufficient braking torque results to produce the maximum braking force that will occur prior to wheel lockup. Longitudinal force, vertical load and vehicle speed are recorded with the aid of suitable instrumentation and data-acquisition equipment.

The peak-braking coefficient of the road surface is determined from the ratio of the maximum value of braking force to the simultaneous vertical load occurring prior to wheel lockup as the braking torque is progressively increased.

The slide-braking coefficient is the ratio of the sliding wheel longitudinal force to the vertical force averaged for 1 s, beginning 0,2 s after test wheel lockup.

4.3 Constant-speed, constant-braking slip method

This method specifies a constant-speed, constant-braking slip method for continuous measurement of peak and slide friction. It provides a rapid uniformity and reference peak-friction check of the test surface based on continuous measurement along the entire track length of interest, and mean values for slide friction based on spot measurements. For this reason, the method is also convenient for determining the uniformity of the peak friction of test tracks.

The test device comprises transducer, instrumentation and actuation controls for forcing the test tyre to roll at any fixed braking slip from 0 % to 40 %, and for the braking of the test tyre to a locked condition over a road surface at a constant speed while the test tyre is under a dynamically suspended fixed load.

The test apparatus is normally brought to a test speed of 65 km/h. The slip giving the maximum braking force is applied or, if sliding friction is measured, the brake is applied with a force sufficient to produce wheel lock. Longitudinal force, vertical load (if measured) and vehicle speed are recorded with the aid of suitable instrumentation and data-acquisition equipment.

The correct slip for the constant-slip, peak-friction value is obtained by a continuous or stepped slip sweep procedure for each combination of tyre, load, speed and track surface.

The peak-braking coefficient of the road surface is determined from the ratio of the maximum value of braking force to the simultaneous vertical load.

The sliding-braking coefficient is the ratio of the sliding wheel longitudinal force to the vertical force average for 1 s, beginning 0,2 s after test wheel lockup.

The static vertical load, if necessary corrected for the dynamic load shift caused by the longitudinal force, is used if the vertical load is not measured dynamically.

4.4 Constant-speed, fixed-braking slip method

This test method approaches the measurement of road surface friction using a fixed-braking slip technique, providing a continuous record of the braking friction along the whole length of the test surface and enabling averages to be obtained for any specified test length. For this reason, it is convenient for determining the uniformity of the friction of test tracks.

The measurements are conducted using a 4.00-8 SRTT, which may be either an ISO patterned-tread tyre mounted on a suitable test device or an ASTM E1551 smooth-tread tyre (see clause A.1). The test device comprises transducer, instrumentation and actuation controls for forcing the test tyre to roll at a fixed braking slip condition over a road surface at a constant speed while the test tyre is under a dynamically suspended fixed load.

The test apparatus is normally brought to a test speed of 65 km/h. The fixed slip is applied along the entire test section. Longitudinal force, vertical load (if measured) and vehicle speed are recorded with the aid of suitable instrumentation and data-acquisition equipment.

The braking coefficient of the road surface is determined from the ratio of the mean value of braking force to the mean value of the simultaneous vertical load or to the static vertical load, if necessary corrected for the dynamic load shift caused by the longitudinal force.

5 Pavement characteristics and surface conditions

Paved surfaces have different traction characteristics, which depend on many factors including surface texture, binder content, usage, environmental exposure and surface conditions (i.e. wet or dry).

The values measured with an SRTT represent the peak- or slide-braking coefficients representative for tyres of the general type in operation on passenger vehicles, on a prescribed road surface, and under user-defined surface conditions. Such surface conditions can include the water depth used to wet the road surface and the type of external water application method; variations in these conditions can influence the test results.

If the test apparatus is equipped with a road-surface watering system, the water shall be applied to the pavement ahead of the test tyres by a nozzle supplied with the test system. The volume of water per unit length of wetted width shall be directly proportional to the test speed. The water layer shall be at least 12,5 mm wider than the test–tyre–road surface contact area width and applied so that the tyre is centrally located between the wetted edges during the actual testing. The standard flow rate is 0,55 l/m travelled distance ± 10 %/m of wetted width.

A knowledge of the maximum steady-state braking friction serves as an additional tool in characterizing paved surfaces. Research shows that for most road surfaces, the maximum or peak-braking-and-cornering (side-force) friction developed between vehicle tyres and road surfaces are similar in magnitude. Thus, maximum braking friction is useful as a reference value in evaluating vehicle stopping and directional performance under different road surface conditions.

The values measured with the equipment and procedures stated in this International Standard do not necessarily agree or correlate directly with those obtained by other road-surface friction-measurement methods.

The measured values represent the braking friction coefficient for a test track surface under the conditions specified by the user. Both dry and externally wetted surfaces may be characterized. The values will depend on surface conditions, which vary with time; therefore the measurements should be repeated frequently — preferably before and after each vehicle test, and at least before and after each test day.

Do not perform wetted tests when wind conditions interfere with test repeatability.

NOTE For further information on measurement on wet surfaces, see annex C.

6 Constant-speed, transient braking force method

6.1 Apparatus

6.1.1 Vehicle

The motor vehicle used for the test shall be capable of maintaining constant test speeds of 20 km/h to 100 km/h within ± 2 km/h, even at the maximum level of application of braking forces on a dry paved surface.

6.1.2 Braking system

The test apparatus shall be equipped with a braking system capable of producing sufficient braking torque to produce the maximum value of braking test wheel longitudinal force at the conditions specified. The system shall be able to control the rate of brake application so that the time interval between initial brake application and peak longitudinal force is at least 0,3 s and subsequently automatically release the brake. In order to minimize tyre wear, a maximum of 0,5 s to brake release is recommended.

6.1.3 Wheel load

The design of the apparatus shall be such as to provide a static vertical load of 4 500 ± 100 N to the test wheel and, on detachable trailers, a static down-load of 500 N to 1000 N at the hitch point. The dynamic load shift shall be not more than 10 % of the tyre—road braking force.

6.1.4 Suspension system

The suspension of the apparatus shall be capable of holding the side slip and camber angles of the test wheel at 0 ± 0,5° within the applicable range of test loads, longitudinal braking force coefficients and vertical suspension displacements, under both static and dynamic test conditions.

6.1.5 Test tyre

For standard test conditions, the test tyre for pavement tests shall be an ASTM E1136 SRTT, in accordance with annex A.

6.2 Instrumentation

6.2.1 Variables

Measure the following variables:

a) speed;

b) longitudinal wheel force;

c) vertical wheel force.

In addition, it is recommended that travelled distance be measured.

6.2.2 Measuring system

The transducers shall be installed according to the manufacturer's instructions where such instructions exist, so that the variables corresponding to the terms and definitions of ISO 8855 or ASTM E867 can be determined. If the transducer does not measure the values directly, appropriate changes to the reference system shall be made. The exposed portions of the system shall tolerate 100 % relative humidity (rain or spray) and all other adverse conditions, such as dust, shock and vibrations, which may be encountered in pavement test operations. The instrumentation shall conform to the requirements of 6.2.3 to 6.2.7 at ambient temperatures between 5 °C and 40 °C.

6.2.3 Overall system accuracy and data-reading resolution

The overall system accuracy and data-reading resolution shall be at least the following.

— Longitudinal and vertical wheel force: ± 1,5 % of applied force from 900 N to full scale over the range of 0 Hz to 5 Hz (e.g. at 1000 N, the applied calibration force of the system output shall be determinable to within ± 15 N).

— Speed: ± 2 % of the indicated speed.

Travelled distance, if measured, should be of an accuracy of ± 1 % of the indicated distance or 1 m, whichever is the greater.

6.2.4 Braking force

The transducer shall measure longitudinal reaction force within a range sufficient for measuring the friction forces of the tested wheel. Under standard conditions, forces between 0 N and 6 000 N will be generated at the tyre–pavement interface as a result of brake application. The transducer shall be of such design as to measure the tyre–pavement interface force with minimum inertial effects; provision of an output directly proportional to force with hysteresis of less than 1 % of the applied load, non-linearity of less than 1 % of the applied load up to the maximum expected loading, and sensitivity to any expected cross-axis loading or torque loading of less than 1 % of the applied load is recommended. The force transducer shall be mounted in such a manner as to experience less than 1° angular rotation with respect to its measuring plane at the maximum expected loading.

6.2.5 Vertical load

The transducer shall measure the vertical load at the test wheel during brake application. The transducer shall have the same specifications as those described in 6.2.4.

6.2.6 Vehicle speed

The transducer shall provide speed resolution and accuracy of ± 1,5 % of the indicated speed or ± 1,0 km/h, whichever is the greater. Output shall be directly viewable by the driver and shall be simultaneously recorded.

6.2.7 Vehicle travelled distance — Optional

If the vehicle travelled distance is measured, it is recommended that the transducer provide a resolution and accuracy of ± 1 % of the indicated distance, or ± 1 m, whichever is the greater.

6.3 Signal conditioning

Transducers that measure parameters sensitive to inertial loading shall be designed or located such as to minimize this effect. If this is not possible, data should be corrected for inertial loading if this effect exceeds 2 % of actual data during expected operation. All signal-conditioning and recording equipment shall provide linear output and shall allow data-reading resolution meeting the requirements of 6.2.3. All systems except the smoothing filter specified below shall provide a minimum bandwidth of at least 0 Hz to 20 Hz (flat to within ± 1 %).

All strain-gage transducers shall be equipped with resistance shunt calibration resistors or equivalent that can be connected before or after test sequences. The calibration signal shall be at least 50 % of the normal vertical load and shall be recorded.

A digital data-acquisition system shall be employed to individually digitize the braking force, vertical load and vehicle speed analogue outputs. The braking force, vertical load and test wheel speed input signals to be digitized shall be sampled (as close to simultaneous as possible to minimize phase shifting) at 100 samples/s for each channel from unfiltered analogue signals. If necessary, vehicle speed may be analogue-filtered to remove noise, since this is a steady-state signal.

To prevent aliasing, caution must be exercized in digitizing data that contains any significant frequencies above 50 Hz or other types of analogue data. The analogue signals shall correspondingly be filtered before digitizing, for which low-pass filters of order 4 or higher shall be employed. The width of the pass band (–3 dB frequency) shall amount to roughly $f_0 \geqslant 5f_{max}$.

The amplitude error of the antialiasing filter should not exceed ± 0,5 % in the usable frequency range. All analogue filters shall be processed with antialiasing filters having sufficiently similar phase characteristics such that the time delay differences lie within the required accuracy for time measurement. Additional filters shall be avoided in the data-acquisition string. Amplification of the signal shall be such that, in relation to the digitizing process, the additional error is less than 0,2 %.

The signal-to-noise ratio shall be at least 20 to 1 on all recording channels and shall be reduced to less than 2 % when processed.

6.4 Test tyre preparation and conditioning

6.4.1 Preparation

Trim the test tyres to remove all protuberances in the tread area caused by mould air vents or flashes at mould junctions. Mount the test tyre on the specified rim (see annex A) using conventional mounting methods.

6.4.2 Pretest conditioning

Perform pretest conditioning of all test tyres prior to testing. Carry out conditioning only once per surface and prior to any actual test measurements, on a dry and level surface. Chirp each tyre 10 times at 35 km/h under test load.

6.5 Test surface

The test surface shall be free of loose material and foreign deposits.

NOTE Not all types of surfaces are suitable for testing under wetted or water-covered conditions (see annex C)