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Road vehicles — Measurement of road surface friction

Véhicules routiers — Mesurage du coefficient d'adhérance

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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.

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)

6.6 Test procedure

6.6.1 Warm up the electronic test equipment as necessary for stabilization.

6.6.2 Install the test tyre on the test position of the test device. If a two-wheeled trailer is being used, use a tyre with a similar loaded radius and high cornering properties on the opposite side, in order to level the axle and minimize trailer yaw during brake torque applications.

6.6.3 Check and, if necessary, adjust the load on the test tyre to the specified test load (see annex A).

6.6.4 Check the test tyre for the specified inflation pressure (see annex A) at ambient temperature (cold), just prior to testing.

6.6.5 Perform pretest tyre conditioning if using a tyre for the first time on the track under test.

6.6.6 When testing on an externally wetted test surface and it is desirable to prevent “tracking” of the wheels of the test vehicle in front of the test wheel, offset the test wheel by 300 mm to 400 mm.

6.6.7 Record tyre identification and other data, including date, time, ambient temperature, test surface temperature, tyre durometer value (Shore), test surface type and water depth (if an externally wetted surface is used). Measure the water depth with a suitable device (e.g. a variable height probe-type device).

6.6.8 Record electrical calibration signals prior to, and after, testing each surface, or as needed to ensure valid data.

6.6.9 Conduct the test at the required test vehicle speed. The standard test speed is 65 km/h, and tests shall normally be conducted at that speed. Multiple tests over a range of speeds should be conducted to quantify the speed dependence of the braking coefficients. Maintain the test speed within ± 4 % of the nominal test speed, or at 2 km/h, whichever is the greater.

6.6.10 When only peak-braking coefficient measurements are being made, it is recommended that the test be conducted using the chirp test methodology with at least eight brake applications per 200 m test section. This will minimize tyre damage due to tyre sliding.

6.6.11 When sliding braking measurements are required, make at least eight determinations of the peak- and sliding-braking coefficient, evenly distributed along a test wheel track section not exceeding 200 m in length, with the test system at the specified test speed.

6.6.12 Normally, at least four measurements shall be carried out in the centre of each of the two wheel tracks used by the vehicles under test. Record the specific details regarding lane and wheel path when reporting the data.

6.7 Data analysis

6.7.1 Digital filtering

Digitally filter the digitized input analogue signals of braking force, vertical load and vehicle speed using a five-point moving average technique.

Calculate an average value for the first five digital data points. Drop the first data point and add the sixth data point, then calculate another five-point average value. Repeat this procedure for all remaining data points. This sequence is done individually on all of the above digitized input analogue signals.

EXAMPLE The following computations illustrate the method using one channel:

(pt1 + pt2 + pt3 + pt4 + pt5)/5 = PT1

(pt2 + pt3 + pt4 + pt5 + pt6)/5 = PT2

(pt3 + pt4 + pt5 + pt6 + pt7)/5 = PT3

A new set of data points (indicated by capital letters) is then defined to represent the filtered data for each channel i.e. (avg. ptx = PT_y):

PT1, PT2, PT3, etc. — tractive force;

PT1, PT2, PT3, etc. — vertical force.

6.7.2 Peak braking force coefficient (PBFC)

The PBFC shall be determined for each run (brake application).

Using the digitally filtered data (PT1, PT2, PT3, etc.), scan the longitudinal channel and determine the highest absolute filtered value, PT_y, prior to wheel lockup. Calculate an average peak braking force value using PT_y and one filtered point directly before (PT_{y-1}) and directly after (PT_{y+1}). This three-point average is the peak-braking force value developed for this individual test.

From its respective digitally filtered data, determine the vertical load value corresponding to the highest absolute value for the braking force. Calculate an average vertical load value using this corresponding value and one point directly before and one directly after it. This three-point average is the vertical load value corresponding to the average peak braking force for this individual test.

Calculate the PBFC by dividing the three-point average peak braking force by the three-point average vertical load. The peak-braking coefficient should be reported to two decimal places.

For each test surface section, calculate the mean and standard deviation for PBFC from the individual determinations.

6.7.3 Sliding braking force coefficient (SBFC)

The digitized input values for the braking force and vertical load shall be summed for one second, beginning 0,2 s after test wheel lockup. Calculate an average braking and vertical value using the cumulative sums.

Calculate the SBFC by dividing the 1 s average slide braking force by the 1 s average vertical load.

For each test, calculate the mean and standard deviation for SBFC from the individual slide determinations.

6.8 Faulty tests

Tests that are faulty or give values differing by more than 0,05 from the average of all tests of the same test section shall be treated in accordance with ASTM E178 recommended practice.

6.9 Test reports

6.9.1 Field report

The field report for each test section shall include

a) identification of the test procedure used,

b) identification and location of the test section,

c) date and time of day,

d) weather conditions,

e) lane and wheel-path tested,

f) speed of test vehicle for each test,

g) PBFC and, if applicable, SBFC for each test,

h) water depth, if wetted surface used (with a description of the water-depth measuring method),

i) ambient and surface temperature,

j) test tyre type and serial number,

k) test tyre inflation-pressure, and

l) test tyre load.

6.9.2 Summary report

The summary report shall include the following for each test section, insofar as it is pertinent to the variables or combinations of variables under investigation:

a) location and identification of test section;

b) grade and alignment;

c) pavement type, mix design of surface course, condition and aggregate type (specific source, if available);

d) age of pavement;

e) date and time of day;

f) weather conditions;

g) lane and wheel path tested;

h) ambient and surface temperature;

i) average, high and low PBFCs and SBFCs for the test section;

j) nominal speed at which the tests were made.

6.10 Precision and bias

6.10.1 Precision

6.10.1.1 Dry surface

The acceptable precision of the dry road surface peak and slide coefficients can be stated in the form of repeatability. An acceptable estimate of the population standard deviation of 0,019 for dry peak coefficient and 0,018 for dry slide coefficient was obtained from 681 tests. Therefore, the confidence interval for any mean peak or slide coefficient value obtained from a number of measurements having a specified degree of confidence can be expressed as the degree of confidence multiplied by the population standard deviation over the square root of the sample size.

EXAMPLE

$$\text{Dry PBFC} = 1{,}960 \times \frac{0{,}019}{\sqrt{8}} = \pm\, 0{,}013$$

$$\text{Dry SBFC} = 1{,}960 \times \frac{0{,}018}{\sqrt{8}} = \pm\, 0{,}012$$

where

1,960 is the degree of confidence;

0,019 is the dry peak standard deviation;

0,018 is the dry slide population standard deviation;

8 is the sample size.

6.10.1.2 Wet surface

Data are not yet available to allow a statement to be made on the precision of this test condition. The broad range of wet surface conditions possible make an acceptable estimate of the population standard deviation difficult for peak and sliding braking friction measurements.

6.10.2 Bias

There are no standards or references with which the results of this test can be compared. As already indicated, the function of the test is to enable comparisons to be made among road surfaces tested with the same tyre. The results of the test method are regarded as adequate for making such comparisons, without an external reference for assessing accuracy.

See note 1, clause 1.

6.11 Calibration

See annex B.

7 Constant-speed, constant-braking slip method

7.1 Apparatus

7.1.1 Vehicle

The motor vehicle used for the test, for which the test tyre shall operate at constant peak braking slip and maximum wheel load, shall be capable of maintaining test speeds of from 20 km/h to 100 km/h, within ± 2 km/h, during a test on a dry paved surface, with a peak friction of at least 1,3.

7.1.2 Braking system

The test wheel speed shall be variable such that the braking slip can be varied continuously or in increments of no larger than 2 % in the range 0 % to 40 %, and controlled such that the desired slip can be maintained constant ± 1 % at maximum wheel load and with a maximum friction of 1,3 throughout the length of the test paved surface at the design test speed. It shall also be possible to apply a braking torque capable of locking the wheel within 0,5 s and to automatically release the brake after a specified time of 1 s or more after wheel lockup for sliding friction measurements.

7.1.3 Wheel load

The design of the apparatus shall be such as to provide a vertical static test wheel load of at least 4 500 N (see A.6) and, on detachable trailers, a static down-load of 500 N to 1 000 N at the hitch point. The steady-state dynamic load shift due to the braking force, if measured continuously during the test, shall be no more than 10 % of the tyre-road braking force. If this is not the case, the load shift shall be no more than 1 % or a load shift correction based on the suspension geometry; the braking force shall be calculated.

7.1.4 Suspension system

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

7.1.5 Test tyre

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

7.2 Instrumentation

7.2.1 Variables

Measure the following variables:

a) vehicle speed;

b) test wheel rotational velocity;

c) longitudinal wheel force;

d) vertical wheel force (if a calibrated dead-weight wheel load system is used, the wheel load does not have to be continuously measured; if there is a dynamic load shift due to the braking force exceeding 1 %, it shall be corrected for by calculation).

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

7.2.2 General requirements for the measuring system

The transducers shall be installed so that the variables of 7.2.1, 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 system shall conform to the requirements of 7.2.3 to 7.2.9 at ambient temperatures of between at least 5 °C and 40 °C.

7.2.3 Overall system accuracy and data-reading resolution

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

— Longitudinal and, if measured, vertical wheel force: ± 1,5 % of applied force from 900 N to full scale over the range of 0 Hz to 5 Hz.

— Speed: ± 2 % of the indicated speed or 2 km/h, whichever is the greater.

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

7.2.4 Longitudinal wheel force

The wheel force measuring transducer shall be of such design as to measure the longitudinal tyre–road interface force. Transducers that provide an output directly proportional to force with hysteresis of less than 1 % of the applied load up to the maximum expected loading are recommended. The sensitivity to any expected cross-axis loading or torque loading shall be less than 1 % of the applied load. The force transducer shall be mounted such that it experiences less than 1° angular rotation with respect to its measuring plane at the maximum expected loading.

7.2.5 Wheel torque for assessing longitudinal wheel force

Torque transducers shall provide an output directly proportional to torque, with hysteresis of less than 1 % of the applied load and nonlinearity up to the maximum expected loading of less than 1 % of the applied load. The sensitivity to any cross-axis loading shall be less than 1 % of the applied load. Static calibration by applying a longitudinal force in the contact area of the laden wheel according to ASTM E556 does not include the free-rolling resistance. This should therefore be compensated for. The free-rolling resistance is normally about 1 % of the wheel load at the standard test speed 65 km/h and may be used as a standard correction.

7.2.6 Vertical wheel load

The vertical wheel load may be assumed to be the same as the static wheel load if the dynamic vertical load shift due to the braking force is less than 1 %. If it is more, the load shift shall be corrected for by calculation, taking into account the suspension geometry. If a wheel load transducer is used, it shall meet the requirements of 7.2.4.

7.2.7 Vehicle speed

The transducer shall provide a speed resolution and accuracy of ± 1,5 % of the indicated speed, or ± 0,8 km/h, whichever is the greater. Output shall be directly viewable by the driver and shall be simultaneously recorded.

7.2.8 Test wheel rotational speed

The transducer shall provide a speed resolution and accuracy of ± 1,5 % of the indicated speed, or ± 0,8 km/h, whichever is the greater.

7.2.9 Vehicle travelled distance (optional)

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

7.3 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 vertical loading if this effect exceeds 2 % of actual data during expected operation. All signal conditioning and recording equipment shall provide linear output and allow data-reading resolution in accordance with 7.2.3. 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 (if measured) 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.

To prevent aliasing, caution must be exercized in digitizing data containing 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 $f_o \geqslant 5 f_{max}$.

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 to ensure 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 %. All signals shall be referenced to a common time base.

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.

7.4 Test tyre preparation and conditioning

7.4.1 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.

7.4.2 Pretest conditioning

Perform pretest conditioning on all tyres prior to testing. Carry out conditioning, at least once per surface and prior to any actual test measurements, on a dry and level surface. Run each tyre at a fixed slip of 15 % for 50 m at 35 km/h under test load.

7.5 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).

7.6 Test procedure

7.6.1 Warm up the electronic test equipment as necessary for stabilization.

7.6.2 Install the test tyre on the test position of the test device. If a two-wheeled trailer is being used, use a tyre with a similar loaded radius and high cornering properties on the opposite side in order to level the axle and minimize trailer yaw during brake torque applications.

7.6.3 Check and, if necessary, adjust the load on the test tyre to the specified test load (see annex A).

7.6.4 Check the test tyre for the specified inflation pressure (see annex A) at ambient temperature (cold), just prior to testing.

7.6.5 Perform pretest tyre conditioning if using a tyre for the first time on the track under test.

7.6.6 When testing on an externally wetted test surface and it is desirable to prevent “tracking” of the wheels of the test vehicle in front of the test wheel, offset the test wheel by 300 mm to 400 mm.

7.6.7 Record tyre identification and other data, including date, time, ambient temperature, test surface temperature, tyre durometer, test surface type and water depth (if an externally wetted surface is used). Measure the water depth using a suitable device (e.g. a variable height probe-type device).

7.6.8 Record electrical calibration signals prior to, and after, testing each surface, or as needed to ensure valid data.

7.6.9 Conduct the test at the required test vehicle speed. The standard test speed is 65 km/h, and tests shall normally be conducted at that speed. Maintain the test speed to within ± 4 % of the nominal test speed, or 2 km/h, whichever is the greater.

7.6.10 Normally, carry out the test in the centre of either wheel track of a vehicle test lane. Record the specific details regarding lane and wheel path used when reporting the data.

7.6.11 Place the test wheel in the constant slip mode approximately 3 s before the test is initiated and continue until the test is completed. If a self-watering system is used, deliver water to the test tyre with the constant slip mode engaged. Indicate the beginning and end of the test by means of the event marker and disengage the test wheel constant slip mode after completion of the test; if applicable, stop the water delivery.

The peak friction is found either by one or more continuous slip sweep measurements covering 0 % to 40 % slip, or by conducting several constant slip tests of about 5 s duration in the slip range 3 % to 15 %, increasing the test wheel slip in increments of about 3 %, followed by a 20 % and a 40 % test. The peak friction and corresponding slip is found by means of curve fitting to the individual data pairs.

The peak slip is then used for the consecutive peak friction measurements along the wheel paths used for vehicle performance testing which do not exceed 200 m in length.

7.6.12 When sliding braking measurements are required, make at least eight determinations of 1 s duration of the sliding braking force coefficient, evenly distributed along the centres of the test vehicle wheel tracks of a test section not exceeding 200 m in length, with the test apparatus at the specified test speed. The measurements may be performed in several repeated runs.

7.7 Data analysis

7.7.1 Peak braking force coefficient (PBFC)

Calculate the PBFC by dividing the average peak braking force by the average vertical load. If the vertical load is not measured, use the static value instead, corrected for dynamic load shift caused by the average braking force if larger than 1 % of the static load.

7.7.2 Peak braking force coefficient speed gradient (PBFCSG)

The change of PBFC with speed shall be reported as PBF per km/h and should be obtained as the slope of the PBFC against the speed curve, which is plotted from at least three speeds in increments of approximately 30 km/h. The standard speed gradient is defined as the slope of the PBFC speed curve at 65 km/h and shall be so indicated.

7.7.3 Sliding braking force coefficient (SBFC)

The digitized input values for the braking force and vertical load (if measured) are summed for one second, beginning 0,2 s after test wheel lockup. Calculate an average braking and vertical force value using the cumulative sums. If the vertical load is not measured, the static value is used, corrected for dynamic load shift caused by the average braking force if it is larger than 1 % of the static load.

Calculate the SBFC by dividing the 1 s average slide braking force by the 1 s average vertical load.

For each test, the mean and standard deviation for slide braking coefficient shall be calculated from the individual slide determinations.

7.7.4 Sliding braking force coefficient speed gradient (SBFCSG)

The change of SBFC with speed shall be reported as SBF per km/h and should be obtained as the slope of the SBFC against the speed curve, which is plotted from at least three speeds in increments of approximately 30 km/h. The standard speed gradient is defined as the slope of the SBFC speed curve at 65 km/h and shall be so indicated.

7.7.5 Braking friction peak/sliding ratio (BFPSR)

The BFPSR shall be determined as the ratio between the PBFC and the SBFC value of the reference test tyre.

7.8 Faulty tests

Tests that are faulty or give values differing by more than 0,05 from the average of all tests of the same test section shall be treated in accordance with ASTM E178 recommended practice.

7.9 Test report

7.9.1 Field report

The field report for each test section shall include

a) identification of the test procedure used,

b) identification and location of the test section,

c) date and time of day,

d) weather conditions,

e) lane and section tested,

f) speed of test vehicle and, if applicable, surface water depth (for each test),

g) PBFC,

h) SBFC,

i) tyre type, and

j) tyre load.

7.9.2 Summary report

The summary report shall include the following for each test section, insofar as it is pertinent to the variables or combinations of variables under investigation:

a) location and identification of the test section;

b) grade and alignment;

c) pavement type and condition;

d) age of pavement;

e) date and time of day;

f) weather conditions;

g) lane and wheel path tested;

h) ambient and surface temperature;

i) water depth, if wetted surface used (with a description of the water-depth measuring method);

j) average, high-peak, low-peak and SBFCs for the test section, as well as the speed at which the tests were made; if values are reported that were not used in computing the average, this should also be reported;

k) average, high and low reference-speed gradients for the PBFC and SBFC for the test section;

l) average, high and low peak/sliding BFPSR for the test section;

m) date of the last calibration.

7.10 Precision and bias

7.10.1 Precision

Data are not yet available to enable a statement to be made on the precision of this test method.

7.10.2 Bias

There are no standards or references with which the results of this test can be compared. As already indicated, the function of this test is to enable comparisons to be made among pavement surfaces tested with the same tyre. The results of the test method are regarded as adequate for making such comparisons without an external reference for assessing accuracy.

See note 1, clause 1.

7.11 Calibration

See Annex B.

8 Constant-speed, fixed-braking slip method

8.1 Apparatus

8.1.1 Vehicle

The vehicle with the test tyre operating at the desired fixed braking slip shall be capable of maintaining test speeds of 65 km/h to 100 km/h within ± 2 km/h during a test on a dry paved surface.

8.1.2 Braking system

The test wheel speed shall be controlled such that the designed test-tyre fixed-braking slip can be maintained throughout the length of the test paved surface at the design test speed. This fixed-braking slip shall be 14 % ± 3 %.

8.1.3 Wheel load

The design of the apparatus shall be such as to provide a static test wheel load as specified in A.6, and on detachable trailers a static down-load of 200 N to 500 N at the hitch point. The dynamic load shift due to the tyre–road braking force must not be more than 10 % of this force.

8.1.4 Suspension system

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

8.1.5 Test tyre

The test tyre for pavement tests shall be a small, 4.00-8 SRTT, in accordance with annex A.

8.2 Instrumentation

8.2.1 Variables

Measure the following variables:

a) speed;

b) longitudinal wheel force;

c) vertical wheel force (the static wheel load corrected for dynamic wheel load shift caused by the longitudinal force may be used).

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

8.2.2 General requirements for the measuring system

The transducers shall be installed 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 system shall conform to the requirements of 8.2.3 to 8.2.8 at ambient temperatures between 5 °C and 40 °C.

8.2.3 Overall system accuracy and data-reading resolution

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

— Longitudinal and, (if measured) vertical, wheel force: ± 2 % of full scale over the range of 0 Hz to 5 Hz;

— 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.

8.2.4 Longitudinal wheel force

The wheel force measuring transducer shall be of such design as to measure the longitudinal tyre-road interface force. Transducers that provide an output directly proportional to force with hysteresis of less than 1 % of the applied load up to the maximum expected loading are recommended. The sensitivity to any expected cross-axis loading or torque loading shall be less than 1 % of the applied load. 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.

8.2.5 Wheel torque for assessing longitudinal wheel force

Torque transducers shall provide an output directly proportional to torque with hysteresis of less than 1 % of the applied load and nonlinearity up to the maximum expected loading of less than 1 % of the applied load. The sensitivity to any cross-axis loading shall be less than 1 % of the applied load. Static calibration by applying a longitudinal force in the contact area of the laden wheel according to ASTM E556 does not include the free-rolling resistance. This shall therefore be compensated for. The free-rolling resistance is normally about 1 % of the wheel load at the standard test speed of 65 km/h and may be used as a standard correction.

8.2.6 Vertical wheel load

The vertical wheel load may be assumed to be the same as the static wheel load if the dynamic load shift due to the longitudinal force is less than 1 %. If it is more, it shall be corrected for by calculation. If a wheel-load transducer is used, it must meet the requirements of 8.2.4.

8.2.7 Vehicle speed

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

8.2.8 Vehicle travelled distance (optional)

If vehicle travelled distance is measured, the overall system accuracy and data-reading resolution should be ± 1 % of the indicated distance, or ± 1 m, whichever is the greater.

8.3 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 practical, data should be corrected for inertial loading. Signal conditioning and recording equipment shall provide linear output and allow data-reading resolution to meet the requirements of 8.2.3. 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 vertical load and shall be recorded.

A digital data-acquisition system shall be employed to individually digitize the braking force, vertical load (if measured) and vehicle speed analogue outputs. The braking force, vertical load (if measured) 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 containing any significant frequencies above 50 Hz or other types of analogue data. The analogue signals shall correspondingly be filtered before digitizing. In this case, low-pass filters of order 2 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 shall 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 %. All signals shall be referenced to a common time base.

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.

8.4 Test tyre preparation and conditioning

8.4.1 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.

Dynamically balance the wheel and tyre assembly if it is anticipated that tests at speeds greater than 100 km/h will be made.

8.4.2 Pretest conditioning

Perform test tyre pretest conditioning on all tyres prior to testing. Carry out conditioning, only once per surface and prior to any actual test measurements, on a dry and level surface. Run each tyre at a fixed slip for 50 m at 35 km/h under test load.

Pretest condition new, smooth-treaded test tyres by running at the fixed slip at the normal tyre inflation-pressure on a dry pavement until such time as a smooth, flat rubber surface is obtained.

8.5 Test surface

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

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

8.6 Procedure

8.6.1 Warm up the electronic test equipment as necessary for stabilization.

8.6.2 Install the test tyre on the test position of the test device.

8.6.3 Check and, if necessary, adjust the load on the test tyre to the specified test load (see annex A).

8.6.4 Check the test tyre for the specified inflation-pressure (see annex A) at ambient temperature (cold), just prior to testing.

8.6.5 Perform pretest tyre conditioning if using a tyre for the first time on the track under test.

8.6.6 When testing on an externally wetted test surface and it is desirable to prevent tracking of the wheels of the test vehicle in front of the test wheel, offset the test wheel by 300 mm to 400 mm.

8.6.7 Record tyre identification and other data, including date, time, ambient temperature, test surface temperature, tyre durometer value, test surface type and water depth (if an externally wetted surface is used). Measure the water depth using a suitable device (e.g. a variable height probe-type device).

8.6.8 Record electrical calibration signals prior to, and after, testing each surface, or as needed to ensure valid data.

8.6.9 Conduct the test at the required test vehicle speed. The standard test speed is 65 km/h and tests shall normally be conducted at that speed. Maintain test speeds of 50 km/h or less to ± 1 km/h and test speeds over 50 km/h to within ± 4 % of the nominal test speed, or 2 km/h, whichever is the greater.

8.6.10 Normally, the test shall be carried out in the centre of either wheel track of the vehicle test lane. Record the specific details regarding lane and wheel-path used when reporting the data.

8.6.11 Place the test wheel in the fixed-slip mode approximately 3 s before the test is initiated and continue until the test is completed. If a self-watering system is used, deliver water to the test tyre with the fixed-slip mode engaged. Indicate the beginning and end of the test by means of the event marker and disengage the test wheel fixed-slip mode after completion of the test; if applicable, stop the water delivery.

8.7 Data analysis

8.7.1 Reference braking force coefficient (RBFC)

Calculate the RBFC by dividing the average reference braking force by the average vertical load. If the vertical load is not measured, the static value is used if the dynamic vertical load shift due to the braking force is less than 1 % of this force. If it is more, correct the static wheel load by calculation based on the braking force and the suspension geometry.

8.7.2 Reference braking force coefficient speed gradient (RBFCSG)

The change of RBFC with speed shall be reported as RBFC per kilometres per hour and should be obtained as the slope of the RBFC against the speed curve, which is plotted from at least three speeds in increments of approximately 30 km/h. The standard speed gradient is defined as the slope of the RBFC speed curve at 65 km/h and shall be so indicated.

8.8 Faulty tests

Tests that are faulty or that give values differing by more than 0,05 from the average of all tests of the same test section shall be treated in accordance with ASTM E178 accepted practice.

8.9 Test report

8.9.1 Field report

The field report for each test section shall include

a) identification and location of the test section,

b) date and time of day,

c) weather conditions,

d) lane and section tested,

e) speed of test vehicle,

f) water depth, if wetted surface used (with a description of the water-depth measuring method),

g) RBFC,

h) RBFCSG,

i) tyre type and serial number or date of manufacture, and

j) tyre load.

8.9.2 Summary report

The summary report shall include the following for each test section, insofar as it is pertinent to the variables or combinations of variables under investigation:

a) identification and location of the test section;

b) number of lanes and presence of lane separators;

c) grade and alignment;

d) pavement type and condition;

e) age of pavement;

f) date and time of day;

g) weather conditions;

h) lane and wheel path tested;

i) ambient and surface temperature;

j) average, high and low reference braking friction for the test section, and speed at which the tests were made (which may be done by adding the speed at which the test was run as a subscript to the RBF); if values are reported that were not used in computing the average, this should be reported;

k) average, high, and low reference braking friction speed gradient for the test section and speed for which the gradient is valid (which may be done by adding the speed at which the test was run as a subscript to the RBFSG); if values are reported that were not used in computing the average, this should be reported;

l) date of the last calibration.

8.10 Precision and bias

8.10.1 Precision

Data are not yet available to enable a statement to be made on the precision of this test method.

8.10.2 Bias

There are no standards or references with which the results of this test can be compared.

As already indicated, the function of this test is to enable comparisons to be made among paved surfaces tested with the same tyre. The results of the test method are regarded as adequate for making such comparisons without an external reference for assessing accuracy.

See note 1, clause 1.

8.11 Calibration

See Annex B.

Annex A
(normative)

Reference tyre specifications

A.1 Standard reference test tyre (SRTT)

Use one of the following as the SRTT:

— ISO patterned-tread, size 4.00-8 tyre, as given in clause A.7;

— size 195/75R14 tyre, in accordance with ASTM E1136;

— smooth-tread, size 4.00-8 tyre, in accordance with ASTM E1551.

A.2 Material and construction

The individual SRTT shall meet all the requirements for material and construction specified in the applicable standard for that tyre.

All steps in manufacturing the tyre shall be certified to ensure that the specifications are met.

After the manufacturing process, the tyre shall be stored according to A.5.

A.3 Uniformity

No balance medium of any type may be added to the tyre to correct balance.

A.4 Tyre use and operational requirements

If the tyre is intended for measuring purposes only, it shall not be designed for general use.

The tyre shall be preconditioned prior to testing as specified in the applicable standard for that tyre.

The tyre shall be operated with a test load according to A.6.

When wear or damage results from tests, or when wear influences the test results, the use of the tyre shall be discontinued. Refer to the applicable standard for a particular reference tyre.

A tyre shall not be used for testing when its characteristics do not conform to its standard specifications. This could be due to tyre ageing effects or storage conditions (see A.5), or both.

A.5 Storage and preservation

Store test tyres in a location such that the ambient temperature is the same for all tyres prior to testing and they are shielded from the sun to avoid excessive heating.

When irregular wear or damage results from tests, or when wear or usage influences the test results, the use of the tyre should be discontinued.

NOTE 1 Experience has shown that 40 complete tests with wheel lockup on wet surfaces and 10 complete tests with wheel lockup on dry surfaces tend to influence the repeatability of the data. More brake applications can be performed on low-coefficient surfaces.

NOTE 2 Test results such as measured braking force may be influenced by tyre groove depth or tread hardness, or both. The magnitude of this dependence is a function of the water depth, pavement characteristics, test speed, tyre ageing effects and break-in (preconditioning).

A.6 Test load, inflation-pressure and rim

The test load, inflation pressure and rim of the reference tyre shall be as given in Table A.1.

Table A.1 — SRTT test load, inflation-pressure and rim

Reference tyre (size)		**Load** N	**Inflation-pressure** kPa	**Rim** mm
Size 195/75-R14 (ASTM E1136)		4 500 ± 100	250 ± 3	14 × 6,0
Size 4.00-8	Patterned (ISO) [a]	1 000	140 ± 3	8 × 3,0
	Smooth (ASTM E1551)	1 400	200 ± 3	
[a] In accordance with A.7.				

A.7 ISO SRTT specifications

A.7.1 General and manufacture

These specifications cover the general requirements for a patterned SRTT to be used for friction measurements according to the fixed slip method specified in clause 8.

The individual standard tyre shall conform to the design specifications as given in Figures A.1 and A.2, and in A.7.2 to A.7.4.

Tread compounding, fabric processing, and all steps in tyre manufacturing shall be certified to ensure that specifications are met.

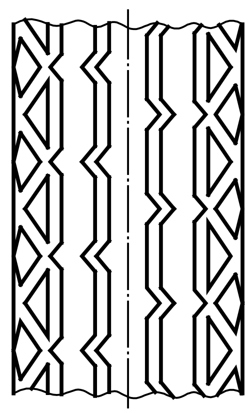
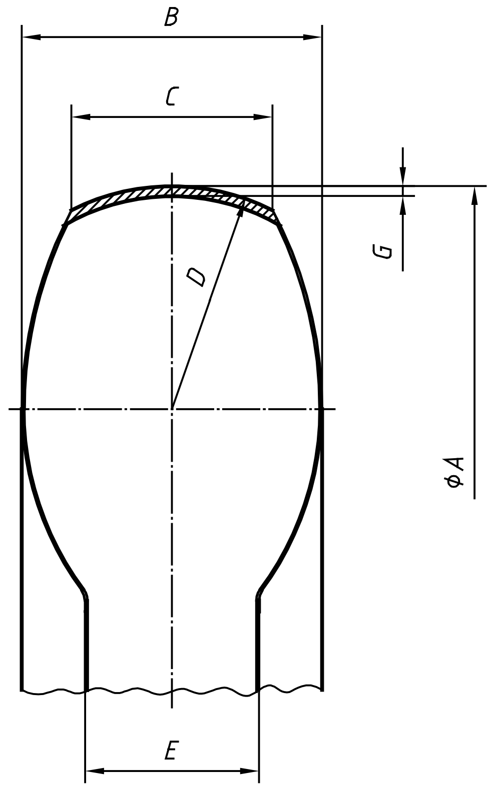


Figure A.1 — ISO SRTT — Tread pattern



A	Overall outside diameter:	new 420 mm, norm 423 mm, max. in service 432 mm
B	Overall width:	new 111 mm, norm 121 mm, max. in service 128 mm
C	Shoulder width:	81 mm
D	Tread radius:	90 mm
E	Rim width:	min. 63,5 mm (2,5"), max. 95,3 mm (3,75")
F	Tread depth:	new 4 mm, min. in service 2 mm

Figure A.2 — ISO SRTT — Dimensions

A.7.2 Chemical requirements

The compounding shall be as given in Table A.2.[1)]

1) Certain proprietary products available commercially have been specified, since exact duplication of properties of the finished tyre may not be achievable with other similar products. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of these products.

Table A.2 — Compounding requirements

Constituent	phr [a]
Table NR SMR 20	50
SBR 1500	50
N 375 black	65
Zinc oxide	3,0
Stearic acid	0,5
Phenolic tackifying resin	2,0
Processing aid: fatty acid salt	2,0
Antiozonant, 6 PPD	1,5
Antiozonant, Wingstay 100	1,0
Microcrystalline wax	2,0
High aromatic oil	12,0
Sulphur	1,5
Accelerator, CBS	1,2
Retarder, CAP	0,2

[a] Parts hundred rubber.

A.7.3 Physical requirements

The physical and mechanical test requirements shall be as given in Table A.3.

Table A.3 — Physical and mechanical requirements

Tensile sheet cure 60 min at 140 °C	
Tensile strength	20 MPa
300 % modulus	10 MPa
Elongation at break	540 %
Hardness (Shore A) at 20 °C	68 ± 2
Resilience	54 %
Relative density (specific gravity)	1,15

A.7.4 Dimensions, weights, and permissible variations

Dimensional details shall be according to Figure A.2. All tyre dimensions shall be subject to the manufacturer's normal tolerances. The specifications shall be as follows.

Tyre carcass:	diagonal
Tyre size designation:	4.00-8
Tread pattern:	see Figure A.2 (Trelleborg T-49)
Speed index:	J
Load index:	71
Ply rating:	6 PR
Tubeless:	No
Date code:	3 digits
Overall outside diameter:	new 420 mm, norm. 423 mm, max. in service 432 mm
Overall width:	new 111 mm, norm. 121 mm, max. in service 128 mm
Shoulder width:	81 mm
Tread radius:	90 mm
Rim width:	min. 63,5 mm (2,5"), max. 95,3 mm (3,75")
Tread depth:	new 4 mm, min. in service 2 mm
Carcass material:	nylon 4 ply
Weight:	2,3 kg

A.7.5 Certification

Upon request, the manufacturer shall furnish the purchaser with certification to the effect that the tyre meets these specifications. All tyres under certification shall be subject to the manufacturer's normal variation.

A.7.6 Marking

It is recommended that the tyre be marked “ISO Friction SRTT”, but tyres with other markings that meet these specifications may also be used.

EXAMPLE Tyres marked Trelleborg (alt. AVON) T-49 HIGH SPEED with UNECE approval mark E16, approval number 02 1294.

Annex B
(normative)

Calibration method

B.1 Speed

Calibrate the test vehicle speed indicator according to the procedure specified by the manufacturer.

B.2 Braking force and vertical test load

Place the test wheel of the assembled unit, with its own instrumentation, on a suitable calibration platform, calibrated in accordance with ASTM method F 377.

Apply the vertical test load, measuring it to within ± 0,5 % accuracy whenever the transducer is calibrated.

Align the transducers longitudinally and laterally, such that the tractive force-sensitive axis is horizontal. This can be accomplished by minimizing the tractive force output for large variations in vertical load. The system should be level during this procedure.

The calibration platform shall utilize low-friction bearings, and have an accuracy of ± 0,5 % of the applied load and a hysteresis of ± 0,25 % of the applied load up to the maximum expected loading. Take care to ensure that the applied load and the transducer-sensitive axis are in the same vertical line.

Perform the tractive force calibration incrementally up to the point where the test tyre starts to slip on the calibration platform, but at least to 50 % of the static vertical load.

B.3 Travelled distance

When measuring travelled distance, calibrate the travelled distance output according to the procedure specified by the manufacturer.

Annex C
(informative)

Measurement on wet surfaces

Even in very small quantities, water has a significant influence on tyre road friction on most surfaces and reduces tyre wear.

Both effects can be beneficial in handling tests, as the risk of overturning is reduced and there is a change in tyre characteristics during the test due to the reduced wear.

On clean road surfaces that have both good microtexture and macrotexture, the tyre-road friction is practically unaffected by the amount of water on the road. This is the case even where there is a relatively large amount of water, as the surface drains the water well enough not to cover the texture completely, and a clean microtexture provides good adhesion even when wet.

Smooth surfaces with little microtexture or macrotexture tend to be more speed-sensitive and have a friction which varies along the track due to variations in microtexture in a range where the wet friction is most sensitive to texture variation.

In order to ensure uniform wet surface friction, it is important that the surface be uniform and have a low percentage of binder, and also that the macrotexture does not produce water puddles but drains away surplus water.

On a well-designed road surface, the friction is less sensitive to the flow rate of water, whether it be a stationary sprinkling system or water supplied through a nozzle that is providing a theoretical water film thickness, up to reasonable test speeds.

Test results may be influenced by wind speed or direction, or both. The magnitude of this dependence is a function of the water depth, application procedures and surface wind protection.

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[8] ASTM ES17, *Standard Specification for Special Purpose, Smooth Tread, Standard Tire*

[9] UNECE Regulation No. 13. Annex 13.

[10] K.J. Law slip friction tester instruction and servicing manual

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[12] BV-11 skiddometer instruction and servicing manual

2) See also ASTM method F408.

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