



Road vehicles — Measurement of road surface friction

Véhicules routiers — Mesure du coefficient d'adhérence

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ISO/TR 8349 was prepared by Technical Committee ISO/TC 22, *Road vehicles* with ISO/TC 31, *Tyres* and the PIARC technical committee on road surface characteristics.

The reasons which led to the decision to publish this document in the form of a technical report type 2 are explained in the Introduction.

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0 Introduction

0.1 Historical background

During its work to establish vehicle handling test methods, sub-committee ISO/TC 22/SC 9, *Vehicle dynamics and road-holding ability* found a need to establish a method of evaluating the friction characteristics of a test surface for handling tests related more to peak friction than to the widely-used ASTM locked-wheel procedure.

The reason for this is that peak lateral and longitudinal friction determines the limits of handling and braking performance. Furthermore, research has shown that there is no general correlation between these properties and locked-wheel friction.

It was also considered desirable to establish a standardized test surface for high-friction tests and perhaps later also for low-friction tests : the work started with a "state of the art" survey.

The subject turned out to be very complicated, due to different philosophies concerning the use of the method and also a reluctance to favour any existing specific equipment or test tyre.

After an initial effort to establish a full method of characterizing the longitudinal and lateral force transmission between tyre and road surface, it was decided to leave this as a working document and continue with a simplified method.

The method chosen uses equipment with a test tyre running at constant slip or constant slip angle, because it allows the friction to be monitored easily along the whole test section, in contrast to peak measuring methods that only measure a very little part of the track at a time. There is equipment on which the slip and slip angle can be continuously controlled to find the peak values and hold them constant, but it was regarded as too expensive for a routine check device.

The reason for including both longitudinal and lateral friction coefficients is that certain test tracks may have different longitudinal and lateral characteristics due to grooving, or other surfaces with directional effects.

Regarding the cost and ease of operation of the equipment, the experience from aircraft runway friction evaluation shows that small and handy devices, which can be towed by a passenger car or are integrated in such a vehicle, are preferred. These devices have small test wheels and are test-specific. In connection with tyre and vehicle testing, there is also a need for evaluation of the tyre-to-road force transmission characteristics of tyres other than the special standardized reference test tyres. In this case the equipment should accommodate all passenger car tyre sizes if the interest is restricted to passenger cars. Equipment capable of handling truck tyres will be substantially larger and more expensive; it is not covered by this Technical Report.

A major question is what the coefficient of friction evaluated from the machine represents and how it can be used. In simple terms, the standardized reference tyre together with the test device is a reference test vehicle performing closely controlled braking and/or cornering continuously at constant or varying speed.

With a well-chosen reference test tyre, the coefficient of friction evaluated on a particular surface can be used as a non-dimensional reference performance level.

Since two surfaces with the same reference tyre coefficient of friction are not necessarily identical, they will give different values with another reference tyre that is sensitive to the difference.

Results from vehicle tests made on one test track can therefore not be compared absolutely based only on the reference tyre coefficient of friction measured on the two tracks. This is particularly evident on water-covered surfaces.

0.2 Reasons for publication of a Technical Report

The reasons for publishing the test methods for measurement of road surface friction as a Technical Report type 2 are the following.

There is a desire to establish a single measurement device with one type of reference tyre and further efforts should be made in order to avoid having four standards rather than one serving the same purpose. In this connection the question of how to specify test equipment and test tyre should be studied further.

Experience in using the method in connection with vehicle handling tests is, however, very limited and the validity of using the friction coefficients that are obtained as a measure of comparability of vehicle test results should be counter-checked carefully for the specific type of vehicle test by a large number of tests.

In certain cases it is of interest to consider what percentage of a theoretical maximum available tyre-to-road friction can be used. In this case, the tyres of the vehicle actually tested should be used instead of a reference tyre. This type of friction evaluation is required in the ECE regulation for antilock devices; it can therefore be considered an additional method, as it makes it possible to a large extent to separate tyre performance from the performance of the rest of the vehicle.

The addition of 100 % longitudinal slip has been suggested — the reason being that it is widely used as a measurement of road surface friction. The “optimum” constant slip and side slip angle method was established since the 100 % slip method did not reflect the friction properties relevant to handling tests.

Braking tests with vehicles equipped with antilock brake systems may, however, be taken up in future SC 9 work. In this case the result can be significantly influenced also by the locked wheel friction. The addition of this value to the other two can also be said to improve surface identification. The draw-back is a more complicated and time-consuming procedure. Furthermore, the problem of tyre wear is considerable with locked-wheel measurements on dry surfaces.

1 Scope and field of application

This Technical Report specifies a method of measuring the characteristic longitudinal and lateral friction force values with specified reference tyres. The method is suitable for a simplified evaluation of the friction properties of a test track surface.

This method uses measurements representing the steady state or quasi-steady state friction force on a test wheel operated at constant load either at a constant longitudinal reference slip or at a constant reference side-slip angle. The reference slip and slip angle are so chosen that, for the specified reference tyres, the friction coefficients obtained will be near the true peak values.

The values measured are intended to form reference numbers indicating certain friction properties of test tracks.

NOTE — The values measured by this method represent frictional data obtained with the equipment and procedures stated herein and do not necessarily agree or correlate directly with those obtained by other friction measurement methods.

The method has, in all essential parts, been used by road research institutes and road authorities and also by airport authorities for evaluating friction properties of roads and airport runways for more than 20 years.

Annexes A to C are integral parts of this Technical Report which, for reasons of convenience, are placed after the main text.

2 Principle

Driving an automotive vehicle or a suitable trailer towed by a vehicle, either of which have one or more test wheels fitted, with apparatus containing transducers, instrumentation, actuation controls, a water supply and its distribution system. The test wheel is equipped with a reference tyre (see 3.2).

The test apparatus is brought to the desired test speed along the desired test path. If applicable, water may be sprayed ahead of the reference tyre. The test wheel is brought to test condition by means of the actuation system. The resulting longitudinal and lateral friction force acting between the reference tyre and the pavement surface (or some other quantity that is directly related to this force), the speed of the test vehicle, the longitudinal slip, and side-slip angle (and lateral and longitudinal acceleration, if these influence measurements and must be corrected for) are recorded with the aid of suitable instrumentation. The test is made at least at two speeds.

The longitudinal and lateral force coefficients (see 7.1 and 7.2) of the paved surface are determined from the resulting recorded data and interpolated within the speed tolerance indicated in 6.1, to a reference speed for the vehicle test which is performed on the track. In addition to this, a speed gradient based on the highest and lowest speed is established.

3 Apparatus

3.1 Vehicle, capable of measuring longitudinal and/or lateral friction forces operating at the longitudinal slip and/or side-slip angles which define the longitudinal and/or lateral force coefficient using a reference tyre according to annex A. The test equipment shall meet the requirements given in annex B.

3.2 Tyre and rim, both meeting the requirements specified in annex A.

3.3 Instrumentation, meeting the requirements given in annex B.

3.4 Signal conditioning and recorder system, meeting the requirements given in annex B.

3.5 Pavement wetting system, as specified in annex B.

3.6 Wheel load : (See annex A.)

4 Calibration

In accordance with annex B and, where applicable, the manufacturer's instructions, calibration of speed, longitudinal slip and force, side-slip angle and lateral force, longitudinal and lateral acceleration, wheel load and water supply shall be made.

5 Test conditions

5.1 Tyres

Reference tyres shall conform to the requirements of annex A regarding use and operational requirements.

5.2 Test sections

Test sections shall basically coincide with the path followed by the vehicles tested on the track. The friction test wheel shall then follow the average wheel paths of the test vehicles in the test.

If vehicle tests are to be carried out on different parts of the test surface, then separate friction measurements shall be carried out on all parts which can be regarded as separate tracks from a friction point of view.

The length of the test section shall, if possible, be the same as that of the track section used for the vehicle test. However, in some cases it may not be possible to maintain the desired test speed throughout the track length used for the vehicle test. In these cases, shorter test sections may be used. The test sections shall, however, be representative and allow measurements for at least 20 m and at least 1 s.

The test section shall be in the same condition as that for which the friction values will serve as the reference.

5.3 Ambient conditions

Ambient conditions such as track surface temperature, air temperature and air humidity shall be within the limits specified for the vehicle test, or the following specifications :

- track surface temperature : 5 to 40 °C;
- air temperature : 5 to 40 °C;
- air humidity : up to 90 % (if the test is performed on a dry surface).

Measurements shall be made according to annex C.

6 Test procedure

Check the test wheel load (if adjustable) and adjust, if necessary, prior to each test to within the value specified in annex A. Set the reference tyre cold inflation pressure specified in annex A just before the warm-up as follows.

Prior to each series of tests, condition the tyre tread surface by travelling for at least 15 s at a speed of 60 km/h and specified conditions for measurement.

After each test, inspect the tyre for damage or other irregularities that could affect the test results; replace the tyre if it is damaged or worn below the wear limit specified in annex A.

6.1 Test speeds

Measurement shall always be made at 20 km/h and at one higher reference speed — which shall be 65 km/h, if the track so permits without exceeding a lateral acceleration of 3 m/s². If, for this or other reasons, a lower speed must be used, this should be as high as possible. If the test can be performed at a speed higher than 65 km/h and friction measurements taken at this speed without exceeding a lateral acceleration of 3 m/s², it is recommended that such a measurement also be included.

The following reference speeds may be used :

25, 35, 45, 55, 65, 75, 85, 95, 105, 115, etc., km/h

The measured speed shall be within ± 1 km/h of the nominal value.

6.2 Longitudinal force coefficient measurement

- 6.2.1 Bring the apparatus to the desired speed.
- 6.2.2 Record appropriate calibration signals.
- 6.2.3 Locate the vehicle laterally so that the reference tyre runs as far as possible over the left wheel path of the test course.
- 6.2.4 Start water delivery, if applicable.
- 6.2.5 Apply longitudinal slip and wheel load running at zero side-slip angle, so that test conditions are reached 3 to 5 s or at least 30 m before the test section.
- 6.2.6 Start recording at least 1 s before the entry into the test section. Record longitudinal force and, if applicable, wheel load and for control purposes, lateral force, lateral acceleration and forward speed, test section entry and end, and ambient conditions.
- 6.2.7 Repeat calibration procedure immediately after the end of the run.
- 6.2.8 Lift the test tyre or return to free rolling state.
- 6.2.9 Repeat the procedure with the reference tyre running as far as possible on the right wheel path of the test course.

6.3 Lateral force coefficient measurement

- 6.3.1 Repeat the procedure for left and right wheel path as in 6.2 but with slip angle and free rolling wheel. In these runs the lateral force and wheel load are the main parameters : longitudinal force measurement is not made.
- 6.3.2 This test is ended by lifting the reference tyre or returning to zero slip angle.

7 Data analysis

7.1 Longitudinal force coefficient, μ_x

Check that

- lateral tyre force does not exceed 20 % of the longitudinal force;
- temperatures are within limits;
- forward speed is within limits.

Average the longitudinal force and the normal force (if measured) between markings for entry and exit of the test section for both runs (left and right wheel path) and use the mean values for calculating the longitudinal force coefficient.

7.2 Lateral force coefficient, μ_y

Check that

- temperatures are within limits;
- forward speed is within limits.

Correct the lateral force data for the influence of lateral acceleration (if it exists).

Average the lateral force and the wheel load (if measured) data within the test section for the two test runs and use the mean values for calculating the lateral force coefficient.