INTERNATIONAL STANDARD

ISO 14512

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Passenger cars — Straight-ahead braking on surfaces with split coefficient of friction — Open-loop test method

Voitures particulières — Freinage en ligne droite sur surface à coefficients d'adhérence différents — Méthode d'essai en boucle ouverte

Reference number
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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

International Standard ISO 14512 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Annexes A and B form a normative part of this International Standard.

Introduction

The dynamic behaviour of a road vehicle is a most important aspect of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, constitutes a closed-loop system which is unique. The task of evaluating the dynamic behaviour is therefore very difficult, since significant interaction of these driver-vehicle-road elements are each complex in themselves. A description of the behaviour of the road vehicle must inevitably involve information obtained from a number of tests of different types.

Since this test method quantifies only one small part of the complete handling characteristics, the results of this test can only be considered significant for a correspondingly small part of the overall dynamic behaviour.

Moreover, insufficient knowledge is available to correlate overall vehicle dynamic properties with accident prevention. A large amount of work is necessary to acquire sufficient and reliable data on the correlation between accident prevention and vehicle dynamic properties in general and the results of this test in particular. Therefore, it is not possible to use this method and test results for regulation purposes.

Passenger cars — Straight-ahead braking on surfaces with split coefficient of friction — Open-loop test method

1 Scope

This International Standard describes an open-loop test method for determining vehicle reactions during a straight-line braking manoeuvre on a surface having a split coefficient of friction.

It applies to passenger cars as defined in ISO 3833.

The method is valid for all braking efforts up to full ABS operation for vehicles so equipped, or just up to the locking limit of the wheels on the high-friction surface for vehicles without ABS.

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 611:1994, *Road vehicles — Braking of automotive vehicles and their trailers — Vocabulary*.

ISO 1176:1990, *Road vehicles — Masses — Vocabulary and codes*.

ISO 3833:1977, *Road vehicles — Types — Terms and definitions*.

ISO 8855:1991, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*.

ISO 15037-1:1998, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars.*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 611 and ISO 8855 apply.

3.2 Symbols

For the purposes of this International Standard, the symbols given in Table 1 apply.

Table 1 — Symbols for parameters

Symbol	Parameter
a_X	Longitudinal acceleration
a_Y	Lateral acceleration
F_p	Brake pedal force[a]
M_H	Steering-wheel torque
p_B	Pressure at master cylinder output[b]
s_B	Braking distance
v_X	Longitudinal velocity
v_Y	Lateral velocity
β	Sideslip angle
δ_H	Steering-wheel angle[a]
ψ	Yaw angle
$\dot{\psi}$ or $\frac{d\psi}{dt}$	Yaw velocity
$\ddot{\psi}$ or $\frac{d^2\psi}{dt^2}$	Yaw acceleration
ω_1, ω_2, ω_3, ω_4	Wheel rotation speed

[a] Control parameters of handling manoeuvre.
[b] Vehicle reaction (see 9.2.1)

4 Principle

The objective of this test method is to determine the effects on course-holding and directional behaviour of a vehicle produced by a braking manoeuvre on a straightaway having a low coefficient of friction on one side.

Test results are strongly influenced by friction coefficients as well as the difference in friction between the left and right side of the course. Other test track surface characteristics (roughness, ice or synthetic materials); which are not quantified by the friction coefficient alone, exert an important influence on the test results. For this reason, it is not possible to describe the surface conditions in a reproducible way. A large difference in the left- and right-side friction conditions is desirable and an interpretation of the test results is only useful in a comparison, for instance with a "reference-vehicle" used in the same test.

The initial condition for the test is driving in a straight line at constant velocity. The position of the steering wheel and accelerator are held as steady as possible in the initial state. The steering wheel continues to be held fixed after the braking manoeuvre is initiated. During the test, the operating functions and vehicle responses are measured and recorded. Characteristic values are determined from the measured signals.

The variables of motion used to describe the effect of braking on course holding and directional behaviour of the vehicle relate to the intermediate axis system X, Y, Z (see ISO 8855).

The location of the origin of the vehicle axis system (X_V, Y_V, Z_V), being the reference point, is independent of the loading condition. It is fixed in the longitudinal plane of symmetry at half wheel base and at the same height above the ground as the centre of gravity of the vehicle at complete vehicle kerb mass (see ISO 1176).

5 Apparatus

The measuring equipment, the transducer installation and the data processing shall be in accordance with ISO 15037-1.

6 Parameters to be determined

The parameters that shall be determined for compliance with this International Standard as well as parameters which are recommended to be determined are given in Table 2. Typical operating ranges of the parameters to be determined for this International Standard are shown in Table 3. For operating ranges for the determination of parameters not given in Table 3, see ISO 15037-1.

Table 2 — Parameters to be determined

Parameter	Required	Recommended
Longitudinal velocity	X	
Yaw velocity	X	
Brake pedal actuation	X	
Brake pedal force[a]	X	
Pressure at master cylinder output[a]	X	
Steering-wheel angle	X	
Longitudinal acceleration		X
Lateral acceleration		X
Braking distance		X
Lateral velocity		X
Sideslip angle		X
Yaw angle		X
Steering-wheel torque		X
Wheel rotation speed		X
[a] One or the other shall be determined.		

Table 3 — Typical operating ranges and recommended maximum errors

Parameter	Typical operating range	Recommended maximum errors of the combined transducer and recorder system
Steering-wheel angle	$-180°$ to $+180°$	$\pm 1°$
Lateral acceleration	-10 m/s^2 to $+10$ m/s^2	$\pm 0{,}1$ m/s^2
Longitudinal acceleration	-10 m/s^2 to $+10$ m/s^2	$\pm 0{,}1$ m/s^2
Brake pressure	0 kPa to 25 000 kPa (0 bar to 250 bar)	$\pm$ 200 kPa ($\pm$ 2 bar)
Brake pedal force	0 N to 2 000 N	$\pm$ 20 N
Braking distance	0 m to 200 m	$\pm$ 1 m
Rotational velocity of wheels	0 s^{-1} to 20 s^{-1}	$\pm 0{,}2$ s^{-1}
Steering-wheel torque	-20 N·m to $+20$ N·m	$\pm 0{,}1$ N·m
Brake pedal actuation	For instance, a stop light switch if mechanically actuated by a brake pedal.	
Transducers for measuring some of the listed variables are not widely available and are not in general use. Many such instruments are developed by users. If any system error exceeds the recommended maximum values, this and the actual maximum error shall be stated in the test report (see general data, annex A).		

7 Test conditions

7.1 General

Limits and specifications for the ambient and vehicle test conditions established in 7.2 to 7.4 shall be maintained during the test. Any deviations shall be shown in the test report (see annex A) including the individual diagrams of the presentation of results (see annex B).

NOTE The ambient temperature may influence both the road friction and the tyre characteristics. Therefore the tests should be carried out under stable ambient temperature conditions.

Comparative studies shall be conducted on surfaces with the same friction coefficient. It is recommended to carry out reference measurements with a second vehicle.

The coefficients of friction have a very large influence on measuring results. Since the coefficients of friction, especially on natural ice surfaces, can change considerably within a short time (temperature, insulation, humidity, polishing effect etc.), it is recommended to regularly check the coefficients of friction.

One possible way of detecting changes in coefficients of friction is to perform an ABS-controlled braking manoeuvre with a reference vehicle and to compare the deceleration values. To get a good repeatability the speed shall not exceed 50 km/h.

7.2 Test track

All tests shall be carried out on a level, clean, uniform hard surface. The slope shall not exceed 2,5 % lengthwise and 1 % across. The difference in coefficient of friction, μ, between high-μ and low-μ should be at least 0,5.

For test track surfaces having a low coefficient of friction, μ, polished artificial and natural ice, or lubricant-wetted plastic sheeting, basalt, marble, stainless steel and other surfaces with coefficients of friction similar to ice, are recommended. However, it is necessary to take into account that these substitute materials may have a slip characteristic which differs from that of natural ice.

If a lubricant is used, it shall be evenly redistributed after every test run.

The low-μ section should be at least 50 m long and sufficiently wide to enable undisturbed measurement recording, even if large yaw angles occur, as well as the determining of a reference coefficient of friction (for instance, by ABS-braking manoeuvres) with all 4 wheels (on low-μ). This reference coefficient of friction only approximates the actual coefficient of friction and is dependent on quality of the ABS control.

As high-μ surface a dry road topping of asphalt, concrete or some other surface having a high coefficient of friction and sufficient width is recommended. If a lubricant is used, wetting of the high-μ surface shall be avoided. If necessary, it shall be regularly cleaned.

7.3 Wind velocity

The wind velocity shall not exceed 5 m/s and shall be recorded in the test report (annex A).

7.4 Test vehicle

7.4.1 Tyres

The tyre conditions shall be in accordance with ISO 15037-1:1998, 5.4.2.

7.4.2 Operating components

Operating components shall be as specified in ISO 15037-1:1998, 5.4.3.

7.4.3 Brake system and drive train

For standard test conditions, adjustment and condition of the drive train (especially the differentials, clutches, locks, free wheel shifts, etc.) shall correspond to the manufacturer's specifications for the vehicle.

7.4.4 Loading conditions of the vehicle

The loading conditions of the vehicle shall be as specified in ISO 15037-1:1998, 5.4.4.

8 Test method

8.1 Condition and temperature of brakes

New wearing parts of brakes (linings, discs, drums) shall be run in.

Before beginning measurements, several braking manoeuvres shall be performed to bring the brake system up to operating temperature.

Prior to each test run the temperature of the brake discs / drums shall be measured to ensure an initial temperature of less than 100 °C for the warmest brake and greater than 20 °C for the others.

8.2 Initial driving conditions

The initial driving conditions for the test shall be driving straight ahead at a constant velocity of 80 km/h. In case of additional initial velocities, steps of 10 km/h or 20 km/h shall be used and recorded in the log (annex A) and presentation (annex B) of results.

During the initial driving state the position of the steering wheel and accelerator-pedal shall be kept constant. The initial driving condition is concluded by starting the brake procedure (time t_0) and is assumed to be sufficiently uniform if the following conditions in time interval (t_0 – 0,8 s) to t_0 are met:

a) The deviation of the steering wheel angle from the mean value shall not exceed ± 3°.

b) The mean value of the longitudinal velocity $\bar{v}_{X_0}$ (see 9.3), shall not deviate from the intended velocity by more than 2 km/h.

c) The change in longitudinal velocity shall not exceed 1 km/h.

d) The maximum deviation of yaw velocity from its mean value shall not exceed 1°/s.

8.3 Performance of braking procedure

Viewed from the longitudinal axis of the vehicle, the test track should be approached in such a way that the border between high-μ and low-μ is located below centre of gravity of the vehicle.

After reaching the steady state conditions, the steering wheel shall be held fixed by the test driver or by a mechanical device. The position of the steering wheel during braking shall not differ more than ± 3° in the observed period (see 8.4) compared with the mean value of the initial state (see 8.2).

Additional tests may be conducted with an unfixed steering wheel (free control). The control mode (fixed or free control) shall be recorded in annex B.

NOTE Depending on the type of vehicle, tests with a free steering wheel may lead to an unexpected or dangerous reaction of the vehicle. It is recommended, to start those tests with a low initial velocity of, for example, 40 km/h.

The braking procedure shall be carried out with maximum deceleration (for vehicles without ABS just up to a locking wheel on the high-μ surface).

Release of the accelerator pedal and actuation of the brakes should take place in the very shortest time. On vehicles with manual transmission, the test run shall be conducted with the clutch engaged. Additional test-runs with the clutch disengaged may be performed. This shall be reported in "General data" in annex A. In the case of automatic transmissions the selected shift lever position and driving program remain unchanged.

8.4 Period of observation

The period of observation is the time interval over which measurements are to be made. The period of observation begins at least 2 s before the beginning of braking (t_0) and lasts until at least t_n +1 s or until leaving the split-μ condition.

8.4.1 Time of brake pedal actuation t_0

The reference point in time t_0 is the moment of brake pedal actuation.

8.4.2 Reference point in time t_n

t_n is the reference point in time at which characteristic values are computed. The time interval t_0 to t_n defines the period used for calculation of the mean values. The recommended value for t_n is t_0 +1 s, other values for t_n may be chosen but it should not be less than 0,5 s. Record the value of t_n in annex B.

8.4.3 Time when brake pedal force reaches the mean value t_m

t_m is the point in time at which the brake pedal force F_p first reaches the mean value of brake pedal force $\overline{F}_p$.

9 Data evaluation

9.1 General

Due to the large volume of data involved, the use of a computer is recommended for evaluation.

At the present level of knowledge it is not yet known which variables best represent the subjective feeling of the driver in these tests and which variables or characteristic values most clearly describe the dynamic reaction of the vehicle. The following specified variables, therefore, represent only examples for the evaluation of results.

9.2 Validity criteria

For the correct performance of a test run the following conditions shall be fulfilled.

9.2.1 Braking action

To ensure that the obtained deceleration is equivalent to a rapid braking manœuvre, the time between the reference point t_0 defined in 8.4.1 and the time $t_0 + t_m$ when the brake pedal force reaches the mean value, shall not exceed 0,3 s.

Figure 1 shows the pattern of brake pedal force versus time. There also can be seen the definition of time and mean value.

The mean value is generally calculated by the following formula:

$$\overline{F}_p = \frac{1}{\Delta t} \int_{t_0}^{t_0+\Delta t} F_p(t)\mathrm{d}t$$

with Δt = 1 s

If any problems should appear when measuring the brake pedal forces, the pressure at the master cylinder output can be used as an alternative. In this case, note that the pressure at master cylinder output is already a vehicle(component)-reaction, which can cause some differences in the results.

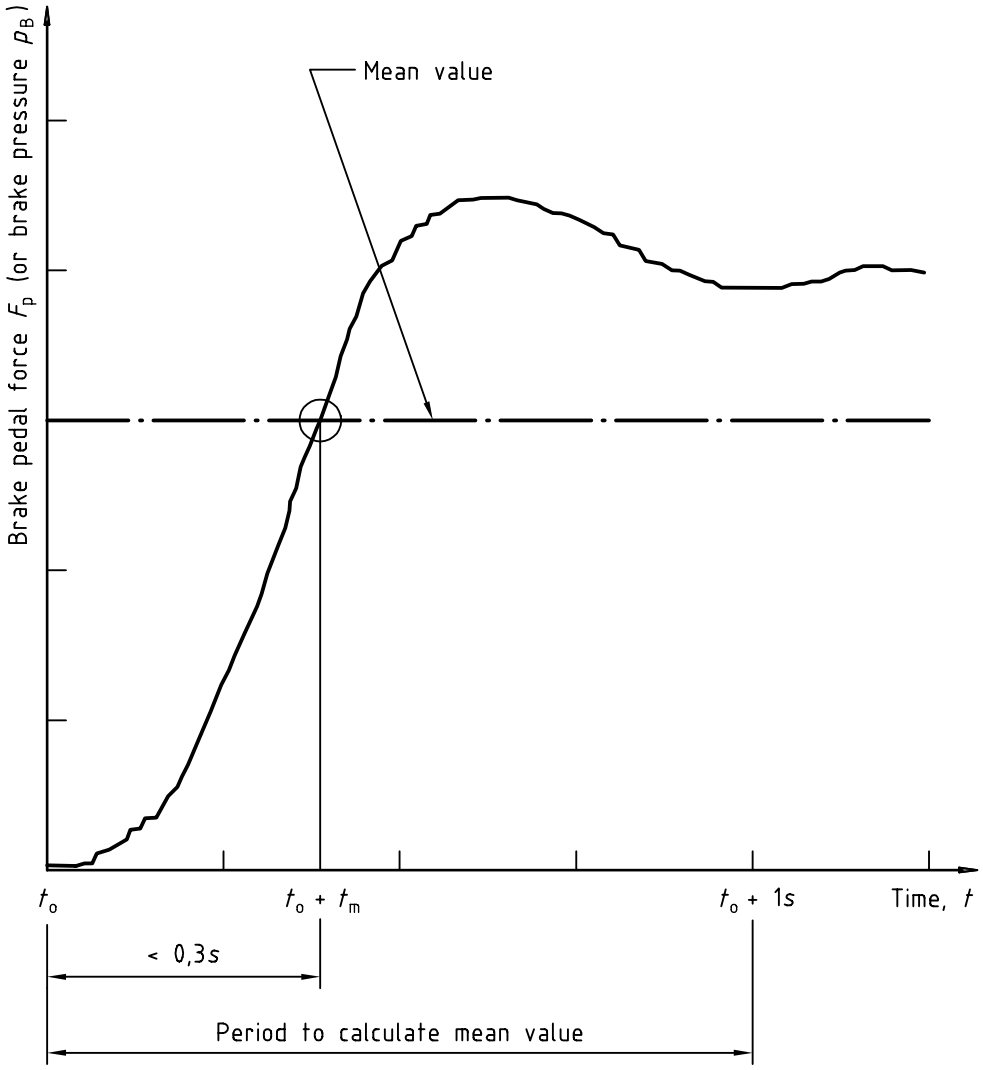

Figure 1 — Definition of t_m and mean value

9.2.2 Split-μ conditions

To correctly determine the characteristic values, it is necessary that the vehicle be in split-μ conditions up to point of time t_n; that is to say, no wheel may cross the line from low-μ to high-μ or vice versa during the braking procedure. The crossing over of the front wheel to high-μ is revealed by a clear increase in longitudinal deceleration; the crossing over of the rear wheel to low-μ is revealed by a clear increase in yaw velocity.

9.3 Mean longitudinal deceleration

The mean longitudinal deceleration $\bar{a}_X$ is determined from the difference between the initial velocity (as described in 8.2) and the mean value of the longitudinal velocity in the time range, t_n–0,1 s $< t <$ t_n+0,1 s.

$$\bar{a}_X = \frac{\left(\bar{v}_{X_0} - v_{t_n}\right)}{t_n}$$

where

$$\bar{v}_{X_0} = \frac{1}{t_{C1}} \int_{t_0 - 0,8\,s}^{t_0} v(t)\,dt$$

with t_{C1} = 0,8 s and

$$v_{t_n} = \frac{1}{t_{C2}} \int_{t_n-0,1s}^{t_n+0,1s} v(t)\mathrm{d}t$$

with t_{C2} = 0,2 s

NOTE Time is given in seconds (s).

9.4 Characteristic values

9.4.1 Yaw velocity

As result, the yaw velocity at point of time t_n is plotted versus the mean longitudinal deceleration. The yaw velocity, $\dot{\psi}_{t_n}$, is generally obtained by integration over the time range, t_n–0,1 s $< t <$ t_n+0,1 s.

$$\dot{\psi}_{t_n} = \frac{1}{t_{C2}} \int_{t_n-0,1s}^{t_n+0,1s} \dot{\psi}(t)\mathrm{d}t$$

with t_{C2} = 0,2 s

9.4.2 Further characteristic values

It is assumed, however, that the maximum yaw acceleration $\ddot{\psi}_{max}$ (maximum rise in yaw velocity in the linear range after initiating the braking manœuvre) versus the mean longitudinal deceleration can provide further valuable information.

This also holds for the observation of the time behaviour of vehicle reaction, for example the point of maximum yaw acceleration after t_0.

10 Test report

General data of the test report shall be presented as shown in annex A. For every change in equipment of the test vehicle (for instance, load) the general data shall be documented anew.

The characteristic values determined for the selected t_n are shown as points versus the corresponding mean deceleration (see 9.4).

The diagram for yaw rate $\dot{\psi}_{t_n}$ is found in annex B.

As possible parameters either the initial velocity or the reference point of time t_n can be selected.

Annex A
(normative)

Test report — General data

Vehicle description:	Type of vehicle:	.....
	Manufacturer:	.....
	Model:	.....
	Year built/first registered:	.....
Drive concept:	Front-wheel drive:	☐
	Standard drive:	☐
	Rear-wheel drive:	☐
	All-wheel drive:	☐
	Locking differential:	☐
	Type:	.....
Brake system:	Brake system:	
	Method of running in brakes:	.....
	ABS:	.....
	Circuit split:	.....
	Brake pads front / rear:	.....
	Calliper piston size front / rear:	.....
Engine:	Identification code:	.....
Transmission:	Manual:	☐ ..... -speed
	Automatic:	☐ ..... -speed
	— continuously variable	☐
	Gear ratio[a]:	1st ..... :1
		2nd ..... :1
		3rd ..... :1
		4th ..... :1
		5th ..... :1
		6th ..... :1
	Final drive ratio[a]:	 1
Steering:	Two-wheel steering:	☐
	Four-wheel steering:	☐
	— without servo assist:	☐
	— with servo assist:	☐
	Front-axle steering ratio:	..... :1
	Steering-wheel diameter:	..... mm

Tyres and wheels:	Dimensions:	front:..... rear: .....
	Tyre make and type:	.....
	Tread depth:	front l. ..... mm front r. .....mm
		rear l. .....mm rear r. .....mm
	Tyre pressure[b]:	
	— Manufacturer's information:	
	— Kerb mass	front..... kPa (bar) / rear .....kPa (bar)
	— Max. authorized total mass	front..... kPa (bar) / rear .....kPa (bar)
	— At test mass:	front..... kPa (bar) / rear .....kPa (bar)
	Rim size:	front..... mm / rear .....mm
	Rim offset:	front..... mm / rear .....mm
Mass:	Complete vehicle kerb mass[a]:	..... kg
	Max. authorized total mass[a]:	..... kg
	Max. authorized axle load front/rear[a]:	front:..... kg rear: ..... kg
	Measured wheel load at test mass:	front l..... kg front r. ..... kg
		rear l..... kg rear r. ..... kg
Dimensions:	Wheelbase:	..... mm
	Track:	front..... mm rear ..... mm
	Length[a]:	..... mm
	Width[a]:	..... mm
	Height[a]:	..... mm
	Height of centre of gravity for kerb mass:	..... mm
Suspension:	Front:	
	— Stabilizers:	☐ yes ☐ no
	— Compensating springs:	☐ yes ☐ no
	Rear:	
	— Stabilizers:	☐ yes ☐ no
	— Compensating springs:	☐ yes ☐ no
	Springs/dampers:	
Test conditions:	Clutch during measurement:	☐ engaged ☐ disengaged
	Gear engaged:	.....
	Selector lever position:	.....
	Driving programme:	.....
		.....
	Weather conditions:	
	— Temperature:	..... °C
	— Wind velocity:	..... m/s
	Reference point for slip angle and lateral velocity:	.....
Test track surface:	Description of test track surfaces:	.....
Testing staff:	Driver:	.....
	Observer:	.....
	Evaluator of data:	.....

[a] According to manufacturer
[b] 100 kPa = 1 bar

Annex B
(normative)

Presentation of results

Results of straight-ahead braking on split μ-surface (ISO 14512)

Initial speed:
Control mode:
Test track surfaces:

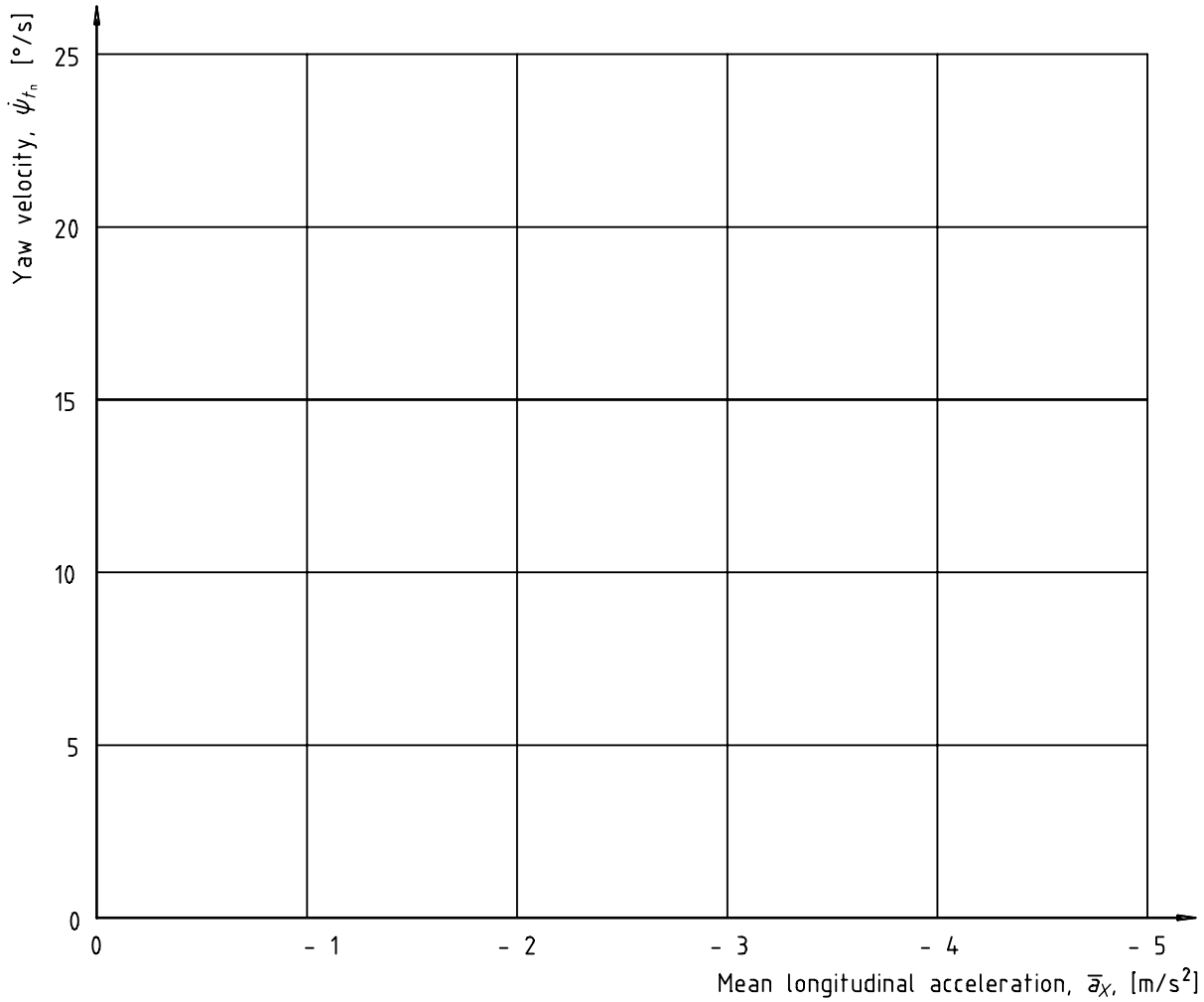

Figure B.1 — Yaw velocity $\dot{\psi}_{t_n}$ during braking as a function of the mean longitudinal acceleration $\bar{a}_X$

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Price based on 11 pages