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Railway applications — Railway braking — Country specific applications for ISO 20138-1

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Foreword

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This document was prepared by Technical Committee ISO/TC 269, *Railway applications*, Subcommittee SC 2, *Rolling stock*.

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Railway applications — Railway braking — Country specific applications for ISO 20138-1

1 Scope

This document provides additional information to assist the understanding and the use of ISO 20138-1. The calculations in this document follow the same principles but they are slightly different.

This document contains country specific calculation approaches currently in use and represents the state of knowledge including for calculating:

- stopping and slowing distances;
- equivalent response time;
- brake performance;
- brake ratio.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

4 Slowing or stopping distance calculation using a method implemented in France

4.1 General

This calculation is based on the alternative method of equivalent response time calculation, as used in the French railway requirements, in particular for trains operating in "G" position.

4.2 Terms, symbols and abbreviations

For the purpose of Clause 4, the terms, symbols and abbreviations defined in Table 1 apply.

Table 1 — Symbols, definitions and units

Term, symbol or abbreviation	Definition	Unit
1	Point when the brake force, deceleration or pressure has been substantially achieved, typically 95 %	—
a_e	Equivalent deceleration (on level track, without considering gradient effect)	m/s^2
g	Standard acceleration of gravity	m/s^2
“G” position	Distributor valve and distributor isolating devices (as defined in EN 15355[9])	
i	Gradient of the track (positive rising/negative falling)	—
s_{grad}	Stopping/slowing distance on a gradient	m
s_{tests}	Stopping distances measured during the tests	m
t_e	Equivalent response time	s
$2 \cdot t_e$	Equivalent response time multiplied by 2	s
v_0	Initial speed	m/s
v_{fin}	Final speed (= 0 in the case of a stopping distance)	m/s
X	Time	s
Y	Factor of nominal braking force, deceleration or pressure	—

4.3 Slowing or stopping distance calculation

4.3.1 French model for “G” position

This model provides a high level of accuracy for the calculation of stopping distances of trains with long build up time (e.g. “G” position). It is currently used by the infrastructure managers in order to evaluate the conformance of a train with the train control system and the length of the signalling sections.

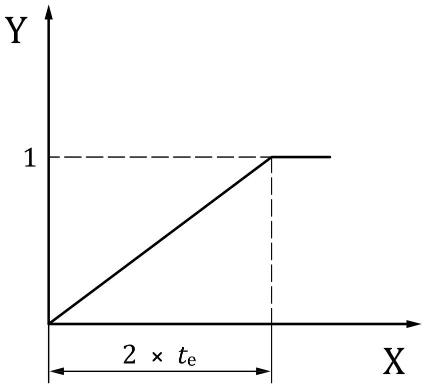
For this French model of slowing or stopping distance calculation, Figure 1 may be used for trains operating in “G” position for brake systems with retarding forces acting on rail contact point.

The model uses a linear development of the effort from 0 to 1 during a time of $2 \cdot t_e$.

The equivalent response time, t_e, can be calculated as set out in Formula (1):

$$t_e = t_a + \frac{t_{ab}}{2} \tag{1}$$

with t_a and t_{ab} in accordance with ISO 20138-1:2018, 5.5.2.



Key

Y	factor of nominal braking force, deceleration or pressure
X	time, in s
1	point when the full brake force, deceleration or pressure has been achieved, typically 95 % of maximum value
2 × t_e	equivalent response time multiplied by 2, in s

Figure 1 — Model based on a linear development of the effort from 0 to 1 during a time of 2·t_e

The stopping ($v_{fin} = 0$) or slowing distance can be calculated as set out in Formula (2):

$$s_{grad} = v_0 \cdot t_e \cdot \frac{a_e}{a_e + g \cdot i} + \frac{v_0^2 - v_{fin}^2}{2 \cdot (a_e + g \cdot i)} - \frac{a_e \cdot t_e^2 \cdot (a_e + 4 \cdot g \cdot i)}{6 \cdot (a_e + g \cdot i)} \tag{2}$$

NOTE 1 The equivalent deceleration, a_e, does not take the effect of the gradient into account.

Formula (3) is valid for stopping/slowing distance calculation with fully established braking forces. The following condition is fulfilled:

$$v_0 - v_{fin} \geq (a_e + 2 \cdot i) \cdot t_e \tag{3}$$

where

s_{grad} is the stopping/slowing distance on a gradient, in m;

v_0 is the initial speed, in m/s;

t_e is the equivalent response time, in s;

a_e is the equivalent deceleration (on level track, without considering gradient effect), in m/s^2;

g is the standard acceleration of gravity, in m/s^2;

i is the gradient of the track (positive rising/negative falling);

v_{fin} is the final speed (= 0 in the case of a stopping distance), in m/s.

NOTE 2 The stopping/slowing distance as calculated by applying Formula (3) will be shorter than calculated according to the method described in ISO 20138-1:2018, 5.7.4.

4.3.2 Calculation using ISO 20138-1:2018, 5.7.5.1 (step model)

ISO 20138-1:2018, 5.7.5.1, gives Formula (4) for calculations on level track ($i = 0$) or with gradient.

It uses the model for theoretical response time $t_{\mathrm{e}} = t_{\mathrm{a}} + \frac{t_{\mathrm{ab}}}{2}$ as “step” model.

$$s_{\mathrm{grad}} = v_0 \cdot t_{\mathrm{e}} - \frac{1}{2}\frac{m_{\mathrm{st}}}{m_{\mathrm{dyn}}} \cdot g \cdot i \cdot t_{\mathrm{e}}^2 + \frac{\left(v_0 - \frac{m_{\mathrm{st}}}{m_{\mathrm{dyn}}} \cdot g \cdot i \cdot t_{\mathrm{e}}\right)^2 - v_{\mathrm{fin}}^2}{2a_{\mathrm{e}}} \qquad (4)$$

With train resistance and dynamic mass which compensate each other and $v_{\mathrm{fin}} = 0$, the formula is simplified as Formula (5):

$$s_{\mathrm{grad}} = v_0 \cdot t_{\mathrm{e}} - \frac{g \cdot i \cdot t_{\mathrm{e}}^2}{2} + \frac{(v_0 - g \cdot i \cdot t_{\mathrm{e}})^2}{2a_{\mathrm{e}}} \qquad (5)$$

where

s_{grad}	is the stopping/slowing distance on a gradient, in m;
v_0	is the initial speed, in m/s;
t_{e}	is the equivalent response time, in s;
m_{st}	is the static mass, in kg;
m_{dyn}	is the dynamic mass, in kg;
g	is the standard acceleration of gravity, in m/s^2;
i	is the gradient of the track (positive rising/negative falling);
a_{e}	is the equivalent deceleration (on level track, without considering gradient effect), in m/s^2;
v_{fin}	is the final speed (= 0 in the case of a stopping distance), in m/s.

4.4 Example of calculation

4.4.1 Test results

This example is based on a long train of 1 000 m in “G” position.

As a reference for further comparison, the tests realized on the tracks have provided the following results for the stopping distances s_{tests}:

Stopping distance on level track	**824 m**
Stopping distance on a down gradient of 5 ‰	**885 m**
Stopping distance on an up gradient of 5 ‰	**776 m**

The equivalent response time, t_{e} (delay time + 1/2 brake build-up time), derived from the results of the tests is 15,5 s.

The equivalent deceleration without including the effect of the gradient, a_{e}, derived from the results of the tests is 0,89 m/s^2.

4.4.2 Comparison of calculation models with test results

The stopping distances, s_{tests}, calculated using Formula (5) (simplified ISO 20138-1 “step model”) are given in Table 2:

Table 2 — Stopping distances calculated using step model

	v_0	g	i	t_e	a_e	s_{grad}	s_{tests}	Difference s_{grad} vs s_{tests}
	km/h	m/s^2	mm/m	s	m/s^2	m	m	%
Level track	100	9,81	0	15,5	0,89	**864,0**	824	5 %
Up gradient	100	9,81	5	15,5	0,89	**834,7**	776	8 %
Down gradient	100	9,81	−5	15,5	0,89	**894,0**	885	1 %

The stopping distances, s_{tests}, calculated using Formula (2) (French alternative method) are given in Table 3:

Table 3 — Stopping distances calculated using French alternative method

	v_0	g	i	t_e	a_e	**Condition** $v_0 \geq (a_e + 2g \cdot i)\, t_e$		s_{grad}	s_{tests}	**Difference** s_{grad} vs s_{tests}
						v_0	$(a_e + 2g \cdot i)\, t_e$			
	km/h	m/s^2	mm/m	s	m/s^2	m/s	m/s	m	m	%
Level track	100	9,81	0	15,5	0,89	27,8	>13,8	**828,4**	824	<1 %
Up gradient	100	9,81	5	15,5	0,89	27,8	>15,3	**777,7**	776	0 %
Down gradient	100	9,81	−5	15,5	0,89	27,8	>12,3	**885,0**	885	0 %

The values in the table demonstrate the following:

- The stopping distances calculated with the French alternative method are shorter than the ones of the simplified “step model” of ISO 20138-1.
- The stopping distances calculated with the French alternative method are more accurate and closer to the test results on the track.

5 Calculation of braking performance implemented in Japan

5.1 General

In Japan, the fundamental law is the Railway Operation Act[3]. In addition, the Technical Regulatory Standards on Japanese Railway are published by the Ministry of Land, Infrastructure and Transport and Tourism (MILT). The technical regulation consists of ministerial ordinances and approved model specifications. Explanatory documents which complement the ministerial ordinances and approved model specifications and help users to interpret these correctly have also been published. These documents are generally used as standards as well as Japanese Industrial Standards (JIS)[4][7][8] and Japan Association of Rolling Stock Industries standards (JRIS)[5][6], etc. in Japan.

5.2 Brake ratio for a single vehicle

The brake ratio is used to compare the capability of single vehicles and is used for design assessment.

The braking force for a single vehicle can be calculated as set out in Formula (6):

$$F_{\text{tot}} = n_{\text{cyl}} \cdot A_{\text{tot}} \cdot p_{\text{c}} \cdot i_{\text{tot}} \cdot \eta_{\text{tot}} \tag{6}$$

where

F_{tot} is the braking force, in kN;

n_{cyl} is the number of brake cylinders;

A_{tot} is the area of a cylinder, in m^2;

p_{c} is the brake cylinder pressure, in kPa;

i_{tot} is the total rigging ratio;

η_{tot} is the mechanical efficiency.

The brake ratio for a single vehicle can be calculated as set out in Formula (7):

$$\theta = \frac{F_{\text{tot}}}{M_{\text{tot}} \cdot g} \cdot C \cdot 100 \tag{7}$$

with

$$C = \frac{\mu_{\text{A}}}{\mu_{\text{C}}} \tag{8}$$

where

θ is the brake ratio for a single vehicle, in %;

F_{tot} is the braking force, in kN;

M_{tot} is the operational mass of the vehicle plus load, in t;

g is the standard acceleration of gravity, in m/s^2;

C is the ratio of friction coefficients;

μ_{A} is the friction coefficient of applied brake block;

μ_{C} is the friction coefficient of cast iron block (assumed to be 0,15).

NOTE The friction coefficient of applied brake block, μ_{A}, and the acceptance criteria of the brake ratio are outside the scope of this document.

5.3 Example for brake ratio calculation

In case of a vehicle with a tread brake unit per wheel, as shown in Figure 2, input data are shown in Table 4.

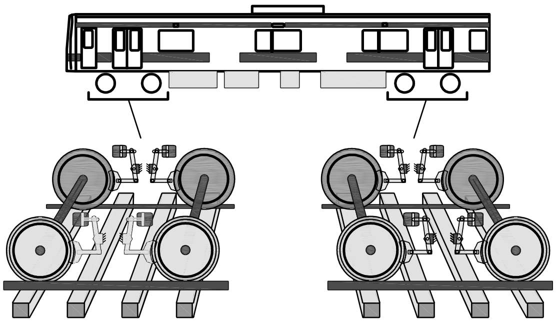


Figure 2 — A vehicle with a tread brake unit per wheel

Table 4 — Input data

Description	Symbol	Example value	Unit
Diameter of brake cylinder	d_{cyl}	0,152	m
Standard acceleration of gravity	g	9,807	m/s^2
Total rigging ratio	i_{tot}	3,6	—
Operational mass	m_{op}	31,4	t
Mass per person	m_p	55	kg/person
Number of brake cylinders	n_{cyl}	8	—
Passenger capacity	n_p	153	—
Brake cylinder pressure	p_c	303	kPa
Mechanical efficiency (including counter force)	η_{tot}	1,0	—
Friction coefficient of applied brake block (composite brake block)	μ_A	0,3	—

The braking force of a vehicle can be calculated as set out in Formula (6):

$$F_{tot} = \left[(0{,}152m)^2 \cdot \pi / 4 \right] \cdot 8 \cdot 303\,\text{kPa} \cdot 3{,}6 \cdot 1{,}0$$

$$F_{tot} = 158{,}4\,\text{kN}$$

The mass of a loaded vehicle can be calculated as set out in Formula 9:

$$M_{tot} = m_{op} + n_p \cdot m_p \tag{9}$$

$$M_{tot} = 31{,}4\text{t} + 153 \cdot \left(\frac{55}{1\,000} \right) \cdot \text{t}$$

$$M_{\text{tot}} = 39{,}82\text{t}$$

The ratio of friction coefficients, C, using composite brake blocks can be calculated as set out in Formula (8):

$$C = \frac{0{,}3}{0{,}15} = 2{,}0$$

In the end, the brake ratio for a loaded vehicle can be calculated as set out in Formula (7):

$$\theta = \frac{158{,}4\,\text{kN}}{39{,}82\,\text{t} \cdot 9{,}807\,\text{m}/\text{s}^2} \cdot 2{,}0 \cdot 100$$

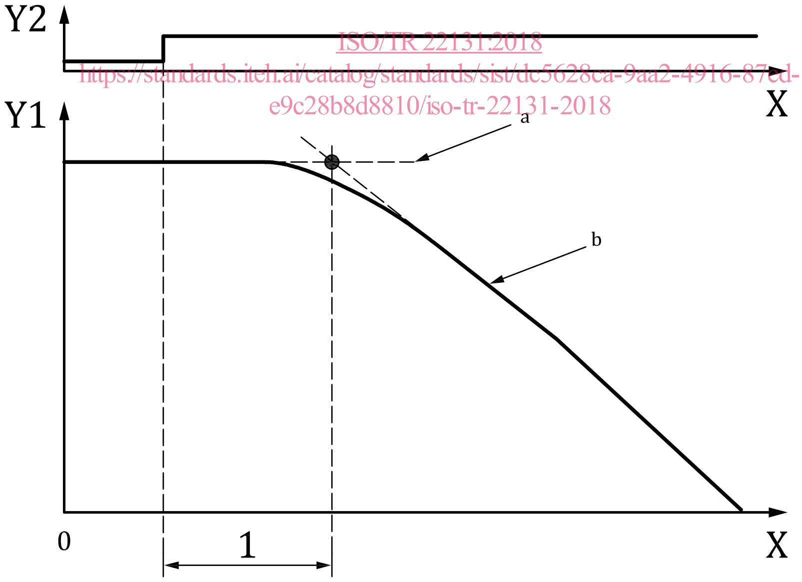
$$\theta = 81\,\%$$

5.4 Equivalent response time

In Japan, an equivalent response time is determined as below.

Case 1: Determination based on train speed

The equivalent response time is determined based on train speed. In this case, the brake command and speed are measured. In the time series chart shown in Figure 3, the horizontal line is extended from the speed at the starting point of the braking. Moreover, another line is extended from around the speed at which the deceleration is almost constant. The equivalent response time is decided as the time between the start of braking and cross point of two extended lines.



Key

Y1 speed

Y2 brake command

X time, in s

1 equivalent response time

[a] Extend the horizontal line from the starting point of the braking.

[b] Deceleration is almost constant.

Figure 3 — Equivalent response time in case 1 “based on train speed”