CALCULATION AND MEASUREMENT GUIDELINES FOR RAIL TRANSPORT NOISE 1996 (ADAPTED TO END)

PROPOSED COMPUTATION METHOD FOR STRATEGIC NOISE MAPPING

Chapter 0 Introduction
Chapter 1 Noise propagation calculation in octave bands: SRM II/ORM method
Chapter 2 Emission values
Chapter 3 Strategic noise mapping

Annex A Noise propagation calculation method for noise mapping (ARM 1.5-method)
Annex B Measurement methods for determining noise emission
Annex C Global dB(A) noise propagation calculation method (SRM I/ARM-1)
CHAPTER 0. INTRODUCTION

This introduction is written by the authors of this document to position the document hereafter in regard of the basic Dutch documents of 1996 and 2002.

0.1. GENERAL INFORMATION

The aim of this document is the proposal of a computation method for railway noise for the purpose of strategic noise mapping based on the Dutch national computation method published as: "Reken- en Meetvoorschrift Railverkeerlawaai 96" (RMR96).

A new document has recently been published as: "Reken- en Meetvoorschrift Railverkeerlawaai 2002" (RMR2002).

According to the publishers of RMR 2002, following major modifications to the RMR 1996 have been included:

- addition of a measurement method for the determination of emission values for new or unknown rail vehicles;
- addition of a method for integration of track conditions (roughness) into the octave band calculation method;
- (slight) modifications to the calculation of reflection coefficients based on the actual widely accepted theories;
- addition of a specific computation method for noise mapping ARM 1.5;
- modification of labelling of method to permit unique translation:
  - ARM 1: global A-weighted computation method (previously SRM I);
  - ORM: octave band computation method (previously SRM II).

The END does not indicate which of the two calculation methods of the RMR 1996 must be used.

In the search of a similar propagation model for all three interim methods, similarly with ISO 9613-2 has been sought.

SRM II (also called ORM) is the only method that stays close enough to ISO 9613.
The additional method ARM 1.5 proposed by the Dutch Authorities in the RMR 2002 for large scale noise mapping has not been retained:

- global dB(A) method compared to octave band method for other sources;
- major simplifications of propagation model as compared to ISO 9613.

On the other hand, the measurement procedure for the determination of new rail vehicle emission categories as integrated in RMR 2002 has been integrated. This procedure was previously published by Dittrich & Janssens, TNO-TPD 2000.

Further also a document of Van der Toorn made available to WG4 has been included (§ 3.3).

In annex, the global computation methods (ARM 1 and ARM 1.5) will be maintained as methods for more simplified situations.

To guide the user through the document, three colour codes are used:

<table>
<thead>
<tr>
<th>Colour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>yellow</td>
<td>part of RMR 1996 to be deleted</td>
</tr>
<tr>
<td>blue</td>
<td>corrections and modification to RMR 1996 according to ISO 9613 or END terminology</td>
</tr>
<tr>
<td>green</td>
<td>modification of RMR 1996 with RMR 2002 or adjacent documents</td>
</tr>
</tbody>
</table>
0.2. CONTENT

This document is based on a non-contextual English translation of the aforementioned Dutch document, RMR 1996.

Chapter 1 Octave band computation method used to be the standard method for noise mapping studies (= chapter 5 of RMR 1996 and RMR 2002)

Chapter 2 For the determination of the emission value both the global dB(A) method for classical trains as the octave band method for high speed trains are given (= chapter 2 and 3 of RMR 1996 and RMR 2002)

Chapter 3 Reference to the emission register and L_{den} calculation aspects is given (= chapter 8 of RMR 1996 and chapter 9 of RMR 2002)

Annex A ARM 1.5 global dB(A) computation method (= chapter 6 of RMR 2002): method proposed by Dutch authorities but not retained for noise mapping


Following chapters of RMR 1996 and 2002 are not retained (because no relation with strategic noise mapping):

Chapter 7 & 8 Measurement methods for environmental noise monitoring

Chapter 9 The information in chapter 9 of RMR 1996 (= chapter 10 of RMR 2002) has been integrated as introduction to each of the corresponding chapters.

Chapter 10 Additional information & guidelines
## CHAPTER 1.
### NOISE PROPAGATION CALCULATION IN OCTAVE BANDS

### 1.0. General information

### 1.1. Specification of Terms

- Receiver point (R)
- Sector
- Sector Surface
- Opening Angle of a Sector
- Total Opening Angle of a Sector
- Viewing Angle
- Source Line
- Line Source Segments
- Point Source (S)

### 1.2. Basic Formula

- Equivalent sound level $L_{Aeq}$
- Summation

### 1.3. Modelling the situation

- Source Lines
- Composition of the ground
- Ground Height Differences
- Standard Embankment
- Level crossing
- Screening slabs (U-type slabs)
- Barriers and screening objects
- Platforms
- Bridge constructions
- Noise absorbent construction
- Reflections
- Residential buildings
- Assessment points

### 1.4. Attenuation by distance $\Delta L_{GU}$

- Data
1.4.2. Calculation 19
1.4.3. Conclusion 19

1.5. Attenuation by propagation $\Delta L_{OD}$ 19
1.5.1. Air attenuation $D_L$ 20
1.5.1.1 Data 20
1.5.1.2 Calculation 20
1.5.2. Ground attenuation $D_B$ 21
1.5.2.1 21
1.5.2.2 Data 22
1.5.2.3 Calculation 23
1.5.3. Meteorological correction factor $C_M$ 24
1.5.3.1 Data 24
1.5.3.2 Calculation 24
1.5.3.3 25

1.6. Attenuation factor for screening $\Delta L_{SW}$ 25
1.6.1. Description 25
1.6.2. Data 26
1.6.3. Calculated results 27
1.6.4. 28
1.6.5. 28
1.6.6. 30

1.7. Determining rail specific absorption 30

1.8. Reduction of levels as a result of reflections $\Delta L_R$ 31
1.8.1. Data 31
1.8.2. Calculation 32
1.8.3. Values 32

1.9. The octave band spectrum of the equivalent noise level 32

1.0. GENERAL INFORMATION

The range of use for the octave band calculation method is larger than that for the global dB(A) calculation method and for the measurement methods. As it is impossible to provide a method that covers all cases, information is given in the individual sections of the calculation method as to which conditions require further examination. Those responsible for the further
examinations must possess a great measure of specific know-how as high demands are placed on their reports.

The propagation method used in the octave band method and specifically the sections referring to ground attenuation and screen attenuation are based on the model of curved sound rays in downwind conditions. When calculating the method using Maekawa, the curve of the sound ray is taken into account in that the actual barrier is reduced by an ineffective part. The downwind conditions provided by this transmission model are not representative of meteorological averages, however. By adding a meteorological correction factor to the model, a “meteo averaged” equivalent noise level, $L_{Aeq}$, is attained.

In this part it is taken that the emission values for each emission section as specified by octave band are known. The geometric input data should be taken from well-detailed chart material (horizontal projections and vertical cross sections of relevant objects). For the purpose of automatic processing, this input should be taken into account schematically in the calculation (curved lines are described approximately in terms of straight sections, the height of the upper edge of the terrain is given as an average value, not acoustically important details are omitted, etc.). This changes the input to an output that requires specific acoustic insight. Specifically in the case of complex acoustic situations, the report as well as the original chart material and the schematically inputted geometry must be provided.
1.1. SPECIFICATION OF TERMS

For the calculation of the transmission (ground effect, screening, meteo correction), the model is based on point sources. For each sector, the considered line segment is localized in one point, called point source (S).

![Diagram showing the concept of line source segment and receiver point (R)]

**Receiver point (R)**

This is the point at which the equivalent sound level should be determined. When determining the noise pollution in a front wall, the receiver point lays in surface of the front wall.

**Sector**

A volume limited by two vertical surfaces whose borders correspond with the perpendicular through the assessment point.
**Sector Surface**
The median surface of two limiting surfaces of a sector.

**Opening Angle of a Sector**
The angle between two limiting surfaces of a sector and the horizontal area.

**Total Opening Angle of a Sector**
The sum of opening angles from all sectors which are significant in the determination of the equivalent sound level in dB(A).

**Viewing Angle**
The angle from which an object (front, barrier, street, etc.) is viewed in horizontal projection from the assessment point.

**Source Line**
The line above the centre of the rail at a particular level above the upper edge of the tracks (BS), which represents the position of noise propagation. Depending on the vehicle type two to four line noise sources can be differentiated.

**Line Source Segments**
The straight line between the intersection points of a line source with the limiting surfaces of a sector.

**Point Source (S)**
The intersection point of a sector area with a line source segment.
1.2. BASIC FORMULA

1.2.1. Equivalent sound level $L_{Aeq}$

The equivalent sound level $L_{Aeq}$ in dB(A) is calculated as follows:

$$L_{Aeq} = 10 \log \sum_{n=1}^{N} \sum_{j=1}^{J} \sum_{i=1}^{8} 10^{\frac{\Delta L_{eq,i,j,n}}{10}}$$

where $\Delta L_{eq,i,j,n}$ specifies the contribution in an octave band (index code $i$) of a sector (index code $j$) and a source point (index code $n$).

$\Delta L_{eq,i,j,n}$ includes following values:

$$\Delta L_{eq,i,j,n} = L_E + \Delta L_{GU} - \Delta L_{OD} - \Delta L_{SW} - \Delta L_R - 58.6$$

with $L_E$ emission value per source height and octave band according to § 2.3.2
$\Delta L_{GU}$ attenuation due to distance (§ 1.4)
$\Delta L_{OD}$ attenuation due to propagation (§ 1.5)
$\Delta L_{SW}$ screening effect, if present (§ 1.6)
$\Delta L_R$ attenuation due to reflections, if present (§ 1.7)

1.2.2. Summation

The octave bands with the nominal centre frequencies 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz are used for summation. The classification of sectors must be arranged in such a way, that the geometry in a given sector can be well described in terms of the sector area geometry. In order to achieve a good representation of the noise emission only one emission route per sector is allowed. The maximum opening angle of a sector is set at five degrees. The number of sectors, $J$, is dependent on the total opening angle of the assessment point and the required sector classification.

The number of source points, $N$, of a sector depends on how often the source line (segment) intersects the sector area.
1.3. MODELLING THE SITUATION

1.3.1. Source Lines

The starting points for modelling the geometric situation is the railhead (BS) for vertical dimensions, and the middle of the rail for horizontal dimensions. The lines which cross the middle of the track at different levels to BS are represented as source lines in the model. There are two source lines, at 0 cm and at 50 cm above BS, for the material categories 1 to 8 inclusive. For category 9, there are four sources lying at 0.5 m, 2.0 m, 4.0 and 5.0 m above the BS. The track is preferably divided in emission sections, in steps of no less than 100 m. In order to model important geographic elements it is advisable to work with smaller step sizes, particularly if the above mentioned section is too large, as can occur in the case of curves, screening or in other certain situations.

1.3.2. Composition of the ground

The composition of the land is divided into two groups: acoustically hard and non-hard. The term acoustically hard (B = 0) refers to: pavement, asphalt, concrete, other hardened/sealed ground, water surfaces and related surfaces. The term acoustically non-hard includes: ballast, grass surfaces, agricultural surfaces with or without vegetation, sandy surfaces, ground without vegetation, etc.

1.3.3. Ground Height Differences

The height of the source, object and assessment point are defined in relation to the average terrain height concerned. This average height is determined by the profile in the regarded sector area as an average over a given horizontal distance. The average height of the ground in the source area is therefore applicable for the source and the average height of the ground within a radius of 5 m from the equivalent barrier is applicable for a barrier.
Figure 1.1  Height in relation to the average terrain level. As a result of the raised tracks the average terrain level is situated in the source area slightly above the upper edge of the terrain, near the embankment.

Figure 1.2  Barrier set upon an embankment; the average terrain level to the left is slightly lower than the upper edge and to the right slightly higher than close to the embankment. The situation to the right is a determining factor for $h_T$.

1.3.4. Standard Embankment

Figure 1.3 shows a cross-section of an actual track embankment. Figure 1.4 shows the corresponding model. The following rules apply when establishing a model:

- the lane is the centre focus of the model; a lane is modelled exactly between the rails for each railway line (the distance between both rails is 1.42 m)
- each lane (A) is modelled at the height of the true railhead (BS) and in the centre of the railway line (between the rails)
- a contour line and a connected obtuse barrier \( C_p = 2 \text{ dB} \) (F) is modelled at a height of 0.2 m below each railway line (the absorbing ballast is situated 0.2 m beneath BS)

- the edge of the embankment (EE) is modelled as a contour line along with the connected obtuse barrier (B) at an actual height in relation to BS (b1) and the upper edge of the terrain (b2) and at a distance of 4.5 m to the next lane; if the actual distance between the centre of the tracks and EE deviates from the above mentioned 4.5 m by more than one metre, then the actual distance concerned is modelled as b3 (in most cases the deviation falls short of one metre and in most cases EE is situated 0.5 m beneath BS)

- a possible barrier located at the edge of the embankment is modelled as a (acute) barrier (D) with its actual height above BS (d1) and with its actual distance from the centre of the tracks (d2); (in most cases barriers are set 4.5 m from the centre of the tracks)

- the embankment base (c) is modelled as a contour line at the height of the actual upper edge of the terrain above BS (c1) and at the actual distance from the centre of the tracks (c2);

- a ratio of 1:1.5 is used for the gradient of the embankment. The edge of the ground corresponds to the line at which the flat section of the embankment begins to decline; this is to be found, according to definition, 4.5 m from the nearest source line.

- the edge of the ground is an obtuse, absorbing barrier \( (C_p = 2 \text{ dB}) \);

- where ballast is present, the whole horizontal ground surface is absorbing \( (B = 1) \) as long as the actual hard sections in the area are not wider than 1 m.

![Cross-section of a standard embankment](image-url)

**Figure 1.3** Cross-section of a standard embankment.
Figure 1.4  Model of a cross-section of a standard embankment

If the actual horizontal embankment dimensions (different embankment width, different gradient) deviate from the standard embankment by more than 0.5 m, the actual distances are used in the usual way.

1.3.5.  Level crossing

The section of the railway tracks with a level crossing is modelled with the respective structure above the crossing and hard ground.

1.3.6.  Screening slabs (U-type slabs)

The height of the walls of U-type slabs, the local height of the upper edge of the terrain and the distance are modelled corresponding to the actual values. The floor of the screening slabs is modelled at 0.2 m beneath BS. The walls are modelled as absorbing barriers with acute vertex angles ($C_p = 0$ dB). The correction for the structure above the tunnel depends on the respective construction concerned.

In the case of U-type slabs with absorbing wall lining (see § 1.3.10) the source lines are found at the specified height above BS.
In the case of U-type slabs without absorbing wall lining, source lines which are situated lower than the upper level of the slabs are modelled at the height of the edge at the height of the train roof.

Generally this results in a maximum height of 4.0 m.

No line sources are modelled for the actual tunnel section.

### 1.3.7. Barriers and screening objects

In order to qualify as a screening object, an object must:

- have complete noise insulation of at least 10 dB higher than the screening effect, in other words, the mass must be at least 40 kg/m² and have no recognizable columns or openings,
- have a viewing angle corresponding at least to the opening angle of the sector in question.

Reflecting barriers near the track path which show no gradient can be modelled as an absorbing barrier. However, the effective height of the barrier above BS (= h\textsubscript{s,eff}) is calculated as follows:

\[
\begin{align*}
    h_{s,\text{eff}} &= h_s \\
    \text{or} & \\
    h_{s,\text{eff}} &= h_s \frac{(1 + a)}{2}
\end{align*}
\]

with: \( a \) absorbing section of the barrier

The lowest half metre of the barrier must be absorbing in all cases.

Noise barriers close to the track path are if possible executed absorbent. § 1.3.10 describes when a barrier is considered absorbent.

In order to calculate the effectiveness of noise barriers which are mounted at the edge of embankments, a 100% absorbing barrier is presumed for octave band calculation methods. In the case of absorbing barriers the actual height above BS is modelled; in the case of noise reflecting or partially noise reflecting barriers the above-mentioned formula for calculating the effective barrier height can be used. The conditions when a real barrier can be considered absorbing are described in § 1.3.10.
The actual effect of the barrier is probably lower if the barrier being represented is situated less than 4.5 m away from the centre of the tracks or if the barrier is higher than 4.0 m above BS and more than 4.5 m away from the track path.

A barrier is always modelled as a vertical barrier, even if in reality the barrier is curved, or mounted under an angle. The top of the barrier has to be modelled at the exact same position of the diffraction edge of the real barrier. The method described above then is used to determine the effective height.

### 1.3.8. Platforms

The height of the platform is set at 0.8 m above BS. Platforms are modelled with two obtuse absorbing barriers at each side of the platform and the side facing the tracks is situated 0.2 m from the centre of the tracks. In the case of the barrier near the tracks, the ground under the track (0.2 m below BS) and the relevant height of the upper edge of the terrain apply. The applicable profile dependant correction factor $C_p$ is determined by considering whether an absorbing lining is present or not (see table 1.4 and § 1.3.10). Platforms which are open on both sides (i.e. lack of a side wall on the track side and the outer side) are not modelled as barriers. Platforms which are open on the track side only are to be considered absorbing.

### 1.3.9. Bridge constructions

In the case of bridge constructions, the actual heights and distances are modelled. The type is defined in accordance with § 2.3.5. If the construction is not absorbing, the entire bridge floor is modelled as hard. In the case of tracks set on ballast or poured-in tracks with at least 15 cm of ballast the whole bridge flooring is modelled as absorbing ground, unless hard sections of the bridge floor are wider than 1 m. In this case the sections concerned are modelled as hard ground elements. In the case of steel bridges the bridge body is modelled as an absorbing ground element.

In the case of steel girder bridges, T-beam bridges and solid plate web bridge, the bridge is modelled as an absorbing obtuse barrier (see table 1.4 and § 1.3.10).

In the case of U-type bridges and M-type constructions, the border is to be modelled with two absorbing obtuse barriers on both sides of the border. For the barrier near the track, the ground under the tracks (-0.2 m BS) is to be used as the reference surface level.

The profile dependent correction factor $C_p$ is determined by considering whether an absorbing lining is present or not (see table 1.4 and § 1.3.10).
In the case of concrete constructions, barriers can be modelled to a height of 2.0 m according to barrier regulations. For higher barriers, the direct noise reflection of the construction can lead to contributions that cannot be calculated without further information and a closer acoustic examination must be carried out.

In the case of steel constructions with screening walls, the effect of the screening cannot be calculated. The extra charge for bridges must however be applied.

1.3.10. Noise absorbent construction

Linings or constructions of screening objects, platforms, and tunnel walls are to be considered absorbing if the track specific absorption is larger than or equal to 5 dB(A). This absorption is referred to in further detail in § 1.7.

1.3.11. Reflections

If objects are found inside a sector that comply with the following conditions (of reflections), \( L_{A_{eq}} \) is also determined by means of reflected noise that reaches the assessment point.

The contribution of reflections to \( L_{A_{eq}} \) is calculated as follows: The sector situated in front of the reflecting surface, when viewed from the receiver point \( W \), is substituted with its transposition (\( W' \)) on the reflecting surface.

![Diagram](image)

Figure 1.5
In order to qualify as a reflecting surface, the object must:

- be vertical;
- have a viewing angle that corresponds to the opening angle of the relevant sector;
- be situated at least two metres above the upper edge of the terrain, when the entire sector angle is taken into account;
- have an absorption coefficient of <0.8;
- be so distanced from the track path, that screening and reflection of passing trains do not have to be taken into consideration.

The influence of the reflections on $L_{Aeq}$ has to be more closely examined, if:

- the reflecting surface forms an angle greater than 5 degrees with the vertical;
- the reflecting surfaces have irregularities that are of the same magnitude as the distance between the surface and assessment point or the distance between the surface and the source point.

In the case of multiple reflections, the reflection is taken repeatedly. The contribution of source points, where the noise reaches the assessment point after four or more reflections, is not to be taken into account. In rural areas one reflection is often enough.

**1.3.12. Residential buildings**

The average height of a single storey in a residential building is set at 3 m. An inclined roof is also considered a whole storey. However modelling a sloping roof as a whole storey should not result in unrealistic reflections in the direction of the assessment point.

**1.3.13. Assessment points**

For strategic noise mapping, the assessment points have to be selected at a height of 4 m.

Assessment points must be modelled so that reflections against the façade in front of an assessment point do not contribute to the sound (pressure) level.

Objects in front of the first building line, which are higher than 1 m above BS, must be modelled. Small objects such as bays or small sheds do not have to be taken into consideration.

Assessment points in front of buildings should be selected at the level of the first storey (this corresponds to a height of 5 m above the upper edge of the terrain) and in the case of
residential buildings with three or more storeys, at the height of the top storey (i.e. 1 m beneath the roof ridge). An assessment point 1.5 m above the upper edge of the terrain can also be chosen for accessible ground, for rating of outside temperatures and for rating of screening effects.

1.4. ATTENUATION BY DISTANCE $\Delta L_{GU}$

1.4.1. Data

In order to calculate the geometric propagation factor the following data is necessary:

- $r$ distance between source and assessment point, measured along the shortest connection line [m];
- $\nu$ angle between sector area and section of the source line [in degrees];
- $\phi$ opening angle of the sector [in degrees].

1.4.2. Calculation

The calculation of $\Delta L_{GU}$ is as follows:

$$\Delta L_{GU} = 10 \log \frac{\phi \sin \nu}{r}$$  \hspace{1cm} 1.3

1.4.3. Conclusion

If the angle $\nu$ takes on a value smaller than the opening angle of the sector concerned, further examinations must be carried out to determine $\Delta L_{GU}$.

1.5. ATTENUATION BY PROPAGATION $\Delta L_{OD}$

Losses on the transmission path $\Delta L_{OD}$ are composed of the following factors:

$$\Delta L_{OD} = D_L + D_B + C_M$$  \hspace{1cm} 1.4

where $D_L$ air attenuation
$D_B$ ground attenuation
$C_M$ meteorological correction factor.
1.5.1. Air attenuation $D_L$

The given values for $\delta_{\text{air}}$ are derived from the third band spectrum ISO DIS 3891 at 10°C and relative humidity of 80%. Specifically in the case of the high frequency bands, certain compensations for the intense dispersion character of the absorption have been added.

The given values for $d_{\text{air}}$ are taken from ISO 9613-2. They are function of temperature and relative humidity. For values of $d_{\text{air}}$ not covered by table 1.1., see ISO 9613-1.

1.5.1.1 Data

In order to calculate $D_L$ the following data is necessary:

- $r$ the distance between source and assessment point, measured at the shortest connection line [m]

1.5.1.2 Calculation

Calculation is as follows:

$$D_L = r \delta_{\text{air}} \times 1000$$

where $\delta_{\text{air}}$ air absorption coefficient

The values for $\delta_{\text{air}}$ can be found in table 1.1:

<table>
<thead>
<tr>
<th>Octave band index code</th>
<th>medium frequency [Hz]</th>
<th>$\delta_{\text{air}}$ [dB/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>125</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>250</td>
<td>0.001</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>0.002</td>
</tr>
<tr>
<td>5</td>
<td>1000</td>
<td>0.004</td>
</tr>
<tr>
<td>6</td>
<td>2000</td>
<td>0.010</td>
</tr>
<tr>
<td>7</td>
<td>4000</td>
<td>0.023</td>
</tr>
<tr>
<td>8</td>
<td>8000</td>
<td>0.058</td>
</tr>
</tbody>
</table>
ADAPTATION AND REVISION OF THE INTERIM NOISE COMPUTATION METHODS FOR THE PURPOSE OF STRATEGIC NOISE MAPPING

WP 3.2.1: Railway Noise - Description of the calculation method

Atmospheric attenuation coefficient $\alpha$ [-]
for octave bands of noise [dB/km]
at temperature $T$ [°C]
& relative humidity $\text{RH}$ [%]
per nominal midband frequency [Hz]

<table>
<thead>
<tr>
<th>$T$ [°C]</th>
<th>RH [%]</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>70</td>
<td>0.1</td>
<td>0.4</td>
<td>1.0</td>
<td>1.9</td>
<td>3.7</td>
<td>9.7</td>
<td>32.8</td>
<td>117</td>
</tr>
<tr>
<td>20</td>
<td>70</td>
<td>0.1</td>
<td>0.3</td>
<td>1.1</td>
<td>2.8</td>
<td>5.0</td>
<td>9.0</td>
<td>22.9</td>
<td>76.6</td>
</tr>
<tr>
<td>30</td>
<td>70</td>
<td>0.1</td>
<td>0.3</td>
<td>1.0</td>
<td>3.1</td>
<td>7.4</td>
<td>12.7</td>
<td>23.1</td>
<td>59.3</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
<td>0.3</td>
<td>0.6</td>
<td>1.2</td>
<td>2.7</td>
<td>8.2</td>
<td>28.2</td>
<td>88.8</td>
<td>202</td>
</tr>
<tr>
<td>15</td>
<td>50</td>
<td>0.1</td>
<td>0.5</td>
<td>1.2</td>
<td>2.2</td>
<td>4.2</td>
<td>10.8</td>
<td>36.2</td>
<td>129</td>
</tr>
<tr>
<td>15</td>
<td>80</td>
<td>0.1</td>
<td>0.3</td>
<td>1.1</td>
<td>2.4</td>
<td>4.1</td>
<td>8.3</td>
<td>23.7</td>
<td>82.8</td>
</tr>
</tbody>
</table>

Table 1.1 Air absorption coefficient $\delta_{\text{air}}$ as a function of the octave band (i)

1.5.2. Ground attenuation $D_B$

Subdivision into three ground areas is required due to the fact that, in the model of curved sound radiation, ground reflections near the source and the observer occur and also, if the distance between source and observer is large enough, in the area in between. Each of these areas may present different ground compositions, in which case three different absorption factors are necessary for the calculation.

The term acoustically hard here refers to: pavement, asphalt and other sealed surfaces, water surfaces etc. The term acoustically non-hard refers to: grass surfaces, agricultural ground with or without vegetation, sandy surfaces, ground without vegetation etc.

1.5.2.1

When determining the ground attenuation $D_B$, the horizontally measured distance between source and assessment point (Symbol $r_o$) is divided into three areas: source area, assessment area and middle area. The source area has a length of 15 m and the assessment area a length of 70 m. The remaining section of the distance $r_o$ between the source and assessment point forms the middle area.

If the distance between the source and assessment point is less than 85 m, the length of the middle area is zero.

If the distance $r_o$ is less than 70 m the length of the assessment area is equal the distance $r_o$. 

Project team: Wölfel Meßsysteme · Software GmbH & Co (main contractor) - AIB-Vinçotte EcoSafer - AKRON n.v.-s.a. - LABEIN Technological Centre S.L. - Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG - LÄRMKONTOR GmbH
If the distance $r_o$ is less than 15 m both the length of the source area and the length of the assessment area is equal to the distance $r_o$.

The (ground) absorption factor is calculated for all three areas. The absorption contribution corresponds to the ratio of the section length of the area concerned, if it is not acoustically hard, divided by the total length of the area concerned. If the length of the middle area is zero, the absorption contribution is one.

### 1.5.2.2 Data

To calculate ground attenuation the following factors are necessary:

- $r_o$ horizontally measured distance between source and assessment point [m];
- $h_b$ height of the point source above the average terrain level inside the source area [m];
- $h_w$ height of the assessment point above the average terrain height inside the assessment area [m];
- $B_b$ absorption factor in the source area [-]
- $B_m$ absorption factor in the middle area [-]
- $B_w$ absorption factor in the assessment area [-]
- $S_w$ effectiveness of ground attenuation inside the assessment area [-]
- $S_b$ effectiveness of ground attenuation inside the source area [-]

If $h_b$ is less than zero, the value zero is given to $h_b$, and the same applies for $h_w$.

If a barrier does not apply to the sector concerned, both $S_w$ and $S_b$ are given a value of one. If a barrier is applicable, $S_w$ and $S_b$ are calculated using equations 1.9a and 1.9b as shown in § 1.6.
1.5.2.3 Calculation

Equation 1.6a to 1.6e are based on the equations in table 1.2:

<table>
<thead>
<tr>
<th>octave band index</th>
<th>centre frequency [Hz]</th>
<th>soil attenuation dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
<td>$-3\gamma_o(h_h + h_w, r_o)$</td>
</tr>
<tr>
<td>2</td>
<td>125</td>
<td>$[S_h\gamma_2(h_h, r_0) + 1]B_b$</td>
</tr>
<tr>
<td>3</td>
<td>250</td>
<td>$[S_h\gamma_3(h_h, r_0) + 1]B_b$</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>$[S_h\gamma_4(h_h, r_0) + 1]B_b$</td>
</tr>
<tr>
<td>5</td>
<td>1000</td>
<td>$[S_h\gamma_5(h_h, r_0) + 1]B_b$</td>
</tr>
<tr>
<td>6</td>
<td>2000</td>
<td>$B_b$</td>
</tr>
<tr>
<td>7</td>
<td>4000</td>
<td>$B_b$</td>
</tr>
<tr>
<td>8</td>
<td>8000</td>
<td>$B_b$</td>
</tr>
</tbody>
</table>

Table 1.2 Equation 1.6a to e inclusive for determining ground attenuation $D_B$ as a function of the octave band (i). Symbols printed in italics correspond to the values which must be substituted for variables $x$ and $y$ in $\gamma(x,y)$.

The functions are defined as follows:

For $y \geq 30x$

$$\gamma_o(x,y) = 1 - 30 \frac{x}{y}$$  \hspace{1cm} 1.6a

For $y < 30x$

$$\gamma_o(x,y) = 0$$  \hspace{1cm} 1.6b

$$\gamma_2(x,y) = 3.0 \left[ 1 - e^{-y/50} \right] e^{0.12(x-5)^2 + 5.7 \left[ 1 - e^{-2.8 \times 10^{-6} y^2} \right] e^{-0.09x^2}}$$  \hspace{1cm} 1.6b

$$\gamma_3(x,y) = 8.6 \left[ 1 - e^{-y/50} \right] e^{-0.09x^2}$$  \hspace{1cm} 1.6c

$$\gamma_4(x,y) = 14.0 \left[ 1 - e^{-y/50} \right] e^{-0.46x^2}$$  \hspace{1cm} 1.6d
\[ \gamma_5(x,y) = 5.0 \left[ 1 - e^{-y/50} \right]^{-0.90x^2} \]  

1.6e

The values in brackets following the functions concerned in equation 1.6.a to 1.6.e inclusive (in italic) are used to substitute variables x and y.

1.5.3. Meteorological correction factor \( C_M \)

Calculation of ground attenuation is based on downwind noise propagation. \( C_M = 0 \) calculates downwind noise propagation, which may be an appropriated condition for meeting a specific community noise limit.

But when using the computation method for long-term averages such as required for strategic noise mapping a variety of meteorological conditions, both favourable and unfavourable to propagation have to be included.

1.5.3.1 Data

In order to calculate the meteorological correction factor \( C_M \), the following information is necessary:

- \( r_o \) horizontally measured distance between source and assessment point [m]
- \( h_b \) height of the source point above the average terrain level inside the source area [m]
- \( h_w \) height of the assessment point above the average terrain level inside the assessment area [m].

1.5.3.2 Calculation

The calculation is as follows:

For \( r_o > 10(h_b + h_w) \)

\[ C_M = C_o \left( 1 - 10 \frac{h_b + h_w}{r_o} \right) \]  

1.7a*

For \( r_o \leq 10(h_b + h_w) \)

\[ C_M = 0 \]  

1.7b

* According to ISO 9613-2
1.5.3.3 $C_0$

$C_0$ is a constant which depends on local meteorological statistics for wind speed and direction, and temperature gradients.

Experience indicates that value of $C_0$ in practice are limited to the range from 0 to approximately +5 dB:

- favourable propagation during 50% of the time period: ±3 dB;
- favourable propagation during 33% of the time period: +5 dB.

For strategic noise mapping, specific assumptions about average meteo-conditions are made. These are discussed in § 3.2.2.

1.6. ATTENUATION FACTOR FOR SCREENING $\Delta L_{SW}$

(including factors $S_w$ and $S_b$ from the ground attenuation equation 1.6.a to 1.6.e inclusive)

1.6.1. Description

If objects found inside a sector have at least a viewing angle that corresponds with the opening angle of the sector concerned and if we can presume that these objects interfere with sound transmission, the attenuation factor $\Delta L_{SW}$ is taken into account, along with reduced ground attenuation (expressed in terms of $S_w$ and $S_b$ in accordance with equation 1.5).

The formula for calculating the attenuation contributed by an object of variable shape contains two factors. The first factor describes the screening by an equivalent idealised barrier (a thin, vertical plane). The height of the equivalent barrier corresponds to the height of the obstructing object. The upper edge of the barrier corresponds to the highest edge of the obstacle. If it is possible to place the barrier in various positions, the position at which the highest attenuation occurs is chosen.

The second factor is of importance only if the profile, deviates from that of the idealised barrier. The profile is defined as the cross-section of the sector plane of the attenuating object. The attenuation of the object is equal to the attenuation of the equivalent barrier minus a correction factor $C_p$ depending on the profile. If several attenuating objects are present in a sector, only the object that - in the absence of the others - would cause the most attenuation is taken into account.
As this effect describes the contribution of noise by diffraction over a barrier, the direct noise transmission through the barrier should be neglectable. Therefore the barrier should have a mass of at least 10 kg/m² and the openings should be less than 1% of the surface.

The equations given hereafter are not valid for a reflecting barrier that:

- or is higher than 4 m;
- or is positioned closer than 4.5 m of the centre of the track.

In this situation, the calculated screening values give an overestimation of the screening effect.

1.6.2. Data

In order to calculate attenuation the following data is necessary:

- \( z_b \) height of the source relative to the reference height (= horizontal plane where \( z = 0 \)) [m]
- \( z_w \) height of the assessment point relative to the reference height (= horizontal plane where \( z = 0 \)) [m]
- \( h_b \) height of the point source above the average terrain level inside the source area [m]
- \( h_w \) height of the assessment point above the average terrain level inside the assessment area [m]
- \( h_T \) height of the upper edge of the idealised barrier relative to the average terrain level in a 5 m range around the barrier. If the values on both sides of the barrier differ, \( h_T \) represents the highest of the two values [m]
- \( r \) distance between the source and assessment point measured along the shortest connection line [m]
- \( r_w \) horizontally measured distance between the assessment point and the barrier [m]
- \( r_o \) horizontally measured distance between the assessment point and the source point [m]
- profile of the screening object
1.6.3. Calculated results

- the reduced ground attenuation expressed by factors $S_w$ and $S_b$ from equation 1.6a to 1.6.e.
- screening effect $\Delta L_{SW}$.

![Diagram of noise calculation method](image)

Figure 1.6  A sector area with an idealised barrier, points K, T and L are shown.

For the calculation, three points on the barrier are determined (see Figure 1.1)

- **K**: intersection point of the barrier and the line of sight (= directly between the source and assessment point)
- **L**: intersection point of the barrier and a curved sound ray, that reaches the assessment point from the source point in downwind conditions
- **T**: upper edge of the barrier

The broken line BLW is a schematic representation of the curved sound ray under downwind conditions.

These three points are to be found at the heights $Z_K$, $Z_L$ and $Z_T$ respectively above the reference height. The distance between point K and L is calculated as follows:

$$Z_L - Z_K = \frac{r_w(r_o - r_w)}{26r_o} \quad 1.8$$
Also:

\( r_t \) is the sum of the partial distances BL and LW
\( r_T \) is the sum of the partial distances BT and TW.

1.6.4.

Factors \( S_w \) and \( S_b \) taken from equation 1.5a to h inclusive are calculated as follows:

\[
S_w = 1 - \frac{r_o - r_w}{r_o} \frac{3h_e}{3h_e + h_w + 1} \tag{1.9a}
\]

if \( h_e < 0 \) then \( S_w = 1 \)

\[
S_b = 1 - \frac{r_w}{r_o} \frac{3h_e}{3h_e + h_b + 1} \tag{1.9b}
\]

if \( h_e < 0 \) then \( S_b = 1 \)

\( h_e \) is the effective barrier height calculated as follows:

\[
h_e = Z_t - Z_L \tag{1.10}
\]

1.6.5.

The attenuation factor \( \Delta L_{SW} \) is calculated as follows:

\[
\Delta L_{SW} = HF (N_f) - C_p \tag{1.11}
\]

where

- \( H \) screening performance
- \( F (N_f) \) function with argument \( N_f \) (= Fresnel number)
- \( C_p \) correction factor depending on the profile

If the attenuation factor \( \Delta L_{SW} \) as calculated with equation 1.11 is negative, the following applies \( \Delta L_{SW} = 0 \).

\( H \) is determined as follows:

\[
H = 0.25h_t 2^{i-1} \tag{1.12}
\]

where \( i \) octave band index
The maximum value of $H$ is 1.

The definition of the function $F$ can be taken from equation 1.13a to $f$ inclusive, as shown in table 1.3. The values for $C_p$ can be found in table 1.4.

<table>
<thead>
<tr>
<th>valid for interval $N_f$</th>
<th>definition $F(N_f)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>from</td>
<td>to</td>
</tr>
<tr>
<td>$-\infty$</td>
<td>-0.314</td>
</tr>
<tr>
<td>-0.314</td>
<td>-0.0016</td>
</tr>
<tr>
<td>-0.0016</td>
<td>+0.0016</td>
</tr>
<tr>
<td>+0.0016</td>
<td>+1.0</td>
</tr>
<tr>
<td>+1.0</td>
<td>+16.1845</td>
</tr>
<tr>
<td>+16.1845</td>
<td>$+\infty$</td>
</tr>
</tbody>
</table>

Table 1.3 Definition of function $F$ with variables $N_f$ for 5 intervals of $N_f$ (Equation 1.13a to $f$ inclusive)

<table>
<thead>
<tr>
<th>$C_p$</th>
<th>Object (T = top angle in degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 dB</td>
<td>thin wall with a vertical angle (\leq 20^\circ)</td>
</tr>
<tr>
<td></td>
<td>Ground elevations where (0^\circ \leq T \leq 70^\circ)</td>
</tr>
<tr>
<td></td>
<td>all ground elevations with thin walls, if the total height is less than twice the wall height</td>
</tr>
<tr>
<td></td>
<td>all buildings</td>
</tr>
<tr>
<td>2 dB</td>
<td>edge of a filled land site</td>
</tr>
<tr>
<td></td>
<td>ground elevation where (70^\circ \leq T \leq 165^\circ)</td>
</tr>
<tr>
<td></td>
<td>all ground elevations with thin walls, if the total height is more than twice the wall height</td>
</tr>
<tr>
<td></td>
<td>noise absorbing edge of the railway side of a platform</td>
</tr>
<tr>
<td></td>
<td>edge of the platform not facing the railway track</td>
</tr>
<tr>
<td></td>
<td>edge of a railway line situated on a viaduct or bridge, except U-type bridge or M-track</td>
</tr>
<tr>
<td></td>
<td>noise absorbing edge of a U-type bridge facing the railway line</td>
</tr>
<tr>
<td></td>
<td>edge of a U-type bridge not facing the railway line</td>
</tr>
<tr>
<td></td>
<td>absorbing edge of a M-track facing the railway line</td>
</tr>
<tr>
<td></td>
<td>edge of a M-track not facing the railway line</td>
</tr>
<tr>
<td>5 dB</td>
<td>edge (non-absorbing(^1)) of the side of a platform facing the railway line</td>
</tr>
<tr>
<td></td>
<td>edge (non-absorbing(^1)) of the side of a platform facing the railway line U-type bridge</td>
</tr>
<tr>
<td></td>
<td>edge (non-absorbing(^1)) of the side of the M-track facing the railway line</td>
</tr>
</tbody>
</table>

Table 1.4 Correction factor $C_p$ depending on profile. $T$ is the upper angle of the cross-section of the object.

\(^1\) see §1.3.10
N_f is determined as:

\[ N_f = 0.37 \varepsilon 2^{i-1} \]  

1.13

where \( \varepsilon \) acoustic pathway, defined as follows:

for \( z_T \geq z_K \)

\[ \varepsilon = r_T - r_L \]  

1.14a

for \( z_T < z_K \)

\[ \varepsilon = 2r - r_T - r_L \]  

1.14b

In cases where the profile of the screening object does not correspond to a profile in table 1.4, the attenuation of the object must be determined by means of further examination.

1.6.6.

If the sound insulation is less than 10 dB above the calculated attenuation \( \Delta L_{SW} \), the complete noise reducing effect of the object must be determined by means of further examination.

1.7.  DETERMINING RAIL SPECIFIC ABSORPTION

The absorption coefficients \( \alpha \) will be averaged using a weighting factor. As weighting factor the averaged A-weighted 1/3 octave spectrum of the traffic spectrum is used.

Following this, \( \Delta L \) can be read from all third octave bands by means of formula 1.16 of absorption values, with the weighted average value of \( \alpha \). \( \Delta L \) is rounded off to the full dB and has a maximum value of 10 dB(A).
Table 1.5  Weighting factors Ki for railway noise to be used in the calculation of a unit value in dB(A) for the absorption value of sound barriers.

Where for railway traffic: $\Sigma K_i = 261$

The traffic specific absorption can be expressed in dB(A) with the help of equation 1.15.

$$\Delta L_{A,\alpha,\text{traffic}} = -10 \log \left( \frac{\sum (K_i \cdot a_i)}{\Sigma K_i} \right)$$  \hspace{1cm} 1.15

### 1.8. REDUCTION OF LEVELS AS A RESULT OF REFLECTIONS $\Delta L_R$

#### 1.8.1. Data

In order to calculate level reductions as a result of absorption caused by reflections, the following data is necessary:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>-16.2</td>
<td>-24.0</td>
<td>1</td>
</tr>
<tr>
<td>125</td>
<td></td>
<td>-21.0</td>
<td>2</td>
</tr>
<tr>
<td>160</td>
<td></td>
<td>-19.2</td>
<td>3</td>
</tr>
<tr>
<td>200</td>
<td>-10.0</td>
<td>-17.0</td>
<td>5</td>
</tr>
<tr>
<td>250</td>
<td></td>
<td>-15.0</td>
<td>8</td>
</tr>
<tr>
<td>315</td>
<td></td>
<td>-13.2</td>
<td>12</td>
</tr>
<tr>
<td>400</td>
<td>-6.1</td>
<td>-11.7</td>
<td>17</td>
</tr>
<tr>
<td>500</td>
<td></td>
<td>-10.8</td>
<td>21</td>
</tr>
<tr>
<td>630</td>
<td></td>
<td>-10.4</td>
<td>23</td>
</tr>
<tr>
<td>800</td>
<td>-4.9</td>
<td>-10.0</td>
<td>25</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td>-9.7</td>
<td>27</td>
</tr>
<tr>
<td>1250</td>
<td></td>
<td>-9.4</td>
<td>29</td>
</tr>
<tr>
<td>1600</td>
<td>-5.0</td>
<td>-9.4</td>
<td>29</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>-10.6</td>
<td>22</td>
</tr>
<tr>
<td>2500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3150</td>
<td>-15.0</td>
<td>-17.1</td>
<td>5</td>
</tr>
<tr>
<td>4000</td>
<td></td>
<td>-21.0</td>
<td>2</td>
</tr>
<tr>
<td>5000</td>
<td></td>
<td>-24.0</td>
<td>1</td>
</tr>
</tbody>
</table>
1.8.2. Calculation

The calculation is as follows:

\[ \Delta L_R = N_{\text{ref}} \delta_{\text{ref}} \]

where \( \delta_{\text{ref}} \) is level reduction by means of reflection.

1.8.3. Values

\( \delta_{\text{ref}} \) is defined as: 10 log (\( \rho \))

\[ \rho \] reflection coefficient = 1 - \( \alpha \)

\[ \alpha \] absorption coefficient

It is recommended that the user tries to obtain accurate absorption coefficients for all octave bands.

In absence of values following values are recommended (by RMR-method):

- for buildings \( \delta_{\text{ref}} = 0.8 \text{ dB} (\alpha = 0.17) \) is valid for all octave bands.
- for all other objects \( \delta_{\text{ref}} = 1.0 \text{ dB} (\alpha = 0.21) \) is valid for all octave bands, unless the object is proven to be sound absorbing.

The highest value for \( N_{\text{ref}} \) is 3: reflections of 4\(^{th}\) and higher orders are not taken into account.

1.9. THE OCTAVE BAND SPECTRUM OF THE EQUIVALENT NOISE LEVEL

For a precise determination of the equivalent noise level in residential buildings, it is preferable to have access to the octave band spectrum that is used in the case of noise fields valid for facades. By means of the method described, approximately eight values are obtained for the equivalent noise level in the various octave bands. The A-weighting is already included. In all reports it is necessary to specify the relevant octave spectrum along with the equivalent noise level in dB(A).
The dependent equivalent sound level $A$ in octave band $i$, symbol $L_{eq,i}$, is calculated as follows:

$$L_{eq,i} = 10 \log \left( \sum_{j+1}^{J} \sum_{n=1}^{N} 10^{\Delta L_{eq,i,j,n} / 10} \right)$$

1.17

where the definitions of the values and their effects are the same as in equation 1.1a.
CHAPTER 2. EMISSION VALUES

2.1. Existing Rail Vehicle categories

2.2. Global dB(A) emission values
   2.2.1. Emission value in dB(A) of an emission section
          2.2.1.1 Main formula
          2.2.1.2 Data
          2.2.2. Maximum Speeds

2.3. Emission Values per Octave Band
   2.3.1. Sound source height
   2.3.2. Track
   2.3.3. Specifications
   2.3.4. Calculation method
   2.3.5. Emission from concrete and steel bridge structures
          2.3.5.1 Concrete structures
          2.3.5.2 Steel Structures
   2.3.6. Maximum Speeds
2.1. **EXISTING RAIL VEHICLE CATEGORIES**

Prior to the calculation of the *equivalent continuous sound pressure level* all vehicles that use an identified railway line and follow the appropriate service guidelines are divided into the following railway vehicles categories. These are primarily differentiated based on propulsion system and wheel brake system.

In annex B, measurement methods are proposed to add additional railway vehicles to this database:

- to add vehicles to the existing (10) categories;
- to add additional categories.

**Category 1: Block braked passenger trains**

- Exclusively electric passenger trains with cast-iron blocks including the corresponding locomotive, as well as trains from the Dutch 1964 series and passenger trains belonging to Deutsche Bahn (DB);
- Electrical motor mail vehicle.

**Category 2: Disc braked and block braked passenger trains**

- Electric passenger trains primarily with disc brakes and additional cast-iron blocks, including the corresponding locomotives, as for example the InterCity-Material of the IMC-III, ICR and DDM-1 types,
- Passenger trains belonging to the French Railway Society (SNCF) and the Trans Europe Express (TEE);
- Electric locomotives such as those from the 1100, 1200, 1300, 1500, 1600 and 1700 series of the Belgian Railway Society (SNCB/NMBS).

**Category 3: Disc braked passenger trains**

Exclusively passenger trains with disc brakes and engine noise, as for example the municipal material (SGM, sprinter).

**Category 4: Block braked freight trains**

All types of freight trains with cast-iron block brakes.
Category 5: Block braked diesel trains
- Exclusively diesel-electrically driven passenger trains with cast-iron block brakes including the corresponding locomotive as for example the DE I, DE II, DE III types;
- Diesel – electric locomotives as for example the locomotives of the 2200/2300 and 2400/2500 series.

Category 6: Diesel trains with disc brakes
- Exclusively diesel–hydraulically driven passenger trains with disc brakes and engine noise.

Category 7: Disc braked urban subway and rapid tram trains
- Urban subway and rapid tram trains.

Category 8: Disc braked InterCity and slow trains
- Exclusively electric passenger trains with disc brakes including the corresponding locomotives, as for example InterCities of the ICM-IV, IRM and SM90 types;
- Electric passenger trains with primarily disc brakes and additional sinter and ABEX cast-iron blocks including the corresponding locomotives as for example the InterCities of the ICM-III and DDM-2/3 types.

Category 9: Disc braked and block braked high speed trains
- Electric trains with primarily disc brakes and additional cast-iron blocks on the engine car, as for example the TGV-PBA or Thalys (HST) types.

Category 10: Provisionally reserved for high speed trains of the ICE-3 (M) (HST East) type

Vehicles not mentioned here are allocated to the next appropriate category based on their drive unit, wheel brake system or maximum speed.

Figure 2.1 shows side views of the various categories and outlines the number of individual units.

One unit of any given category determines the sound emission. In the case of drawn trains, the locomotives and carriages or railway cars act as individual units. In the case of integrated trains, the connected sections should be regarded as one unit.
Figure 2.1. Train categories for the calculation and measurement guidelines for rail transport noise: type (number of units)
2.2. GLOBAL DB(A) EMISSION VALUES

2.2.1. Emission value in dB(A) of an emission section

2.2.1.1 Main formula

\[
E = 10 \log \left( \sum_{c=1}^{y} \frac{10^{\frac{E_{r,c}}{10}}}{10} + \sum_{c=1}^{y} \frac{10^{\frac{E_{n,c}}{10}}}{10} \right)
\]

with:
- \(E_{n,c}\): emission term per rail vehicle category for non braking trains
- \(E_{r,c}\): emission term for braking trains
- \(c\): train category
- \(y\): total number of categories present

The emission values per rail vehicle category are determined from:

\[
E_{n,c} = a_{c} + b_{c} \log v_{c} + 10 \log Q_{c} + C_{b,c}
\]

\[
E_{r,c} = a_{r,c} + b_{r,c} \log v_{c} + 10 \log Q_{r,c} + C_{b,c}
\]

The standard emission values \(a_{c}, b_{c}, a_{r,c} \& b_{r,c}\) are given in table 2.1:

<table>
<thead>
<tr>
<th>category</th>
<th>non-braking trains</th>
<th>braking trains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a_{c})</td>
<td>(b_{c})</td>
</tr>
<tr>
<td>1</td>
<td>14.9</td>
<td>23.6</td>
</tr>
<tr>
<td>2</td>
<td>18.8</td>
<td>22.3</td>
</tr>
<tr>
<td>3</td>
<td>20.5</td>
<td>19.6</td>
</tr>
<tr>
<td>4</td>
<td>24.3</td>
<td>20.0</td>
</tr>
<tr>
<td>5</td>
<td>46.0</td>
<td>10.0</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>19.6</td>
</tr>
<tr>
<td>7</td>
<td>18.0</td>
<td>22.0</td>
</tr>
<tr>
<td>8</td>
<td>25.7</td>
<td>16.1</td>
</tr>
<tr>
<td>9</td>
<td>22.0</td>
<td>18.3</td>
</tr>
</tbody>
</table>
Table 2.1. Standard emission values as a function of railway category c

2.2.1.2 Data

To calculate the emission value, the following data are needed:

- $Q_c$ average quantity of non-braking vehicles of the considered rail vehicle category [h$^{-1}$]
- $Q_{r,c}$ average quantity of braking vehicles of the considered rail vehicle category [h$^{-1}$]
- $v_c$ average speed of rail cars [km/h$^{-1}$]
- $b$ track type [-]

Trains are considered "braking" when the brake system is active.

To determine the emission value E, train categories according to the list in § 2.1 are used, distinguishing between braking and non-braking trains. For material types not included in this list the emission value can be determined by measurements according to procedures A or B in Annex B.

The following types of superstructures are also distinguished:

- Railway tracks with single block or double block (concrete) sleepers, in ballast bed (index code $b = 1$);
- Railway tracks with wooden or zigzag concrete sleepers, in ballast bed (index code $b = 2$);
- Railway tracks in ballast with non-welded tracks, tracks with joints or switches (index code $b = 3$);
- Railway tracks with blocks (index code $b = 4$);
- Railway tracks with blocks and ballast bed (index code $b = 5$);
- Railway tracks with adjustable rail fixation (index code $b = 6$);
- Railway tracks with adjustable rail fixation and ballast (index code $b = 7$);
- Railway tracks with poured in railway lines (index code $b = 8$);
- Railway tracks with level crossing.

$C_{b,c}$ indicates the emission difference between a railway car on a track with concrete sleepers and one on another track type under identical circumstances. Not named track types are classified as $b = 3$, unless measurements are carried out on this track type according to § 2.1.
The value of $C_{b,c}$ is given in table 2.2. For railway crossings 2 dB are added to the value in table 2.2 according to the track type before and after the crossing. If these values differ, the construction with the highest values is used.

<table>
<thead>
<tr>
<th>category</th>
<th>b=1</th>
<th>b=2</th>
<th>b=3</th>
<th>b=4</th>
<th>b=5</th>
<th>b=6</th>
<th>b=7</th>
<th>b=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>-</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2.2. Correction term $C_{b,c}$ as a function of railway category and track type/state $b$

<table>
<thead>
<tr>
<th>structure type</th>
<th>track type on structure</th>
<th>index code b (SRM 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT &amp; U-type bridge</td>
<td>adjustable fixtures</td>
<td>4</td>
</tr>
<tr>
<td>plate &amp; girder bridge</td>
<td>cross-ties on ballast (either wood or concrete)</td>
<td>1 or 2</td>
</tr>
<tr>
<td></td>
<td>adjustable fixtures</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>adjustable fixtures filled with ballast</td>
<td>7</td>
</tr>
<tr>
<td>steel deck bridge</td>
<td>block type fixation</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>block type fixation filled with ballast</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>embedded rails</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 2.3 Correction factor for various types of concrete and steel structure compounds
2.2.2. **Maximum Speeds**

In this unit the emission level for train speeds can be determined using a maximum speed per category as shown in table 2.4. For new material measured in accordance to Annex B, the maximum speed is used for the measurement.

For vehicles not mentioned in § 2.1, the maximum speed as specified by the manufacturer applies.

<table>
<thead>
<tr>
<th>category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum calculable speed [km/h]</td>
<td>140</td>
<td>160</td>
<td>140</td>
<td>100</td>
<td>140</td>
<td>120</td>
<td>100</td>
<td>160</td>
<td>300</td>
<td>330</td>
</tr>
</tbody>
</table>

Table 2.4  Maximum calculable speed per category

2.3. **EMISSION VALUES PER OCTAVE BAND**

2.3.1. **Sound source height**

The emission values per octave band are determined for five different sound source heights:

- at the level of the railhead (emission value $L_{Ebs}$);
- 0.5 m above the railhead (emission value $L_{Eas}$);
- 2.0 m above the railhead (emission value $L_{Eas}$);
- 4.0 m above the railhead (emission value $L_{Ease}$);
- 5.0 m above the railhead (emission value $L_{Ease}$);

Not all train categories have dominant emission at all heights. More specifically, high speed trains have important source levels at higher heights. For vehicles designed for lower speed, the emission values at higher heights can be set to zero.

2.3.2. **Track**

In order to determine the emission value per sound source level one uses the categories for railway vehicles given in § 2.1. The emission route is simultaneously standardised, depending on the type of track and condition of the railway tracks, as follows:
Railway tracks with single block or double block (concrete) sleepers, in ballast bed (index code bb = 1);
- Railway tracks with wooden or zigzag concrete sleepers, in ballast bed (index code bb = 2);
- Railway tracks in ballast bed with non-welded tracks, tracks with joints or switches (index code bb = 3);
- Railway tracks with blocks (index code bb = 4);
- Railway tracks with blocks and ballast bed (index code bb = 5);
- Railway tracks with adjustable rail fixation (index code bb = 6);
- Railway tracks with adjustable rail fixation and ballast bed (index code bb = 7);
- Railway tracks with poured in railway lines (index code bb = 8);
- Railway tracks with level crossing.

When determining the emission values, distinctions are also made, according to how many track disconnections occur on the emission route concerned:
- jointless rails (fully welded tracks) with or without jointless switches or crossings (index code m = 1);
- rails with joints (= tracks with joints) or an isolated switch (m = 2);
- switches and crossings with joints, 2 per 100 meters (m = 3);
- more than 2 switches per 100 meters (m = 4);

### 2.3.3. Specifications

The following specifications are necessary to calculate the emission values per octave band:

- $Q_c$: the mean number of non-braking vehicles in the railway vehicle category concerned [h$^{-1}$]
- $Q_{r,c}$: the mean number of braking vehicles in the railway vehicle category concerned [h$^{-1}$]
- $v_c$: the mean speed of passing non-braking railway vehicles [kmh$^{-1}$]
- $v_{r,c}$: the mean speed of passing braking railway vehicles [kmh$^{-1}$]
- bb: type of track/condition of the railway tracks [-]
- m: estimation of the occurrence of track disconnections [-]
- n: number of points or junctions on the emission route concerned [-]
- a: length of the emission route in question, at least equivalent to the length of the point or junction [m]

Trains qualify as braking when the brake gear has been activated.
2.3.4. Calculation method

The calculation proceeds as follows:

\[ L_{E,i}^{\text{bs}} = 10 \log \left( \sum_{c=1}^{8} 10^{E_{\text{bs},nr,i,c} / 10} + \sum_{c=1}^{8} 10^{E_{\text{bs},r,i,c} / 10} \right) \] 2.3a

In the calculation model category 9 has no \( L_{E}^{\text{bs}} \):

\[ L_{E,i}^{\text{as}} = 10 \log \left( \sum_{c=1}^{9} 10^{E_{\text{as},r,i,c} / 10} + \sum_{c=1}^{9} 10^{E_{\text{as},nr,i,c} / 10} \right. \\
+ \sum_{c=1}^{9} 10^{E_{\text{brake},i,c} / 10} + 10^{E_{\text{motor},i} / 10} + 10^{E_{\text{diesel},i} / 10} \right) \] 2.3b

\[ L_{E,i}^{2m} = 10 \log \left( 10^{E_{2m,i,c} / 10} \right) \] 2.3c

\[ L_{E,i}^{4m} = 10 \log \left( 10^{E_{4m,i,c} / 10} \right) \] 2.3d

\[ L_{E,i}^{5m} = 10 \log \left( 10^{E_{5m,i,c} / 10} \right) \] 2.3e

The following applies for categories 1, 2, 3, 6, 7 & 8:

\[ E_{\text{bs},nr,i,c} = E_{nr,i,c} - 1 \]
\[ E_{bs,r,i,c} = E_{r,i,c} - 1 \]
\[ E_{as,nr,i,c} = E_{nr,i,c} - 7 \]
\[ E_{as,r,i,c} = E_{r,i,c} - 7 \]

The following applies for categories 4 & 5:

\[ E_{bs,nr,i,c} = E_{nr,i,c} - 3 \]
\[ E_{bs,r,i,c} = E_{r,i,c} - 3 \]
\[ E_{as,nr,i,c} = E_{nr,i,c} - 3 \]
\[ E_{as,r,i,c} = E_{r,i,c} - 3 \]

The following applies for category 9:
$E_{as,nr,i,c} = E_{nr,i,9-as}$
$E_{as,r,i,c} = E_{r,i,9-as}$
$E_{2m,i,c} = E_{i,9-2m}$
$E_{4m,i,c} = E_{i,9-4m}$
$E_{5m,i,c} = E_{i,9-5m}$

with:

$E_{nr,i,c} = a_{i,c} + b_{i,c} \lg v_c + 10 \lg Q_c + C_{bb,i,m}$  \hspace{1cm} 2.4a

$E_{r,i,c} = a_{i,c} + b_{i,c} \lg v_{r,c} + 10 \lg Q_{r,c} + C_{bb,i,m}$  \hspace{1cm} 2.4b

$E_{\text{brake},i,c} = a_{i,c} + b_{i,c} \lg v_{r,c} + 10 \lg Q_{r,c} + C_{\text{brake},i,c}$  \hspace{1cm} 2.4c

For $c = 5$

$E_{\text{diesel},i} = 10 lg \left( \frac{10^{a_{\text{diesel},i,j} + b_{\text{diesel},i,j} \lg v_5 + 10 \lg Q_5}}{10} \right)$

2.4d

For $c = 3$ and $c = 6$

$E_{\text{motor},i} = 10 lg \left( \frac{10^{a_{\text{motor},i,c} + b_{\text{motor},i,c} \lg v_r + 10 \lg Q_r}}{10} \right)$

2.4e

For $c = 9$

$E_{9-2m,i} = 10 lg \left( \frac{10^{a_{9-2m,i} + b_{9-2m,i} \lg v_9 + 10 \lg Q_9}}{10} \right)$

2.4f

$E_{9-4m,i} = 10 lg \left( \frac{10^{a_{9-4m,i} + b_{9-4m,i} \lg v_9 + 10 \lg Q_9}}{10} \right)$

2.4g

$E_{9-5m,i} = 10 lg \left( \frac{10^{a_{9-5m,i} + b_{9-5m,i} \lg v_9 + 10 \lg Q_9}}{10} \right)$

2.4h

The values for the emission index codes can be taken from tables 2.5 & 2.6.
### Table 2.5

<table>
<thead>
<tr>
<th>( \gamma_{\text{train}} )</th>
<th>index code</th>
<th>octave band with centre frequency [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>1</td>
<td>a</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>a</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>a, ( v &lt; 60 )</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>b, ( v &lt; 60 )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>motor</td>
<td>a, ( v &lt; 60 )</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>b, ( v &lt; 60 )</td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>-10</td>
</tr>
<tr>
<td>4</td>
<td>a</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>a, ( v &lt; 60 )</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>b, ( v &lt; 60 )</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>diesel</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>-10</td>
</tr>
<tr>
<td>6</td>
<td>a, ( v &lt; 60 )</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>b, ( v &lt; 60 )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>motor</td>
<td>a, ( v &lt; 60 )</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>b, ( v &lt; 60 )</td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td>( v \geq 60 )</td>
<td>-10</td>
</tr>
<tr>
<td>7</td>
<td>a</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>a</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>15</td>
</tr>
</tbody>
</table>
WP 3.2.1: Railway Noise - Description of the calculation method

<table>
<thead>
<tr>
<th>octave band with centre frequency [Hz]</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
<th>8k</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

railcar

<table>
<thead>
<tr>
<th>category</th>
<th>index code</th>
<th>a</th>
<th>b</th>
<th>a</th>
<th>b</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-1s</td>
<td></td>
<td>7</td>
<td>14</td>
<td>57</td>
<td>52</td>
<td>57</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>10</td>
<td>1</td>
<td>41</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>11</td>
<td>13</td>
<td>56</td>
<td>-27</td>
<td>-19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>18</td>
<td>28</td>
<td>28</td>
<td>-50</td>
<td>-41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>10</td>
<td>57</td>
<td>50</td>
<td>53</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
<td>28</td>
<td>12</td>
<td>18</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
<td>28</td>
<td>36</td>
<td>22</td>
<td>37</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
<td>28</td>
<td>13</td>
<td>56</td>
<td>-27</td>
<td>-19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>26</td>
<td>25</td>
<td>59</td>
<td>56</td>
<td>73</td>
</tr>
</tbody>
</table>

pushed/pulled units

<table>
<thead>
<tr>
<th>category</th>
<th>index code</th>
<th>a</th>
<th>b</th>
<th>a</th>
<th>b</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-1s</td>
<td></td>
<td>7</td>
<td>14</td>
<td>57</td>
<td>52</td>
<td>57</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>10</td>
<td>1</td>
<td>41</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>11</td>
<td>13</td>
<td>56</td>
<td>-27</td>
<td>-19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>18</td>
<td>28</td>
<td>-50</td>
<td>-41</td>
<td>-34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>10</td>
<td>57</td>
<td>50</td>
<td>53</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
<td>28</td>
<td>12</td>
<td>18</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
<td>28</td>
<td>36</td>
<td>22</td>
<td>37</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
<td>28</td>
<td>13</td>
<td>56</td>
<td>-27</td>
<td>-19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>26</td>
<td>25</td>
<td>59</td>
<td>56</td>
<td>73</td>
</tr>
</tbody>
</table>

Table 2.6 Emission index code $a_c$ and $b_c$ for railcars and pulled/pushed units of railway vehicles of category $c = 9$ per sound source level and octave band (i)

<table>
<thead>
<tr>
<th>octave band</th>
<th>$C_{rem,i,c}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>$c = 1, 4, 5$</td>
</tr>
<tr>
<td>1</td>
<td>-20</td>
</tr>
<tr>
<td>2</td>
<td>-20</td>
</tr>
<tr>
<td>3</td>
<td>-20</td>
</tr>
<tr>
<td>4</td>
<td>-2</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2.7 Correction factor $C_{rem,i,c}$ for brake noise as a function of the railway vehicle category (c) and the octave band (i)
**Track roughness**

The extra noise emission of a rough track or the noise reduction of a smoother track will be included for existing categories by integration of the difference in the energetic sum of wheel and track roughness in the correction for the track characteristics.

This methodology is only correct for a jointless track \((m = 1)\). This parameter is therefore dependent on speed \((v)\) and train category \((c)\).

For \(m=1\), it yields that \(C_{c,i,b,b}^{i,m}\) will be calculated for different train categories by:

\[
C_{c,i,b,b}^{i,m} = C_{c,i,b,b}^{i} - (L_{i,rtr,ni}^{i}(\lambda_{i}) \oplus L_{i,rveh,c}^{i}(\lambda_{i})) + (L_{i,rtr,loc}^{i}(\lambda_{i}) \oplus L_{i,rveh,c}^{i}(\lambda_{i}))
\]

with:

- \(C_{bb,i}\) the track correction from table 2.10
- \(L_{i,rtr,ni}^{i}(\lambda_{i})\) average rail roughness in the Netherlands, according to § B.3.4 Annex B
- \(L_{i,rtr,loc}^{i}(\lambda_{i})\) local rail roughness of the track on which the calculation are being carried out
- \(L_{i,rveh,c}^{i}(\lambda_{i})\) wheel roughness of different train categories, according to table 2.8
- \(\oplus\) energetic summation (§ B.2.2.7 Annex B)

To determine the local wheel roughness, measurements have to be carried out according to § B.2.4.1 Annex B.

The measured rail roughness of the local situation is measured at representative locations and integrated in the model. These locations have to be selected from the total length of the track that will be included in the model. These locations have to be specified in the measurement report.

If calculations are carried out with a lower value of rail roughness than average, the track exploitation company has to guarantee that, by monitoring and additional grinding, the low rail roughness level can be maintained.

Determinant for this is that the differences in rail roughness, averaged over the considered part of the track, the calculated total noise emission per train category, (sum of all source heights and octave bands) remain equal to the value of the original calculation, and that the local increase per train category remains limited to maximum 1 dB(A).

---

* According to RMR 2002
### Table 2.8 Data to determine rail roughness, according to the type of brake system in function of the wavelength

<table>
<thead>
<tr>
<th>Wavelength [cm]</th>
<th>Disc brake + blocks</th>
<th>Only disc brakes</th>
<th>Cast-iron block brake</th>
<th>Disc brake + added cast-iron block brake</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.2</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>7</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>12.7</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>10.1</td>
<td>2</td>
<td>9</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>8</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>6.3</td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>3.2</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>2.5</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>1.6</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>0.8</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>

For the nine categories in this standard the following relation between brake system and train category applies:

- categories 1, 4, 5, 7 & 9: pushed units: cast-iron block brake
- category 2: disc brake + added block brake
- categories 3, 6, 8 & 9: pulled units: disc brake

For new train categories that are being measured in accordance to Annex B, the average wheel roughness is determined by measurements.

The disc brake system with added block brakes is currently unavailable in the Netherlands, but its introduction is always possible.
If wheel and rail roughness are expressed in 1/3 octave bands, they are transposed to octave bands by equation B.16.

**Track type**

For other track types \( m = 2, 3 \) or 4, the correction factor for track types is based on:

\[
C_{bb,im} = C_{3,i} \cdot 10^{10g(1+f_m A_i)}
\]  

2.5b

with:
- \( C_{bb,i} \) the track correction from table 2.10
- \( f_m \) table 2.9
- \( A_i \) table 2.11

The factor \( f_m \) can take on the following values, where \( m \) does not equal 1:

<table>
<thead>
<tr>
<th>description</th>
<th>m type</th>
<th>( f_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>track with rail joints</td>
<td>2</td>
<td>1/30</td>
</tr>
<tr>
<td>1 switch</td>
<td>2</td>
<td>1/30</td>
</tr>
<tr>
<td>2 switches per 100 m</td>
<td>3</td>
<td>6/100</td>
</tr>
<tr>
<td>more than 2 switches per 100 m (depot)</td>
<td>4</td>
<td>8/100</td>
</tr>
</tbody>
</table>

Table 2.9
octave band & C_{bb,i}  \\
<table>
<thead>
<tr>
<th></th>
<th>bb = 1</th>
<th>bb = 2</th>
<th>bb = 3</th>
<th>bb = 4</th>
<th>bb = 5</th>
<th>bb = 6</th>
<th>bb = 7</th>
<th>bb = 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>-</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>8</td>
<td>8</td>
<td>-</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>-</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>9</td>
<td>-</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>2</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2.10 Correction factor $C_{bb,i}$ as a function of structures above station compounds/railway track condition (bb) and octave band (i).

The values for $A_i$ can be found in table 2.11.

<table>
<thead>
<tr>
<th>Octave band i</th>
<th>$A_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5, 6, 7, 8</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2.11 Code index for noise emission in the case of impact $A_i$ as a function of the octave band (i).

2.3.5. Emission from concrete and steel bridge structures

2.3.5.1 Concrete structures

For concrete structures and the applied tracks, the emission of both, the rolling noise and the noise radiation of the structure itself, is contained in the track correction table (table 2.6 & 2.10). Therefore, in the case of low frequencies, the effectiveness of screens, mounted on the constructions, is overestimated. This calculation model is consequently only suitable for
screens with a maximum height of 2 m above BS. For higher screens, more precise acoustic analysis is necessary.

The correction factor for different track types on various types of concrete structures can be found in table 2.12.

<table>
<thead>
<tr>
<th>Structure type</th>
<th>track</th>
<th>index code</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>bb (ORM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b (ARM)</td>
</tr>
<tr>
<td>TT &amp; U-type bridge</td>
<td>adjustable fixtures</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>plate &amp; girder bridge</td>
<td>cross-ties on ballast (either wood or</td>
<td>1 or 2</td>
</tr>
<tr>
<td></td>
<td>concrete)</td>
<td>1 or 2</td>
</tr>
<tr>
<td></td>
<td>adjustable fixtures</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>adjustable fixtures filled with ballast</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>steel deck bridge</td>
<td>block type fixation</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>block type fixation filled with ballast</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>embedded rails</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

Table 2.12 Correction factor for track types on various types of concrete structure. The codes in this table refer back to the index codes in table 2.10

### 2.3.5.2 Steel Structures

For steel constructions and the track type constructions installed thereupon, the emission is contained in the corresponding correction factor for tracks as a result of the rolling noise (table 2.6 & 2.10). Sound emissions from the construction itself are incorporated into the final emission level by raising the emission factor E by $\Delta L_{E,\text{bridge}}$, i.e. the additional calculation extra charge for bridges.

As a result, the effectiveness of screens mounted on the constructions is highly overestimated. The reliability as far as calculating screens on steel constructions is concerned, is therefore questionable.

In the case of a bridge with screens the additional calculation for bridges must be determined separately (§ A.2) or by following the method described in § B.2.4.
2.3.6. Maximum Speeds

In this unit the emission level for train speeds can be determined using a maximum speed per category as shown in table 2.13.

<table>
<thead>
<tr>
<th>category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum calculable speed [km/h]</td>
<td>140</td>
<td>160</td>
<td>140</td>
<td>100</td>
<td>140</td>
<td>120</td>
<td>100</td>
<td>160</td>
<td>300</td>
<td>330</td>
</tr>
</tbody>
</table>

Table 2.13 Maximum calculable speed per category

For vehicles not mentioned in § A.1, the maximum speed as specified by the manufacturer applies.
CHAPTER 3. STRATEGIC NOISE MAPPING

3.1. Emission Register 54

3.2. Strategic noise mapping 55
   3.2.1. Emission values 55
   3.2.2. Meteo 56
   3.2.3. Assessment points 57

3.3. Summary of input data for computation method 57
   3.3.1. Emission data 58
   3.3.2. Assessment data 59
3.1. EMISSION REGISTER

As the emission data are the basics for any noise calculation, those data could be contained in a national or regional register (in the Netherlands, called "Akoestische spoorboekje").

The emission register contains all parameters required for determination of the emission values:

a. a map with indication of the track position for the considered region under management of the emission register manager;

b. a description of the tracks with start and end point, and if present all stations and their position;

c. the track intensity in units per hour, averaged over a year, for day, evening and night period, with a distinction between braking and non braking trains and vehicle category;

d. the average speed per vehicle category per section, and if necessary per period;

e. a description per track of the track construction and if present all bridge constructions, level crossings, switches and/or other particularities;

Considering the fact that these data need to be directly used for acoustical surveys, they need to comply with the minimum requirements for accuracy. With this, the efficiency should not be neglected: collecting and storing data requires a certain amount of effort that can increase exponentially if the requirements become too strict.

For each type of data mentioned above, the minimum requirements are described below.

**Map**

The map must state a unique link between the gathering of data and the track route. A certain scale level is not imposed as it depends on the complexity. In most cases, a scale of 1/25 000 is sufficient, but in some urban areas 1/10 000 is necessary. A stepless adjustable electronic version must -for each route- provide the link with the data.

**Tracks**

The start and end of each track must accurately be stated in metres. For a multi track route, the type of track must be stated. For the position of stations, a global indication with an accuracy of 100 m and the name is sufficient.
Vehicle intensity
Use of the track must be stated per track, in units per hour, rounded up to 0.1 unit. The statement is done per vehicle category according to § 2.1, over day, evening and night period.

Speed profile
Speeds on the route, averaged over a year, are stated per vehicle category, including indication where the vehicles at normal conditions in the service use their brakes. If several speed profiles need to be used, an indication of which part of the vehicles use which profile is necessary (see also intensities). Speeds are to be rounded up to the nearest 5 km/h.

Track
The position – beginning and end – of the constructions described in § 1 are indicated with an accuracy of 1 m. In very complex situations (several switches over distances less than 100 m) an indication of the number of joints over the complex situation is sufficient, depending on the total number of switches.

Barriers (not mandatory)
If the position of barriers is included in the register, the following data should be stated:

a. beginning and end [m];
b. track along which it is placed;
c. indication whether it is placed on the left or the right side of the track;
d. height [dm].

Height (not mandatory)
The height must be given per at least 100 m of track in dm above NAP.

3.2. STRATEGIC NOISE MAPPING

3.2.1. Emission values
The calculated noise levels at the assessment points fulfil the criteria for strategic noise mapping if the emission register contains corresponding data:
for $L_{\text{day}}$ yearly average of vehicle density during day period for each vehicle category;

for $L_{\text{evening}}$ yearly average of vehicle density during evening period for each vehicle category;

for $L_{\text{night}}$ yearly average of vehicle density during night period for each vehicle category.

The global evaluation parameter $L_{\text{den}}$ is then calculated according to the procedure in EC-document 6660, annex I.

$$L_{\text{den}} = 10 \lg \frac{1}{24} \left( 12 \times 10^{L_{\text{day}}/10} + 4 \times 10^{L_{\text{evening}}/10} + 8 \times 10^{L_{\text{night}}/10} \right)$$

with: $L_{\text{day}}$ A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the day periods of a year

$L_{\text{evening}}$ A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the evening periods of a year

$L_{\text{night}}$ A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year

### 3.2.2. Meteo

The standard computation method considers down wind conditions.

Strategic noise mapping aims the computation of long-term average values.

Similar to the other interim calculation methods, following hypotheses should be realised:

- down wind:
  - day period: 50%;
  - evening period: 75%;
  - night period: 100%.

Following the recommendation of ISO 9613-2 and according to END periods, following values can be deducted:

- $C_{\text{o day}} = 1.4$ dB
- $C_{\text{o evening}} = 0.7$ dB
- $C_{\text{o night}} = 0.0$ dB
3.2.3. Assessment points

According to END, the assessment points are to be situated:

- height: 4 m;
- distance to façade: 2 m;
- calculation without reflection on the considered façade.

This is possible in the SRM I and SRM II calculation methods: reflection is not taken into account.

3.3. SUMMARY OF INPUT DATA FOR COMPUTATION METHOD

A list of input data requested for the above defined calculation method is summarised hereafter.


The Dutch statutory calculation-scheme for Rail-traffic Noise requires a description of the situation in terms of:

- co-ordinates, in a user defined rectangular co-ordinate system of:
  - tracks;
  - obstacles like buildings;
- sound barriers;
- observation point(s);
- track type;
- passing trains;
- numbers and types of passing trains;
- driving speeds of the trains;
- sound absorbing surfaces;
- the fraction of the ground between track and observer that is sound absorbing;
- other surfaces, like sound barriers.
3.3.1. Emission data

(Data could be contained in Emission Register, see § 3.1.)

**Track sections**

If the characteristics of the track, of the rolling stock or of driving conditions depend on the position along the track, different straight track sections are defined by the positions of their outer points. The characteristics and conditions should be virtually homogeneous along a section. Track type (1-9) and density of rail joints (1-4) are specified for each section.

**Track type (1-9)**

1. track with concrete single block or twin block sleepers in ballast bed;
2. track with wooden or zigzag concrete sleepers in ballast bed;
3. track with ballast bed and
   - rails with joints;
   - rails with not more than two crossings with joints within 50 m;
4. track with blocks;
5. track with blocks and ballast bed;
6. track with controllable rail fixation;
7. track with controllable rail fixation and ballast bed;
8. track with poured-in rail;
9. track with level crossing.

**Density of rail joints (1-4)**

1. jointless rail (fully welded) with or without jointless switches and crossings;
2. rails with joints;
3. switches and crossings with joints, 2 per 100 m;
4. more than 2 crossings per 100 m (the number of crossings can be stated).

**Vehicle specifications**

Category:

1. passenger train with tread brakes;
2. passenger train with both disc brakes and tread brakes;
3. passenger train with disc brakes;
4. goods train with tread brakes;
5. diesel train with disc brakes;
6. underground or express tramway vehicle with disc brakes;
7. intercity train with disc brakes;
8. high speed trains with disc brakes and/or tread brakes.

For each category:
1. vehicle intensity (number of passing trains per hour) \([1/h]\);
2. driving speed (for trains that are passing at constant speed) \([\text{km/h}]\);
3. percentage of braking vehicles \([\%]\);

Sound power levels of non-standard vehicles (not fitting within categories 1-7): in decibels relative to 1 pW, at track height and at 0.5 m above railhead, for the octave bands with centre frequencies 63-8000 Hz.

3.3.2. Assessment data

**Buildings**
Specified are:
- sizes (by the positions of the corners, in the co-ordinate system that has been chosen);
- height (ride height in case of a peaked roof) \([\text{m}]\);
- reflection factor of façades \([\%]\).

**Sound barriers**
Specified are:
- height \([\text{m}]\);
- shape types: sharp or obtuse top (angle between 0° and 70° or between 70° and 165°);
- reflection coefficients of barrier surfaces (standard or customised).

**Soil**
Specified are:
- fraction of sound absorbing soil surface between track and observer \([-]\),
or
hard and sound absorbing areas are specified separately by stating the character of each area (reflecting or absorbing) and the positions of the border lines.

- height of ground surfaces [m]

**Assessment point**

For each point is specified:

- position [m];
- whether or not it is on a façade or in an open field.

**Maximum number of reflections per sound ray**

The maximum number of reflections per sound ray is specified. A possible sound transmission path – sound ray – is only taken into account if it can be constructed with not more than the specified maximum number of reflections.