United Nations ECE/TRANS/WP.29/GRB/2018/8

Economic and Social Council

Distr.: General
2 July 2018

Original: English

Economic Commission for Europe

Inland Transport Committee

World Forum for Harmonization of Vehicle Regulations

Working Party on Noise

Sixty-eighth session
Geneva, 12-14 September 2018
Item 11 of the provisional agenda
Influence of road surface on tyre rolling sound emissions

Proposal for a draft Resolution on road surface labelling

Submitted by the expert from the Netherlands*

This draft Resolution has been prepared by the expert from the Netherlands in line with the considerations at the sixty-seventh session of the Working Party on Noise (ECE/TRANS/WP.29/GRB/65, para. 22). Background information for the draft Resolution is contained in ECE/TRANS/WP.29/GRB/2018/9.

* In accordance with the programme of work of the Inland Transport Committee for 2018–2019 (ECE/TRANS/274, para. 123 and ECE/TRANS/2018/21/Add.1, Cluster 3), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

Resolution on road surface labelling - Guidelines for the performance characterisation and classification of pavement surfaces

Contents

Preamble

The World Forum for Harmonization of Vehicle Regulations (WP.29),

DESIRING to harmonize technical requirements while ensuring high levels of environmental protection, safety, energy efficiency and service life of road pavements;

DESIRING to facilitate the assessment of road pavement surface performance, through a technically sound and easily understandable performance classification, regarding skid resistance, tyre–pavement noise, pavement influence on tyre rolling resistance, and pavement lifespan;

BEARING IN MIND that performance labels exist for many consumer products, such as the performance label for pneumatic tyres, as defined in European Union Regulation 1222/2009, and have been found very helpful in stimulating industry to improve product performance;

BEARING IN MIND that a harmonised characterisation of pavement service performance can be used in multiple ways within the road construction contracting process:

- Specification for road construction tenders, enabling road authorities, or other legal entities, commissioning pavement works, to specify functional performance of pavement surfacing, by specifying performance classes of important functional characteristics;
- Corroboration (“creating trust”) for contractor bids for tenders;
- Works approval, by providing the framework against which the delivered characteristics can be compared;
- Threshold value during warranty period or maintenance period;

BEARING IN MIND that a road surface label complements the existing tyre label, since a tyre label characterises the performance of a particular tyre model on a standardised road surface, whereas a road surface label characterises the performance of a particular road surface (type);

BEARING IN MIND that a combination of tyre labels and road surface labels increases the possibilities to optimise tyre-road interaction as a whole, instead of optimising separate components;

BEARING IN MIND that a road surface label does not, in itself, prescribe minimum requirements, and such requirements can be prescribed by parties using labels in tendering requests for road works;

BEARING IN MIND that contract requirements for road surfaces are not limited to the aspects considered in the road surface label, and within those aspects are not limited to label class boundaries;

BEARING IN MIND that many methods exist for characterisation of skid resistance, tyre –pavement noise, pavement influence on tyre rolling resistance, and pavement lifespan, but that harmonised methods are not available presently and are not likely to be available within 3-5 years, and therefore a choice of non-harmonised characterisation methods is necessary;

BEARING IN MIND that skid resistance and tyre-pavement noise are strongly dependent on vehicle speed, but that a standard speed for characterisation is necessary for simplification;

BEARING IN MIND that road surface performance may differ under different types of tyres, especially distinguishing between truck tyres and car tyres, but that characterisation of road surface properties mostly is done using car tyres or the likes thereof, and cars constitute the majority of traffic;

BEARING IN MIND that road surface performance may decline over time, but prediction of such decline over time is very difficult, and therefore performance characterisation is best based on “young” performance, and requirements limiting the decline can be made in road construction contracts;

BEARING IN MIND that this Resolution does not hold regulatory status within Contracting Parties;

RECOMMENDS that this Resolution should be used when establishing road surface labels with pavement performance indicators.

1. Introduction

1. This Resolution establishes a framework for the provision of harmonised information on essential road surface characteristics through labelling, allowing clients to make an informed choice when contracting for pavement works incorporating new road surfaces.

2. The aim of this Resolution is to increase the safety, and the economic and environmental efficiency of road transport by promoting noise-reducing, safe, fuel-efficient and long-life road surfaces.

3. Road surface labels will encourage the road construction industry to develop, build and manage safe, liveable, sustainable, durable and economic roadways. Such labels could be the basis for discussions between local, regional and national governments/road authorities and road builders regarding the quality of road surfaces. Road surfaces labels

would increase transparency in road building, initiate innovation and allow for a better understanding between road builders and tyre manufacturers.

4. The main preconditions for this Resolution on road surface labels are:

- Compatible with the existing tyre label;
- Compatible with existing international standards and measuring methods;
- Includes (only) essential road surface features - for both new and existing roads;
- Allows for (meaningful) innovation (product and process).

5. The road surface label is intended to be used in multiple ways within the road construction contracting process:

- Specification for road construction tenders: Enabling road authorities, or other legal entities, commissioning pavement works, to specify functional performance of pavement surfacing, by specifying performance classes of important functional characteristics.
- Corroboration ("creating trust") for contractor bids for tenders;
- Works approval, by providing the framework against which the delivered characteristics can be compared;
- Threshold value during warranty period or maintenance period.

6. This Resolution delivers guidelines for the performance characterisation and classification of pavement surfaces to be used when making road surface labels. The conditions for the road surface labelling are given in the scope. The prescription how a road surface label should be drafted is given the section requirements. Background information to this Resolution is given in document TRANS/WP.29/2018/9, "Background information on Road surface labelling - Guidelines for the performance characterisation and classification of pavement surfaces".

2. Scope

7. This Resolution on Road surface labelling contains the specifications for characterisation and classification of the performance of road surfaces (wearing course), regarding four performance indicators:

(a) Noise reduction;

(b) Skid resistance;

(c) Rolling resistance reduction;

(d) Lifespan.

8. This Resolution applies to all kinds of paved road surfaces.

9. The use of the road surface label with the scales and determining methods given in this Resolution is not mandatory. The label is intended to be an instrument for use in contracts between client and contractor and for communication between the road authority and the community.

10. A road surface label does not, in itself, prescribe minimum requirements for the quality of road surfaces. Such requirements should be prescribed by contractors and clients using labels in tendering requests for road works.

11. The road surface label is complementary to tyre labels. The road surface label is not intended to change or replace tyre labels, although it partly concerns the same phenomena.

3. Definitions

12. For the purpose of this Resolution:

12.1. "Road surface" means the upper layer of a road pavement;

12.2. "Client" means the legal entity that commissions a contract for road pavement works, either construction, rehabilitation or maintenance, that incorporate the construction or application of a new road surface;

12.3. "Contractor" means the legal entity, responsible for the construction or application of a new road surface under the contract;

12.4. "Contract" means the contract between the client and the contractor whereby the client commissions the contractor to perform road pavement works, either construction, rehabilitation or maintenance, that incorporate the construction or application of a new road surface;

12.5. "Road surface label" means a graphical representation of the four performance indicator classes of a road surface, according to the format described in Annex IV;

12.6. "Noise reduction" or "NR" means the reduction of tyre-pavement rolling noise in dB(A), relative to a virtual reference surface, as defined in Annex II;

12.7. "Skid resistance" or "SR" means the wet friction coefficient, as defined in Annex III;

12.8. Rolling resistance reduction" or "RRR" means the reduction of rolling resistance coefficient, relative to a virtual reference surface, as defined in Annex IV;

12.9. "Lifespan" or "LS" means the time in years between opening to traffic of a road pavement surface and the moment that such road surface no longer meets one or more of the contract requirements for road surface condition, as described in Annex V.

4. Requirements

13. The noise reduction class should be based on the noise reduction (NR) according to the 'A' to 'G' scale specified in Annex I, para 1, and determined in accordance with Annex II of this Resolution.

14. The skid resistance class should be based on the skid resistance (SR) according to the 'A' to 'G' scale specified in Annex I, para 2, and determined in accordance with Annex III of this Resolution.

15. The rolling resistance reduction class should be based on the rolling resistance reduction (RRR) according to the 'A' to 'G' scale specified in Annex I, para 3, and determined in accordance with Annex IV of this Regulation.

16. The lifespan class should be based on the lifespan (LS), according to the 'A' to 'G' scale specified in Annex 1, para 4, and can determined in accordance with Annex V.

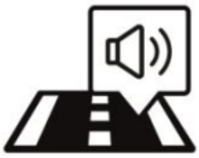
17. The road surface label should be in accordance with the illustration given in Annex VI, with black arrows indicating the proper class for each of the performance indicators.

Annex I

Classification of road surface characteristics

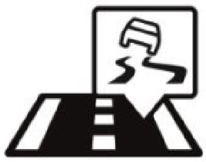
1. Noise reduction

Table 1
Noise reduction (NR) classes

	**Noise reduction (NR)** in dB(A)
A	NR ≥ 11.0
B	8.0 ≤ NR < 11.0
C	5.0 ≤ NR < 8.0
D	2.0 ≤ NR < 5.0
E	-1.0 ≤ NR < 2.0
F	-4.0 ≤ NR < -1.0
G	NR < -4.0

2. Skid resistance

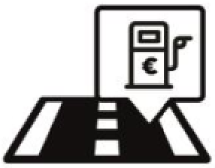
Table 2
Skid resistance (SR) classes

	**Skid resistance (SR)** in friction coefficient
A	SR ≥ 1.14
B	0.91 ≤ SR < 1.14
C	0.78 ≤ SR < 0.91
D	0.64 ≤ SR < 0.78
E	0.52 ≤ SR < 0.64
F	0.38 ≤ SR < 0.52
G	SR < 0.38

3. Rolling resistance reduction

Table 3

Rolling resistance reduction (RRR) classes

	**Rolling resistance reduction (RRR)** in kg/t
A	$RRR \geq 2.0$
B	$1.5 \leq RRR < 2.0$
C	$1.0 \leq RRR < 1.5$
D	$0.5 \leq RRR < 1.0$
E	$0.0 \leq RRR < 0.5$
F	$-1.0 \leq RRR < 0.0$
G	$RRR < -1.0$

4. Lifespan

Table 4

Lifespan (LS) classes

	**Lifespan (LS)** in years
A	$LS \geq 18$
B	$15 \leq LS < 18$
C	$12 \leq LS < 15$
D	$10 \leq LS < 12$
E	$8 \leq LS < 10$
F	$4 \leq LS < 8$
G	$LS < 4$

Annex II

Determination of noise reduction

(a) The noise reduction should be determined at 80 km/h for light motor vehicles, in accordance to the procedures for a single road surface detailed in this Annex. Other methods may be used if they provide the same results, within the accuracy of the original method.

(b) For contract tendering, i.e. before constructing a road surface, indicative values of the noise reduction may be based on laboratory testing. However, the values of the in-situ performance, as determined according to this Annex, are decisive.

(c) The noise reduction NR is defined as the difference between the pass-by levels of light motor vehicles at 80 km/h on a “virtual reference surface” and the pass-by levels of the specific road surface in newly-laid condition. The noise reduction is therefore positive if tyre-pavement noise on the specific road surface is less than on the “virtual reference surface”. The “virtual reference surface” is defined as a set of pass-by sound levels representing a Dense Asphalt Concrete (AC-surf) of average age. The properties of the reference surface were determined by averaging about 10 different sites of different age in different speed ranges.

(d) The above can be extended beyond the definition of NR to other vehicle categories and other speeds for a specific road surface. It can be further extended to the “initial road surface correction” ($C_{initial}$), of a “road surface type” (a group of road surfaces with similar composition and characteristics) when at least five sections of that road surface type have been measured. The initial road surface correction ($C_{initial}$), is defined as the difference between the pass-by levels of a certain class of vehicles on the specific road surface type in newly-laid condition relative to the levels on a “virtual reference surface”. Note that $C_{initial}$ is negative if tyre-pavement noise on the specific road surface is less than on the “virtual reference surface”, so opposite to the noise reduction.

(e) Comparing the pass-by levels on a newly laid surface with the pass-by levels on the reference surface of average age does of course overestimates the life-averaged noise reducing effect of the surface. This overestimation is taken care of in the term C_{time} that represents the acoustic degradation over the lifetime of the road surface type. The total road surface correction (C_{road}) is now composed as the sum of the initial road surface correction (C_{inital}) and the time effect (C_{time}), $C_{road} = C_{inital} + C_{time}$. In this Annex only the determining of the initial road surface correction (C_{inital}) is described. However, this Annex describes more than just determining the noise reduction NR of a specific road surface.

1. Measurements

1.1. Measuring method

To determine the initial road surface correction for a road surface type, measurements must be conducted according to the Statistical Pass-By method (SPB measurements).

For characterisation and classification of the noise reduction of a specific road surface, the measurement should be performed between 2 and 9 months after opening to traffic of the specific road surface.

The method for performing the SPB measurements is specified in ISO 11819-1:2001 In the SPB method, the noise levels of separate vehicle passages are measured. Within this, a distinction is made between the three vehicle categories defined in ISO 11819-1:2001:

- Light motor vehicles, cars (1);
- Dual-axle heavy-weight motor vehicles (2a);
- Multi-axle heavy-weight motor vehicles (2b).

To determine the noise reduction NR, only the light vehicles (1) are considered.

To determine the road surface correction, only the light (1) and multi-axle heavy-weight vehicles (2b) are relevant. The road surface correction for dual-axle heavy-weight vehicles (2a) is not determined separately, but treated as equivalent to the road surface correction for multi-axle heavy-weight vehicles (2b). In practice, the number of heavy-weight vehicles that pass a measurement location is often too small to be able to establish a separate road surface correction for this category. For light motor vehicles, the vehicles as defined under category 1b in Annex B of NEN-EN-ISO 11819-1:2001 are disregarded.

For passing vehicles, the maximum sound pressure level (sound level L_{Amax}) with the frequency spectrum in octave bands (from 63 Hz to 8000 Hz) and the vehicle speed, is measured at 7.5 m from the centre of the traffic lane. Deviating from the aforementioned standard, which prescribes a measurement height of 1.2 metres, the measurement height is 3.0 m. A measurement height greater than 1.2 metres was chosen in order to minimize the influence of soil effects and, possibly, guard rails on the sound level. Therefore, the criteria stipulated in the aforementioned ISO standard for the acoustic properties of the soil at the measurement location do not need to be strictly fulfilled. It is, however, recommended to take these criteria into account as much as possible when choosing measurement locations.

To determine the initial road surface correction (C_{inital}) of a road surface type, measurements are required for (at least) five different, geographically separated builds with the same road surface type or product. A road section that has been constructed within the same day is considered as a single build.

1.2. Guideline for the number of vehicles to be measured

As a guide, measurements for at least 100 light vehicles and 50 multi-axle heavy-weight vehicles must be available at each measurement location to determine the initial road surface correction (C_{inital}) of a road surface type. However, it can occur that these numbers are not reached at a particular location, for example because too few heavy goods vehicles pass by. The result of that location can still, however, be included in the further analysis for determining the road surface correction. Ultimately, the size of the 95% confidence interval of the average across all the measurement locations determines whether the end result is sufficiently reliable. Therefore, less reliable results at one location (for example due to relatively small numbers of vehicles) can be compensated by more reliable results at another location. This is explained further in section 3.

1.3. Temperature correction

The sound emission of vehicles is dependent, among others, on the temperature of the air and the road surface. A lower temperature produces a higher noise emission, due to a change in the properties of the tyre and the road surface. On the basis of the available measurement data, a temperature correction for light and heavy motor vehicles has been established. With this, all the measurement results are normalized to a reference temperature of 20˚C. According to the ISO standard, measurements may only be taken at an air temperature between 5˚C and 30˚C.

The temperature corrections $C_{temp,m}$ for light (m = 1) and heavy-weight vehicles (m = 2b) respectively are determined as follows from the air temperature T_{air} at 1.5 metres above the road surface at the measurement location, in degrees Celsius:

$C_{temp,1} = 0.05 \cdot (T_{air} - 20)$ (2a)

$C_{temp,2b} = 0.03 \cdot (T_{air} - 20)$ (2b)

2. Determining the average sound level per vehicle category and per measurement location

During a SPB measurement, for each vehicle passage, the speed of the vehicle right in front of the microphone is measured as well as the sound. For each measurement location, the linear regression lines for light and heavy vehicles are determined from the sound level measured as a function of the logarithm of the measured speed.

The results for the light or the heavy motor vehicles of a measurement location cannot be used to determine the road surface correction if half of the 95% confidence interval of the regression line for that measurement location, *at the average speed* of the light or heavy motor vehicles measured, after rounding to one decimal place, is larger than

$0.3 \cdot \sqrt{(99/(N_1-1))}$ for light vehicles and (3a)

$0.8 \cdot \sqrt{(49/(N_{2b}-1))}$ for heavy vehicles. (3b)

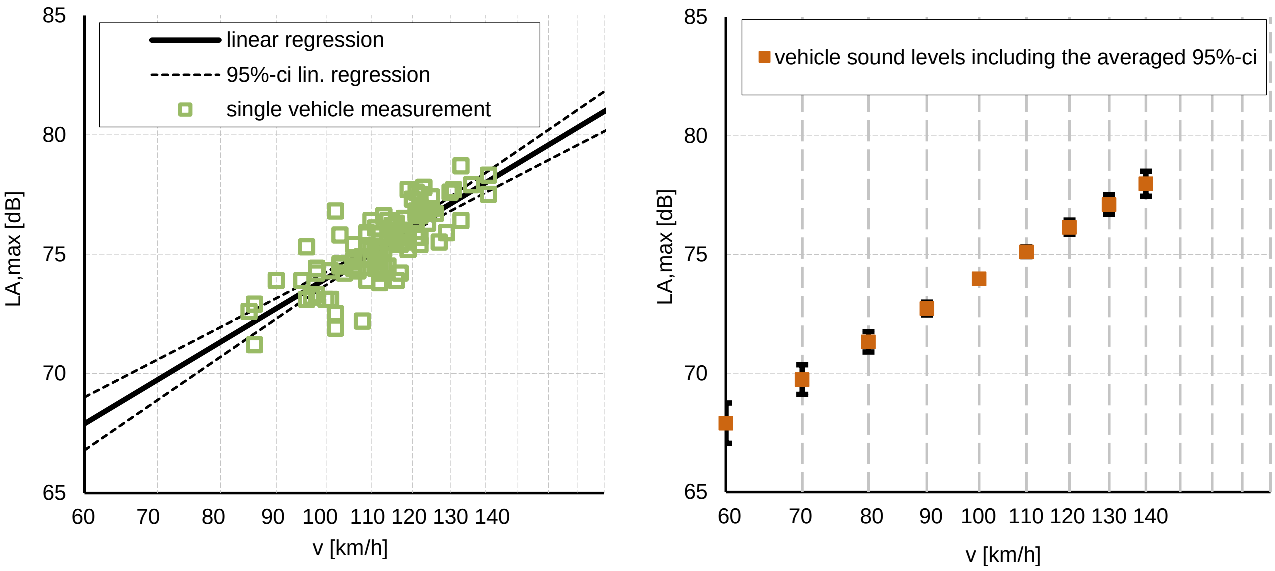
N_1 is the number of light vehicles measured and N_{2b} is the number of heavy-weight vehicles measured.

The averaged A-weighted sound level and the 95% confidence interval of that sound level follow from the regression line, for discrete values of speed of 30, 40, …. 130 km/h (in increments of 10 km/h, for heavy vehicles up to 100 km/h), after temperature correction as described in section 1.3.

In the example of figure 1, the graph on the left depicts the maximum sound levels measured L_{Amax} of vehicle passages from the same category (in this case, light motor vehicles) as a function of the measured speed, with the regression line and the limits of the 95% confidence interval of the regression line. The graph on the right depicts the values of the regression line in increments of 10 km/h.

Figure 1

Example of the linear regression line (left, with 95% confidence interval) by the measured sound levels LAmax as a function of the logarithm of the measured speed at a single measurement location of a single vehicle category (light motor vehicles), with the values of the regression line in increments of 10 km/h on the right, with confidence interval.



The sound level value of the regression line for a specific speed value (in increments of 10 km/h) is classified as 'reliable' when half of the 95% confidence interval for that speed, after rounding to one decimal place, is smaller or equal to:

$0.3 \cdot \sqrt{(99/(N1-1))}$ for light motor vehicles and

$0.8 \cdot \sqrt{(49/(N2b-1))}$ for heavy motor vehicles.

Table 1 shows the limits of the 95% confidence interval indicated as a function of the number of measurements.

Table 1

The sound level per vehicle category at a specific speed at a measurement location is classified as 'reliable' when half of the 95% confidence interval is no larger than the stipulated values Δ95% ci$_{max}$.

Light vehicles		*Heavy-weight vehicles*	
Number of passages	*Δ95%ci$_{max}$*	*Number of passages*	*Δ95%ci$_{max}$*
25	0,7	10	1,9
50	0,5	15	1,6
75	0,4	25	1,1
100	0,3	50	0,8
125	0,3	60	0,7
150	0,2	75	0,7
200	0,2	100	0,6
300	0,2	150	0,5
500	0,1	250	0,4
1000	0,1		

3. Noise reduction based on a measurement at one single location

To determine the noise reduction (NR) based on one SPB-measurement the following minimum number of vehicle passages shall be measured:
- 100 light motor vehicles (m=1)
- 50 heavy motor vehicles (m=2b)

Only the sound level values of the regression line for a specific speed value (in increments of 10 km/h) are presented as a 'reliable' SPB-result when half of the 95% confidence interval for that speed, after rounding to one decimal place, is smaller or equal to:
$0.3 \cdot \sqrt{(99/(N_1-1))}$ for light motor vehicles and
$0.8 \cdot \sqrt{(49/(N_{2b}-1))}$ for heavy motor vehicles.

The reliable sound level values are compared with the values of the reference surface. The reference surface values can be calculated with:

$L_{ref,\ m=1}(v) = 77.2 + 30.6 \log(v / v_{0.m=1})$ for light vehicles with $v_{0.m=1}$ = 80 km/h
and $L_{ref,\ m=2b}(v) = 84.4 + 27.0 \log(v / v_{0.m=2b})$ for heavy vehicles with $v_{0.m=2b}$ = 70 km/h

The noise reduction (NR) at a specific speed is defined as the difference between the SPB-result and the value of the reference surface. In table 2 an example is given for a SPB-measurement with 106 light motor vehicle passages. The stipulated $\Delta 95\%ci_{max}$ has to be smaller or equal to 0,3 dB for that number of passages.

Table 2

The sound level for light vehicles and its corresponding noise reduction (NR) is classified as 'reliable' when half of the 95% confidence interval (put in parentheses) is no larger than the stipulated values $\Delta 95\%ci_{max}$.

	speed [km/h]						
[dB]	***50***	***60***	***70***	***80***	***90***	***100***	***110***
SPB-result ($L_{m=1}$ ($\Delta 95\%ci_{max}$))	65.8 (1.0)	68.4 (0.6)	70.5 (0.3)	72.4 (0.3)	74.0 (0.4)	75.5 (0.6)	76.8 (0.8)
Reference surface (L_{ref})	71.0	73.4	75.4	77.2	78.8	80.2	81.4
Noise Reduction (NR)	-	-	4.9 [1)]	4.8	-	-	-

[1)] Note that the value at 70 km/h is not the proper NR, as the latter is defined at 80 km/h

4. Averaging of the measurement results of different locations

Note that this section is not relevant for the determining of the noise reduction NR of a specific road surface.

4.1. Verification of the spread across the locations

With the results of section 1 and 2, for each discrete speed value v_m (in increments of 10 km/h), per vehicle category m (m = 1 or 2b), there are values of the total A-weighted sound levels of vehicle passages measured at different locations k (k = 1, 2, ….) $L_{k,m}(v_m)$, for (at least) five locations. Of the available values at a specific speed, a proportion can be classified as 'reliable' on the basis of the 95% confidence interval according to the limits indicated in section 2. Next, for each speed it is checked whether, for these reliable values, the range (min-max) across the different locations is smaller than 2.0 dB(A). If the range is larger, the location with the value that most deviates from the mean of the values classified as reliable, must be disregarded for the vehicle category in question. If necessary, this process is repeated until the range is smaller than 2.0 dB(A). If fewer than five locations remain, there is insufficient measurement data to be able to determine the road surface correction. New measurement data would need to be added in order to determine the road surface correction.

Table 3 gives an example of the averaged levels $L_{k,m}(v_m)$ of six measurement locations, represented in columns (as a function of speed), and table 4 gives the corresponding values of $\Delta 95\%ci_{k,m}(v_m)$ (half of the corresponding 95% confidence interval). The values classified as 'reliable' are shown in green in table 3. At 80 and 90 km/h it is clear that the range of the values shown in green across the measurement locations is larger than 2.0 dB(A) and that the values for location 6 (in the red box) deviate the most from the average of the green values. Measurement location 6 is therefore disregarded for determination of the road surface correction of the vehicle category in question.

Table 3

Example of measurement results $L_{k,m}(v_m)$ for six locations, with verification of the spread across locations and calculation of the mean $L_{mean,m}(v_m)$ across the locations.

speed v_m [km/h]	*$L_{i,m}(v_m)$ Averaged sound levels $L_{A,max}$ of vehicle passages, measurement location i, vehicle category m = 1 (light vehicles)*						*$L_{mean,m}(v_m)$ Weighted mean across the measurement locations*
	location 1	*location 2*	*location 3*	*location 4*	*location 5*	*location 6*	
30	60.32	59.78	59.28	58.40	57.55	61.10	**58.84**
40	62.95	62.60	62.32	61.10	60.80	64.60	**61.68**
50	65.64	65.70	65.50	63.41	63.82	67.46	**64.36**
60	68.26	68.30	68.41	66.09	66.40	70.22	66.78
70	70.20	70.08	70.68	68.36	**68.40**	72.56	68.66
80	71.71	71.78	72.26	**70.32**	**70.22**	**74.58**	70.58
90	73.04	**73.29**	73.65	**72.05**	**71.83**	**76.36**	72.43
100	**74.23**	**74.63**	74.89	**73.60**	73.26	77.96	74.23
110	**75.30**	**75.85**	**76.01**	75.00	74.56	79.40	75.62
120	76.28	76.96	**77.04**	76.28	75.75	80.72	76.78
130	77.19	77.98	**77.98**	77.45	76.97	81.93	77.75

Table 4

Example of Δ95%cik,m(vm) values (half of the 95% confidence interval) for the data in table 3.

speed v_m [km/h]	*Δ95%$ci_{i,m}(v_m)$ Half of 95% confidence interval, corresponding to $L_{i,m}(v_m)$*						***Δ95%$ci_{mean,m}(v_m)$ corresponding to $L_{mean,m}(v_m)$***
	location 1	*location 2*	*location 3*	*location 4*	*location 5*	*location 6*	
30	1.62	1.44	1.55	1.21	1.19	1.05	**0.6**
40	1.48	1.24	1.32	0.99	0.97	0.79	**0.5**
50	1.31	1.03	1.17	0.69	0.79	0.58	**0.4**
60	1.15	0.82	1.02	0.47	0.45	0.37	0.3
70	0.85	0.63	0.86	0.30	0.23	0.35	0.2
80	0.60	0.46	0.67	0.19	0.25	0.28	0.1
90	0.40	0.32	0.51	0.20	0.29	0.30	0.1
100	0.25	0.22	0.37	0.29	0.43	0.35	0.1
110	0.23	0.19	0.26	0.39	0.80	0.42	0.1
120	0.41	0.39	0.24	0.54	0.97	0.53	0.2
130	0.53	0.51	0.30	0.59	1.20	0.62	0.2

4.2. Determining the weighted mean across the locations

For each vehicle category m, of the (at least five) averaged sound levels $L_{k,m}(v_m)$ of the separate measurement locations k at speed v_m (in increments of 10 km/h), a weighed mean $L_{mean,m}(v_m)$ is calculated using the formula below.

$$L_{mean,m}(v_m) = \frac{\sum_i \frac{L_{k,m}(v_m)}{\Delta 95\%ci_{k,m}(v_m)^2}}{\sum_i \frac{1}{\Delta 95\%ci_{k,m}(v_m)^2}} \qquad (4)$$

In this formula, $\Delta 95\%ci_{k,m}(v_m)$ is half of the 95% confidence interval at measurement location *k* and for vehicle category *m*. The size of the confidence interval therefore determines to what extent the result of a measurement location counts towards the mean. All values are included in the mean $L_{k,m}(v_m)$, thus not only values classified as 'reliable' as described in section 4.1. The smaller the confidence interval, the less those values will contribute towards the mean.

For the mean values across the locations at speed v_m, $L_{mean,m}(v_m)$, also half of the size of the corresponding confidence interval, $\Delta 95\%ci_{mean}(v_m)$, is determined, as follows:

$$\Delta 95\%ci_{mean,m}(v_m) = \frac{1}{\sqrt{\sum_i \frac{1}{\Delta 95\%ci_{k,m}(v_m)^2}}} \qquad (5)$$

In the example in tables 3 and 4, the values $L_{mean,m}(v_m)$ and $\Delta 95\%ci_{mean,m}(v_m)$ are shown in the last column.

4.3. Regression analysis

From the mean values across all locations at discrete speed values (in increments of 10 km/h), for each vehicle category *m* the relationship between the total A-weighted sound level and the logarithm of the speed can be derived, with linear regression according to $a_m + b_m \log (v/v_{0,m})$. The linear regression is based only on those mean values that meet the following criteria:

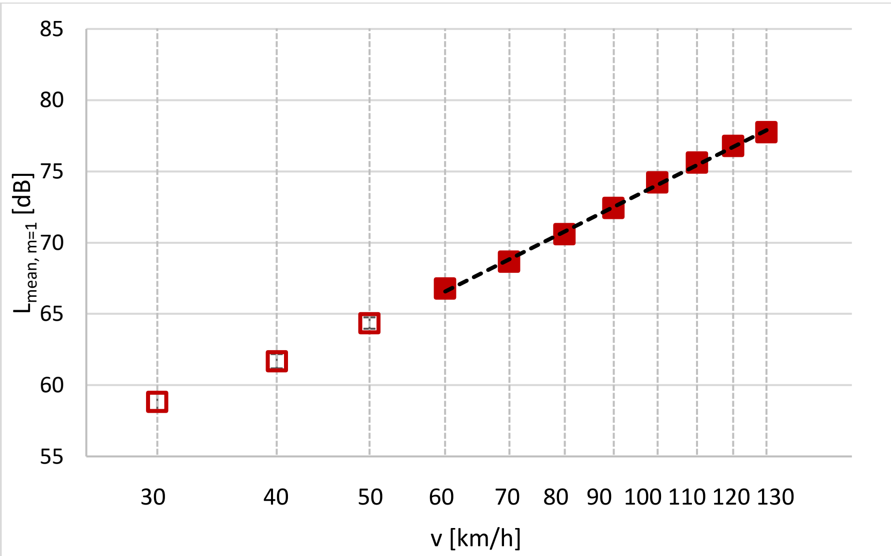
(i) light vehicles (m = 1): range of speed 30-130 km/h and $\Delta 95\%ci_{mean,m}$ (after rounding to a single decimal place) ≤ 0.3

(ii) multi-axle heavy-weighted vehicles (m = 2b): range of speed 30-100 km/h and $\Delta 95\%ci_{mean,m}$ (after rounding to a single decimal place) ≤ 0.8.

In the example in table 3, this means that the values of $L_{mean,m}(v_m)$ shown in red for the speed range 30 to 50 km/h are disregarded for determination of the regression line, which is depicted in figure 2.

Figure 2

Example of the measurement results across the measurement locations $L_{mean,m}(v)$ as a function of the logarithm of speed (v/v_0) for light vehicles ($m = 1$, $v_0 = 80$ km/h) with the regression line. On the basis of the values of $\Delta 95\%ci_{mean,m}(v)$ from table 4, the values $L_{mean,m}(v)$ are disregarded for the speed range 30 to 50 km/h for determination of the regression line



4.4. Determining the initial road surface correction from the difference with the reference road surface

From the difference between the values a_m and b_m from section 4.3 and the values $a_{ref,m}$ and $b_{ref,m}$ for the reference road surface, the values ΔL_m and $_m$ are established, which determine the initial road surface correction ($C_{initial}$):

$\Delta L_m = a_m - a_{ref,m}$ (6a)

$\tau_m = b_m - b_{ref,m}$, (6b)

with

$a_{ref,1} = 77.2$ and $b_{ref,1} = 30.6$ for light vehicles ($m = 1$) and

$a_{ref,2b} = 84.4$ and $b_{ref,2b} = 27.0$ for heavy vehicles ($m = 2b$).

The values ΔL_m and τ_m determine the initial road surface correction $C_{initial,m}$ according to the formula:

$C_{initial,m}(v_m) = \Delta L_m + \tau_m \log(v_m / v_{0,m})$ (7)

4.5. Speed interval within which the initial road surface correction is valid

Section 4.2 gives the formula for calculating the size of the 95% confidence interval $\Delta 95\%ci_{mean,m}(v_m)$ of the mean value $L_{mean,m}(v_m)$ across the measurement locations. The initial road surface correction is only valid for those speeds where $\Delta 95\%ci_{mean,m}(v_m)$, after rounding to a single decimal place, is smaller than or equal to 0.1 for light vehicles ($m = 1$) and smaller than or equal to 0.4 dB(A) for heavy-weighted vehicles ($m = 2b$). Generally speaking, the valid speed range for the road surface correction will differ for light and heavy vehicles. In the example in table 3 and 4, the initial road surface correction is valid at the speed range from 80 to 110 km/h.

4.6. Noise reduction NR for a road surface type

The noise reduction NR for a road surface type (group of similar road surfaces) is the negative of the $C_{initial}$ of light motor vehicles at 80 km/h:

$NR = - C_{initial,\ m=1}$ *(v=80km/h) in dB(A)* (8)

Annex III

Determination of skid resistance

The skid resistance (SR) should be determined at 80 km/h in accordance with technical test specifications (in German) [TP Griff-StB 07 (SKM): Technische Prüfvorschriften für Griffigkeitsmessungen im Straßenbau; Teil: Seitenkraftmessverfahren (SKM), Ausgabe 2007, FGSV Köln DE], within 2-9 months after opening to traffic.

Other methods may be used if they provide the same results, within the accuracy of the original method.

For contract tendering, i.e. before constructing a road surface, indicative values of the skid resistance may be based on laboratory testing. However, the values of the in-situ performance, as determined according to this Annex, are decisive.

Annex IV

Determination of rolling resistance reduction

The rolling resistance reduction (RRR) should be determined at 80 km/h in accordance to the procedures detailed in this Annex. Other methods may be used if they provide the same results, within the accuracy of the original method.

For contract tendering, i.e. before constructing a road surface, indicative values of the rolling resistance reduction may be based on laboratory testing. However, the values of the in-situ performance, as determined according to this Annex, are decisive.

1. Procedure for determining rolling resistance reduction

The rolling resistance reduction (RRR) is the difference between a reference rolling resistance coefficient (RRC) and the RRC of the road surface to be assessed. The rolling resistance coefficient (RRC) is the ratio of horizontal force over vertical force; hence its physical unit is Newton/Newton. For ease of comprehension it is expressed here as kilogramforce/tonforce (kg/t), as is common international practice.

The reference rolling resistance coefficient is determined on a “virtual” reference road surface, being either a stone mastic asphalt (SMA) or an open-graded asphalt, both with 11 mm maximum aggregate size.

There are two methods to determine the rolling resistance reduction:

(i) direct measurement of the rolling resistance, both of the pavement to be assessed and a reference surface, and calculation of the RRR, and

(ii) an estimated rolling resistance reduction based on road surface texture measurements.

To obtain the most accurate result, a direct measurement of the rolling resistance is preferred. However direct measurement devices may be harder to obtain than texture measurement devices. The choice for a certain method is the responsibility of the contractor applying for the road surface label.

2. Direct rolling resistance measurements

2.1. Measurement method

A direct measurement of the rolling resistance of a road surface in-situ is performed by using specially designed measurement trailers. The resistance of the test wheel(s) to rolling is measured in traffic, at normal vehicle speeds. While driving, the measurement system will measure the backward force experienced by the rolling tyre (e.g. with force transducers or by accurately measuring the angle of a swivel arm).

A measurement standard (e.g. ISO, CEN) is not yet available. In principle, therefore, any rolling resistance measurement device can be used to determine the rolling resistance reduction label, as long as the following requirements can be met:

- Measurements should be conducted with the SRTT (Standard Reference Test Tyre) [ASTM F2493-18]. The rubber hardness values H_A (expressed in “Shore A”) should be within the range 62 to 73 at a temperature of 23 ^{0}C. The tyre load should be 400±40 kg. Tyres should be broken in for at least 400 km on a trailer or 200 km on a 4 wheeled powered vehicle. Minimum tread depth should be 70% of new;
- Tyre temperatures on the middle of the tyre side wall must be logged continuously. Measurement results must be corrected for temperature by the procedures indicated below. Air and road temperatures can be logged optionally;

- The tyre should be warmed up before measurements until a stable tyre sidewall temperature is reached. The tyre pressure should be corrected to meet 210±10 kPa in running conditions;
- The measurement speed should be stable during the measurements. The allowed speed is 80±1 km/h. Measurements obtained at different nominal speeds should be corrected to a representative value at 80 km/h. The applied correction should be documented;
- Measurement results should be disposed in the case of steep slopes (>2%), sharp corners, etc. Corrections for parasitic influences should be kept small by eliminating these influences as much as possible. Correction procedures should be used to compensate the effect of slopes, wind and acceleration during the measurements;
- The measured road surface must be dry and free of dirt;
- During measurements the allowable air temperature is between 5 and 35 ^{0}C;
- The road surface length should be preferably 400m or longer. In case of shorter measurement lengths, multiple runs may be averaged, and the minimum travelled distance should be 400m. The minimum road surface length should be 50 m;
- Measurements should be conducted on road surfaces in new, but broken in, conditions (2-24 months old);
- Measurements are normally conducted with the measurement wheel between the wheel tracks. Deviations must be indicated.

2.2. Reference road surface

To minimize the effects of systematic errors between measurement systems, the rolling resistance reduction is calculated as a reduction of resistance with respect to a “virtual” reference road surface, being a stone mastic asphalt (SMA) [EN 13108-5] or open-graded asphalt [EN 13108-7] with 11 mm maximum aggregate size. The measurement system used to perform the measurements must also measure the rolling resistance of this 0/11 reference road surface, in order to have a reference measurement value for that particular system.

Rolling resistance measurements on 0/11 reference road surfaces must be conducted at least:

- Once a year on at least five different 0/11 reference tracks of at least 400 m length. The tracks must be in good condition and between 2 till 60 months old. For long term multiyear stability of results it is advised to keep this control group of tracks as stable as possible and change a maximum of 25% of the tracks compared to last control group measurement. The average value of this group of road surfaces is used to calculate the “virtual reference road surface”
- Once a day on one of the above used reference tracks for every day that the measurement system is used. The measurement result on this “daily reference road surface” should be compared to earlier measurements on this same road surface during the last “virtual reference road surface” experiment. Deviation smaller than 0.5 kg/t should be used for a day to day calibration of the measurement system. If a deviation greater than 0.5 kg/t occurs, then further measurement results should be discarded and the cause of this deviation should be solved, by checking, repairing or adjusting the measurement system or by expelling this reference road surface from the “virtual reference road surface” group. In that case another “daily reference road surface” should be assigned and used.

2.3. Interpretation of measurement results

Because the reference values are typically obtained under different ambient conditions, all measured values should be corrected to a reference tyre side wall temperature of 25^{0}C. The temperature corrected measurement value should be determined with the following formula:

(1) $RRC_{Ttyre\ corrected} = RRC_{uncorrected} - 0.17 \cdot (25 - T_{tyre\ side\ wall})$

The label value for the rolling resistance reduction RRR of a specific road surface should be calculated as follows:

(2) $RRR_{label} = RRC_{Ttyre\ corrected,reference\ road\ surface} - RRC_{,Ttyre\ corrected,test\ road\ surface}$

The obtained values should be rounded to one decimal digit.

3. Estimated rolling resistance reduction based on texture measurements

3.1. Measurement method

In-situ road surface texture should be measured using a measurement system that complies with the requirements of ISO 13473-3 class D for vertical resolution (i.e. better than 0.03 mm) and class E for wavelength range (i.e. larger than 200 mm).

The raw texture profile should be processed according to standard ISO 13473-1 to obtain the texture parameters Mean Profile Depth (MPD) and Root Mean Square (RMS), as defined in ISO 13473-1.

The obtained profile texture parameters should be averaged over the complete road surface length to obtain a representative result which can be used to estimate rolling resistance. The road surface length should be 400 m or longer. In case of shorter measurement lengths, multiple runs may be averaged, and the minimum travelled distance should be 400 m.

3.2. Interpretation of measurement results

To calculate the label value for the rolling resistance reduction the following model should be used:

(3) $RRR_{label} = -1.47 \cdot MPD + 0.24 \cdot \frac{MPD}{RMS} + 1.99$

Note that this model is only valid for standard asphalt road surfaces and MPD-values in the range between 0.4 mm and 2.3 mm. The valid RMS-values range is between 0.3 mm and 1.7 mm.

The obtained rolling resistance reduction values should be rounded to one decimal digit.

Annex V

Determination of lifespan

The methodology and road surface condition criteria to determine lifespan have to be specified in the contract requirements for road surface construction, separately for the tender phase of contracting and for the warranty period in the contract, because there is no single uniform methodology to determine lifespan. This is because:

- Road surface deterioration is highly dependent on project-specific factors, such as climate, drainage, and traffic (intensity, weight, speed, manoeuvring, incidents);
- Criteria for acceptable road surface condition (severity and extent of distress such as unevenness, cracking, ravelling, abrasion, joint condition, or others) may differ between road categories (from motorways to rural roads) and may differ between pavement types, countries, regions or road authorities;
- Accurate lifespan prediction before or just after pavement completion is impossible, since no methodology exists to accurately predict pavement distress development over time and cumulative traffic; and therefore the client needs to specify the required substantiation for a-priori lifespan claims.

In the tender phase of a contract, the client can specify what information is solicited from the contractor to substantiate his claims for the lifespan of the road surface to be constructed.

For the warranty period of the contract, the client can specify the criteria for acceptable road surface condition for a specified period.

Annex VI

Format of the label

The layout of the road surface label should comply with the example below, with the black class indicators indicating the proper class for each performance criterion.