United Nations ECE/TRANS/WP.29/GRB/2019/2

# Economic and Social Council

Distr.: General
12 November 2018

Original: English

## Economic Commission for Europe

Inland Transport Committee

### World Forum for Harmonization of Vehicle Regulations

**Working Party on Noise**

**Sixty-ninth session**
Geneva, 22-25 January 2019
Item 10 of the provisional agenda
**Influence of road surface on tyre rolling sound emissions**

# Revised proposal for a draft Resolution on road surface labelling

## Submitted by the expert from the Netherlands*

This document contains a revised consolidated version of the draft Resolution that was previously submitted to the sixty-eighth session of the Working Party on Noise (ECE/TRANS/WP.29/GRB/2018/8 and 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.

# Draft Resolution on the assessment of performance and classification of road pavement surfaces – Guidelines for road surface labelling

## Contents

# I. Statement of technical rationale and justification

## 1. Introduction

1.1. Since vehicles interact with road pavement surfaces through the wheels on pneumatic tyres, vehicle and tyre performance, besides other factors, is linked to the effectiveness of such interaction. Hence, that effectiveness is affected by criteria related not only to vehicle and tyre design features, but the quality of pavement surface layer, as well.

1.2. This document is aimed at the possible improvement of the said interaction proposing the assessment of performance and classification of road pavement surfaces.

1.3. The performance assessment of pavement surface layers is considered regarding environmental protection (tyre-pavement noise), safety (skid resistance), energy efficiency (rolling resistance) and service life of layers.

1.4. The purposes of assessment and characterisation may include contract specifications, pavement product comparison and pavement product improvement. As several different characterisation methods exist, there is a need for a harmonized and easy-to-understand classification method.

1.5. The proposed approach for assessment and characterization is based on the performance labels similar to those already used for several consumer products. Particularly relevant is the labelling of pneumatic tyres, regulated in Directive 1222/2009/EC of the European Commission. With this approach a road surface label complements the existing tyre label, since a tyre label characterizes 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. Thus, 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.

1.6. The direct purpose of road surface labelling is easier, transparent communication between the client and contractor; between road authorities and road users, taxpayers and residents. Moreover, it promotes recognition towards society and politics and promotes a better public awareness of road surface performance. The deeper purpose of road surface labelling is to stimulate the development and application of better road surfaces with less cost to society.

1.7. Performance labels are a categorisation of requirements or performance indicators, often from class A (excellent) to G (minimal). Examples include energy labels for washing machines, buildings and cars, but the labels may also concern properties other than energy. For example, tyre labels display the wet skid resistance and noise properties of tyres in addition to rolling resistance (influencing fuel consumption).

1.8. The following sections describe the background for the proposed labelling for road surfaces (wearing courses) with the following four performance indicators of which the first three correspond with the three performance indicators on the tyre label according to Directive 1222/2009/EC:

- Traffic noise reduction;
- Wet skid resistance;
- Rolling resistance;
- Lifespan.

1.9. The first three indicators of road surface performance are all indicators of tyre-pavement interactions, and therefore influenced by tyre properties and ambient conditions. Therefore standard tyres should be used as far as feasible to measure these indicators of road surface performance. Where possible, relevant conditions (e.g. temperature or measuring speed) should be standardized as well, or limited in range, or variations should be corrected for. Wet skid resistance and tyre-pavement noise are strongly dependent on vehicle speed, but that a standard speed for characterisation is necessary for simplification.

1.10. At present there are no European harmonized methods for characterisation of the four pavement performance indicators, but such methods are being developed by the European Committee for Standardization (CEN) Technical Committee 227 Road materials, Working Group 5 pavement surface characteristics. While such harmonized methods are not yet available, this document motivates the use of certain characterisation methods, and boundaries for label classes (A to G inclusive). When harmonized methods become available, they should preferably be adopted to replace the present methods.

1.11. The labelling system is intended to be used for specific road surfaces, meaning a road pavement section at a certain location, e.g. road number xxx between kilometer y.y and z.z.

1.12. This means that, before construction of a specific road surface, e.g. in the tendering phase of a contract, the label classes only can be determined indicatively, either by measurements on one or more already constructed similar surfaces, or by predictive laboratory testing. After construction of the road surface, its label classes can be determined in-situ.

1.13. Labelling road surface types (e.g. a specific asphalt mix, or a finishing treatment of a Portland cement concrete surface), instead of road surface sections, was considered but rejected because of the following reasons:

- The properties of different sections of the same road surface type can differ considerably, because constructing road surfaces is influenced by many factors (e.g. the weather) that vary between construction projects. Therefore, a general value for a road surface type would not give sufficient certainty for each specific road surface.
- Labelling a road surface type based on previous experience, like e.g. the average value of five reference sections, would hamper innovation, because new surface types would need to be applied at least five times before being able to get a label.

1.14. A road surface label itself does not prescribe minimum requirements to the performance criteria it indicates; such requirements can be prescribed by parties using labels in tendering requests for road works. 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.

1.15. The 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.

1.16. The 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.

1.17. Road surface 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.

## 2. Benefits and necessity: Accessibility, safety, liveability, sustainability, durability and economy

2.1. Roads exist to facilitate the mobility of people and goods. Important political and social issues concerning roads include accessibility (and therefore availability), safety, liveability, sustainability, durability and economy. These themes are related to road surface performance indicators as shown in the table below.

| *Themes from politics and society* | *Performance indicator to address from a tyre-road surface perspective* |
|---|---|
| Safety | Skid resistance |
| Liveability | Noise reduction, Rolling resistance |
| Sustainability | Environmental Cost Indicator |
| Accessibility, availability | Lifespan |
| Economy | Rolling resistance, lifespan |

2.2. For the safety of a road the skid resistance performance is key, for the liveability (theme) the tyre-road surface noise, and for both sustainability (CO2) and economy the rolling resistance is very important. For accessibility and availability, the lifespan of the road, both mechanically and functionally, is an important parameter. This lifespan can be further worked out in, for example, resistance to crack formation, resistance to rutting and ravelling. Finally, sustainability can be expressed in an Environmental Cost Indicator of a road surface.

*How does it benefit society?*

2.3. Road surface labels encourage the optimisation of road surfaces, e.g. for tyre-pavement noise, skid resistance, rolling resistance and lifespan, and help to make choices between different road surfaces. Such improvement of road surface performance will reduce the road-related costs of mobility for society and environment, in reducing fuel consumption, CO2 emission, accident costs and noise nuisance.

2.4. For example, reducing rolling resistance by approximately 10-30 per cent yields fuel savings of 2-6 per cent, and the risk of accidents at good skid resistance is 2-5 times less than with a very poor skid resistance. Silent road surfaces reduce nuisance, noise-related sleep problems, and the need and costs for visually less appealing sound barriers.

2.5. Benefits for the whole of Europe have yet to be calculated. For the Netherlands 4% fuel savings yields about 1 Mton $CO_2$ reduction annually (for national roads + provincial roads) and approximately €325 million social benefits (for national roads alone). Better skid resistance could save significantly on the annual €8 billion of Dutch traffic accident costs. Lower noise can save €400 million for heightening the present 400 km of noise barriers in the Netherlands. The figures for the Netherlands may be extrapolated to estimate benefits for other countries or regions.

2.6. The road surface label can easily be used in the management stage in order to more accurately determine the replacement time in advance and to be able to communicate with society. It encourages road builders to develop products with enhanced rolling resistance, optimum skid resistance, less noise, and an increasing lifespan. Road surface labels stimulate road authorities to tune requirements to specifics situations. Importantly, road surface labels enable the tax payers that finance the road, the road user and local residents to easily appreciate what road surface quality they are getting.

2.7. In addition, it facilitates the cooperation between the road industry and tyre industry and other relevant partners, resulting in faster innovation cycles (shorter turnaround of new products) and makes the optimisation of tyre-road interaction really possible. Indeed, a tyre can be optimized for a particular type of road surface, but might be less optimized for another type. Alternatively, a road surface can be optimized for a particular type of tyre, but might be less favourable for a different type of tyre. If these two sectors - the tyre industry and road construction industry - understand each other better, tyre-road interaction can be optimized as a whole. Road surface labelling should lead to the recognition of a road as a product that is industrially designed, built and maintained.

# 3. Scope

3.1. The performance assessment and labelling of pavement surface layers only considers the road surface. For example, for the topic of safety the skid resistance is included, but the layout of the road (i.e. limiting visibility) is not. Presently, the label is limited to road pavements, later it could possibly be extended to airfields or other types of pavements. The label is intended to cover all types of paved road surfaces: asphalt mixes, Portland cement concrete, natural stone tiles or blocks, fired clay brick, concrete paving blocks, etc.

3.2. This document recommends the use of the road surface labelling. The voluntary labelling road surfaces is primarily the responsibility of the contractor.

3.3. Road surface characteristics may differ widely between different types of pavements, and required values may also differ much between different applications (e.g. motorway vs low-volume rural road). Therefore, with only 7 label classes (A-G), the range of characterisation values within one label class needs to be rather large. Therefore, contract specifications need not be limited to label class boundaries. Of course, additional requirements can be set in the contract besides the road surface label.

3.4. No check of compatibility between specifications is built-in within the road surface labelling system, as it is mainly intended for professional road agencies and road contractors. Also: specifications that today are impossible to realize, individually or in combination (e.g. >15 dB noise reduction and >30 years of lifespan under heavy traffic) may be possible in the near future.

# 4. The road surface labelling concept and examples

4.1. General

4.1.1. The labelling system is deliberately kept as simple as possible and still tries to stimulate improvement and optimisation (seeking balance between stimulating improvement and clarity / simplicity), similar to the tyre label. Therefore, only one set of scale values is chosen for each of the four considered most essential road surface performance indicators. For each indicator there exists more than one method to measure or determine a value. The characterisation methods are chosen to match existing regulations and practices as well as possible. In the future, these can be replaced by harmonized European standards when these become available.

4.1.2. The boundaries of the label classes are recommended such that F or E are common now, D and C represent current good practice, B is a challenge and A is not attainable at present, but should pose a realistic challenge for the next 5-10 years.

4.1.3. It is recommended that clients not only require the contractor to provide the label classes of the road pavement surface type to be constructed, but also the specific values for each of the performance indicators, together with the underlying measurement reports.

4.1.4. The recommended label scales are based on in-situ properties, measured using different concepts for different properties: standardized tyres under standardized conditions (for skid resistance, rolling resistance), representative traffic (for tyre noise reduction), or actual traffic (for lifespan). Laboratory tests on laboratory-made surface specimens may be used to predict in-situ behaviour for purposes of road surface product development. However, "the proof of the pudding is in the eating", so the in-situ values are decisive. For noise reduction, skid resistance and rolling resistance, i.e. properties that can be determined within a year after construction of a road surface, the label class for innovative products should preferably be based on a set of pilot sections. For lifespan, this is not practically feasible as the actual performance of the in-situ road surface only shows after many years. By necessity, this label class therefore has to be based on predictive laboratory tests.

4.1.5. For measuring in-situ properties of road surfaces, methods are used that can be executed in the run of traffic, to avoid traffic disturbance or unsafe measuring.

4.1.6. It is recognized that e.g. wet skid resistance and tyre-pavement noise are highly dependent on vehicle speed, and that the speed-dependency may differ strongly between pavement types or categories. Nevertheless, for simplicity the label scale is based on only one speed, 80 km/h. Similarly, the label scale is only based on passenger cars, not considering vans, trucks, motorcycles or others. If desired, alternatively a composite value could be based on e.g. 10% trucks and 90% cars.

4.1.7. It is also recognized that road surface characteristics often will change over time. Skid resistance will decrease due to aggregate polishing and tyre-pavement noise may increase as surface texture roughens and sound-absorbing pores get clogged. For noise reduction, skid resistance, and rolling resistance, "young" values are used, and the decline may show by the road surface "dropping out of its label class". Limiting such a drop is not part of the road surface label, but is recommended to be to be covered in road construction contracts.

4.2. Noise reduction

4.2.1. The characterisation method of road surfaces in Annex II of the Resolution is based on the correction term for the influence of the pavement on the tyre rolling noise, as defined in sections 2.2.3 "Rolling noise" and 2.2.6 "Effects of the type of road surface" of the environmental noise directive 2015/996/EC, for m=1 (light motor vehicles) and A-weighted over all octave bands i.

4.2.2. As reference road surface, described in section 2.2.2 "reference conditions" of 2015/996/EC, the Dutch reference is recommended. This is a numerical equation ("virtual road surface") based on measurements on several sections of asphalt concrete, similar to the IS0 10844 reference surface, averaged over a typical lifespan1. The measurements are done according to ISO 11819-1:1997 Statistical Pass-By method (SPB), but with a microphone height of 3 m, to avoid in-situ measuring problems caused by guard rails.

4.2.3. It is recognized that the European Commission (EC) has asked CEN Technical Committee 227 Road materials, Working Group 5 pavement surface characteristics to develop a harmonized European method for acoustic characterisation of road surfaces, to be

[1] The advantage of a numerical reference, over a physical reference such as the ISO 10844 reference surface, is that differences between actual sections of that reference surface are averaged, just as variations over time, e.g. due to wearing.

used in 2015/996/EC. As that method is not yet available, a non-harmonized method is used in the meantime.

4.2.4. In general, dense asphalt surfaces such as Asphalt Concrete (EN 13108-1) and Stone Mastic Asphalt (EN 13108-5) with upper sieve sizes of 5 to 16 mm typically will have label class E, whereas coarse surface dressings and brushed Portland Cement Concrete may be F, and two-layer Porous Asphalt (PA5) may be C, sometimes reaching B.

4.2.5. In-situ monitoring of road surfaces can be done by CPX method (ISO 11819-2:2017), which can be converted to noise reduction values.

4.2.6. As the label scale is based on “initial” values, the noise reduction at the end of road surface lifespan may be lower than the label class value. This should be kept in mind when using the label in long-term contract specifications.

4.3. Wet skid resistance

4.3.1. The friction coefficient is the ratio of horizontal force over vertical force, hence its physical dimension is Newton/Newton or dimensionless.

4.3.2. The skid resistance trailer according to CEN/TS 15901-9 is a compact, robust and versatile measurement system for longitudinal wet skid resistance (Braking Force Coefficient), enabling full-length skid resistance evaluation.

4.3.3. Unfortunately, the measurement procedure for determining wet grip of tyres for the tyre label is not suited for in-situ assessment of road pavements, as it requires deceleration of the test vehicle from 80 to 20 km/h and is therefore not applicable in in-traffic conditions.

4.3.4. For conversion between different traffic speeds, a constant loss of 0.05 per 20 km/h speed increase can be used for practical purposes, although not being fully correct.

4.3.5. For several types of pavements, especially asphalt mixes but also Portland Cement Concrete, wet skid resistance may fluctuate significantly in the first weeks or months of traffic loading, because of the traffic wearing off any cement coat, grittings, and/or bituminous mastic covering the surface of the mineral aggregate. The label scale for skid resistance is based on the skid resistance value obtained after 2-9 months of traffic, after the initial fluctuations, and at the beginning of long-term skid resistance decline due to polishing. The initial fluctuations are outside the scope of the label, and should be covered separately in contract specifications, e.g. by minimum requirements, if desired.

4.3.6. Over time the skid resistance of the road surface may decrease to in-situ values below the label class. This should be kept in mind when using the label in long-term contract specifications.

4.3.7. Prediction of in-situ wet skid resistance, based on laboratory-made road surface specimens, is still very challenging. However the Friction after Polishing test [EN 12697-49:2014] provides a relative ranking of road surfaces that correlates well with in-situ ranking. Also, previous European research (project SKIDSAFE) developed a laboratory machine to characterize skid resistance in the laboratory (SR-ITD, skid resistance interface testing device).

4.4. Rolling resistance

4.4.1. General

4.4.1.1. Rolling resistance is influenced by many factors:

- Tyre parameters (load, size, structure, composition, etc.);
- Conditions (temperature of air, pavement and tyre, …);

- Pavement parameters:
  - Pavement texture: microtexture, macrotexture, megatexture, unevenness [ISO 13473-1 and -2];
  - Pavement deflection under (heavy) traffic load;
  - Elasticity (or contrarily: visco-plastic energy loss) of pavement under loading.

4.4.1.2. For a road surface label the tyre parameters and conditions should be kept constant. Of the pavement parameters, deflection and elasticity are excluded, as these are probably more related to the entire pavement (sub)structure, and less to the wearing course. Furthermore, the influence of microtexture, megatexture and unevenness is considered to be of minor importance, relative to macrotexture, and therefore ignored.

4.4.1.3. As the label scale is based on “initial” values, the rolling resistance reduction at the end of road surface lifespan may be lower than the label class value. This should be kept in mind when using the label in long-term contract specifications.

4.4.2. Examples of measurement systems and analysis procedures in practice.

4.4.2.1. There are several measurement systems in use today. In Europe there are currently two “publicly available” measurement devices in use: the trailer of the Gdańsk University of Technology (TU Gdansk) and the trailer of Belgian Road Research Centre. Currently there are no official standards for performing rolling resistance measurements. Therefore, there can be differences in absolute rolling resistance values between measurement systems. The current results indicate that these differences between measurement systems mainly consist of a constant bias. Differences between road surfaces are less dependent on the specific measurement system and/or the analysis of results. Therefore the label values of a specific road surface are determined as a reduction compared to a “virtual” reference road surface, being a stone mastic asphalt (SMA) or open-graded asphalt with 11 mm maximum aggregate size.

4.4.2.2. The TU Gdansk rolling resistance trailer is a three-wheel trailer (see figure 1). The two front wheels are bearing/support wheels. The rear wheel is the measurement wheel. The measuring wheel is attached to the trailer frame by a swivel arm; the angle of the swivel arm provides a measure of the rolling resistance force on the measuring wheel. In recent years, improvements have been made to the trailer to further limit the effects of unwanted variations on the measurement result.

**Figure 1**
**The TU Gdansk measurement trailer for measuring rolling resistance on road surfaces.**


4.4.2.3. In 2012 the effects of temperature differences on rolling resistance coefficient values were investigated for the TU Gdansk trailer [M+P.DVS.12.08.3]. The temperatures of the tyre side wall, the road surface and air were measured simultaneously with the rolling resistance. It was found that the temperature dependence in rolling resistance was most accurately described using the tyre side wall temperature. Later, TU Gdansk also suggested a correction based on air temperature values as this might be easier to measure for some parties.

4.4.2.4. Both methods can be used to obtain temperature corrected results, but absolute values cannot be compared directly if different temperature correction methods are used.

Corrections for the TU Gdansk trailer were found to be the following:

$$\mathrm{RRC}_{,\mathrm{Ttyre\ corr,Ttyre\ ref\ 25°C}} = \mathrm{RRC}_{\mathrm{uncorrected}} - 0.17 \cdot (25 - \mathrm{T}_{\mathrm{tyre\ wall\ side}})$$

$$\mathrm{RRC}_{\mathrm{Tair\ corr,Tair\ ref\ 20°C}} = \mathrm{RRC}_{\mathrm{uncorrected}} \cdot \left(1 + 0.014 \cdot (\mathrm{T}_{\mathrm{air}} - 20)\right)$$

4.4.2.5. The following rolling resistance reference values were determined based on the average rolling resistance of 15 road sections with 0/11 graded road surfaces, measured by the TU Gdansk trailer:

$$\mathrm{RRC}_{\mathrm{RR,ref\ Ttyre\ corr}} = 9.50 \quad \text{[kg/t]}$$

$$\mathrm{RRC}_{\mathrm{RR,ref\ Tair\ corr}} = 8.58 \quad \text{[kg/t]}$$

4.4.3. Background information on relation rolling resistance versus texture

4.4.3.1. In 2012 [M+P.DVS.12.08.3] an extensive measurement campaign was conducted to determine the relation between rolling resistance and road surface texture. Rolling resistance values were based on measurements performed by TU Gdansk. Texture values were based on measurements performed by M+P. This research and other research has shown that there is a significant relation between road surface texture and rolling resistance.

4.4.3.2. Several models, based on the texture parameters MPD, RMS and Skewness [ISO 13473-1, -2 and -3] were tested. The following model was found to have the best fit [M+P.PGEL.17.06.1]:

$$\mathrm{RRC} \quad = \mathrm{C1} \cdot \mathrm{MPD} + \mathrm{C2} \cdot \frac{\mathrm{MPD}}{\mathrm{RMS}} + \mathrm{C3}$$

with C1, C2 and C3 constants.

4.4.4.3. Please note that due to model inaccuracies, the rolling resistance which is estimated using texture parameters can be different from direct rolling resistance results. This may lead to differences of up to ± 0.7 kg/t (95 per cent confidence interval), which would mean plus or minus two rolling resistance classes.

4.5. Lifespan

4.5.1. The lifespan encompasses all types of surface distress:

- Unevenness;
- Cracking;
- Ravelling;
- Abrasion by studded tyres;
- Etc.

4.5.2. The distress type that first reaches the serviceability limit values (defined in contract or in national or international regulations) is critical, i.e. defines lifespan. For different types of road surface, different distress types may be critical. Also, each distress type is influenced by many factors, such as traffic loading and climatic conditions.

4.5.3. Lifespan in-situ may seem obvious, but depends on the limits that are set to pavement condition (distress levels, such as rut depth, amount and severity of cracking or ravelling, etc.) that define “end of life”. In the same situation, acceptance of higher distress levels will give longer lifespan. Acceptable distress levels will often differ between road categories (from motorways to rural roads) and may differ between countries, regions or road authorities. Furthermore, lifespan of a specific pavement quality is dependent on traffic (intensity, weight, manoeuvring).

4.5.4. Lifespan prediction just after pavement completion, or in the lab in the pavement design phase, is even more challenging. Presently no methodology (e.g. test methods or prediction model) exist that can accurately predict pavement distress development over time and cumulative traffic. Neither for individual distress types, nor for interacting combinations of distress, or to determine which distress type will be critical (i.e. first reaches the serviceability-limit set for that distress type). There are several ways to produce affirmation of lifespan claims, such as: long-term performance of reference pavements, numerical modelling, combinations of lab tests, etc. However, these are mainly indicatory, not real “proof”.

## 5. References


5.1. Design Manual for Roads and Bridges (DMRB) – Volume 7 Pavement Design and Maintenance – Section 3 Pavement Maintenance Assessment – Part 1 HD 28/15 Skidding Resistance; Highways England et al.

5.2. M+P.DVS.12.08.3 “Influence of road surface type on rolling resistance – Results of the measurements 2013”, revision 4, 20-11-2013.

5.3. M+P.PGEL.17.06.1: “Enhancements of texture vs rolling resistance model”, M+P consulting engineers, Vught (NL) June 12th, 2017.

5.4. prEN 13036-2a Road and airfield surface characteristics — Test methods — Part 2a: Assessment of the skid resistance of a road pavement surface by measurement of the sideway-force coefficient, October 18th, 2017.

# II. Text of the Resolution on the assessment of performance and classification of road pavement surfaces - Guidelines for road surface labelling

## Preamble

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

RECOGNIZING that interaction between vehicle tyres and road surface layers depends on the effective performance of the both factors;

DESIRING to ensure 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 a harmonized 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 this Resolution does not hold regulatory status within Contracting Parties;

RECOMMENDS to use this Resolution for the assessment of performance of road surface layers when establishing road surface labels with pavement performance indicators.

## 1. Objectives

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

1.2. 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.

1.3. The implementation of the road surface labels will encourage the road construction industry to develop, build and manage safe, livable, sustainable, durable and economic roadways.

1.4. The main preconditions for the use of road surface labels are:

- Compatibility with the existing tyre labelling scheme in the European Union;

- Compatibility with existing international standards and measuring methods;
- Applicability for both new and existing roads;
- Allows for innovation (product and process).

1.5. The road surface labelling 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.

1.6. 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.

## 2. Scope

2.1. This Resolution 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.

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

## 3. Definitions

For the purpose of this Resolution:

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

3.2. "*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;

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

3.4. "*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;

3.5. "*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;

3.6. "*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;

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

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

3.9. "*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. Specifications

4.1. The noise reduction class is 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.

4.2. The skid resistance class is 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.

4.3. The rolling resistance reduction class is 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.

4.4. The lifespan class is 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.

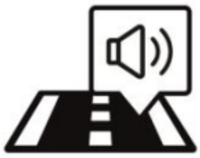
4.5. The format of the road surface label to be used is specified in Annex VI, with black arrows indicating the proper class for each of the performance indicators.

# 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 |

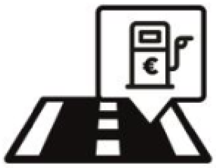
2. Skid resistance

**Table 2**
**Skid resistance (SR) classes**

|  | **Skid resistance (SR)** in friction coefficient |
|---|---|
| A | SR ≥ 0.83 |
| B | 0.68 ≤ SR < 0.83 |
| C | 0.59 ≤ SR < 0.68 |
| D | 0.50 ≤ SR < 0.59 |
| E | 0.42 ≤ SR < 0.50 |
| F | 0.33 ≤ SR < 0.42 |
| G | SR < 0.33 |

3. Rolling resistance reduction

**Table 3**
**Rolling resistance reduction (RRR) classes**

|  | **Rolling resistance reduction (RRR)**<br>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)**<br>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:

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

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

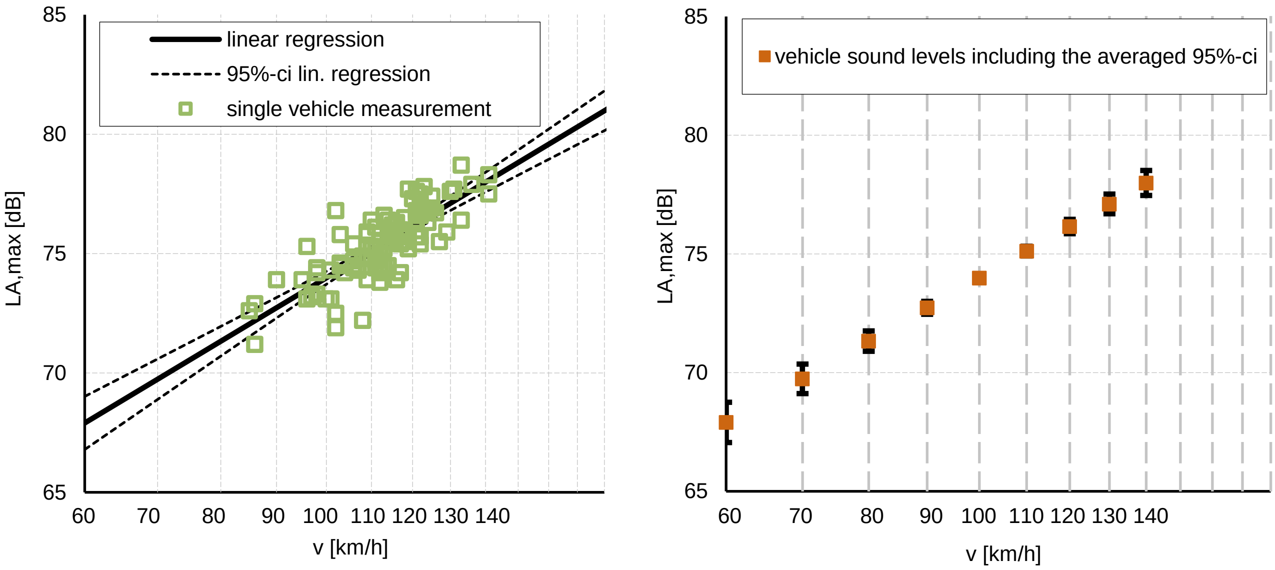
$0.8 \cdot \sqrt{(49/(N_{2b}-1))}$ for heavy vehicles. (3b)

$N_1$ 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·√(99/(N1-1)) for light motor vehicles and

0.8·√(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 Δ95%$ci_{max}$ 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 $\Delta 95\%ci_{max}$.**

| *[dB]* | *speed [km/h]* | | | | | | |
|---|---|---|---|---|---|---|---|
| | ***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]* | *$\Delta 95\%ci_{i,m}(v_m)$ Half of 95% confidence interval, corresponding to $L_{i,m}(v_m)$* | | | | | | *$\Delta 95\%ci_{mean,m}(v_m)$ 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:

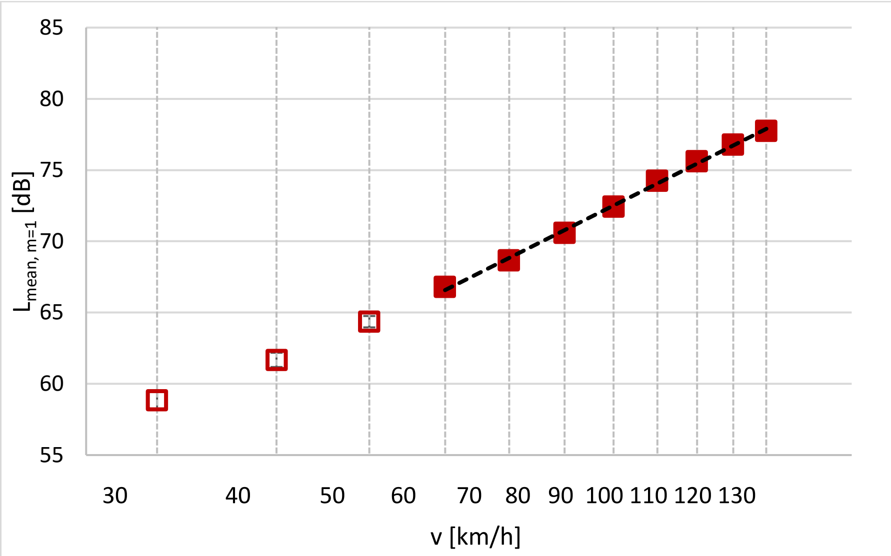
(i) light vehicles (m = 1): range of speed 30-130 km/h and $\Delta 95\%ci_{mean,m}$ (after rounding to a single decimal place) $\leq 0.3$

(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) $\leq 0.8$.

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 $\Delta L_m$ and ${}_m$ are established, which determine the initial road surface correction ($C_{initial}$):

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

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

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 $\Delta L_m$ and $\tau_m$ determine the initial road surface correction $C_{initial,m}$ according to the formula:

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

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:

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

# Annex III

## Determination of skid resistance

The skid resistance (SR) should be determined at 70 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 skid resistance may be based on laboratory testing. However, the values of the in-situ performance, as determined according to this Annex, are decisive.

The Skid Resistance (SR) is defined as the longitudinal coefficient of friction (COF) between wetted road surface and tyre, as determined at 70 km/h using a standardized measurement tyre in a standardized friction tester, after the applicable corrections, in accordance to the procedures detailed in this Annex.

1. Measurement system

The measurement system consist of a towing vehicle, containing a controller and data acquisition system and a water supply system, coupled to a measurement trailer according to CEN/TS 15901-9:2009 or equivalent. This trailer contains a measurement wheel, the axis of which is parallel to the road surface and perpendicular to the driving direction. The measurement wheel is connected to one of the bearing wheels of the trailer through a single-gear box. The measurement wheel is subjected to 86% slip ratio, meaning that the circumferential velocity of the measurement wheel is 14% of that of the freely rotating bearing wheels (of the same circumference as the measurement wheel).

The measurement wheel is fitted with a smooth PIARC measurement tyre (165 R 15) inflated to 200 ± 10 kPa. Measurement tyres should only be used between 12 and 36 months after their production date. Before first use, a measurement tyre should be ‘broken in’ for at least 25 km on a road surface with a SR between 0.40 and 0.60. Tyres must not be used if they are damaged or excessively worn (wear indicator less than 2 mm deep).

The measurement wheel is loaded though a spring/damper system by such a mass, that the static normal force ($F_{Nst}$) - measured on a horizontal plane - equals1962 ± 9.81 N.

The dynamic longitudinal force ($F_x$) on the measurement tyre, when dragged along the road surface, caused by the friction, is measured with a force transducer with an inaccuracy of not more than 0,2% and a maximum deviation of 9.81 N. The force must be measured and recorded at least once for each 0.5 m travelled distance.

The system supplies a water film on the road surface, (the outflow opening of the nozzle is located 0,41 m in front of the measurement tyre axis), of at least 0.15 m width and a nominal thickness of 0.5 mm, calculated on a theoretical smooth surface without texture. The system measures the average water flow and average driving speed during the friction measurement. If the average water flow deviates more than 10% from the theoretical value for the average driving speed, this must be reported with the measurement results.

If the amount of water in the water tank in the towing vehicle has such an influence on the pitch of the vehicle (and hence of the friction force $F_x$) that the COF can change by more than 0.01, the COF has to be corrected. To determine this correction ($c_w$), the suspension characteristics of the towing vehicle must be taken into account.

The inaccuracy of the measurement of travelled distance may not be more than 1%.

2. Execution of measurements

For road surface labelling the measurements should be executed for each lane required by the client (but at least the slow lane). For right-hand driving countries, the measurements should be executed in the right wheel path, i.e. with the centre of the measurement wheel at a distance of 0.6 m to the left of the inside of the right lane marking. For left driving countries, the measurements should be executed in the left wheel path, i.e. with the centre of the measurement wheel at a distance of 0.6 m to the right of the inside of the left lane marking.

For road surface labelling, the friction measurement for acceptance testing of a road surface should be executed either before 24 hours after opening to traffic, or between 6 and 20 weeks after opening to traffic.

For road surface labelling, the measurements should be executed at a speed of 70 ± 3.5 km/h. For other purposes other speeds may be used, with an accuracy of ± 5%. If the speed deviates more than specified, this deviation must be reported with the measurement results.

At the start of the measurement section, the measurement tyre must have a stable temperature. Therefore, the measurement tyre must be warmed up by lowering the tyre onto the wetted road surface at a distance before the measurement section, specified in Table 1.

**Table 1**
**Warming-up length, depending on time since previous measurement**

| *Time since previous measurement* | *Warming-up length* |
|---|---|
| T < 10 minutes | ≥ 100 m |
| 10 ≤ T < 20 minutes | ≥ 300 m |
| 20 ≤ T < 30 minutes | ≥ 500 m |
| T ≥ 30 minutes | ≥ 1000 m |

Air temperature and road surface temperature should be measured for each measurement location or at least twice a day, with an accuracy of 1°C.

Measurements should not be performed at an air temperature below 2°C or over 30°C, and at road surface temperature below 2°C or over 45°C.

4. Calculation

4.1. Measured Coefficient of Friction

The measured Coefficient of Friction ($COF_{meas}$) is determined by:

$$\mathrm{COF_{meas}} = \mathrm{A} + \mathrm{B} * ((\mathrm{F_x} + \mathrm{c_w})/\mathrm{F_{Nst}})$$

where:

$F_x$ = the measured longitudinal friction force on the measurement wheel [N]

$c_w$ = the correction for pitch of the towing vehicle, derived from the amount of water in the water tank [N]

$F_{Nst}$ = the static normal force (1962 N)

A, B = correction constants depending on road surface category (“porous” or “dense”, see below), taking into account differences between production years of the PIARC measurement tyres. For production year 2016, for “porous” surfaces A = 0 and B = 1, for “dense” surfaces A = 0.110 and B = 0.830. For other years the constants have to be determined by statistic comparison to the 2016 tyres. (Actually the present corrections refer back to the 1998 production year.)

"Porous" surfaces are capable of draining water below the road surface, through the bulk of the surface layer. These include Porous Asphalt, Silent Thin Surfacings with over 14% void content, Porous Cement Concrete. "Dense" surfaces can only drain water in the surface macro texture. These include Asphalt Concrete, Stone Mastic Asphalt, Cement Concrete, Slurry Seals and Chip Seals.

The $COF_{meas}$ must be calculated, with a resolution of three decimal places, at least once for each 0.5 m travelled distance. From these values, per 100 m the average $COF_{meas}$ per 5 m and per 100 m are calculated to at least three decimal places.

4.2. Seasonal correction

The average $COF_{meas}$ per 5 m and per 100 m can be corrected for the influence of the measurement season using the following formula:

$$\mathrm{COF_{season}} = \mathrm{COF_{meas}} - 0.022 * \sin\left((360/365) * \left(\mathrm{N_{day}} + 60\right)\right)$$

where:

$COF_{season}$ = the COF corrected for seasonal influences [-]

0.022 = the amplitude of seasonal influence [-]

Nday = the day number of the measurement date within a year (January 1st is 1, February 1st is 32, etc.)

60 = the phase shift in days

The argument of the sine function is in degrees.

The $COF_{season}$ should be calculated with a resolution of at least three decimal places.

4.3. Determination of SR

For labelling of new road surfaces, up to 12 months old, the SR is defined as the $COF_{meas}$ as determined in section 4.1.

For labelling of road surfaces, more than 12 months old, the SR is defined as the $COF_{season}$ as determined in section 4.2

5. Reporting

Reporting is done per measurement section of 100 m and should contain the following data:

General data:

- Location of the measurement (road, carriageway, lane, transverse position within lane, chainage or length from a specified zero point)
- Direction of measurement relative to normal driving direction, if not identical
- The category of road surface, including specification of either "porous" (Porous Asphalt, Silent Thin Surfacings with over 14% void content, Porous Cement Concrete) or "dense" (Asphalt Concrete, Stone Mastic Asphalt, Cement Concrete, Slurry Seals and Chip Seals).
- Measurement date (time optional) and measurement number within that date or within a project.
- Target driving speed

- A note whether or not seasonal correction is applied
- Measured air temperature
- Measured road surface temperature
- A note if the average water flow and/or average driving speed deviates more from the target values than specified in sections 2 and 3 above.

Friction data

- The average SR ($COF_{meas}$ or $COF_{season}$) for each 100 m length, rounded to two decimal places
- The average SR ($COF_{meas}$ or $COF_{season}$) for each 5 m length, which is below a customer-specified threshold value, rounded to two decimal places

Data which are constant over all 100m-sections of a contiguous measured length may be reported only once for that measured length.

If a measurement length is not an integer multiple of 100 m, the remaining shorter section(s) at the beginning and/or end of the measurement length are treated as 100m-sections.

6. Accuracy

6.1. Calibrations

The system must be checked and calibrated on the following aspects at least once a year and as often as necessary:

- Static calibration of friction force transducer;
- Static calibration of the skid resistance trailer on a calibration plateau (horizontal force on the measurement wheel);
- Static vertical calibration of wheel load;
- Distance calibration;
- Water flow meter calibration.

6.2. Round Robin Tests

Measurement systems must prove their accuracy (repeatability and deviation of group average) at least 5 times per year in a round robin test with at least one other similar measurement system. Repeatability is a measure of variation between repeated runs on the same road section for one system with the same tyre and driver within short intervals (less than half an hour). Deviation from group average is a measure of bias of a system relative to the group of systems.

In the round robin test, two straight measurement sections (one with a dense surface and one with a porous), each of 500 m length, must be tested, using three different measurement tyres per measurement system. Per section all systems must first perform a 'washing' measurement run, the data of which are discarded. After 'washing', all systems should perform four measurement runs with their first tyre on both sections, then four runs on both sections with their second tyre, and then four runs with their third tyre.

For each section-system-tyre combination, the repeatability is determined as 2.77 times the square root of the average over all five 100m-sections of the variance of $COF_{meas}$ over all four runs per 100m-section. This repeatability should be $\leq 0.040$.

Furthermore, for each section-system-tyre combination, the average ($COF_{sys}$) of $COF_{meas}$ over the entire 500m length and all five runs is determined. Also, the average ($COF_{ave}$) over all system-tyre combinations for each section is calculated, taking account only system-tyre combinations that meet the repeatability requirements. For both sections, the deviation from group average ($|COF_{sys} – COF_{ave}|$) should be $\leq 0.020$.

For each section separately, a system-tyre combination that doesn't meet the requirements for maximum deviation from the group average must be removed from the $COF_{ave}$ calculation, starting with the system-tyre combination with the largest deviation. After this step a new calculation must be made and once again the above mentioned procedure must be followed until all remaining system-tyre combinations meet the requirements. When more than half of the system-tyre combinations do not meet the requirements, a new round robin test must be performed.

If a section-system-tyre combination does not meet both requirements (repeatability and deviation from group average), the system-tyre combination must not be used for measurements on the surface category (dense or porous) of that section.

# 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.

1.3. 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 shall comply with the example below, with the black class indicators indicating the proper class for each performance criterion.