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Influence of road surface on tyre rolling sound emissions

Background information for the draft Resolution on road surface labelling

Submitted by the expert from the Netherlands*

This document provides background information for the draft Resolution on road surface labelling - Guidelines for the performance characterisation and classification of pavement surfaces (ECE/TRANS/WP.29/GRB/2018/8).

* 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.

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Background information on the Resolution on Road surface labelling - Guidelines for the performance characterisation and classification of pavement surfaces

Contents

1. Introduction

1.1. Performance characterisation of pavement surface layers, regarding environmental protection (tyre-pavement noise), safety (skid resistance), energy efficiency (rolling resistance) and service life is necessary for several purposes. These include contract specifications, pavement product comparison and pavement product improvement. As several different characterisation methods exist, there is a need for a harmonised and easy-to-understand classification method, similar to the performance labels that are defined for several consumer products. Particularly relevant is the labelling of pneumatic tyres, regulated in Directive 1222/2009/EC of the European Commission. This document describes the background to the Resolution on Road surface labelling, TRANS/WP.29/2018/8. The recommended road surface label complements the tyre label.

1.2. 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.

1.3. 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).

1.4. This document describes the background to a label 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:

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

1.5. 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 standardised as well, or limited in range, or variations should be corrected for.

1.6. At present there are no European harmonised 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 harmonised methods are not yet available, this document motivates the use of certain characterisation methods, and boundaries for label classes (A to G inclusive). When harmonised methods become available, they should preferably be adopted to replace the present methods.

1.7. 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 kilometre y.y and z.z.

1.8. 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.

1.9. 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.

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 (CO_2) 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, CO_2 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 optimised for a particular type of road surface, but might be less optimised for another type. Alternatively, a road surface can be optimised 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 optimised 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 label 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. The use of the road surface label is 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 realise, 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. Discussion of 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 harmonised 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: standardised tyres under standardised 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 recognised 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 recognised 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 lifespan[1]. 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 recognised that the European Commission (EC) has asked CEN Technical Committee 227 Road materials, Working Group 5 pavement surface characteristics to develop a harmonised European method for acoustic characterisation of road surfaces, to be used in 2015/996/EC. As that method is not yet available, a non-harmonised 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 German SKM (SeitenKraftMessung in German, Sideways Force Measurement) and British SCRIM (Sideways force Coefficient Routine Investigation Machine) device [CEN/TS 15901-8 and -6, and prEN 13036-2a] are very similar and the most commonly used in Europe. However, procedures for measurement (and correction for temperature and season) differ between the United Kingdom [Design Manual for Roads and Bridges (DMRB) - HD 28/15 Skidding Resistance] and Germany [TP Griff-StB 07 (SKM)]).

4.3.3. Many other devices and procedures exist to measure wet skid resistance, but on road pavements in Europe, none are more widespread than SCRIM/SKM.

4.3.4. 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.

4.3.5. 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.

[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.

4.3.6. 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.

4.3.7. 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.

4.3.8. 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 characterise 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:

(1) $$RRC_{,Ttyre\ corr,Ttyre\ ref\ 25°C} = RRC_{uncorrected} - 0.17 \cdot (25 - T_{tyre\ wall\ side})$$

(2) $RRC_{Tair\ corr,Tair\ ref\ 20°C} = RRC_{uncorrected} \cdot \left(1 + 0.014 \cdot (T_{air} - 20)\right)$

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:

$RRC_{RR,ref\ Ttyre\ corr} = 9.50$ [kg/t]

$RRC_{RR,ref\ Tair\ corr} = 8.58$ [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]:

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

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.