CEDR Transnational Road Research Programme
Call 2018: Noise and Nuisance

Funded by Belgium, Denmark, Ireland, Netherlands, Norway, Sweden, United Kingdom

STEER

strengthening the effect of quieter tyres on european roads

D4.1: Recommendations for improved representativity of tyre labelling

Work package: WP4

Type of document: Deliverable

Date: 2022-04-11

Main institutions responsible for this deliverable: BRRC, SINTEF, VTI

Other Partners:

G+P

Nokian Tyres

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CEDR Call 2018: Noise and Nuisance

STEER: Strengthening the Effect of quieter tyres on European Roads

D4.1: Recommendations for improved representativity of tyre labelling

Due date of deliverable:	2021-09-30
Actual submission date:	2021-09-30
Draft submission:	2021-09-30
Final submission:	2022-04-11

Start date of project: 2019-12-01

End date of project: 2021-12-31

Author(s) of this deliverable: Luc Goubert, Truls Berge and Ulf Sandberg

Main author/person responsible: Luc Goubert

Second author: Truls Berge

Third author: Ulf Sandberg

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Executive summary

The noise label on a tyre is assigned by means of a pass- by measurement on a reference pavement which is described in an ISO standard which originates from 1994, has been revised in 2014 and is currently again under revision. The properties of the ISO track have not changed a lot during these revisions, and it remains a very shallow textured, hence smooth surface. The surface was originally meant to minimize the tyre/road noise to measure as precisely as possible the engine noise emission of the tested vehicles. Later, the ISO test track has, nevertheless, been chosen for the measuring of the tyre noise and the assigning of the tyre noise label. Although the ISO test track is very smooth, a relatively large span on the mean texture depth is allowed.

In this document, a survey is further made of the common texture on roads in Europe, in particular in the funding countries. Only fragmentary data are available, although there is a comprehensive measurement campaign of the texture in some Northern and Central European countries available. For the sake of simplicity, texture is classified as smooth, medium and rough. It is shown that for the considered countries, most high-speed roads are in the medium texture category and a smaller fraction in the rough texture category, which is logical as a minimum texture is necessary to avoid the risk of aquaplaning. Local roads are in some countries mostly smooth textured but in other countries mainly medium textured. It can be concluded that the smooth ISO test track is by far not representative for the common pavement types used on the high-speed roads and neither for a significant fraction of the local roads. For another fraction of the local roads, it is.

Several independent studies carried out in Norway, the Netherlands and Switzerland, investigating to what extent a smooth surface like the ISO surface can acoustically “rank” tyres in a way which is representative for real life pavements used in Europe, yield fairly consistent results. The ranking found on an ISO test track can be well reproduced on other smooth textured pavement, such as low noise pavements (thin asphalt layers, two- layer porous asphalt), whereas the ranking found on common, medium textured pavement (such as SMA 11, SMA 16, …) is not consistent with the ranking found on the ISO test track. This is true for car tyres; for truck tyres even on medium textured pavements the acoustic ranking is reasonably well reproduced.

A third and potentially important reason for the lack of representativity of the tyre noise label is the following: the labelling regulation does not require that all variants of tyres (dimensions, load index, speed index) within a certain family (line) are tested. Therefore, it is common that tyre manufacturers save money by testing only the noisiest tyre(s) within such a family, and then giving the other tyres the same label. Tyres within one family can potentially differ very much, but all types get the noisiest label, limiting the ability of consumers to choose the quietest tyre and jeopardizing further the correlation between real life noise emission and the tyre noise label. It was the intention of the STEER consortium to conduct a measurement campaign to quantify this effect, but this was not included in the project by CEDR. The measurements will be carried out anyway by TU Gdansk at the expense of partner VTI, but these results are not available yet when this deliverable is finalised. Depending on the outcome of the measurement campaign, the STEER consortium will do recommendations to reduce drastically this “tyre family effect”.

Based on the findings described in this deliverable, the authors recommend choosing a second reference surface for noise labelling of tyres with a higher texture and to standardize it. A good candidate for such a second, rough reference surface might be the SMA 11, which now is part of the virtual reference pavement in the common European traffic noise prediction model CNOSSOS-EU, as it is considered as a common pavement used (more or less) in all European countries. This pavement type must be more precisely defined if it shall be standardized for noise-measuring purposes, since the present CEN standard includes too high tolerances.

A second important recommendation is reducing the range of macrotexture in the existing ISO 10844 the current MPD range of 0.30-0.70 mm to 0.40-0.70 mm.

Depending on the outcome of the measurement campaign of the “tyre family effect”, the consortium will recommend doing nothing (if it turns out to be small) or – if it would be significant – to introduce the obligation to test all members of a tyre family but with a quick and cheap method, namely on a laboratory drum, covered with a replica of an ISO 10844 surface.

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1 Introduction

The labelled noise values on tyres should be well correlated with the noise emission of the corresponding tyre samples on the market when rolling on typical, actual road surfaces in Europe, particularly on the pavements applied on the main road networks. A tyre label – albeit reproducible – but uncorrelated to real life noise emission is useless. This problem potentially applies to both representativity of the tyres (if only some of the tyres in a certain line are tested) and of the ISO 10844 standard reference surface [ISO, 2014]; if the latter ranks tyres differently than the major road pavements do. An additional potential problem of representativity is that tyres during labelling have much lower inflation pressure than the same tyres should have in actual traffic.

This deliverable summarizes the results of studies carried out in the frame of the STEER project regarding the influence on the representativity of tyre noise label of:

- The ISO 10844 test track
- The tyre inflation pressure and load during the measurements
- The temperature during the measurements
- The testing of only one tyre type of a “family” of tyres

2 Representativity issues with respect to the ISO 10844 standard reference surface

A comprehensive literature review was conducted on the representativity of the ISO 10844 test track for the European roads and full details can be found in [Goubert, 2021]. The main conclusions of this study are as follows:

Regional distribution of surfaces.

- Secondary and local roads and streets in European countries with a "moderate" climate (The Netherlands, Belgium, Germany, Denmark, the non-mountainous part of Switzerland) generally have pavements, such as thin surface layers, SMA and dense asphalt having relatively small maximum aggregate sizes, which have a relatively "smooth" macrotexture, as long as they are relatively recently built and not worn. Smooth-textured pavements are useful for lowering tyre/road noise and rolling resistance compared to rough pavements [Sandberg, 1987].
- However, pavements used on the highway network (such as SMA 11, SMA 14 or exposed aggregate cement concrete pavements) usually have a "medium" texture for safety reasons, i.e. in order to ensure good grip at high speed under rainy conditions. In Sweden, Norway, Finland, with their colder climate, studded tyres are used in wintertime, pavements with larger aggregate sizes are used (typically SMA 16 or remixes of those) for a better wear resistance, provided a high-quality aggregate is used. All secondary and high-speed roads belong to the medium or even the rough texture class. The smooth ISO 10844 surface has no resemblance to the medium- or rough-textured highways in the north European climatic zone.

Representativity of ISO test track:

- The smooth surface of the ISO test track is wanted because the influence of the surface has to be kept to a minimum in order to optimize the noise on the tyre and vehicle side.
- The surface texture of ISO test tracks can in principle vary over a wide range (MPD from 0.30 to 0.70 mm). The entire range can be considered to fall into the same texture category as the "smooth-textured" surfaces mentioned above. The lower range has extremely smooth texture; which are usually unwanted on roads, for safety reasons (wet grip, especially on high-speed roads). In some countries (especially with colder climates) these ISO surfaces are not at all representative of actual road or street surfaces. The problem is that most ISO surfaces are likely to be constructed with macrotexture in the extremely low range; i.e., around 0.4 mm or even lower. A study about aging of AC8 pavements (similar to ISO) shows that with time they become more rough and not smoother.
- The extremely large range (MPD of 0.70 mm is no less than 2.3 times 0.30 mm) allowed in the ISO 10844 is a problem as it means that noise measurements on surfaces having MPD near the lower limit may give quite different results than on surfaces near the higher limit. It contributes to the uncertainty of such noise measurements.

Performance of tyre labels on different surfaces.

- What may to some degree "save" the performance and use of the very smooth-textured ISO surface is if tyre/road noise measured on these will rank tyres in a similar way as on roads and streets in service. This has indeed been demonstrated in some projects, yielding a fair to reasonable correlation between measurements on ISO test tracks and smooth pavement types.
- Nevertheless, and opposite to the previous paragraph, for passenger car tyres (C1), there appears to be a poor – in fact hardly existent – relation between noise emission on the ISO test track and noise emission on the medium- or rougher-textured, in-service road surfaces. This conclusion is robust, as it is based on data from the old Norwegian/Dutch study from 2005 and has been confirmed later in the NordTyre project.
- A more recent Swiss study seems to further back up the earlier conclusion that a smooth surface can rank tyres (for noise emission) in a similar way as other smooth pavement types, but not very well when ranking tyres on rough textured pavements.

- For truck tyres (C3), there seems to be a better correlation between labelled values and normal road surfaces, also the more roughly textured, such as SMA11. This is probably due to the fact that the noise behaviour of such tyres is less dependent on the road surfaces characteristics, such as texture.

An overall conclusion is that ISO surfaces may differ substantially in texture (which may vary by a factor of 2.3 between the smoothest and the roughest) and that the smoother range of such surfaces have little or no resemblance to the surfaces of roads or streets in service. When the ISO 10844 standard was originally designed, the standard included a warning that it was not suitable for use to measure the noise emission of tyres [ISO, 1994 (it was later removed, probably for political reasons, as legislators later accepted it for tyre/road noise measurements). ISO surfaces today can have even smoother texture than allowed in the original standard. Even though this leads to questions regarding representativity the advantage is that the smooth surfaced ISO track helps minimize the influence of the test track on tyre and vehicle noise optimization.

3 The influence of tyre inflation pressure and load on the representativity of the tyre label

The noise labelling of tyres is done according to UN ECE Reg117, with 4 tyres mounted on a test vehicle, measured on the ISO 10844 surface. The tyre inflation pressure and load is defined in this regulation, based on the load index of the tyre. Based on these requirements, the inflation pressure for C1 tyres can often be in the range of 150-200 kPa. This is lower than the recommended inflation pressure for M1 vehicles, normally around 220-260 kPa. A lower inflation pressure can increase the contact area between the tyre treads and the road surface, and this may increase the noise level, depending on the road surface type. To investigate the influence of the tyre inflation pressure, a test of 6 different C1 tyres has been performed at the drum facilities of Gdansk Technical University (GUT), where the inflation pressure was varied from 180 kPa to 240 kPa, at a test speed of 80 km/h. A replica of the ISO surface was used for the tests.

The influence of test load has been made in a previous project (LEO) between GUT and SINTEF [Berge et al, 2016], and only the main results are presented in this deliverable. The detailed results from the tyre inflation pressure and load measurements have been given in the STEER Internal report, [Berge, 2021].

In Figure 1 and Table 1 the main increase in the measured noise level, due to changes in the tyre inflation pressure reduced is presented.

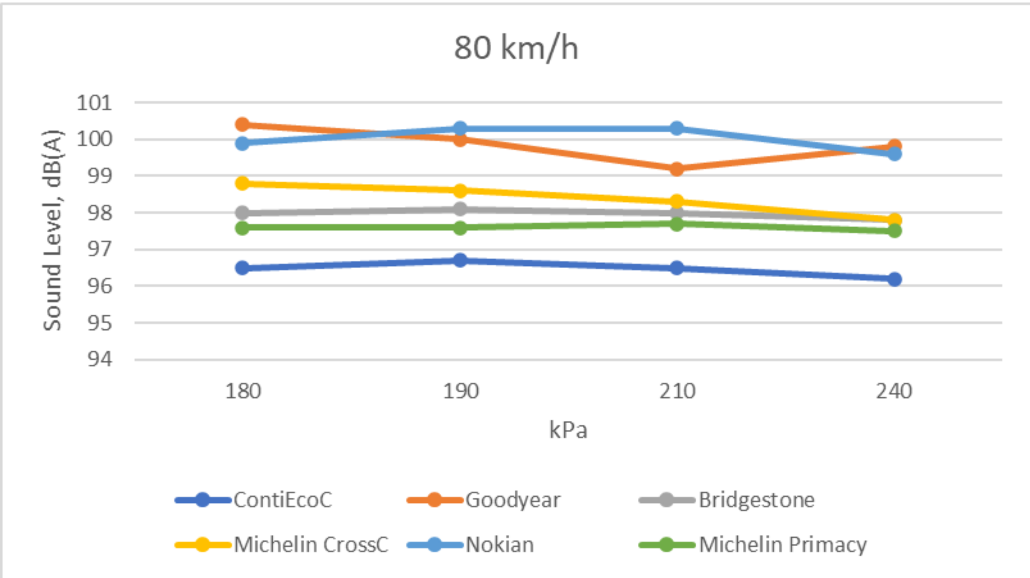


Figure 1: Tyre inflation pressure influence on measured noise levels for 6 C1 tyres

Table 1: Maximum increase in A-weighted sound level due to reduced tyre inflation pressure. Speed = 80 km/h

Tyre	Type	Dimensions	Increase in dB(A)
Conti EcoContact 6	Summer	175/60 R19	0.3
Goodyear EffG Perform.2	Summer	205/55 R16	1.2
Bridgestone Ecopia EP500	Summer	175/60 R19	0.3
Michelin CrossClimate+	All-season	205/55 R16	1.0
Nokian Hakkapeliitta R3	Winter	225/55 R16	1.0
Michelin Primacy 4	Summer	205/55 R16	0.2

For the overall A-weighed sound level, three of the tyres showed a significant influence of the tyre inflation pressure in the range of 180 to 240 kPa. The sound level increased in the range of 1-1.2 dB, when the inflation pressure was reduced from 240 kPa down to 180-190 kPa.

The ranking of the tyre based on the noise label value do not change within the tyre inflation pressure variation tested in this project.

In the LEO project, the influence of the loading of the tyres was investigated for 11 C1 summer tyres. This test was made on normal trafficked roads (SMA8-SMA16 surfaces) in Norway and a SMA8 surface in Poland, and not on an ISO 10844 test surface. A CXP trailer was used for the test, which means that the test conditions differ from ECE Reg.117 (microphones close to the tyres and a single tyre tested). However, the results should give an indication on the sensitivity of the tyres for the loading, within the range of extra loading used in the test.

The reference load of all tyres was the "standard" loading of the CPX trailer used for the test (339 kg). This loading is between 50 and 82 % of the loading according to the individual load index of the test tyre. Then, between 53 and 90 kg was added to the trailer, depending on the tyre used. The loading then increased between 15 and 26 %, except for one tyre, where the initial loading of 82 % was unchanged during both test conditions. Note that the test requirements for the load of a tyre according to Reg.117, is that the individual loading of each tyre on the vehicle axles shall be within 50 to 90 % of the reference load as indicated by the load index and the average load of the test vehicle shall be within 75 ± 5 % of the reference load. Thus, both test conditions are within the load specifications of Reg.117.

The measurements show that on the average, the noise ***increased*** with 0.55 dB on Norwegian SMA-surfaces. However, some of the tyres are more sensitive to the loading of the tyre than others, as shown in Figure 2.

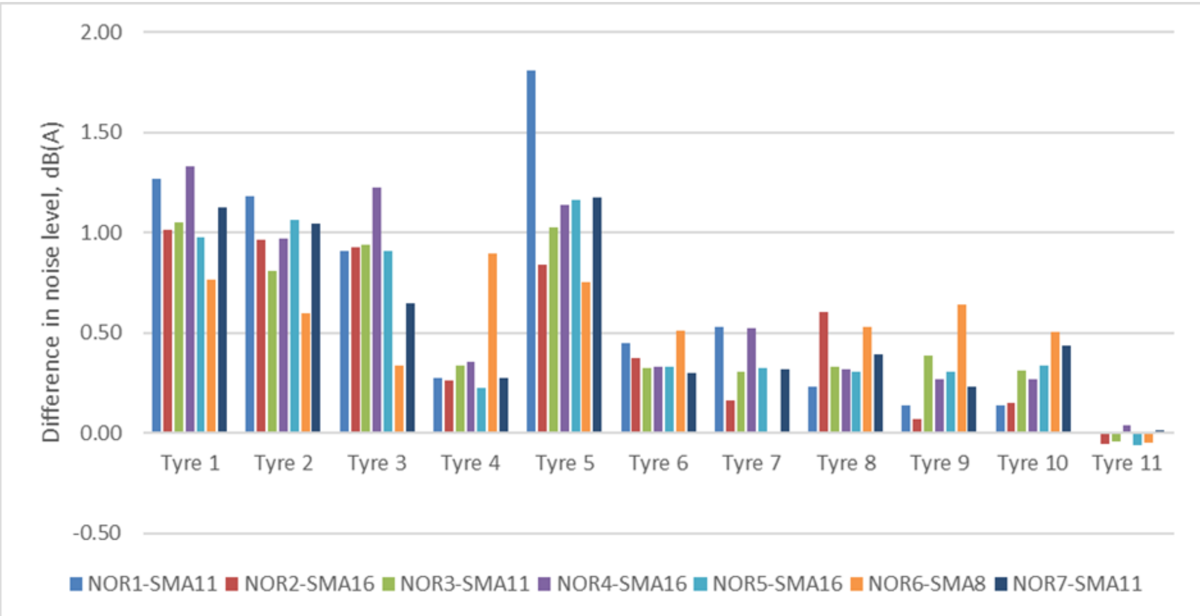


Figure 2: Change in sound level on 7 SMA surfaces, due to added load [Berge et al., 2016]

The label values for these 11 tyres varied from 68 dB(A) (tyre 7) and 74 dB(A) (tyre 4). Two of the tested surfaces were SMA8 (one in Norway and one in Poland). Both these surfaces were quite new surfaces and not exposed to any winter conditions or studded tyres (in Norway). A smooth SMA8 surface can be considered as relative similar to the ISO 10844 surface, which in principle is a DAC8 surface.

A regression analysis between the labelled values and the measured values did not show any correlation. In fact, the tyre with the lowest label value (68 dB(A)) was in fact one with the highest noise value on the SMA8 surfaces. The extra loading did not improve the correlation and the ranking of the tyres on the tested surfaces compared to the ranking of EU label values.

A general conclusion on the influence of increased tyre inflation pressure and/or the loading of tyres for the representativity of the label, based on these investigations are:

1. The increase if tyre inflation pressure has no effect on the noise ranking of the tyres, compared to the EU noise label values, but some tyres are more sensitive to the inflation pressure than others. Based on this limited investigation on a drum, there seems to be no clear reason to change the requirements of Reg.117, regarding tyre inflation pressure to improve the representativity of the EU noise label system. However, it is recommended to use a more representative tyre inflation pressure which is used for normal traffic conditions.
2. The loading of the tyres seems not to be the main reason for the lack of representativity of the EU noise labelling of tyres compared to the ranking on normal road surfaces.

4 Representativity of one or a few tyres within a tyre line

4.1. Introduction

Since the labelling regulation does not require that all variants of tyres (dimensions, load index, speed index) within a certain family (line) are tested, it is common that tyre manufacturers save money by testing only the noisiest tyre(s) within such a family, and then giving the other tyres the same label. It may also be that a few tyre variants are chosen to represent all variants in a certain range within a tyre line.

To measure only the (estimated) noisiest tyre in a line is perfectly legal, and practical as well, as the measurements for labelling are allowed to be the same as the measurements for type approval. Type approval intends to make sure that a certain noise level is not exceeded. But unfortunately, it does not assign each tyre a representative noise level, only a maximum noise level. The label will then show a noise level which is conservative for most of the tyre variants, but as the real noise level (at labelling conditions) can only be better than or equal to the labelled value, one cannot say that the system is violated from a legal aspect.

This simplification in the measuring system unfortunately means that when consumers select tyres, they will not have the full potential of the labelling system to select the quietest tyres. When such a simplified procedure is implemented, the consumers might in the best case only be able to compare the noisiest tyres in tyre lines, which seriously limits the value of the labelling system.

This problem was originally included in the project application to CEDR. However, CEDR required cuts in the project and this particular part was then cut away, so it was not part of the final project plan. However, VTI considered that this part is crucial for the project and, therefore, applied for a special project dealing with this issue from the Swedish Transport Administration (STA). This was granted to VTI by STA under a special contract with the title “Märkning av bildäck – Effekter av att bullermätning görs på bara en liten andel av däcken” (in Swedish, English translation is ”Tyre labelling – Effects of noise measurements made only on a small part of the tyres”). The intention is that the results shall be used in STEER despite the work is made in a separate project. However, as time was lost due to the need to establish a new project, the results will be useful in STEER only at the end of the project.

4.2. Test method and test surface

Since the measurements require very high repeatability to distinguish between tyres which may not seem to be so different, with less than 1 dB uncertainty, it is virtually impossible to do this in the standard way by coast-by measurements on a car, both for reasons of uncertainty and for project budget. Instead, it was decided to do this in the laboratory of the Gdansk University of Technology (GUT) in Poland, where they have a suitable drum facility with replica road surfaces and where temperature variation and other uncertainty factors can be minimal; see Figure 3. The measurement method will be similar to the CPX method (ISO 11819-2:2017) but adapted for indoor drum measurements. Loading and inflating tyres will be according to ECE R117. Thus, GUT is a sub-contractor here.

It turned out that GUT had removed its old ISO replica surface from the drum facility. Therefore, VTI produced a replica of a newly laid ISO 10844 surface near Skövde in Sweden, which had been approved to meet the ISO requirements. This replica was in plastic which then was transported to Poland where a copy in epoxy was made and fitted on the laboratory drum surface. It turned out that the final replica looks very good and similar to the original surface on the test track (although in another colour). Its texture will be measured and compared to the texture on the test track. The MPD value of the original surface on the test track was 0.40 mm. However, it is not yet known what the value was of the selected 1 m long sample, but this will be measured later when mounted on the drum.

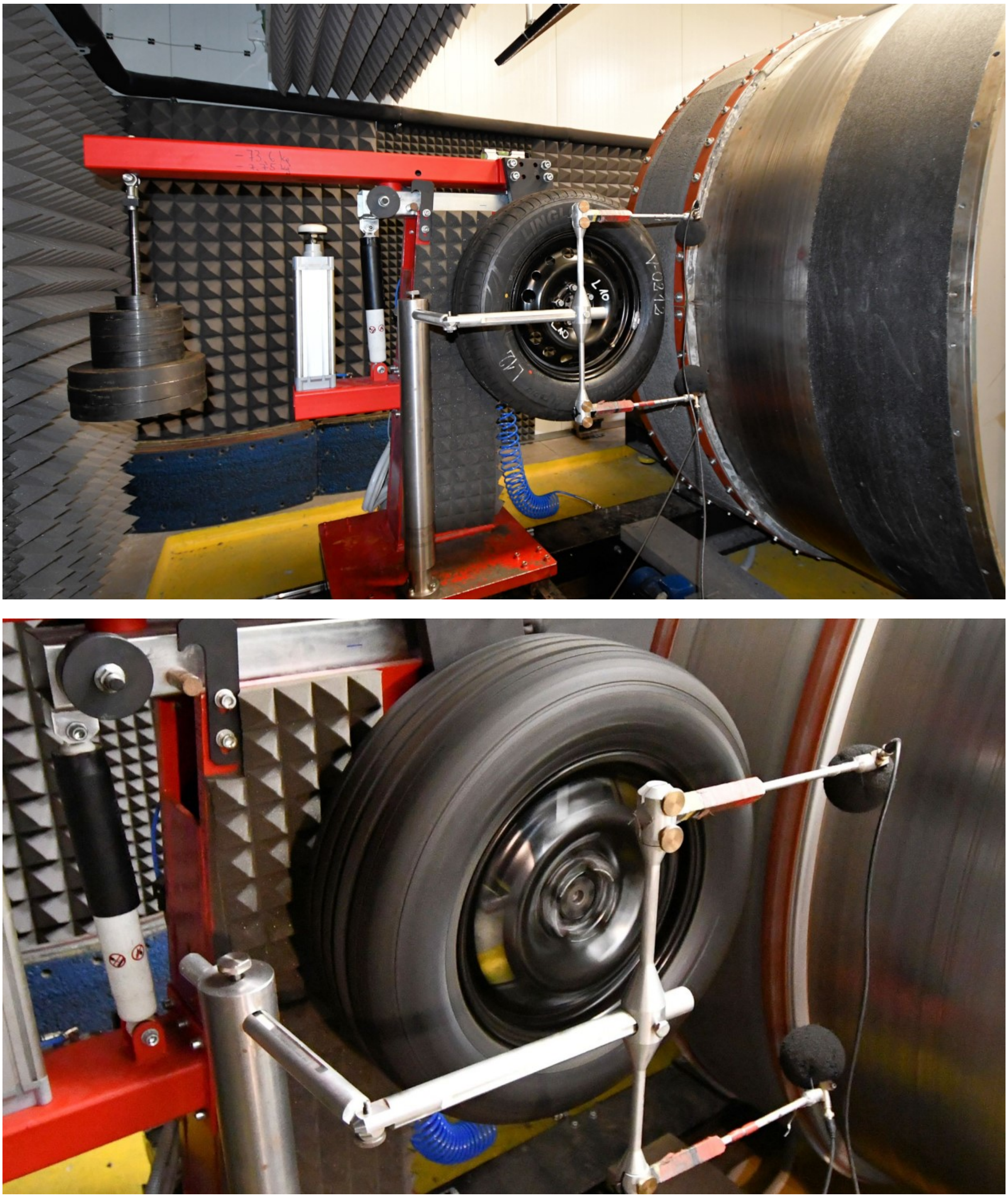


Figure 3: The laboratory drum facility at the GUT in Gdansk. The drum diameter is 2.0 m and it may be loaded not only with car tyres but also with truck tyres. An overview above and a zoom-in on the tyre/drum contact area below. Note the three drum surfaces (from left to right: ISO replica, smooth steel, sandpaper). Note also the position of the microphones.

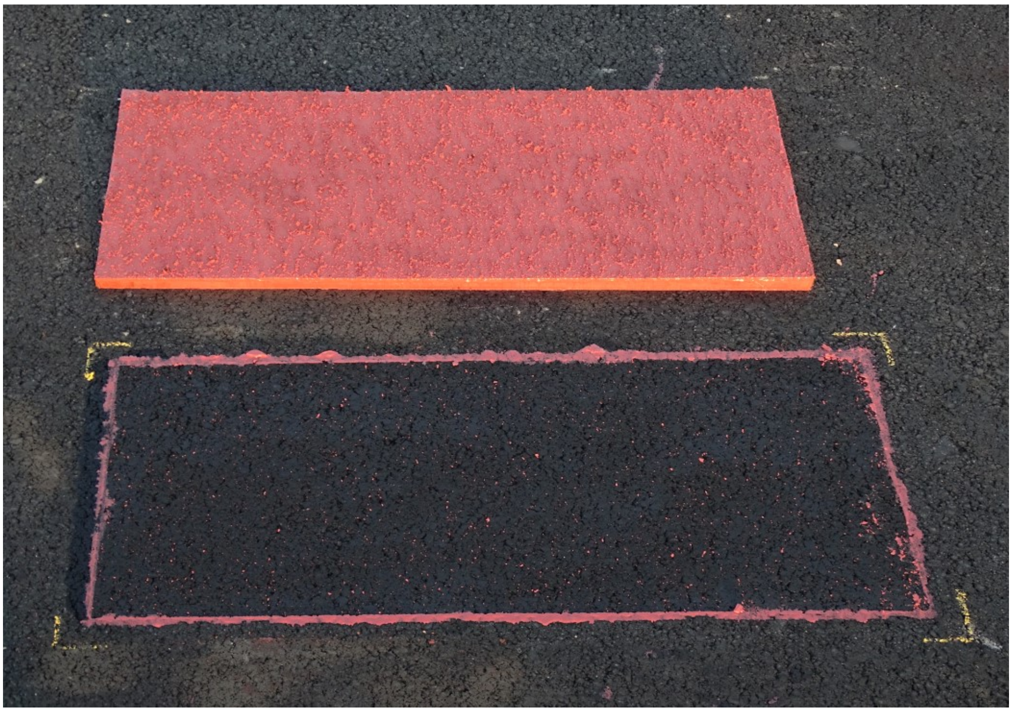


Figure 4: The original ISO 10844 surface on the Hagelberg test track near Skövde, Sweden, along with a mould in plastic of it (lying upside-down) which later was the negative copy for the replica on the GUT drum.

4.3. Test tyres

As test objects in the project, after very careful selection and lots of searching, A major criterion was that the line should include many variants covering a wide range of dimensions, loads and speeds. The project budget allowed a maximum purchase of around 50 tyres. VTI finally selected and purchased 53 car tyres of very different dimensions (e.g., test loads vary from 270 to 670 kg). Three tyre lines were chosen:

- Pirelli Cinturato P1 Verde: representing a European (and international) quality brand
- Yokohama BluEarth-ES (ES32): representing an international (non-European) quality brand
- LingLong Greenmax HP010: representing an international budget brand

A picture of the test tyres, stored in the VTI lab before they were transported to Poland for measurements appear in Figure 4.3.

For each of the selected test objects (tyres) the label values were noted in a table, along with all dimensional data and capacity in terms of speed and load, but also the week of production. Some data about the test tyres are presented in Table 4.1 in condensed form. Attempts were made to obtain as wide ranges within each line as possible (and available).

Table 4.1: Selected condensed data about the test tyres.

Tyre line	Number of tyres	Rim range	Width range	Profile ratio range	Test load range	Max speed range
Pirelli Cinturato P1 Verde	22	14 - 17	165 - 215	50 - 70	294 - 524	190 - 240
Yokohama BluEarth-ES (ES32)	16	13 - 18	145 - 245	40 - 70	270 - 570	190 - 270
LingLong Greenmax HP010	15	14 - 17	185 - 235	50 - 65	361 - 665	210 - 240

Labelled values were first noted from the two large tyre on-line shops, www.dackonline.se and www.dack365.se, from which most of the tyres were purchased. Many were also purchased from a local tyre workshop which offered a substantial discount. When the tyres arrived, it appeared that a few of them did not have a label fixed on them, which is mandatory. In all other cases, except a couple, it appeared that the label values given on the mentioned web sites fitted those which were read from the labels fixed on the tyres. The discrepancy might be due to human error. In case of such discrepancy, always what was fixed on the tyre was used in our tables and analyses.

Figure 4.3: The test tyres stored before measurements.

For at least one dimension for each of the tyre lines, four tyres of identical construction were purchased. The intention with this was to get an idea of how much the measured values for these nominally identical tyres will differ (to study tolerances and uncertainties), but also make it possible later to make measurements with these tyres using the coast-by method, when a full vehicle (car) is used on a test track, in which case of course four tyres are needed.

In several cases, tyres were selected in pairs where the pair had the same dimension but differed in terms of load index, or in speed index (and sometimes also in labelled values). This will give, as a bonus effect, an idea of how much these (assumed) slight tyre modifications will influence tyre/road noise emission.

Before testing, the tyres have been run-in according to ECE R117 by the crew in the TUG lab during the spring of 2021. Noise testing was made in June-August 2021 in the range 70-90 km/h as required in ECE R117.

4.4. Observations when selecting test tyres

The three selected tyre lines demonstrate different policies in terms of noise testing. Here are some observations from the analysis of the labelled values:

- Despite the extremely wide range of tyre dimensions, the Yokohama tyres are all labelled with the same noise level (68 dB). It is very unlikely that this noise level is representative of all the tyres. This is a blatant example of the justification for the project described in this chapter.
- The same is valid for the energy label, which is C for all the tyres. For the safety label, however, the smaller tyres are labelled C while the medium and larger are labelled B.

- All the LingLong tyres are labelled the same; i.e., 71 dB for noise, C for energy and B for safety. However, there is one exemption, namely one of the reinforced tyres, which is labelled 72 dB. The range in dimensions for the LingLong tyres is not as wide as that of the Yokohama tyres, yet it is unlikely that all except one tyre would be correctly labelled at 71 dB.
- The Pirelli tyres are labelled with two noise levels: 17 tyres are labelled 69 dB, while 5 are labelled 70 dB. The latter include one small tyre and four large tyres. Energy labels are A, C and E. Safety labels are A and B (mostly B).

It shall also be recognized that the selected tyre lines were chosen since they have same labels for most if not all of the tyres included in our test. When looking at other tyre lines, the picture is more mixed: some have different (noise) label values, while some (the majority it seems to us) have the same label for the entire line or maybe two levels for two parts of the line (the latter similar to our Pirelli line used here).

4.5. Measurement results

Unfortunately, GUT was not able to deliver the results in time for this deliverable. Therefore, this sub-chapter will be possible to write in October-November 2021, when the results are available. They will be included in the STEER Final Report and in a separate report for the Swedish project.

Please note that this investigation was cut out of STEER due to a decision by CEDR that the budget had to be cut; thus, these results are not formally promised within STEER.

4.6. Implications of the results for STEER

This will be possible to write no earlier than in November 2021, when the results are available and analysed. However, two options are considered a priori:

1. Results will show that the measured noise levels within a line differ at most 1.5 dB (1 dB ±0.5 dB for uncertainty) for tyres that are labelled with the same level. The overestimation of the noise label within a tyre line due to considering only the noisiest tyre is then maximum 1 dB, which is not unreasonable. Then the conclusion is that the present way of labelling is acceptable and need no change.
2. Results will show that the measured noise levels within a line differ more than 1.5 dB (1 dB ±0.5 dB for uncertainty) for tyres that are labelled with the same level. The overestimation of the noise label within a tyre line due to considering only the noisiest tyre is then 2 dB or more. Consumers will then not be able to identify the quietest tyres. Then the conclusion is that the present way of labelling is not acceptable and needs to be changed.

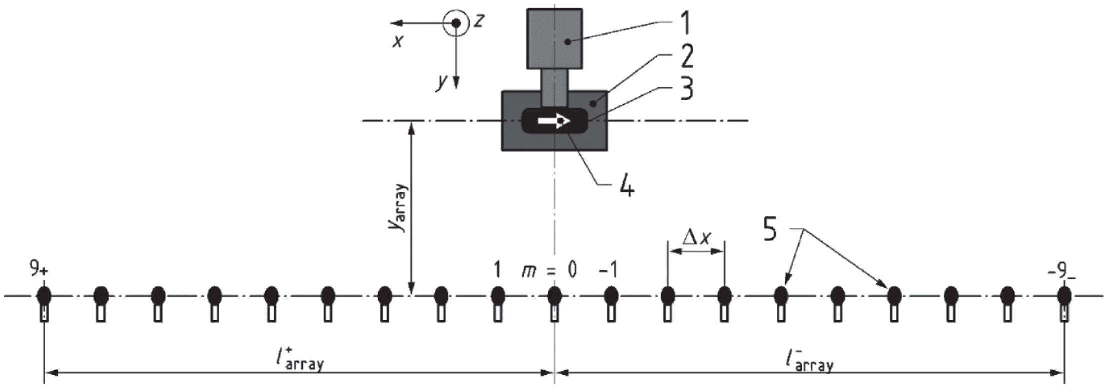
The change, if needed, should mean that each tyre variant within a line should be measured to determine its noise label. How to do this in a practical way is further discussed below.

4.7. Simplified test method to make measurements of all tyre variants practical to conduct

If the second case in the previous sub-chapter will appear to be the result of the experiments, a procedure to measure many more tyres than presently will have to be defined.

The present measurement method, using the coast-by method with test vehicle passing through an ISO 10844 test area (outdoor test track) at speeds 70-90 km/h is already rather cumbersome and time consuming (needs 4 test tyres, a test vehicle, driver, and proper weather), so to extend this for measuring every variant tyre in the line would mean substantial increase of resources and increased cost. Therefore, a much more practical method is proposed, namely measurements indoor in a laboratory, utilizing a drum with appropriate surface and with microphones close to the tyre/drum contact patch. It is the socalled CPX method (CPX = Close-ProXimity) adapted from trailer to laboratory drum conditions. The method, applied on a measurement trailer, is standardized in ISO 11819-2 [ISO, 2017].

A drum method for measurement of tyre/road noise is already under development in the ISO tyre committee; currently available as a draft international standard ISO/DIS 20908 [ISO, 2021]. Discussion about a similar method is also ongoing in a WG of the ISO noise committee (ISO/TC 43/SC 1/WG 42). The 20908 method needs a drum facility, located in an acoustically verified test room lined with sound absorbing material, using several microphones at a distance of around 2 - 5 m from the tyre centre. This is because it is tried to simulate the outdoor coast-by method. The drum surface shall be covered by a replica ISO 10844 surface. Figure 4.4 shows one of the possible set-ups according to the ISO/DIS 20908.



Key

1 rig
2 drum
3 tire
4 rotation direction
5 microphones

Fig. 4.4: Set-up of measurements according to ISO/DIS 20908. The *Yarray* distance is assumed to be at least 1.75 m.

If the tyre manufacturer has access to such a facility as needed for ISO 20908, it is excellent, and the measurements suggested here can be made on this facility. However, the author thinks that the 20908 method is too complicated and resourceful. A simpler method is possible to apply in this particular application, using the tyre manufacturer's already existing laboratory drum facilities. The exception is that it must be equipped with a replica ISO 10844 surface if it is not already having such a surface.

First, it shall be noted that such a facility, especially the simpler variant that we propose, cannot properly measure the noise level valid for the method in ECE R117; i.e. for coast-by running at 7.5 m microphone distance. But it can enough well measure noise emission differences between tyres. Thus, the idea here is to select the tyre which is used for type approval as a reference in this drum method and just measure the difference in noise level against the other tyre variants in that tyre line. Such differences would hardly exceed 4 dB and when measuring such limited differences for tyres of the same line (having rather similar acoustic properties) the uncertainty should be less than 0.5 dB. The difference in noise level compared to the type approved tyre would be used to calculate what the noise label for each tyre variant would be.

It is necessary to use a replica of an ISO 10844 test track surface on the drum, since just plain steel or sandpaper will not give representative noise emission. Such surfaces may be produced in the way described above, but in the future, it is better to produce such a surface by 3D printing, based on a 3D digitization of a real ISO 10844 surface. ISO/DIS 20908 mentions this option. Once a digitized surface profile is obtained, this surface may be used for 3D printing of all drum surfaces worldwide.

Our simplified method is described below in a condensed way:

- A drum facility having a drum with a diameter of at least 1.7 m shall be used.
- The drum shall be covered with a replica of an ISO 10844 surface
- At least two microphones shall be used, at positions relative to the test tyre as described in ISO 11819-2; i.e., at 0.2 - 0.3 m from the tyre contact patch. More of the positions in 11819-2 may be used but are not required. Noise levels of the microphones shall be averaged to get one final result
- The drum surroundings should be properly noise controlled (but with rather modest requirements)
- Drum circumferential speed during measurements shall be in the range 70-90 km/h for C1 tyres
- The tentative name of the method is suggested to be “Differential tyre noise test on laboratory drum”.
- Quality of the measurements should be assured by the Type Approval Authority as already foreseen in chapters 3.3 to 3.5 of Regulation no 117 (2016/1350)

Most tyre manufacturers already have such a facility (except maybe for the replica ISO surface and with different microphone positions) and they most probably already test their tyres (all variants in the line) in the development process; thus, the extra labour and time consumption for this task will be limited. It may even mean less labour and costs for some since they will not need to test so many tyres on the outdoor test track. Instead, they can rely on this differential noise testing method.

5 Representativity of measurements at temperatures very different from the temperatures of operation

5.1. Problem statement and discussion

A major problem for the labelling system is that winter and normal tyres (the latter referred to here as "summer tyres") are optimized for operation in very different seasons but are tested and labelled (for noise) under summer or at least not winter conditions; ideally and usually around or above 20 ^{o}C. To compensate for the effect on noise of the varying temperatures, temperature corrections are made. This is acceptable for summer tyres since the temperature range (from 5 to 40 ^{o}C) is the range in which summer tyres are supposed to operate but is arguable for winter tyres which normally operate at temperatures from -20 to +10 ^{o}C.

Furthermore, summer tyres are often used at temperatures around or not far above 0 ^{o}C, which is outside the temperatures currently allowed for testing. Also, non-studded winter tyres are often used also in summer, despite this has several disadvantages.

This issue is a representativity problem since measured levels for labelling at "summer temperatures" are not necessarily representative of operations at "winter temperatures" of (say) from -20 to +10 ^{o}C even though temperature corrections overlap in the range 5-10 ^{o}C.

The temperature correction is designed for having in mind that measurements are made in the range 5 to 40 ^{o}C (road temperature) referenceable to a nominal temperature of 20 ^{o}C but does not say anything about how tyres operate in winter temperatures. Of course, it is not impossible that noise ranking of winter tyres at 20 ^{o}C has a good correlation to noise ranking at (say) -10 ^{o}C, but there is no published information available about this. However, knowing how sensitive tyres are to low temperatures, and that this depends on tyre materials optimised for different seasons, the correlation between performance at very low temperatures vs at 20 ^{o}C may not be so good.

Tyres designed to be used in winter climate include such different types as all-season tyres, winter tyres optimized for mid-European conditions and winter tyres optimized for Nordic winter conditions. Especially, the all-season tyres are currently increasingly popular (probably since you do not need to change tyres two times per year and do not need storage room for a set of tyres). However, optimizing for a wide temperature range will mean that there will be better optimizations for more limited ranges. The question is now: at what temperature range should all-season tyres be tested in order to be fairly compared to summer tyres at moderate to high temperatures and fairly compared to winter tyres at low temperatures?

Consequently, testing at "not representative" conditions can be a serious issue that can compromise the aim of the noise labelling system. At the present time it is arguable if the noise limits and labelled levels are representative of actual winter conditions and is fair in the ranking for winter tyres, and the case for all-season tyres is unclear.

To find out how representative and fair the present noise labelling is for winter and all-season tyres operating in their intended climate, new research is needed. This should also include summer tyres legally operating in winter climate.

Ideally, the tyres should be tested in the temperature range for which they are optimized and intended to operate. It is a similar problem as for labelled wet grip performance of winter tyres, which has resulted in the inclusion of new labels for winter tyre safety. Unfortunately, we expect that this problem is much worse for rolling resistance since temperature effects have higher influence on rolling resistance than on noise emission.

As long as we do not know how severe this representativity problem is, one must consider the current labelling levels for winter-optimized tyres as having significant extra unknown uncertainties.

5.2. Recommendations

At the moment, STEER cannot recommend that tyre noise testing (for labelling) should be made at winter temperatures since we do not know how severe the problem is. Winter testing may also complicate testing for some tyre manufacturers. No temperature corrections are available for low temperatures. In the future, the solution may be to go indoors with all noise testing, using a laboratory where temperatures can be set at a desired level (say 0 and 20 ^{o}C) and tyres are tested at a temperature for which they are designed to operate.

The recommendation is that research is done to study how tyre noise properties change over a wide temperature range, ideally including the temperature range from -10 to +40 oC of air temperature. This should include studying the ranking of various types of tyres based on low vs high temperatures. Such studies may be funded by transport and environmental authorities, such as NRA:s.

When it comes to testing in a more representative and fair way for winter tyres, it is difficult to make realistic recommendations; except that research is needed.

One would need to make experiments to determine the performance of tyres in summer temperatures versus winter temperatures and how such performance may differ among tyres. Testing at low temperatures could be made in conjunction with ordinary winter tests in northern Europe if an ISO 10844 surface would be paved there and kept free from snow or ice. Such test may much easier be made in a laboratory setting, with a drum covered by a replica of an ISO surface and where temperature may be varied. It would be possible to do at the facility of Gdansk University of Technology. This can be funded by for example the Nordic NRA:s.

The same research needs apply to testing on wet versus dry road. For example, if microphones were set-up on both sides of the wet grip testing track (UN ECEC R 117), noise measurements could be done in the same way as for the regular noise test. It should be checked if such conditions may be reproduceable. The mentioned laboratory facilities at VTI in Sweden and BASt in Germany could also be considered for research on wet versus dry surface noise emission; even while varying temperatures from 5 to 20 ^{o}C. Also this can be funded by NRA:s.

6 Recommendations to improve the representativity of the tyre label

Regarding the ISO 10844 test track, the authors make the following recommendations:

In order to investigate the representativity of the tyre labels in future studies, regional differences in predominance of pavements should be considered. Evaluation regarding representativity of tyre labels should only be made taking into account the predominance of a certain pavement in a European context.

A second reference surface for noise labelling of tyres with a higher texture could be considered to increase the representativity of tyre labelling in countries with predominantly rough road surfaces. This was actually suggested at earlier ISO meetings (it was on the working program as early as in 2006) but was dropped when the standard was updated. There was no formal voting leading to this change of working program, but the most obvious reason is that no resources, especially from the tyre industry was available to implement additional standardization workload for a second reference surface. As a second surface may increase tyre industry costs of testing, this can also be a reason for no present interest in a second test surface among the tyre industry. One possible second reference pavement, actually considered in the ISO work 20 years ago, may be the SMA 11 which now is part of the virtual reference pavement in the common European traffic noise prediction model CNOSSOS-EU, as it is considered as a common pavement used (more or less) in all European countries, and also was proposed in the ROSANNE project. However, this pavement type must be more precisely defined if it shall be standardized for noise-measuring purposes, since the present CEN standard includes too high tolerances. It must be recognized that introducing a second ISO test surface, will double the number of required measurements per tyre, although the workload is largely influenced by all preparations of tyres and test vehicles which are needed irrespective of number of test surfaces. If a second test surface is located as an extension of the present ISO test surface, the extra workload is very small as the measurements on both surfaces can be made in the same runs.

Moreover, the range of macrotexture in the existing ISO 10844 may be reduced from the current MPD range of 0.30-0.70 mm to 0.40-0.70 mm, in order to reduce the acoustic variability of the ISO test tracks. The lower limit could even be an MPD of 0.5 mm, but then the upper limit should be changed to (say) 0.8 mm.

7 References

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