NordTyre – Car tyre labelling and Nordic traffic noise

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ABSTRACT

Labelling new vehicle tyres is mandatory in all EU and EEC countries. The label includes wet grip, rolling resistance and noise. Noise labels are based on measurements made on standard test tracks with asphalt concrete having small aggregate. Nordic road administrations initiated a project on the tyre/road contribution to traffic noise emission from their roads. The long term aim is to clarify which combinations of tyres and pavements yield the lowest noise emission throughout their lifetime. In the initial stage it shall be clarified if labelled noise levels are representative of the tyre/road noise emission from new tyres on typical Nordic roads, and if there is correlation between the noise emission and tyre abilities concerning rolling resistance, wet grip, snow grip and ice grip. 31 sets of car tyres were procured to represent the tyre population. CPX trailer noise measurements were made on 31 different road surfaces in Denmark, Norway and Sweden. The preliminary main conclusions are that the labelling system needs to be improved to obtain noise levels representative of real noise emission, and that low noise levels are not contradictory to high fuel efficiency or road grip.

Keywords: Tyre/road noise, Labelling

1. BACKGROUND AND AIM

A new Directive on tyre/road noise came into force 1 November 2012 [1]. Road administrations need input on the effect of the Directive on tyre/road noise in their effort to reduce noise annoyance and to influence future regulation of tyre/road noise emission. Nordic road authorities decided to carry out a project to

- establish a platform based on scientific evidence on the tyre/road contribution to traffic noise emission from roads in the Nordic countries, clarifying which combinations of tyres and pavements will yield the lowest noise emission throughout their lifetime, influencing the environment along roads and highways. This knowledge shall be the basis for decision making concerning actions to mitigate traffic noise in the Nordic countries
- clarify the noise emission from tyres, including Nordic winter tyres (Tyre Directive classes C1, C2 and C3) and its possible correlation with rolling resistance, wet grip, snow grip and ice grip. These results can be used to define new tyre noise level limits that could be used in a future revision of the EU tyre labelling, Reg (EC) No1222/2009, and the tyre noise limits in Reg (EC) No 661/2009, including rolling resistance, and supplementing the labelling of wet grip with labels of snow grip and ice grip

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2. Method applied

We selected representative tyres and pavements, measured CPX noise levels and other tyre characteristics and looked at the relation between manufacturer's noise labels and noise levels measured on the selected pavements. These results were finally used to simulate "Effect scenarios", i.e. scenarios of what could be obtained by replacing existing pavements and by regulating tyre/road noise.

3. LIMITATIONS

Only new car tyres (tyre class C1A, B and C in [1]) were considered in the present part of the project. Plans are to extend the project to also deal with lorry tyre noise.

4. SELECTED TYRES

The overall intention was to select an appropriate number of passenger car tyres to represent the tyres applied on Nordic cars. Based on interviews and on the availability of tyres from different tyre lines at the project start in May 2012, a total of 31 tyre lines were procured (29 normal tyres and two special tyres). The tyres represented a cross-section of 1) Small / Medium / Large tyres; 2) Summer / All year / Winter tyres; and 3) Premium / Medium / Low price tyres. Reference is made to the project report [2] for details. The tyres are believed to be representative of the vehicle fleet tyres in the Nordic countries, but we cannot prove that they are in fact the most representative tyres.

Tyre prices ranged from 54 to 139 € per tyre, excluding rim and V.A.T. The sizes investigated were: "small" (typically 175 mm wide on 14" rim); "medium" (205 mm wide on 16" rim) and "large" (225 mm wide on 16" rim). The range of labelled noise levels was 66 – 75 dB. The labelled rolling resistance classes were B – F, and the labelled wet grip classes were A – E.

5. SELECTED PAVEMENTS

A number of pavements were selected to represent the spectrum of wearing courses encountered on Nordic roads, with slightly higher representation of quieter pavements than of pavements known to be associated with high traffic noise levels. Descriptions of the pavements can be found in [2], i.e. pavement designation, construction year, mean profile depth (MPD) and mega texture level (L_{ME}).

Road sections built in 2010 at Igelsø in Denmark could demonstrate the properties of five Danish noise reducing thin asphalt layers and one reference pavement. Six sections of highway M64 (Herning-I) were selected among 12 sections constructed in 2006, and three sections were selected among eight test sections and a reference pavement built in 2008 on highway M68 (Herning-II).

Five Norwegian road sections built in 2005 at Mastemyr with SMA pavement having different maximum aggregate and five road sections at Hønefoss with dense asphalt concrete having various maximum aggregate sizes were selected. The latter were built in 2005 except for a section with AC 11d built in 2002. All Norwegian road sections had been worn by vehicles with studded tyres.

Four Swedish road sections built in 2010 at Höör in southern Sweden were selected, i.e. SMA 11, SMA 8, AC 11d and AC 8d. These were supplemented by a section with SMA 16 built in 2006 at Hörby, also in Southern Sweden. These sections had all been trafficked by vehicles having studded tyres.

6. MEASUREMENT RESULTS

The following measurement results were collected during the summer 2012, except for the results of braking performance tests which were made in February 2013:

CPX noise levels were measured on a laboratory drum, primarily to find out whether there was a difference between tyre/road noise levels on the right and left side of the tyre [3].

CPX noise measurements were made by the Danish Road Directorate (DRD) on pavements in Denmark and Sweden [4], SINTEF measured CPX noise levels on pavements in Norway [5]. A total range of 11 dB was found in noise levels between the noisiest tyre on the noisiest pavement and the quietest tyre on the quietest pavement.

The Technical University of Gdansk (TUG) measured rolling resistance coefficients on its drum facility [6], and Test World Ltd measured snow and ice grip for winter and all-year tyres [7].

7. DATA ANALYSIS

Initially a Multiple Factor Analysis (MFA) was carried out to identify patterns in the noise data.

This is mentioned in [2]. Later it was decided to give priority to looking at "pavement families" rather than at the "pavement clusters" identified in the MFA, when determining the potential change in tyre/road noise a road administration can obtain by replacing an existing pavement with a quieter type.

8. MEASURED NOISE LEVELS VS NOISE LIMITS AND NOISE LABELS

8.1 Compliance with Directive noise limits

Figure 1 shows the manufacturer's labelled noise level and the Directive noise limits [1] for each of the 29 normal tyres. Noise limits differ for tyre class C1A and C1B-C and for summer (S) or all-year tyres (A) or winter tyres (W) as indicated in the figure. Almost a third of the tyre label values exceed the Directive noise limits. Tyres were procured in May 2012, i.e. before the new noise limits came into force 1 November 2012, while manufacturers' labels were read off their websites in January 2013.

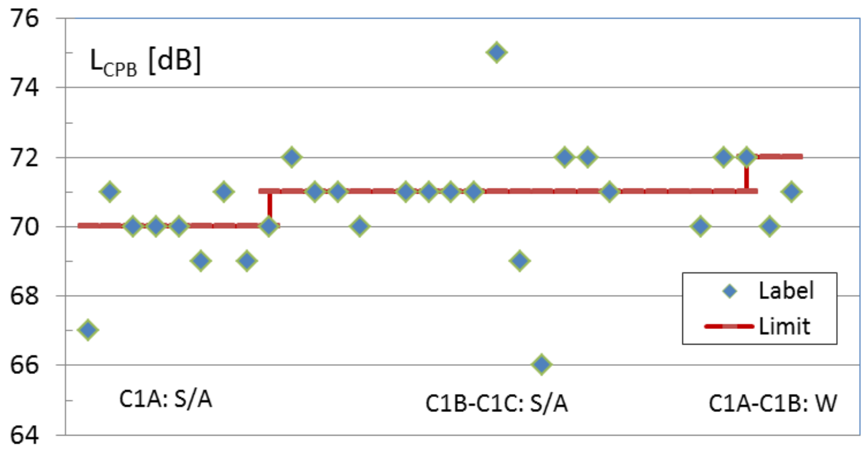

Figure 1 – Noise label values compared with the noise limits in the new Directive [1]

8.2 Relation between CPX noise levels and noise labels

In the present project all noise levels were measured with a CPX trailer. The labelling of car tyres is not based on noise levels measured in this way but as Controlled Pass-By (CPB) measurements of the noise levels from a car coasting past a fixed microphone. According to [8] the difference between the CPX noise level and the coast-by noise level L_{CPX} - L_{CPB} = 22.5 dB on a dense road surface while L_{CPX} - L_{CPB} = 23.3 dB on a porous road surface.

The measurement results in the present report were collected on more or less dense pavements and they may be translated into CPB noise levels by subtracting 22.5dB. A few pavements may be denoted semi-porous thin asphalt layers and for those a slightly higher number should perhaps be subtracted.

Tyre/road noise levels from the tyre manufacturers' websites have been used as an independent variable (X-axis) in Figure 2 where the dependent variable (Y-axis) is the noise level measured with the DRD trailer on an SMA 11 pavement (DRD22). The fraction R^2 of explained variance is only 1 % (R^2 = 0.0098). In other words, the variables are not correlated.

The label values in Figure 1 were read by DRD from manufacturer's websites and then double checked by comparing with the labels tabled by the Swiss Federal Office of Energy SFOE.

One tyre is labelled the quietest (66 dB; summer tyre Dunlop SP Sport M0) while measured on the SMA 11 (DRD22) it was among the noisiest tyres. The noisiest tyre according to its labelled 75 dB is a summer tyre, Marshal Matrac XM. Removing these two extremes would change R^2 to 0.013.

This lack of correlation may have several reasons. Manufacturers are said to limit their cost of testing tyre noise levels by not measuring the noise level for every tyre dimension, just the assumed worst one within a tyre line, as long as it complies with the Directive noise limit. Thus the exact dimension measured in the present project may not be the dimension used for labelling. Another reason could be differences in the properties of different test track used by different manufacturers for the labelling measurements, or general measurement uncertainty. The results from the present project used in Figure 2 were measured on the same day with the same equipment on the same section of road.

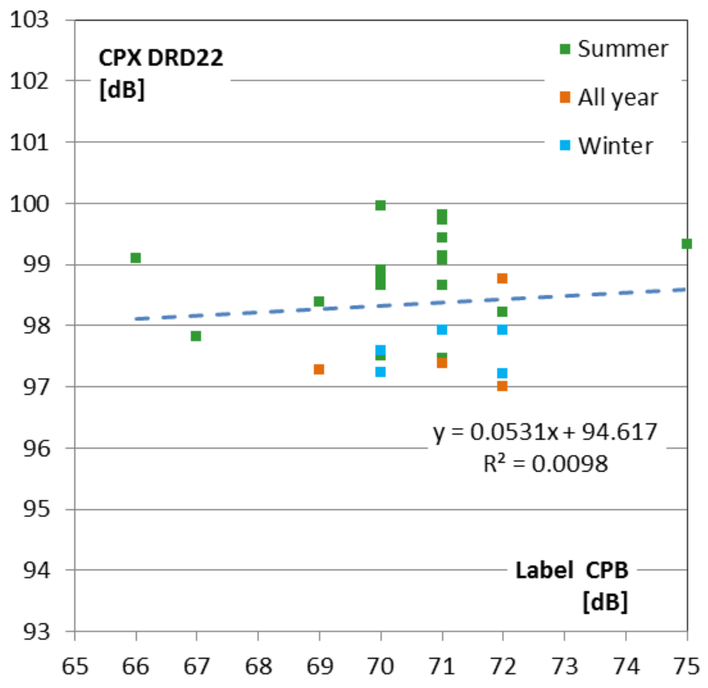

Figure 2 – CPX noise level on SMA 11 (DRD22) as a function of the label given by the manufacturer

9. SCENARIOS

To find out what noise reduction could potentially be obtained by replacing the pavement and regulating the tyre/road noise, some scenarios were generated. The tyre/road noise component of the passenger car noise was modified and the consequential changes in overall vehicle pass-by noise levels estimated.

9.1 Procedure

Tyre/road noise and propulsion noise contributions to the overall passenger car noise level were calculated applying the Nord2000 prediction method. To illustrate the process, Figure 3 shows the pass-by noise levels at 7.5 m distance, 1.2 m above the road surface, from a light vehicle on a dense asphalt concrete pavement (AC 11d) as a function of the (constant) vehicle speed. The total noise level is composed of the tyre/road noise and the propulsion system noise. If we modify the tyre/road noise by selecting another pavement or another population of tyres this will result in a change in the overall noise level.

The balance between tyre/road noise and propulsion system noise depends on the sound propagation from source to receiver, and we calculated scenarios for different propagation situations.

9.2 Limitation

As already mentioned, only tyre/road noise from new passenger car tyres are dealt with in this part of the NordTyre project. Winter tyres were excluded from scenario simulations of the effect of regulating the tyre use because it would not make sense to assume the exclusion of all summer and all-year tyres and then having a vehicle fleet equipped with only winter tyres, characterised by their noise levels measured during the summer.

9.3 Definition of scenarios

First, the average tyre road noise level from all tyres on all pavements in each "pavement family" was determined. Then the effect of removing all but the quietest tyre line from the tyre population was determined. Finally the combined tyre/road and propulsion noise levels were determined presupposing three different sets of propagation conditions a) – c) defined below. The effects of replacing the pavement or regulating the use of tyres were expressed as the change in overall noise level relative to a reference case: all summer and all all-year tyres on SMA 16 or SMA 11, respectively. In the following only results having SMA 16 pavement as a reference are mentioned.

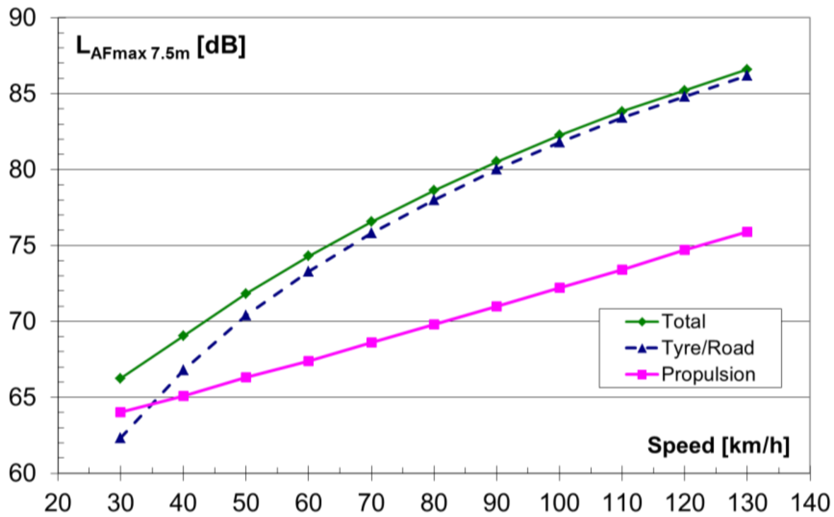

Figure 3 – Light vehicle pass-by noise level at 7.5 m distance as a function of speed calculated with Nord2000 for AC 11d. Total noise and its components of tyre/road noise and propulsion system noise

The starting point for the calculations was a passenger car driving at a constant speed of 50, 80 and 110 km/h, respectively. The air temperature was assumed to be 10 ºC, the pavement SMA 16. Three receiver/propagation scenarios were looked at initially. They shall be supplemented in the final report.

Scenario a) Distance 7.5 m from vehicle centre line; 1.2 m above hard terrain (at the SPB measurement position or at a dwelling close to a road); road surface flow resistivity class G [9]

Scenario b) Distance 100 m from vehicle centre line; 1.5 m above flat terrain; no wind (1st floor in residential area); 1 m hard terrain; the rest grassland: flow resistivity class D [9]

Scenario c) Distance 100 m from vehicle centre line; 1.5 m above terrain (1st floor in residential area); moderate downwind to simulate yearly average noise levels; 1 m hard terrain, the rest grassland.

9.4 Effect of replacing the pavement

This section presents the effect of replacing a reference SMA 16 pavement by other pavements grouped into various "families". The average tyre/road noise levels from all summer tyres and all-year tyres on each member of the pavement family were calculated. Winter tyre data were not included in these calculations.

The selected families and the average noise levels from all the summer tyres and all-year tyres are summarized in Figure 4. At the bottom of each column Figure 4 shows the number of pavements included in each family and the error bars show the standard deviations of the average noise levels per pavement family member. The variation in noise levels within each family is due to a mix of factors such as mix recipe, construction procedures, pavement age and exposure to traffic.

Table 1 shows the reduction of tyre/road noise levels by replacing the reference pavement.

Table 1 – Average tyre/road noise reductions obtained by replacing SMA 16 by another pavement family

Pavement	SMA 16	SMA 11	SMA 8	SMA 6	AC 11	AC 8	AC 6
Noise reduction[dB]	0	1.5	3.4	4.2	3.0	3.1	4.2

9.5 Effect of regulating tyre use

As an example of the effect on tyre/road noise obtained by regulating tyre use, Figure 5 shows for each of the selected 24 summer or all-year tyres the overall A-weighted noise level L_{Acpx} averaged over the seven AC 11 pavements included in the measurements. The range from the noisiest tyre (No. 12) to the quietest tyre (No. 19) is 3.5 dB for this family of pavement.

The right part of Figure 5 shows the distribution on 0.5 dB wide noise level classes of the noise levels in the left part of the figure. All tyres yielded between 96.6 dB and 100.1 dB, and six values exceeded 99.5 dB. The figure also displays the energy average noise level, 98.3 dB, from all 24 tyres on the seven AC 11d pavements.

Figure 6 shows how the energy average of the tyre/road noise level from the right part of Figure 5

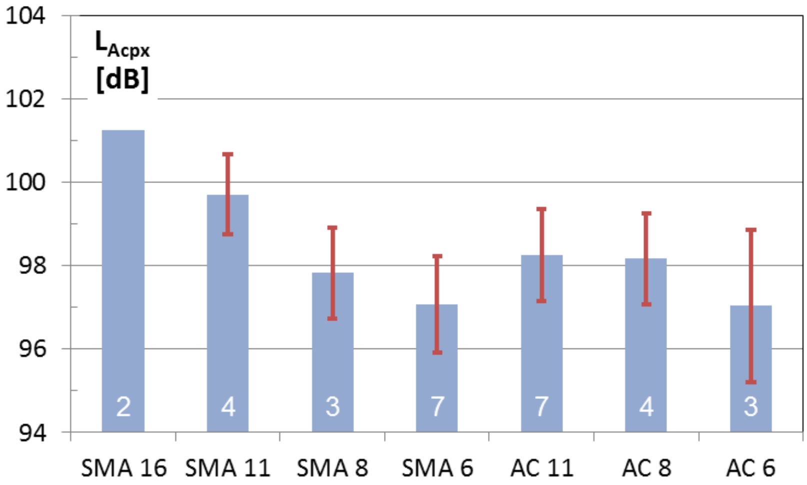

Figure 4 – Average tyre/road noise levels and standard deviation of these noise levels per pavement family

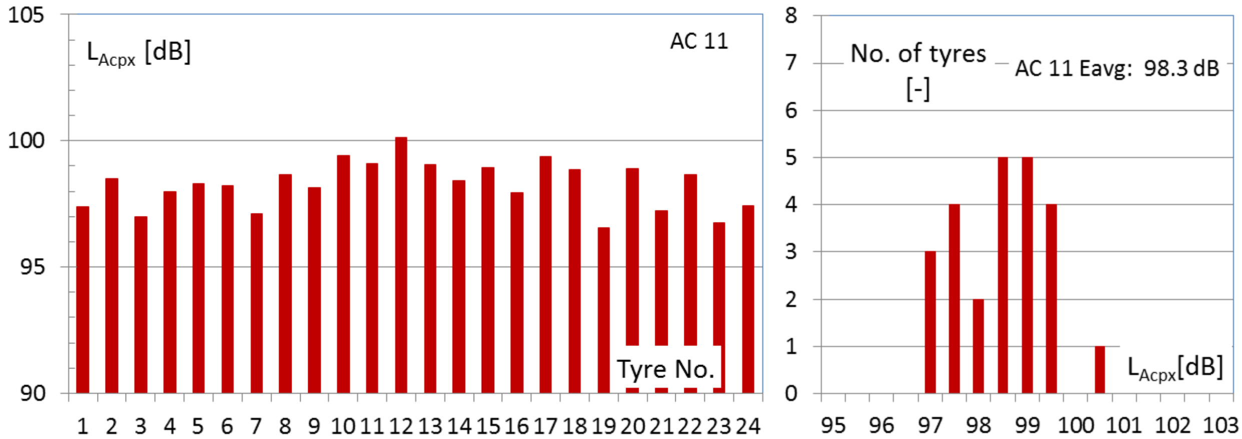

Figure 5 – Average tyre/road noise levels on pavement family AC 11 for each summer or all-year tyre (Left); Distribution of tyre/road noise levels in the left part of the figure on 0.5 dB wide noise level classes (Right)

would develop if the tyres were removed one by one from the set of 24 tyres, beginning with the noisiest tyre ranked according to manufacturers' noise labels. The data point labels in Figure 6 show the ID number of the latest tyre which has been removed to reach at the energy average noise level shown by that data point. The first point with label "0" is the energy average of all 24 noise levels. The range of noise levels in Figure 5 is 3.5 dB and the change in energy average noise level after removing all but the allegedly quietest tyre is disappointingly negative, minus 0.5 dB. See further in Section 12.

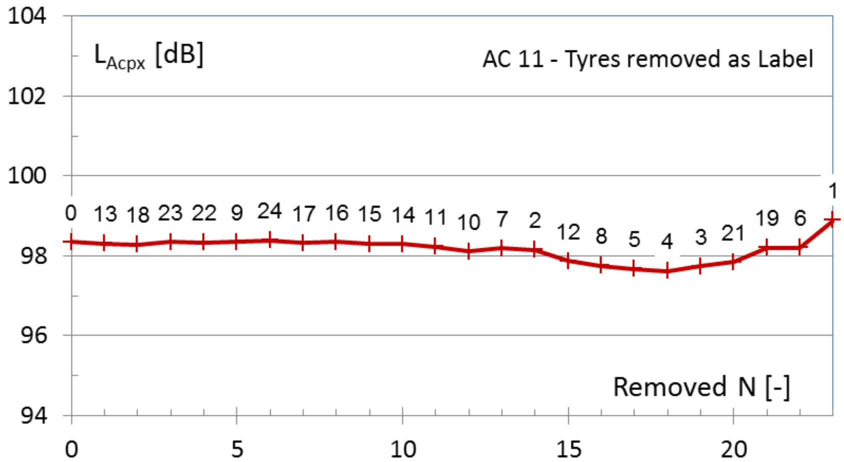

Figure 6 – Energy average of the tyre/road noise levels in Figure 5 as a function of the number of tyres having been removed, beginning with the noisiest tyre (No. 13) as ranked by manufacturers' labels

9.6 Combined effect of replacing pavement and regulating tyre use

Table 2 combines the reductions from Table 1 with the reductions found when simulating tyre noise regulation. Thus the table gives estimates of the total effect on passenger car tyre/road noise of first 1) replacing the pavement and then 2) removing all tyres but the quietest tyre ranked in different ways.

Any regulation of tyre use based on the tyre/road noise emission would have to be based on some kind of classification of tyres. Thus the simulation of the effect obtained by excluding the tyres could, for example, have been based on excluding classes of tyres yielding similar noise levels, class by class, beginning by excluding the noisiest class. The width of tyre classes would have to be decided on, but with a range in noise levels of 3 – 4 dB it would probably be in the order of 1 dB and the total potential tyre/road noise reduction would be smaller by a few tenths of a dB than the values given in Table 2 based on removing all but the quietest individual tyre line.

Table 2 – Tyre/road noise reductions obtained by first replacing the pavement and then excluding all but the quietest tyre ranked in different ways

Tyre/road noise reduction [dB]					
Pavement selection		Tyre regulation, ranking as		Total re. SMA16	
Re. SMA 16		Label	DRD22	Label	DRD22
SMA 16	0.0	-0.4	2.1	-0.4	2.1
SMA 11	1.5	-0.6	1.8	1.0	3.3
SMA 8	3.4	-0.5	1.6	2.9	5.0
SMA 6	4.2	-0.5	1.5	3.6	5.7
AC 11	3.0	-0.5	1.6	2.5	4.6
AC 8	3.1	-0.6	1.4	2.5	4.5
AC 8	3.1	-0.3	1.2	2.8	4.3
AC 6	4.2	-0.3	1.2	3.9	5.4

9.7 Effect on total noise levels

As an example, the combined effect on passenger car pass-by noise levels of 1) replacing the pavement and 2) regulating tyre use by removing all but the quietest tyre line is shown in Table 3 for 50 km/h and 110 km/h in propagation scenario a). The maximum obtainable reduction of the total noise level when regulating the tyre/road noise based on manufacturers' noise labels is 3.6 dB, obtained at 110 km/h. This reduction is a little smaller than would have been obtained by replacing the pavement while not regulating tyre/road noise. Had a different ranking of tyres been applied, up to 5.0 dB reduction would have been obtained, see Section 12.

Table 3 – Noise reductions [dB] in Scenario a) with SMA 16 as a reference

Total pass-by noise level reduction [dB]					
Scenario a)	Replace	Regulate tyres as		Total	
50 km/h	pavement	Label	DRD22	Label	DRD22
SMA 16	0.0	-0.3	1.7	-0.3	1.7
SMA 11	1.2	-0.5	1.4	0.7	2.6
SMA 8	2.6	-0.4	1.3	2.2	3.8
SMA 6	3.1	-0.4	1.2	2.6	4.3
AC 11	2.3	-0.4	1.2	1.8	3.5
AC 8	2.4	-0.5	1.1	1.8	3.5
AC 6	3.1	-0.3	0.9	2.8	4.0

Scenario a) 110 km/h	Replace pavement	Regulate tyres as Label	DRD22	Total Label	DRD22
SMA 16	0.0	-0.4	2.0	-0.4	2.0
SMA 11	1.4	-0.6	1.7	0.9	3.1
SMA 8	3.2	-0.5	1.5	2.7	4.7
SMA 6	3.8	-0.5	1.4	3.3	5.2
AC 11	2.8	-0.5	1.5	2.3	4.3
AC 8	2.9	-0.6	1.3	2.3	4.2
AC 6	3.9	-0.3	1.1	3.6	5.0

10. ROLLING RESISTANCE

Figure 7 shows the rolling resistance coefficients (RRC) measured at 80 km/h in a drum facility in Gdansk [6]. Tests were made both at 50 km/h and 80 km/h on an ISO 10844 replica surface and on an AC 16d replica. All tyres were inflated with a pressure of 210 kPa and loaded with 4000 N.

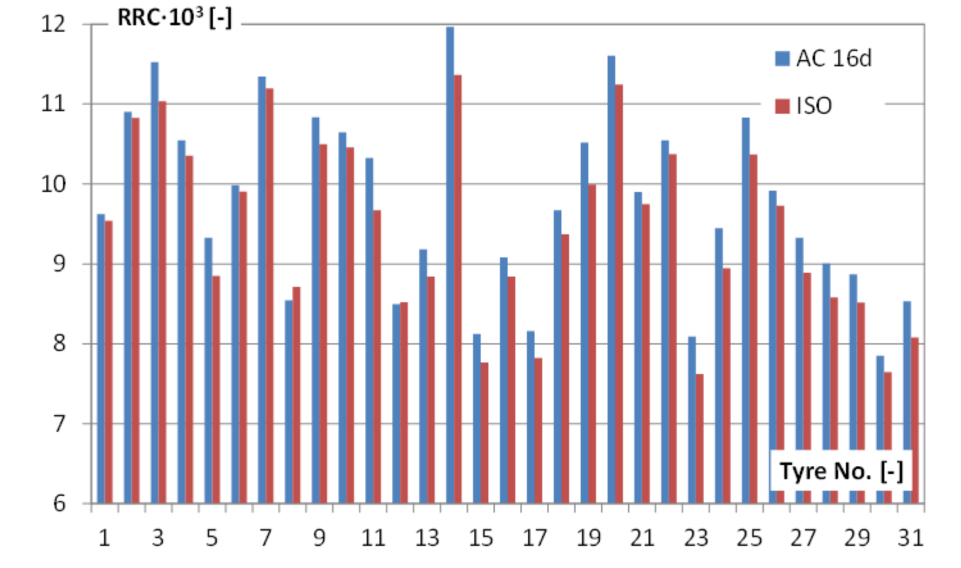

Figure 7 – Rolling Resistance Coefficients (times 10^3) for tyres No. 1 – 31 measured at 80 km/h on ISO and on AC 16d replica surfaces

In Figure 8 the CPX noise levels measured on pavements AC 8d (DRD20) and SMA 11 (DRD22) are shown as a function of the RRC at 80 km/h on ISO and AC 16d replica surfaces, respectively. No correlation is seen between noise level and rolling resistance.

Figure 9 shows the RRC measured by TUG on its ISO replica surface as a function of the fuel efficiency class labelled by tyre manufacturers. There seems to be a general correspondence, but with a large spread.

11. ROAD GRIP

Figure 10 shows the ice and snow grip indices measured by Test World Ltd in its facility at Ivalo, Finland [7], as a function of the wet grip labelled by tyre manufacturers. Braking distances of a car equipped with each set of winter and all-year tyres was measured and compared to a reference measurement with tyre SRTT having an index of 100 [-]. An increase in index equals better performance. Wet grip labels show ratings from A to F, with A as better and F as worse. Wet grip labels according to the Directive [1] encompass classes A, B, C, E and F, not class D. Data point labels in the figure are tyre ID numbers; for ice grip #29 is on top of #27, and for snow grip #28 is on top of #23.

The trend is for a better wet grip the worse the snow and ice grip or vice versa.

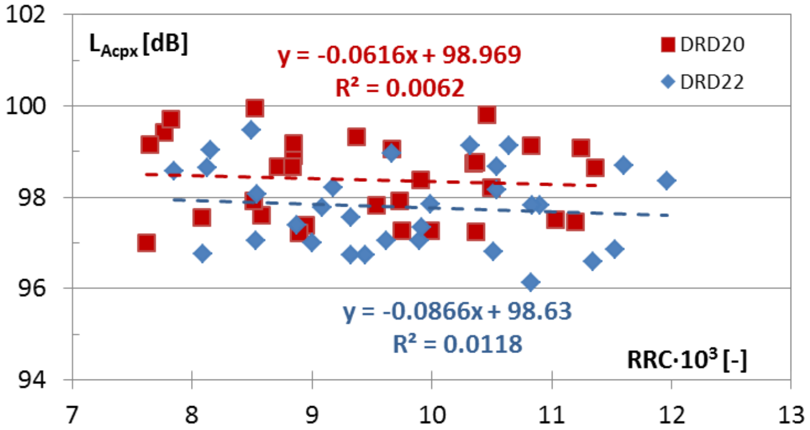

Figure 8 – Noise level on AC 8d (DRD20) and on SMA 11 (DRD22) as a function of the rolling resistance coefficient (RRC) at 80 km/h on ISO, corresponding to AC 8d, and AC 16d replica surfaces, respectively

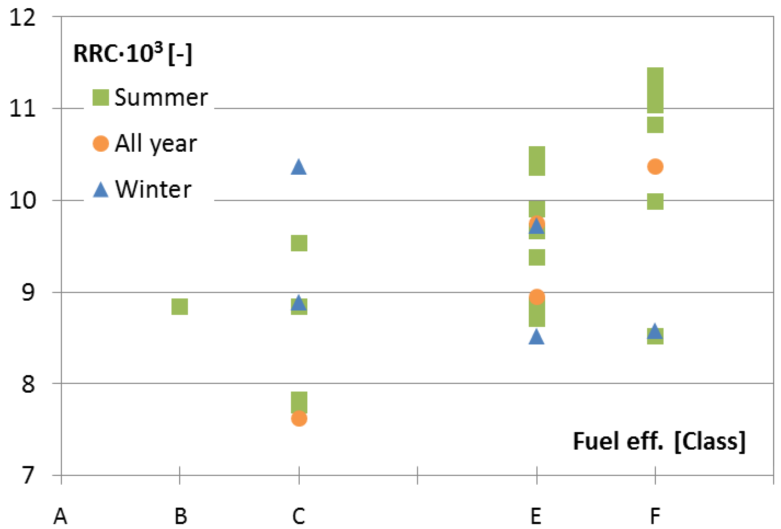

Figure 9 –Measured RRC at 80 km/h on ISO replica surface as a function of labelled fuel efficiency class

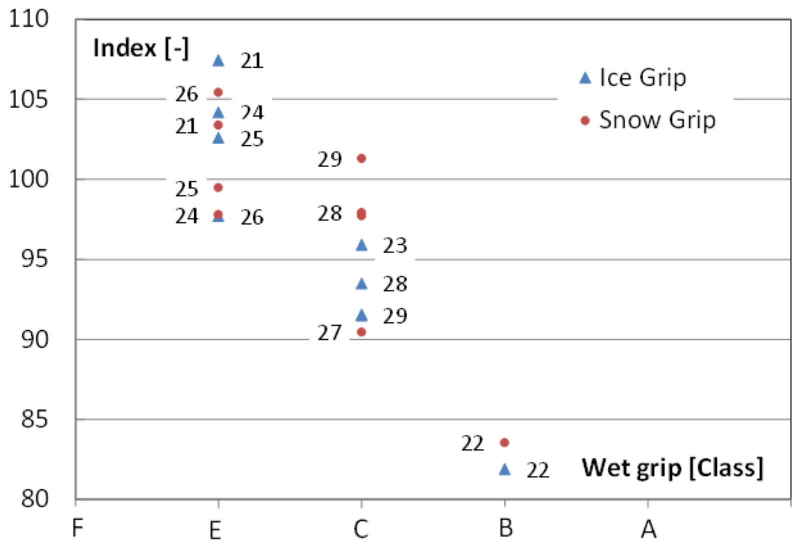

Figure 10 – Relation between measured ice and snow grip index, respectively, and labelled wet grip class

12. DISCUSSION

The lack of correlation between tyre manufacturers' noise label values and measurements results from SMA pavements are reflected in the scenarios. Figure 11, as an example, compares reductions of tyre/road noise on SMA 16 obtained, cf. Section 9.5, by removing the noisiest tyres 1) as ranked by manufacturers' noise labels and 2) as ranked by measurements made on SMA 11 (DRD22) in the present project, respectively. Two "extreme" labels mentioned in Section 8.2 were deleted in the simulation behind the red full-line curve in Figure 11. The labelling system seems to need improvement in order to be representative of tyre/road noise levels on Nordic road surfaces.

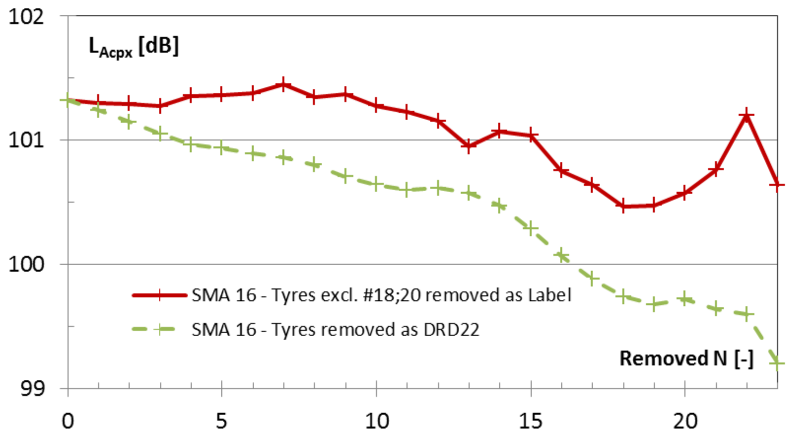

Figure 11 – Energy average tyre/road noise level as a function of the number of tyres removed, beginning with the noisiest tyre ranked by manufacturers' labels or by measurements on SMA 11 in the present project

13. PRELIMINARY CONCLUSIONS

A range of 11 dB was found between noise levels from the noisiest tyre on the noisiest pavement and the quietest tyre on the quietest pavement. The range of average noise levels from all tyres on different pavements was approximately 4 dB, and the range of noise levels from different tyres on the same pavement also was approximately 4 dB.

No correlation was found between tyre manufacturers' noise labels and the noise levels measured on Nordic road surfaces. This may be caused by manufacturers basing the noise label for a whole tyre line on measurements made for only one tyre dimension of this tyre line, or it may be due to variation in test tracks used for such labelling measurements.

A regulation of tyre/road noise based on the noise levels measured in the present project, combined with a change from SMA 16 to a noise reducing thin asphalt layer could imply up to 5 dB reduction of traffic noise from passenger cars.

Rolling resistance coefficients were found to be uncorrelated with tyre/road noise levels, and there was a trend for less good braking performance on ice and snow, the better the labelled wet grip.

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