30 Different Tyres On 4 Surface Types - How Do Truck Tyre Noise Levels Relate to the Test Surface

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Summary

Tyre/road noise from truck tyres is caused by the interaction between the tyre and the road surface. This implies a relevance of both components to the overall rolling noise level. There exists some understanding of the average performance of various tyres (based on testing on an ISO 10844 test surface and the average performance of various road surfaces (based on pass-by measurements of truck noise levels), but little data on the combined effect. In this study a systematic approach is followed to determine the acoustic performance between 40 and 80 km/h of 30 different lines of truck tyres on 4 different surfaces. Truck tyre types include steering, traction and trailer types, both all-season and specific snow/ice versions. Road surfaces include an ISO-10844, a TSL 8, a smooth AC 16 surf and a coarse SMA 11. The paper will show distributions of noise levels from tyres on the tested surfaces and go in to specific correlations between data sets obtained on the test surfaces. Data will be presented in 1/3rd octave bands so possible covariance between surfaces can be traced back to noise generating mechanisms

1. Introduction

Tyre/road noise from passing heavy vehicles constitutes a relevant contribution to the environmental noise level in the vicinity of major road infrastructure. Especially in the sensitive night period noise from such vehicles is dominating. Improving the acoustic climate is pursued by limiting the sound emission of tyres sold in Europe and raising the awareness of the consumers by displaying the type approval noise values together with wet grip and rolling resistance on a label (see Figure 1).

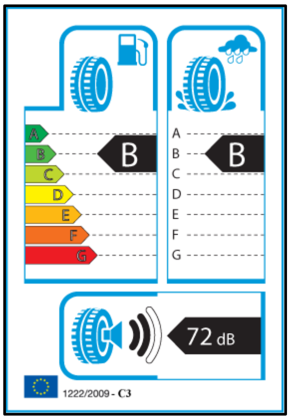

Figure 1. Example of tyre label. The number of “waves” indicate the margin with the type approval limit for that type and size.

2. NordTyre project

The NordTyre project, issued by the Scandinavian road administrations, is to clarify the relations between the labelled tyre/road noise levels and the tyre/road noise levels on Nordic Roads. This paper addresses part 3 of the project that is dedicated to the study of truck tyres. M+P has been awarded the contract for a test program to determine the coast-by noise levels of a series of 30 truck tyre lines according to the methods and test conditions defined in the type approval regulation R117 (ref [1]) but with extensions to lower speeds and added test surfaces.

3. Measurement method

As test vehicle we used a tractor with the same tyres mounted on all wheels. In accordance with the R117 test procedure the tyres at the rear axle where single mounted instead of the more conventional twin mounting. An extra load was applied on the vehicle to fulfil the loading conditions given in R117. The tyre/road noise levels were measured under conditions of coast-by with gearbox not engaged and the engine switched off.

Microphones were placed at both sides at a distance of 7,5 m from the centre of the test lane. Two heights were used: 1,2 m, being the required height in R117 and 3,0 m being the defined height in the emission determination for road vehicles in the harmonized EU calculation method CNOSSOS-EU (ref [2]). At each microphone position the full coast-by event was recorded in one-third-octave bands with the time weighting “F”. From this the *LAFmax* and the *SEL* and related frequency spectra were determined.

4. Test surfaces

The test area was located at a former military airbase in the east of the Netherlands. The test surfaces were laid on a taxiway.
The testing was performed on a surface that fulfils the requirements in the R117 procedure (ISO 10844:2014 (ref. [3]) and on 3 other types of surface:

- a thin noise reducing surface with 8 mm max. aggregate size (TSL 8),
- a dense asphalt concrete with 16 mm max. aggregate size (AC 16),
- an Stone Mastic Asphalt surface with 11 mm max. aggregate size (SMA 11).

The TSL 8 and the AC 16 sections had been artificially smoothened. The texture and acoustic absorption data are given in Table I.

Table I. Overview of test surface properties. Presented are the type designations, the Mean Profile depth (a measure of the surface roughness), the max value of the acoustic absorption coefficient between 315 and 1600 Hz (1/3 octave bands) averaged over the measurement locations.

Pavement type	*MPD [mm]*	*average max absorption coeff. [-]*
TSL 8	0,6	0,32
AC 16	0,3	0,02
ISO 10844	0,4	0,02
SMA 11	1,1 – 1,4	0,02

5. Test protocol

The test sections were located next to each other so in a single coast-by event all four sections were measured. At each section the *SEL* and LAFmax were determined at both sides at 1,2 and 3,0 m height together with the speed of the vehicle. The speed range used in the test included the range of 60 to 80 km/h required in R117 but was extended to 40 km/h to also record urban conditions. In total about 16 coast-by events were recorded for each tyre line.

6. Test tyres

The series of 30 tyre lines was composed as to achieve a representative distribution over manufacturers, types and winter/summer types. Also five retreaded lines were included. To study repeatability two tyre lines were measured two times. From one tyre line two sets of four tyres were included to check reproducibility.
The choice of tyre lines was based on the lines actually found on European and Scandinavian roads.

Table II. Distribution of test tyres over types and sizes.

Tyre type	*size*	*number*
steer	315/70-22,5	8
drive	315/70-22,5	12
trailer	385/55-22,5	10

Table III. Distribution of test tyres over manufacturers.

Manufacturer	*number*
Michelin	9
Bridgestone	4
Continental	5
Goodyear	5
Hankook	2
Pirelli	2
Nokian	2
Pneu Laurant	1

All drive types and two of the steer tyres were of the M+S type. Seven tyre lines were retreaded i.e. the tread profile had been renewed while the carcass remained the same. The re-treading was in six of the cases done by the original manufacturer and in one case by an independent company. From the six lines also the original lines were included in the test.

7. Data analysis

Test results for each tyre and road combination were gathered and data on *LAFmax* and *SEL* for each microphone height were combined into a scatter diagram where the values are plotted as a function of the vehicle speed. Through the data points the best fitting function with the form given in (1) was plotted.

$$L = a + b \cdot \, log\left(\frac{v}{v_{ref}}\right) \; with \; v_{ref} = 70 \; km/h \quad (1)$$

Around the best fitting function an interval was calculated representing the 95% confidence interval.

Also the residue was calculated presenting the standard deviation of the individual data points around the best fitting function.

8. Measurement results for *LAFmax*

An examples of a scatter diagrams for *LAFmax* is given in the graph below.

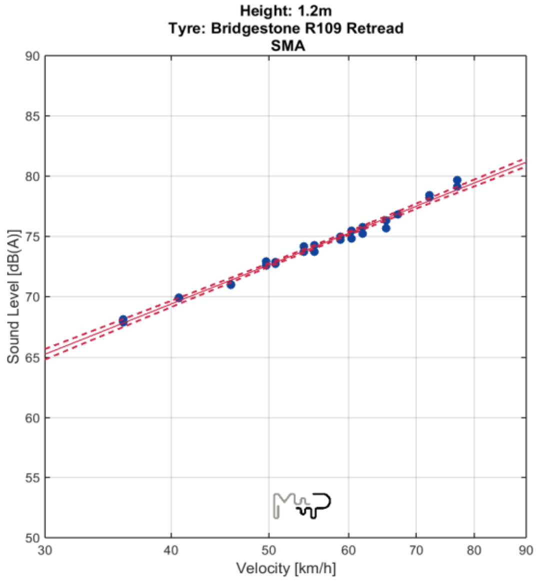

Figure 2. Scatter diagram for test tyres on the SMA test surfaces at a height of 1,2 m. The red full line presents the best fitting function of the form $a+b{\cdot}log(v/v_{ref})$. The dotted lines show the 95% confidence interval of the regression line.

The values of *a*, *b*, the one sided 95% confidence interval (c.i.) and the residue for two tyres at two surfaces at two heights are given in Table IV.

Table IV. Results of regression analysis of *LAFmax* data presented in Figure 2. *a* and *b* are coefficients of the regression function $a+b{\cdot}log(v/v_{ref})$ with v_{ref} = 70 km/h.

Tyre line	Bridgestone R109 retread on SMA11		Michelin X-line energy T on ISO	
Height [m]	1,2	3,0	1,2	3,0
a [dB]	77,5	76,7	74,5	73,5
b [dB]	33	35	33	31
95% c.i. [dB]	0,2	0,3	0,4	0,5
res.[dB]	0,4	0,6	0,7	0,8

9. Measurement results for *SEL*

The same analysis was performed on the *SEL* values. The *SEL* in principle presents an integration over -∞ to +∞. For practical reasons the interval was truncated to -25 m to +25 m around the microphone position. This results in an approximately 0,8 dB lower value. The relation between *SEL* values over different tyre lines and test sections is not affected.

Table V. Results of regression analysis of SEL data. *a* and *b* are coefficients of the regression function $a+b{\cdot}log(v/v_{ref})$ with v_{ref} = 70 km/h.

Tyre line	Bridgestone R109 retread on SMA11		Michelin X-line energy T on ISO	
mic. height [m]	1,2	3,0	1,2	3,0
a [dB]	78,7	78,1	75,2	74,5
b [dB/dec]	25	26	23	23
95% c.i. [dB]	0,2	0,2	0,3	0,4
res.[dB]	0,3	0,4	0,5	0,6

One notices that the height effect between 1,2 m and 3,0 m on the *LAFmax* value is about 1 dB and as expected the effect on the *SEL* value is about half a dB. The difference between the speed exponents for *LAFmax* and *SEL* results is close to 10 as can be expected from the speed and thus integration time effect.

10. Frequency spectra

From the regression analysis the frequency spectra were obtained at a speed of 70 km/h. The spectra were averaged for all drive, for all steer and for all trailer tyres The graphs below show *LAFmax* and *SEL* spectra at 3,0 m height on the TSL 8, AC 16 surf, ISO and SMA 11 surfaces.

Results are given in Figure 3. The steer and trailer tyre noise levels are close to each other, with on average the trailer types on the lower side.
The LAFmax levels for the drive tyres are on average the highest. One notices specific peaks in the frequency spectra for the drive tyres, most clearly on the smooth DAC. The difference between the tyres is smallest on SMA 11. First the level difference between the tyres reduces considerably. Second the spectral shape difference between steer and drive types disappears.

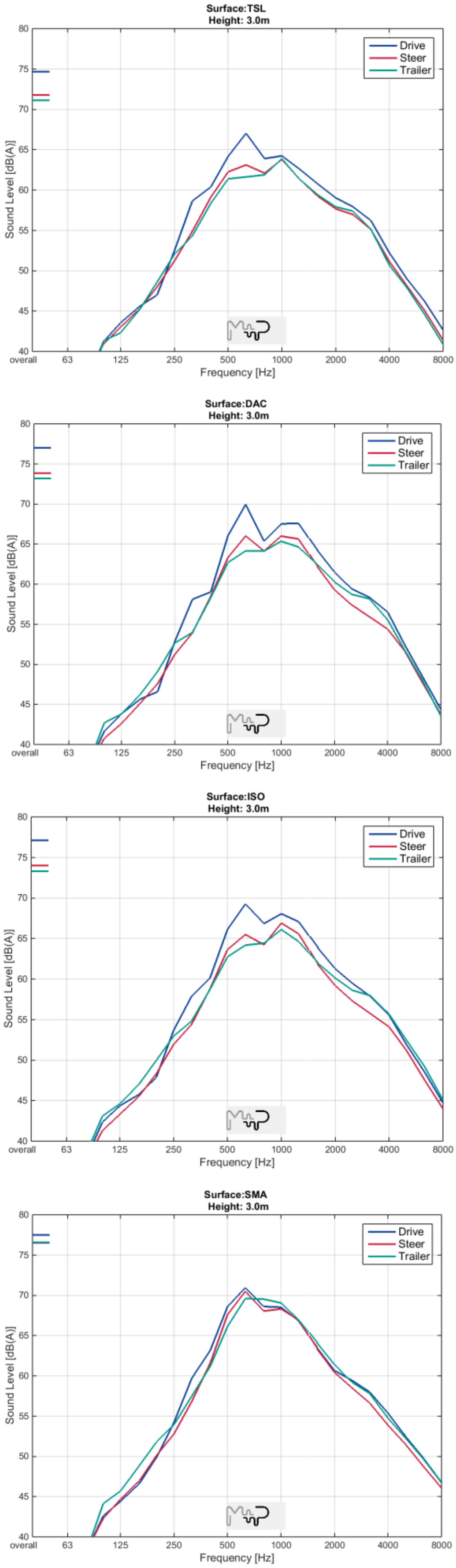

Figure 3. Average spectra for steer, drive and trailer tyres on the four test surfaces. *LAFmax* at 3,0 m.

11. Relation between tyre/road noise levels on different surfaces

The relation between tyre/road noise levels on different surfaces is displayed graphically below. Each point represents a tyre. The x-value is the test result on the ISO surface and its y-value is the test result on the designated surface. Through the data points a best fitting linear function is drawn together with the boundaries of the 95% confidence interval. Also the correlation coefficient is given.

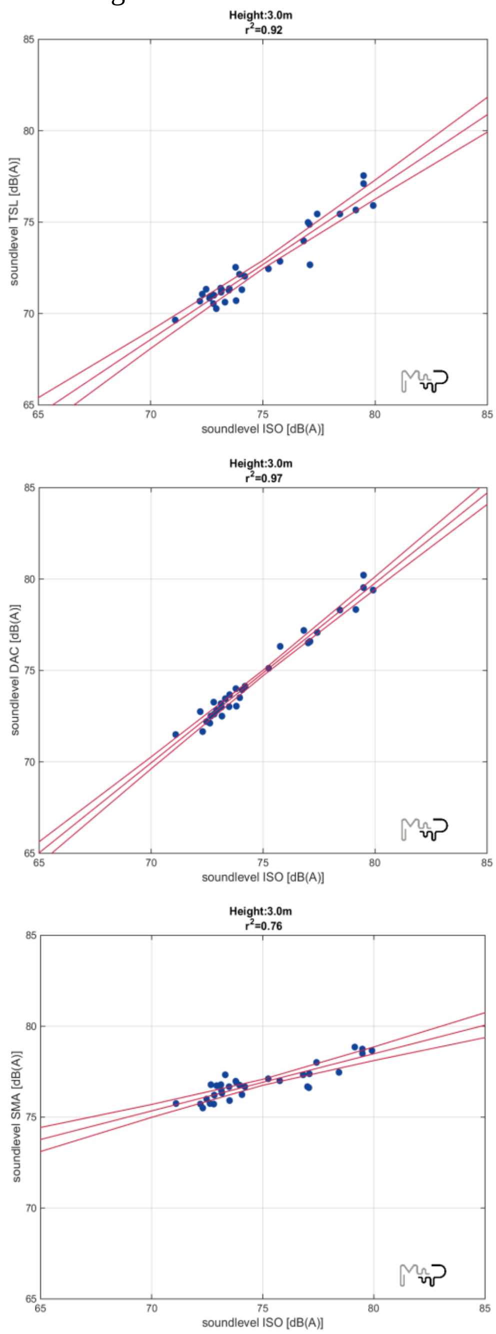

Figure 4. Relation of *LAFmax* levels found on the ISO surface (x-axis) to *LAFmax* levels found on each of the other surfaces (y-axis).

The table give the numerical results of the regression analysis for both *LAFmax* and *SEL* data at 3,0 m. Results for the 1,2 m position are practically the same.

Table VI. Slope and correlation of *SEL* and *LAFmax* levels (3,0 m) .

	SMA 11		*AC 16 surf*		*TSL 8*	
	slope	corr.	slope	corr.	slope	corr.
L_{AFmax}	0,3	0,76	0,98	0,97	0,82	0,92
SEL	0,28	0,68	0,96	0,97	0,92	0,92

A shallow slope for SMA 11 indicate that a level difference found between two tyres on the ISO test surface is on average smaller on an SMA 11 surface. A low correlation indicates that a selection of low noise tyres, based on ISO test results does only partially reflect the low noise tyres at the SMA 11 surface.
The finding that differences between tyres disappear on the coarser SMA surface is reflected in the graphs in Figure 4. A 4 dB difference between tyre types on other surfaces reduces to about 1 dB on the SMA 11 surface. On an average, noise levels were 2.3 dB lower on TSL 8 than on the ISO surface while they were 2.1 dB higher on the SMA 11. On the AC 16 surf the average noise level was about the same as on ISO.

12. Comparison of repeated tests

For two tyres the test program was repeated to investigate the repeatability. One was repeated directly after finishing the first test. The other was repeated about a week later. Absolute level differences were within 0,5 dB.

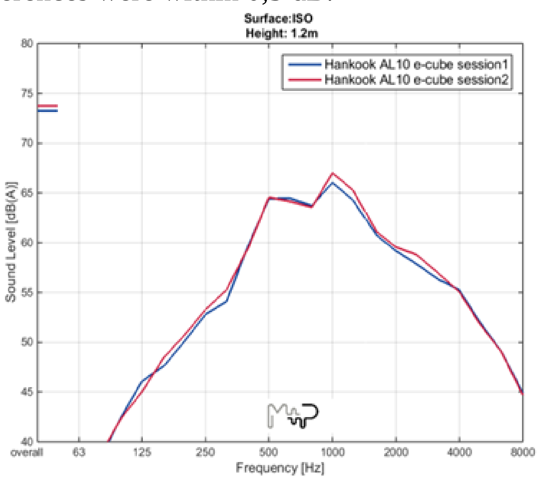

Figure 5. Results of repeated measurements after a week on the same tyre set (*LAFmax* @ 1,2 m on ISO).

13. Comparison with label values

An interesting topic that can be studied with the data set is the relation between the label values for the tyre lines and the test results. For that the test results on the ISO section at 70 km/h were corrected according to the procedure given in R117. The test value is rounded down to the lower integer and 1 dB is subtracted from the test result for measuring inaccuracy. The resulting values are compared to the label values attributed to that tyre line. Results are shown graphically in Figure 6.

The average difference we found was 1,2 dB with a standard deviation of 1,9 dB.

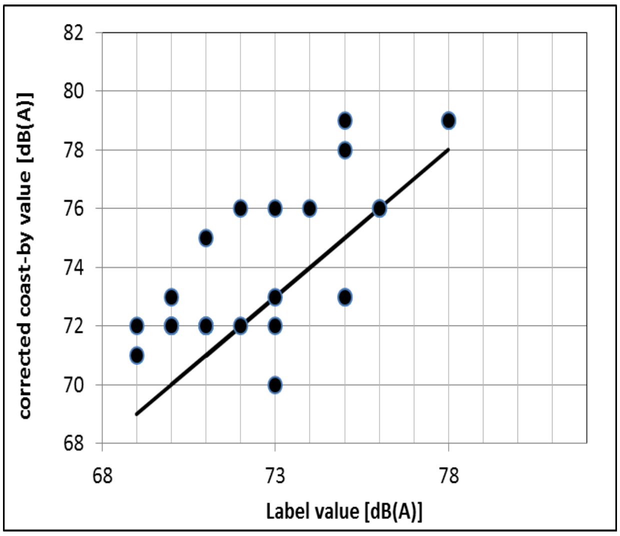

Figure 6. Relation of test results at 70 km/h on ISO section with label values. Test results have been corrected according to R117 procedure.

14. Comparison of two tyre sets within the same tyre line

The representativity of a test result for all tyres within a tyre line was looked into by repeating the tests for a second set of four tyres from the same tyre line.
Notice that the coast-by testing already includes 4 tyres of the same line so some averaging of variation within a tyre line already occurs in the test procedure.

Figure 7 present *LAFmax*@1,2 m on the ISO surface and *SEL*@3,0 m on the SMA 11 surface. The tyre was of the line: *Nokian Hakkapeliitta Truck E* which is a drive axle tyre for Nordic conditions. The tread profile exhibits a coarse pattern with evenly spaced blocks.

The two tests show nearly identical overall levels. The spectral shapes of the *LAFmax* signals on the ISO surface, however, are quite different. This can be explained by the narrow tonal components caused by such tyre type. A small variation in speed may shift such tonal peaks to an adjacent one-third octave band.

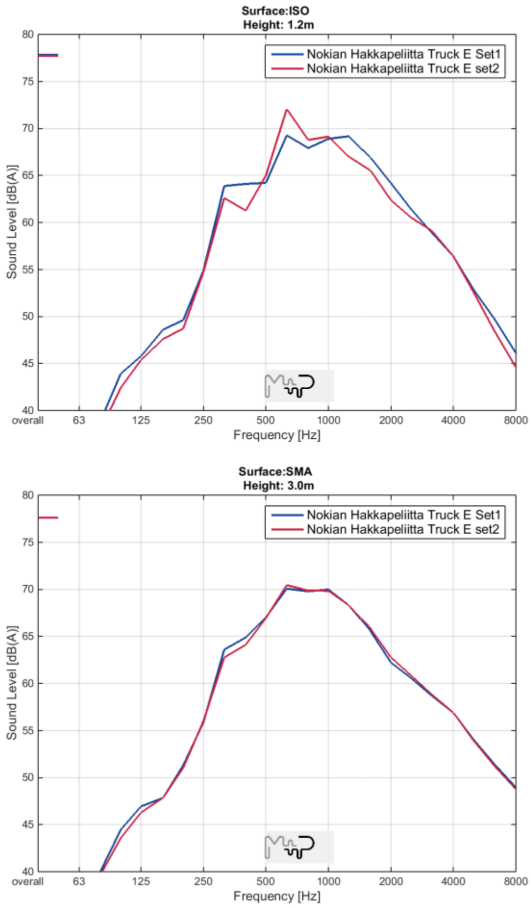

Figure 7. Results of comparison of tests on two tyre sets of the same tyre line. Top: *LAFmax*@1,2 m on ISO, bottom: SEL@3,0 m on SMA 11.

15. Discussion and conclusion

This paper gives an overview of the results of a series of tests on 30 truck tyre lines of steer, drive and trailer type on 4 different surfaces. The main objective of the *NordTyre project Part 3 – Truck tyres* is to develop a data base with accurate acoustic data on a representative series of truck tyre lines. The reliability of the data has been looked into on the basis of repeated measurements and on the basis of the statistical uncertainty in the regression analysis.

A first analysis of the data shows interesting features:

- Average tyre/road noise differences between tyres observed on an ISO surface are about 70% smaller when compared on a coarse SMA surface
- The ranking of tyres based on test result on the ISO surface is poorly reflected in the ranking on the coarser SMA 11 surface
- Comparison of the corrected test results for the tyre lines with the label values shows that the label values are on average about 1 dB lower. The difference of 1,2 dB can far a large part be explained by the specific test conditions. The air temperature during the tests was between 5 and 12°C while normalized test conditions would be 20°C. In line with R117 no correction is applied although literature indicates an effect in the order of 0,5 dB/10°C. In addition the test surface was with 0,4 mm MPD slightly rougher than the minimum value required in ISO 10844 explaining another few tenths of a dB.

The results of the coast-by testing and detailed description of the tyre properties and the test surface properties are given in a series of 3 reports prepared for the Steering group of the NordTyre project (ref [4], [5] and [6]).

16. Acknowledgement

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References

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[2] S. Kephalopoulos, M. Paviotti, F. Anfosso-Lédée, "Common Noise Assessment Methods in Europe (CNOSSOS-EU)", 2012

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[4] G.J. van Blokland *et al*, "Test section surface properties for NordTyre Part3", report nr. M+P.DRD.13.01.3, April 2015.

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[5] G.J. van Blokland *et.al.*," Properties of truck tyres tested for NordTyre Part 3", report nr. M+P.DRD.13.01.5, April 2015