Dense road surfaces with small aggregate size - tyre/road noise reduction after repaving

Nils-Åke Nilsson[a] and Nils Ulmgren[b]

[a]Acoustic Control AB, Tumstocksvägen 1, SE-187 66 Taeby, Sweden
[b]NCC Roads Sweden AB, R&D Center, Bryggervägen 13, SE194 36 Upplands Väsby, Sweden
na.nilsson@acoustic.se

Open, porous road surfaces normally suffer from clogging particularly in inner city situations with low vehicle speed. After a relatively short time pore clogging could almost eliminate the noise reduction effect. A ***dense*** low noise road surface with small aggregate stone size could here offer substantial noise reduction due to reduced surface roughness without any clogging problems, despite its low sound absorption.
In this paper is presented data on the ***"repaving insertion loss"*** in dB(A) when exchanging a worn older SMA16 by a newly paved dense SMA8-type pavement (VIACOGRIP). Comparative results will also be shown for various types of newly paved dense AC16 and SMA16 in comparison to the newly paved SMA8.
The technique for noise reduction mentioned above could be believed to have "***improved long term endurance"*** as compared to the same degree of noise reduction achieved by open graded technique particularly in city centres.
For the Scandinavian countries where studded tyres are allowed, further reduction of stone size could be possible at acceptable wear rate if studded tyres are taxed or prohibited e.g. in environmental zones. This could lead to a further increased reduction of tyre/road noise in such zones.
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1 Introduction

Tyre/road noise is the dominating source for passenger cars already from a constant speed of 35 km/h. Therefore tyre/road noise reduction is an urgent task in efforts to reduce road traffic noise. Reduction of tyre/road noise is also a must in order to utilize the low drive-line noise from new quiet car designs such as hybrid electric cars or pure electric vehicles. However for inner city applications where low speeds prevail, open graded drainage surfaces suffer from clogging. The objective of this paper is therefore to investigate the potential of using smooth dense surfaces as a tyre/road noise mitigation method instead of open ones.

2 Test site

The studied Thin Asphalt Pavement VIACOGRIP8 was paved on an approximately 300 m long road section on Blackebergsvägen in Stockholm, see Fig 1. The existing pavement of type SMA16 at the Blackeberg test site, (shown in Fig 2) was used as test reference surface.

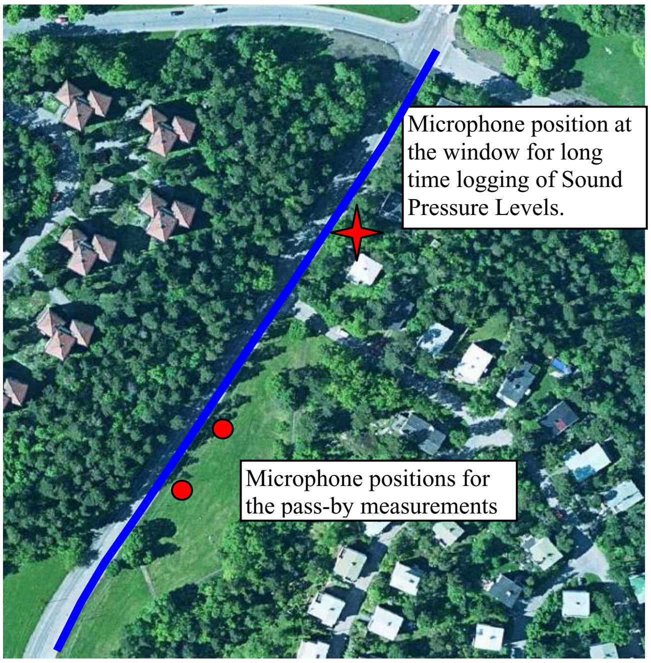

Fig. 1 Aerial photo over the test site paved with the Very Thin Asphalt Pavement VIACOGRIP8.

Fig. 2 Photo from the test site at Blackebergsvägen before repaving with the smoother VIACOGRIP8 surface.

A close up photo shows the surface texture of VIACOGRIP8 directly after paving (see Fig 3).

Fig. 3 Close up photo of the Thin Layer VIACOGRIP 8 with a Swedish 5 krona coin as reference.

The existing road before repaving the surface was a SMA16 and was used as reference for testing the effect of the new smoother road surface with 8 mm max stone size, NCC/VIACOGRIP 8. Apart from the old SMA16 at the Blackeberg test site, three other sites in the same region were also monitored since these surfaces were also repaved at approximately the same time compared to the VIACOGRIP 8 at Blackebergsvägen.

Fig. 4 Reference road surface of type AC 16 at Kirunagatan in Stockholm. A Swedish 5 krona coin has been used in the close-up for reference. The picture also shows the single wheel trailer for tyre/road measurements used in this study.

Fig. 5 Reference road surface type SMA 16 at Vandagatan in Stockholm. A Swedish 5 krona coin has been used in the close-up for reference.

Fig. 6 Reference road surface type AC 16 at Tranebergsvägen in Stockholm. A Swedish 5 kronor coin has been used in the close-up for reference.

3 Test vehicle and test tyres

3.1 Test vehicle

The vehicle used for testing has been a Volvo V70 Bi-fuel manufactured in 2003. This car is representative for medium sized passenger car. Measurements were performed using the Close-Proximity (CPX) method with microphones mounted onto the test vehicle (see Fig 8). Pass-by tests were performed simultaneously with the CPX-measurements (Pass-by tests = Test vehicle driven with constant speed and engine on).

Fig. 7 Test vehicle Volvo V70 Bi-fuel used for both the Pass-by and CPX-tests. The test vehicle was supplied with test tyres of type Goodyear Hydragrip of type 195/65R15.

3.2 Single wheel trailer for measurement of tyre/road noise

CPX-measurements were also performed with the single wheel trailer developed by Acoustic Control AB with support from the QCITY project. Trailer measurements were performed both for testing the VIACOGRIP8 and the other three pavements mentioned above. The advantages of using the single wheel trailer are that the microphones can be mounted in well controlled positions relative to the test wheel. Free field conditions around the test tyre also ensure a minimum of influence from reflexes. .Boundary parameters like tyre load, tyre temperature and pressure could also be more easily controlled.

This means that the measured sound pressure levels could more easily compared and evaluated from test site to test site even if the measurements were performed different dates. See Ref. 1)

Fig. 8 Photo of the single wheel trailer for measurements of tyre/road noise here mounted with the reference test tyre Goodyear Hydragrip 195/65R15.

3.3 Test tyres

The test tyres has been Goodyear Hydragrip, see Fig 8 and 9. Tyre dimensions are **195/65R15** i.e. 195 mm wide; the height of the side rubber is 65 % of the width (127 mm). The rim diameter is 15". The total diameter of the tyre is 635 mm. The test tyre has been selected in cooperation with the Acoustics Department at Goodyear in Luxembourg. With respect to noise emission the selected tyre Hydragrip 195/65R15 is representing an average tyre out of the current tyre population.

4 Measurements and results

Tests have been performed for a worn SMA16 before and on the VIACOGRIP8 after repaving. The below listed type of measurements have been performed.

1. Monitoring of sound levels at the resident façade.
2. Pass-by measurements
3. CPX measurements with microphones mounted on a Volvo V70 passenger car
4. CPX measurements with aid of a single wheel trailer:
   - VIACOGRIP8 at Blackebergsvägen
   - reference AC16 at Kirunagatan
   - reference AC16 at Tranebergsvägen
   - reference SM16 at Vandagatan

4.1 Monitoring of road traffic noise at resident façade.

One week before and one week after repaving, the traffic noise was monitored at the façade with aid of a Larson Davis 824 1/3-octave band logger. (Microphone position shown in Fig 10). In addition, the number of vehicle passages per hour and percentage heavy vehicles was registered.

Fig. 9 Microphone position during traffic noise logging.

The monitored A-weighted sound levels as a function of time and the equivalent day level $L_{d,06\text{-}18}$ before and after repaving are presented in Fig 10. The traffic flow data is presented for available days. The traffic flow during the week 29 before repaving was 3000 vehicles day compared to 5000 during week 37 after repaving. Week 29 occurs in the vacation period with lower than normal traffic flow. The sound levels were therefore adjusted for comparison to the same traffic flow. The "normalized" equivalent day-time sound level (06-18) was then $L_{Aeq,(06\text{-}18)} = 60{,}9$ dB(A) before and $L_{Aeq,(06\text{-}18)} = 57{,}6$ dB(A) after repaving. The "Repaving Insertion Loss" between the old worn SMA16 and the new VIACOGRIP8 then was

ΔL_{day} = 3.3 dB(A).

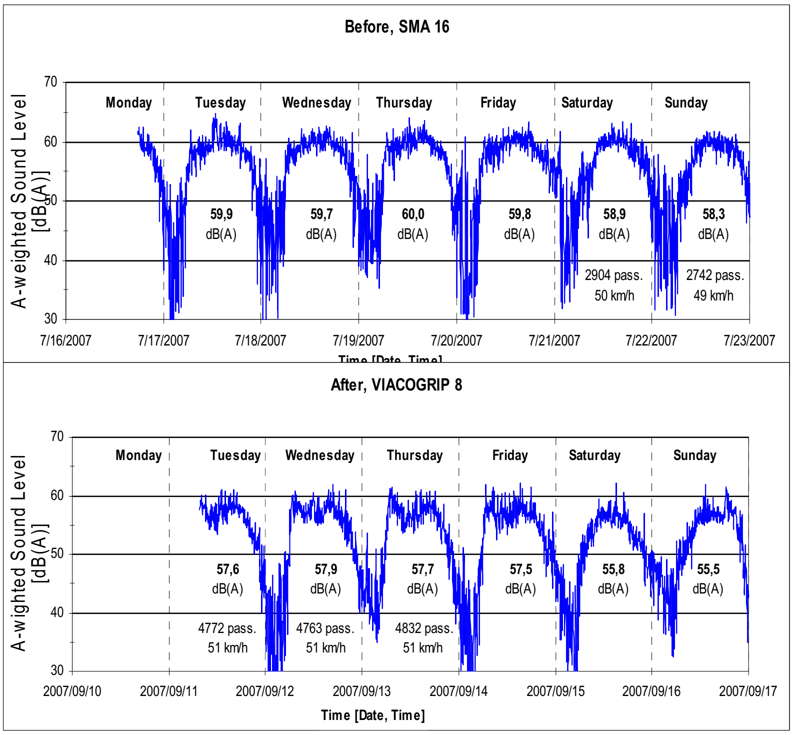

Fig. 10. Results from monitoring traffic noise levels before and after repaving with VIACOGRIP8.

4.2 Tyre/road noise measured with aid of the Pass-by method

The tyre/road noise was measured according to the Pass-by method described in the ISO standard 7188:1994, where the test vehicle is driven along the measurement test section at constant speed, with the engine turned on and running at appropriate gear. Microphones at 7.5 m from the middle of the vehicle path and 1.2 m above ground.
Speed and position was monitored during the whole measurement procedure with aid of a GPS-system storing data together with a time code on a flash memory. Data is sampled every 10 millisecond. with a precision of ±0.2 km/h.

Equipment	Brand	Type
7-channel signal analysis system	Brüel & Kjaer	Portable PULSE
Microphones	Brüel & Kjaer	4189 A21
Microphone wind shields	Brüel & Kjaer	
Sound level calibrator	Norsonic	
GPS speed and position logging system	Race Technology	DL1
Weather monitoring system	Vaisala	

Table 1 Used equipment for the Pass-by measurements.

In Fig 11 below, the measured Sound Level data are presented together with least square curve fits for both the VIACOGRIP 8 and the reference road surface.

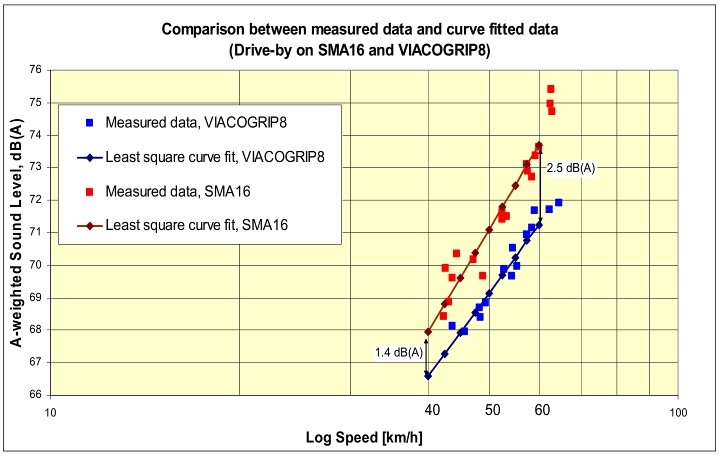

Fig. 11 Tyre/road pass-by noise presented as A-weighted sound levels. Method: ISO 7188:1994.
Note that all square symbols are actual data for sound level vs. GPS-measured vehicle speed.

Note that the difference in A-weighted sound level is 2.5 dB(A) at 60 km/h, but only 1.4 dB(A) at 40 km/h. The reduced effect of the VIACOGRIP8 for lower speeds is due to influence from engine noise. This conclusion is confirmed by the CPX-measurements presented in section 4.3.

4.3 Tyre/road noise measured with the Close-Proximity method (CPX)

Parallel to the Pass-By method, the Close Proximity (CPX)-method was also used, performed according to the standard proposal, ISO CD 11819-2 (to applicable extent). The CPX-method includes microphones attached onto the test vehicle close to the test tyre (see Fig 7) where the minimum length of the tested road is 20 m.
Speed was monitored using the GPS-system described in section 4.2. Used equipment is presented in Table 2 below.

Equipment	Brand	Type
12-channel signal analysis system	Brüel & Kjaer	Portable PULSE
Microphones	Brüel & Kjaer	4189 A21
Microphone wind shields	Brüel & Kjaer	
Sound level calibrator	Norsonic	
GPS speed and position logging system	Race Technology	DL1

Table 2 Used equipment during CPX measurements.

Data from the two microphones, in front and rear of the test tyre, were averaged. The average sound pressure levels was evaluated for each car passage including least square fit to each third octave band from which the broad band A-weighted Sound level were calculated. In Fig 12 below is presented the measured and evaluated data for A-weighted sound level vs. speed in log scale.

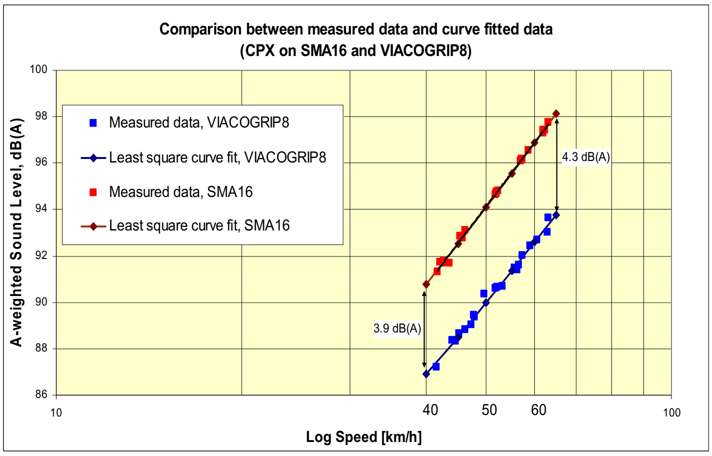

Fig. 12 The CPX-measured and curve fitted A-weighted Sound Levels as a function of speed. The speed axis is presented in logarithmic scale.

In Fig 12 it can be seen that the measured data well fall into the least square curve fit and that it forms a straight line when the sound level is plotted as a function of speed in logarithmic scale. This could be view as an indication of high quality of gathered data. Note that the CPX-method suggest that the difference between the reference and VIACOGRIP8 is larger compared to the Pass-by method. This is because the CPX data is more unaffected by background noise since the microphone positions is closer to the test tyre. At lower speeds though, even the CPX-results exhibit a minor influence from contribution of engine noise.

In Figure 13 are presented A-weighted sound pressure levels in 1/3 octave bands for the VIACOGRIP8 surface and the worn reference road surface SMA16 at 60 km/h. (for each 1/3-octave band was performed a separate curve fit vs. speed) The "Repaving Insertion Loss" at 60 km/h for the old SMA16 vs. VIACOGRIP8 is then

IL = 4.1 dB(A).

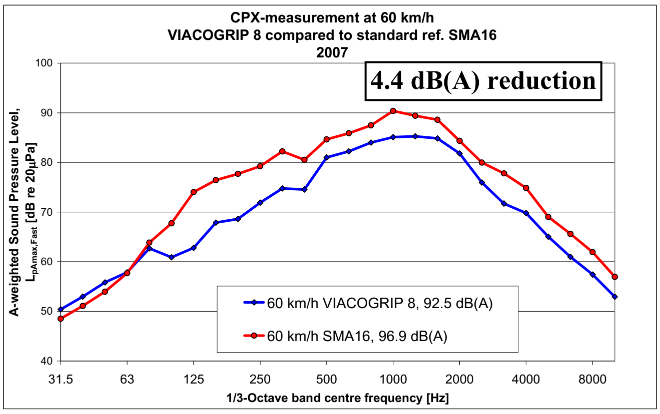

Fig. 13 A-weighted Sound Pressure Level for the VIACOGRIP8 and the old reference road surface SMA16 at 60 km/h, measured with aid of the CPX-method.

4.4 Close-Proximity method (CPX) using the single wheel trailer

The CPX measurement technique described in chapter 4.3 was utilized. In Fig 14 below is presented the A-weighted sound level (broad band data) $L_{AmaxFAST}$ dB(A) vs. speed for the VIACOGRIP8 compared to the three newly paved road surfaces.

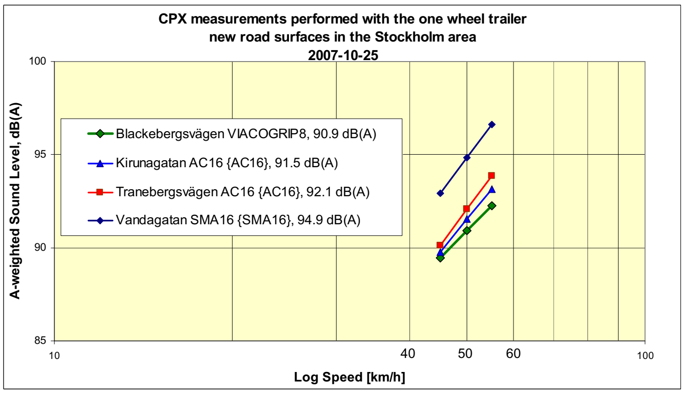

Fig. 14 The least square curve fit of CPX measured A-weighted sound levels as a function of log speed.

It can be seen that the new VIACOGRIP8 is up to 4 dB(A) quieter compared to the newly paved standard asphalt pavements SMA16 and AC16 .

Within the QCITY project we will continue to evaluate how the aging processes influence the noise reduction effect for VIACOGRIP8 and other asphalts surfaces.

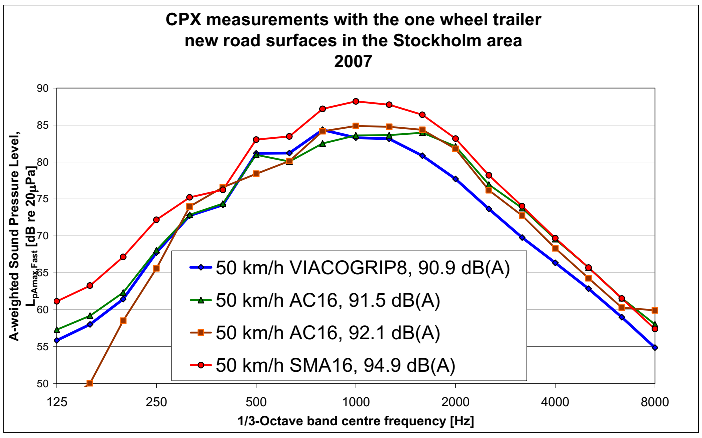

Fig. 15 A-weighted Sound Pressure Level in third octave bands at 50 km/h for an array of newly paved road surfaces (VIACOGRIP8, SMA16 and AC16) using the single wheel trailer and the CPX method.

5 Conclusions

Tyre/road noise for an array of different dense road surfaces has been studied by pass-by- and CPX-tests as well as by monitoring actual traffic noise at the residential buildings.

Results reveal that the "Repaving Insertion Loss" is 3-4 dB(A) for SMA16 with 16 mm max stone size (before repaving) as compared to a NCC/VIACOGRIP with 8 mm max stone size.

This is comparable to the "Repaving Insertion Loss" for single layer drainage or open graded surfaces as compared to SMA16. It therefore seems reasonable to consider development of dense surfaces as an alternative solution when 3-4 dB(A) lower tyre/road noise is wanted.

This type of low noise surfaces would be suitable for city areas with lower speeds where open low noise surfaces would give problem with clogging.

Acknowledgments

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This support is gratefully acknowledged.

References

[1] Nils-Åke Nilsson, Martin Höjer, "A single wheel trailer for tire/road noise measurements enabling both the CPX- and pass-by methods"' Euronoise (2008)

[2] www.qcity.eu

[3] Henrik Malker, Åsa Stenman, Nils-Åke Nilsson: "Noise Reduction by Thin Asphalt Pavement with 8 mm max Stone Size (NCC VIACOGRIP 8)" QCITY Technical Progress Report WP5.8 Stockholm Validation Site.