DELIVERABLE 5.5

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	Performance report of applied measures – Gothenburg

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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

The objective of this study is to evaluate the pavement VIACOGRIP 8 with added rubber granulate. This technical report covers the measured sound reduction effect after repavement with VIACOGRIP 8. The studied pavements are compared to a one year old standard ABT11 pavement in good condition (almost unworn) which gave up to 2.5 dB(A) units in reduction. Comparisons are also made to a 1 year old normally worn ABS16. **The Viacogrip surface gave 5.1 dB(A) lower noise emission** compared to the ABS16 surface (measurements ABS16 performed in Stockholm fall 2008). The objective of this study was primarily to find a recipe that lead to a durable wear-resistant road surface. To meet this prerequisite a rather small amount of crumb rubber has been used in the asphalt mix. After evaluating the durability for the surface 2009 and 2010 the amount of crumb rubber could be gradually increased in order to improve the noise reducing capability of the surface.

In this deliverable is also reported a study that looks at the insertion loss for the new low Z-bloc platform screens mounted close to tramcar running on the Gothenburg tram network. The performed measurements are primarily aiming at a verification of the insertion loss for the screen.

0.2 STRATEGY USED AND/OR A DESCRIPTION OF THE METHODS (TECHNIQUES) USED WITH THE JUSTIFICATION THEREOF

Performed tyre/road noise measurements have been performed according to the CPX-method, which is further described in chapter 2.1. The evaluation of the Z-bloc low tram screens have been done using a drive-by method described in chapter 2.2.

0.3 BACKGROUND INFO AVAILABLE AND THE INNOVATIVE ELEMENTS WHICH WERE DEVELOPED

Not applicable

0.4 PROBLEMS ENCOUNTERED

Not applicable

0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

NCC has been responsible for the manufacturing and paving operations related to the VIACOGRIP 8 pavement at Flygfältsvägen. SEA has contributed by planning and selecting the test sites. SEA has also been involved in planning the Z-bloc screen measurements. ACL has performed and evaluated the noise measurements.

0.6 CONCLUSIONS

Measurements have been performed in order to study the tyre/road noise reduction for a VIACOGRIP pavement relative a standard ABT11 pavement. The measurements show that the tyre/road noise can be reduced by 2.5 dB for the 40 mm thick pavement relative a one year old standard ABT1 pavement in good condition. Relative to a one year old ABS16 the Viacogrip gave **5.1 dB(A) units of reduction**. The 60 mm thick pavement reduced the tyre/road noise by 1.8 dB relative the standard ABT11 pavement. It was expected that that the thicker pavement would give a slightly higher noise reduction, which not was achieved. The reason for the deviations, which are within the measurement uncertainty, could be deviations in thickness and/or variations in void contents.

Measurements have also been performed in order to evaluate the noise reduction for the low Z-bloc screens mounted close to the tram tracks in Gothenburg. Microphone positions were chosen similar as when measuring drive-by noise for passenger cars. The gap between the screen rubber strip and the passing tram was approximately 5 cm. For the new M32 tram the screen insertion loss was measured to IL = 7 dB(A) units. For the older tram types the insertion loss was measured to IL = 6.4 dB(A) units. The M32 tram body has a smaller gap between the body and the ground. Therefore the screens become more effective for this tram type. The difference is nevertheless not that much. It has been shown that the screens are an effective solution to reduce the tram noise. TRAF are now about to perform further studies of for instance possible safety issues caused by the screen.

0.7 RELATION WITH THE OTHER DELIVERABLES (INPUT/OUTPUT/TIMING)

The road pavements evaluated in this study are a further development of the tested road pavements in Stockholm (Deliverable 5.13)

1 INTRODUCTION

In Gothenburg measures have been applied in order to study the noise reduction due to new recipe for a poroelastic road pavement. The tested poroelastic pavements (with thickness 40 mm respective 60 mm) are of porous type with added rubber granulate. The measurement site is placed in an industrial area in Gothenburg were both passenger vehicles and heavy vehicles are driving. The pavements have been evaluated using the CPX-method.

Measures have also been applied in order to study the tram noise insertion loss for a low Z-bloc screen mounted close to the tram track.

2 DESCRIPTION OF MEASUREMENT TECHNIQUES

2.1 CPX-METHOD USING A SINGLE WHEEL TRAILER

CPX-measurements have been performed using a single wheel trailer, which were used for measurements on the asphalt pavement VIACOGRIP8 and the reference pavement. The single wheel trailer for measurement of tyre/road noise has the advantage of measuring the sound at very well defined locations relative to the test wheel. The sound pressure is also measured in the free field with a minimum of influence from the reflexes from the suspension attachment and load bearing boxes. This means that the measured sound pressure levels are the emission levels with correct frequency spectra and can easily be related to the sound levels at the receiver next to the road and to other measurements where the same measurement standards has been used. With the careful control of load, microphone positions, test tyre, test tyre pressure, temperature etc. this method will enable comparison of measurements performed at different locations, dates, temperatures etc.

Figure 1. Photo of the single wheel trailer for measurement of tyre/road noise here mounted with a test tyre Goodyear Hydragrip 215/65R15.

2.1.1 Microphone positions

The measurement set-up and testing methodology is performed according to the draft proposal to a new standard, ISO CD 11819-2. The undisturbed average sound pressure level, for the two mandatory microphone positions, during constant speed is evaluated for each car passage. Each 1/3-octave band is then presented as Sound Pressure Levels vs. velocity and a least square fit is performed to the data. The least square fit function then gives the sound pressure level at any given velocity.

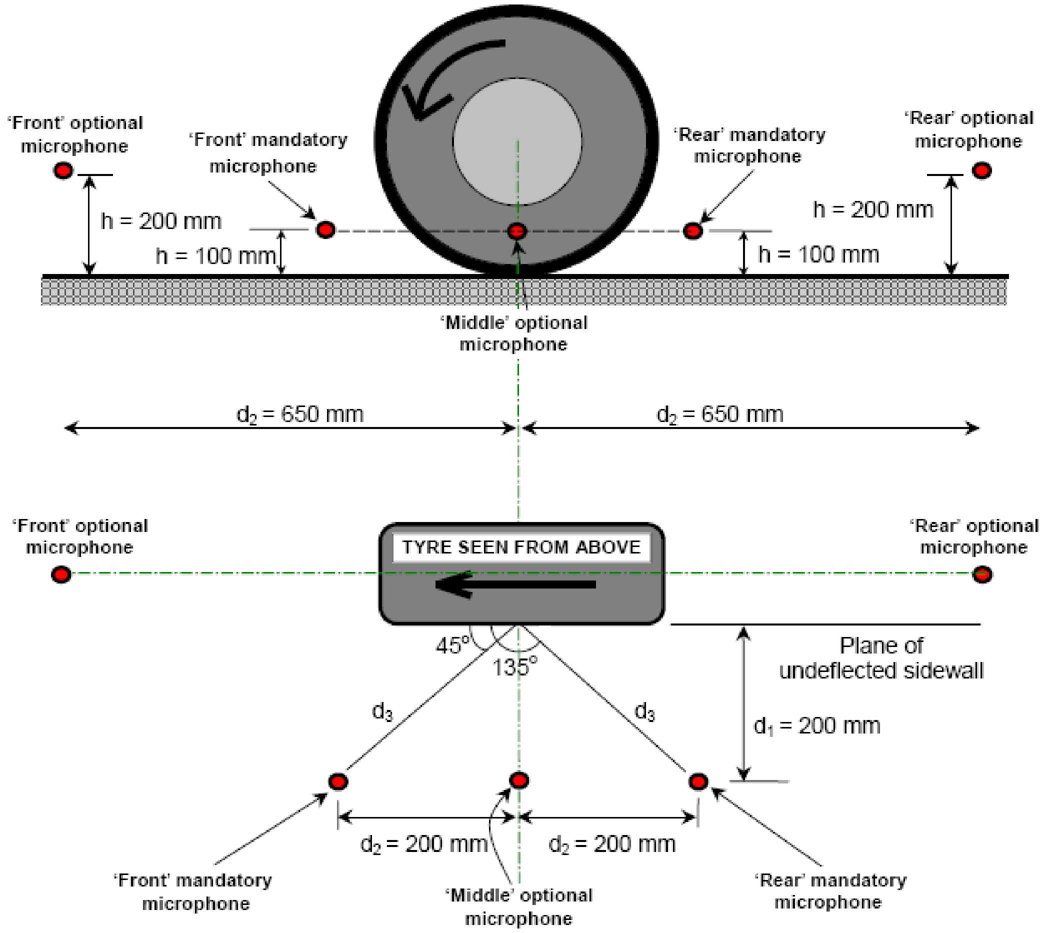


Figure 2. CPX microphone positions according to the draft proposal for a new standard, ISO/CD 11819-2, for CPX-measurements.

2.1.2 Test tyres

The test tyres has been Goodyear Hydragrip, see Figure 1. The test tyre type and dimensions are **215/65R15** i.e. 215 mm wide; the height of the side rubber is 65 % of the width (140 mm). The rim diameter is 15". The total diameter of the tyre is 635 mm. The test tyre has been chosen in cooperation with the Acoustics Department at Goodyear in Luxembourg. The selected tyre Hydragrip 215/65R15 is representing an average tyre with respect to noise emission out of a typical modern tyre population.

Table 1. Used equipment for the CPX measurements

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

2.2 Dynamic stiffness measurements

The dynamic stiffness of a structure is the ratio of the force divided by the responding vibration displacement (integrated vibration velocity or acceleration integrated twice), when the test object is excited with a force from e.g. a hammer impact. The dynamic stiffness has been analysed as a function of frequency (in the continuation called Frequency Response Function, FRF). Normally it is distinguished between point and transfer FRF. Point FRF is obtained when the force and response is measured in the same position. Transfer FRF is obtained when the response is measured at a distance from the force excitation. The mechanisms involved with the sound generation at the tyre/road are mostly local and occur close to the leading and trailing edge of the contact area. Therefore these measurements have been focused only on the point FRFs in order to as closely as possible measure parameters relevant for the excitation process.

The measurements have been performed with aid of a technique utilizing the impedance head concept. The impedance head for measurement of the Dynamic Stiffness of road surfaces was developed by ACL and was first presented at the ICSV conference in 2003 (see ref [1]). The impedance head concept was developed to measure the point FRF on elastic road surfaces. Figure 3 below shows the impedance head developed by ACL.

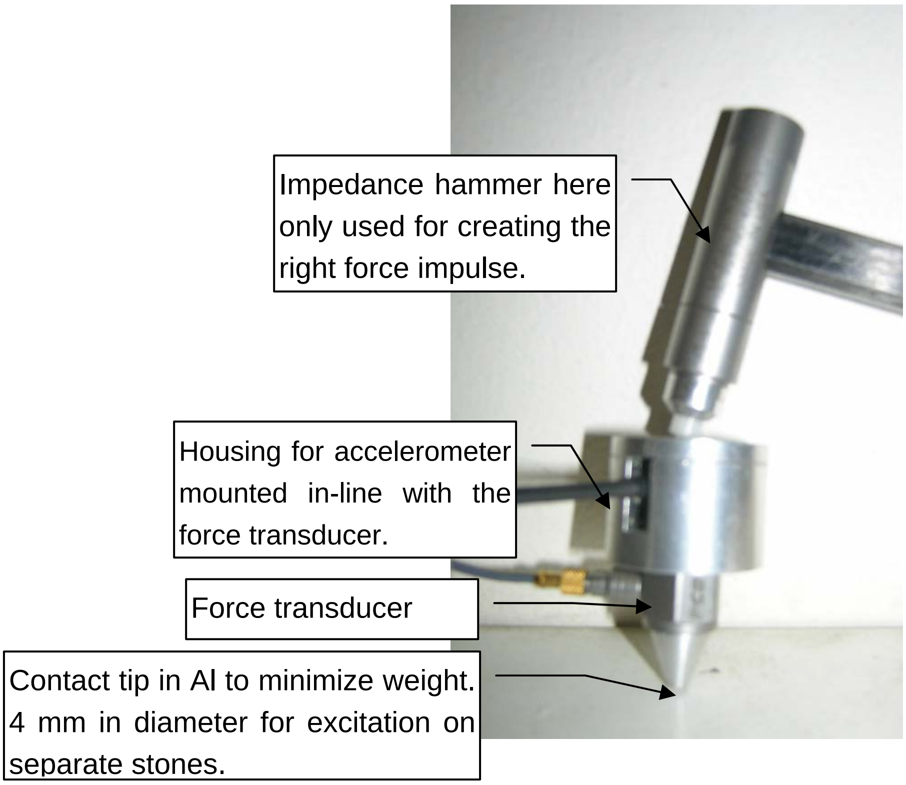


Figure 3 Impedance head for measurement of the dynamic stiffness of road surfaces. The contact tip is optimized to introduce as little weight as possible and with an excitation diameter just enough to excite separate stones.

The used measurement equipment is presented in

Table 2 below.

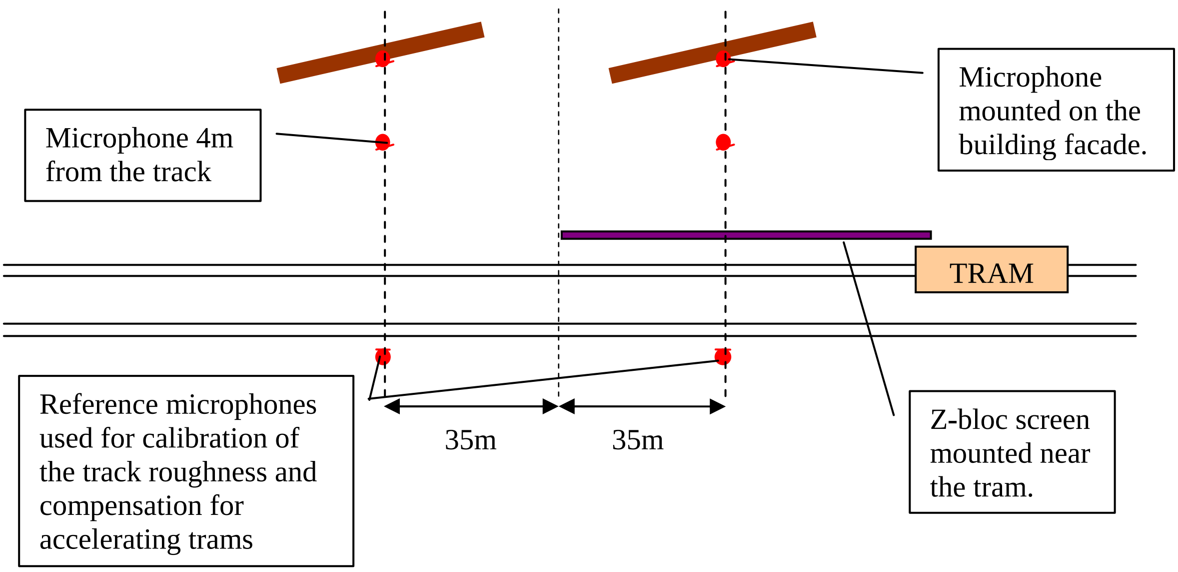
Table 2 Used measurement equipment.

Equipment		**Type**	**Serial no.**
Multi Channel Signal Analyser System		Brüel & Kjaer PULSE 7 ch	2414019
Impedance head	Accelerometer	PCB 353B11	25541
	Force transducer	PCB 208C04	19099

2.3 PASS BY METHOD FOR EVALUATION OF CLOSE MOUNTED SCREENS

Microphone positions used for evaluation of the Z-bloc tram screen are shown in the figures below. The Microphone positions are the same as when evaluating drive by noise according to the drive-by standard ISO 3095:2005. A tram platform is placed before the test site. Because of that all trams did not have constant speed for all passages. The higher sound pressure levels due to the tram accelerating has been compensated for using the reference microphones mounted on the other side of the track. The insertion loss due to the Z-bloc screen is calculated from the difference between the microphones mounted on the building façades.

Site overview



Section

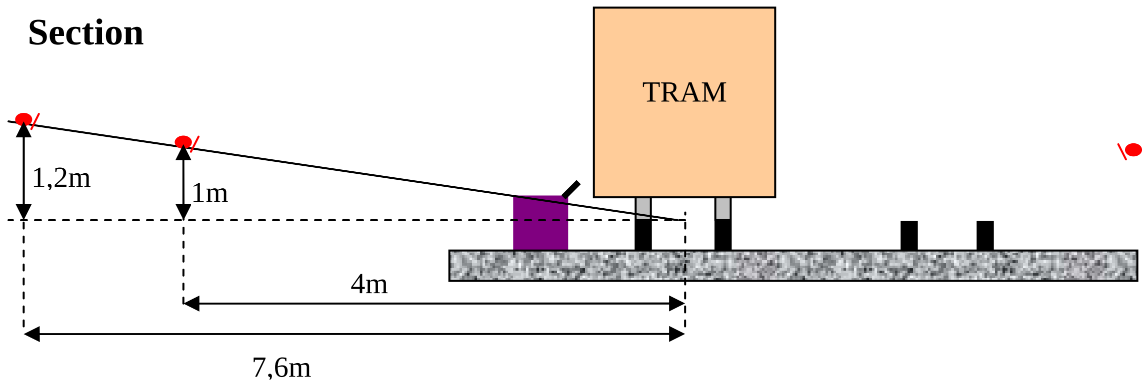


Figure 4. Sketch of the measurement set-up showing microphone positions etc. for evaluation of the Z-bloc insertion loss. The distance between the concrete and the passing tram was measured to be in the range of 7-9 cm. The rubber L-profile mounted on the screen reduces this gap down to approximately 5-6 cm.

The equipment used for the tram Drive-by measurements are presented in Table 3 below.

Table 3. Used equipment for the Drive-by measurements

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	
Optical trigging system for speed measurements		

3 PERFORMED MEASURES GOTHENBURG, 2008

3.1 EVALUATION OF CLOSE MOUNTED Z-BLOC SCREENS FOR TRAMS IN GOTHENBURG

In Gothenburg a test site has been built in order to investigate the noise reducing effect of the close mounted tram screens delivered by Z-bloc. On the 20 November 2008 measurements were performed on the site showed in Figure 5. The track is trafficked by several types of trams. The new tram (of type M32) has a lower body. Therefore the mounted screens are expected to be extra effective for these trams. The "M32" trams have because of this been evaluated separately. The temperature during the measurements was 12 degrees.

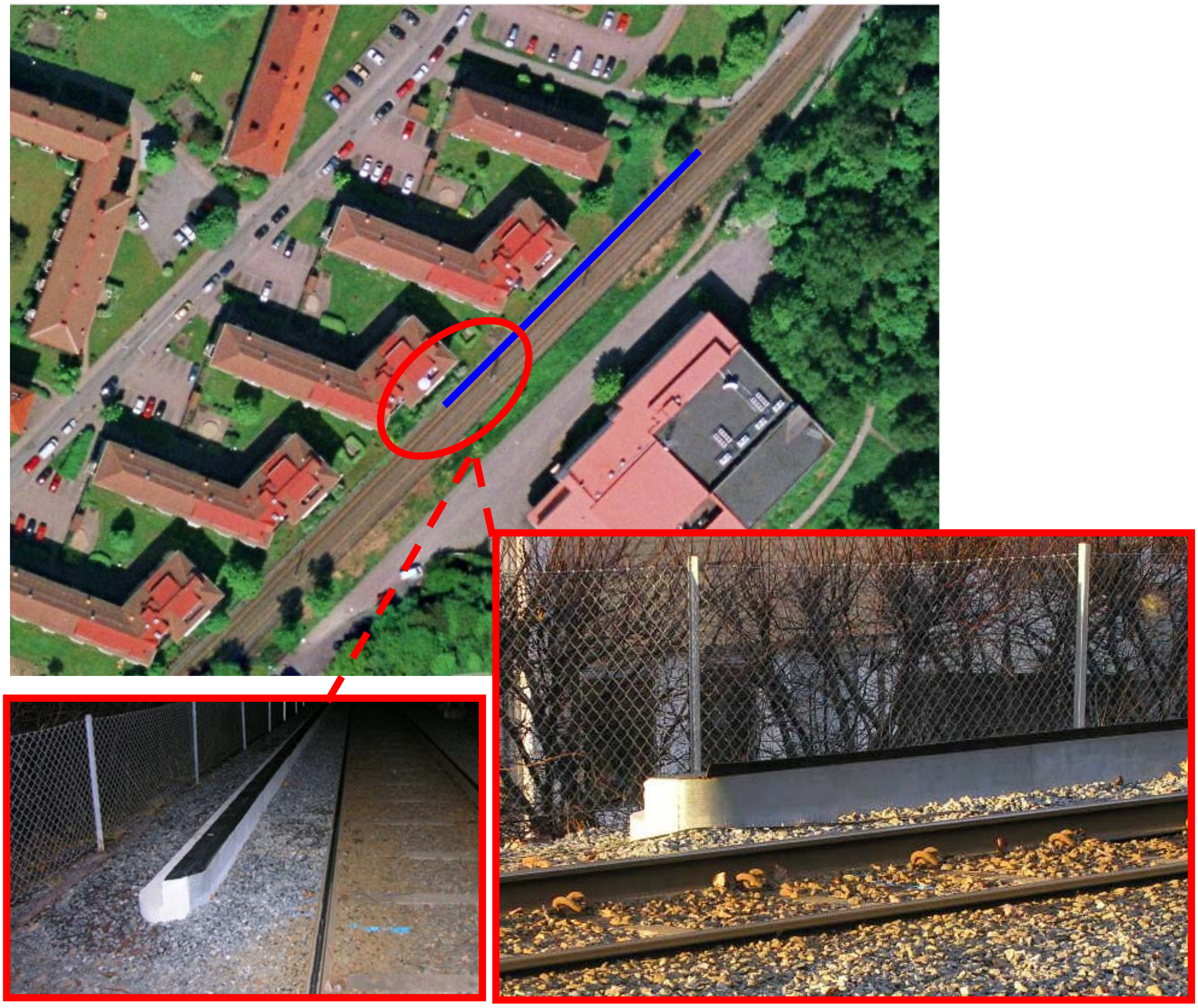


Figure 5. Measurement site for evaluation of the Z-bloc screens mounted near the Gothenburg trams.

3.1.1 Evaluation regardning maximum sound pressure level for tram passage

In Figure 6 below a typical tram passage can be seen.

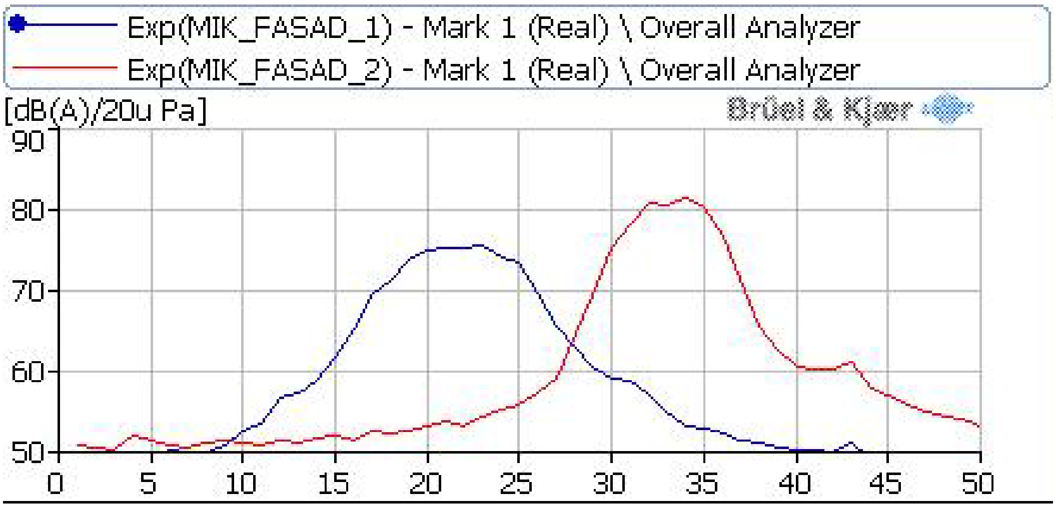


Figure 6. Measured sound pressure level as function oft time for one oft the tram passages.

The averaged maximum sound pressure level for all the M32 passages is showed in Figure 7 below. From the results it can be seen that the screen insertion loss is measured to **IL = 7 dB(A)** units for the "M32" passages.

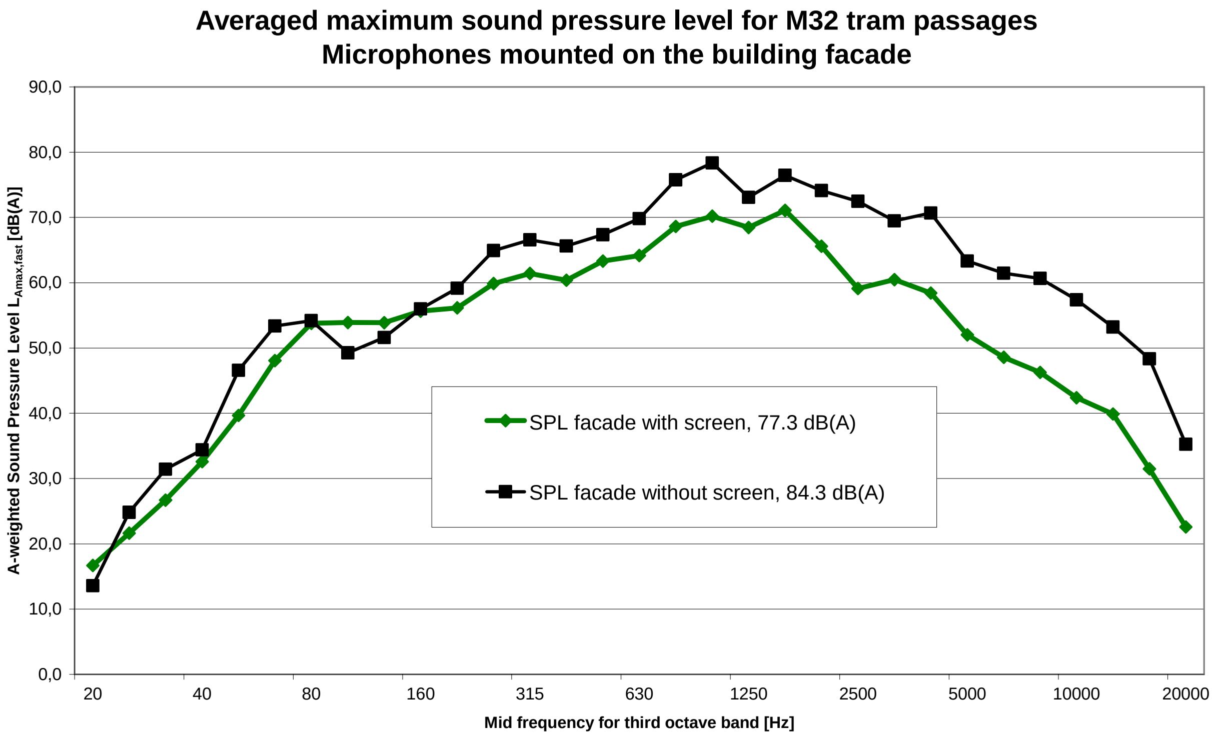


Figure 7. Averaged maximum sound pressure level measured at the building façade for the "M32" tram passages.

The averaged maximum sound pressure level was also calculated for the other tram passages (i.e. all passages except the “M32” trams). The result is showed in Figure 8 below. From the results it can be seen that the screen insertion loss is measured to **IL = 6.4 dB(A)** units for tram passages (“M32” passages excluded).

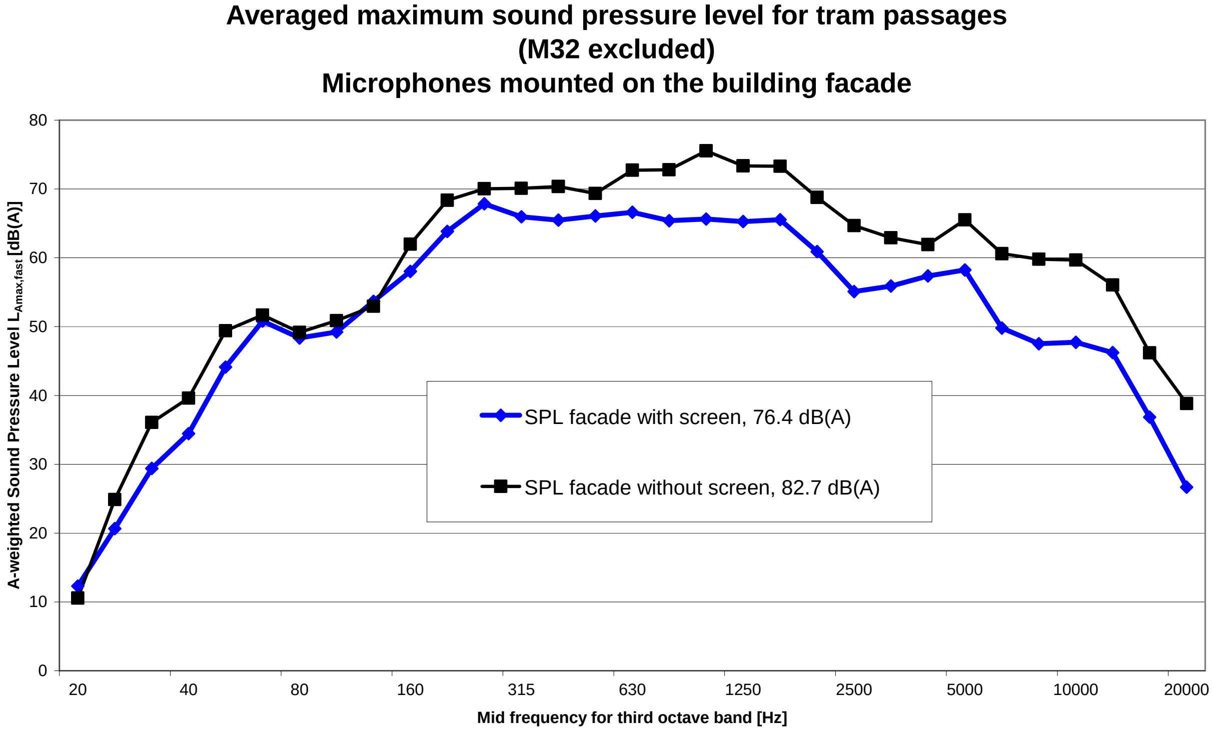


Figure 8. Averaged maximum sound pressure level measured at the building façade for all tram passages except the “M32” tram.

3.1.2 Evaluation regardning SEL (Single Event Level) for tram passage

The insertion loss for the M32 tram has been evaluated using SEL Single Event Levels according to ISO 3095:2005. The time intervals T, used for calculating the SEL-levels, are showed in Figure 9 below. For the M32 tram the insertion loss has been measured to **IL = 6.5 dB(A)** units, evaluated using the SEL levels. This is 0.5 dB(A) units less than using the L_{AmaxF} as descriptor for evaluating the insertion loss.

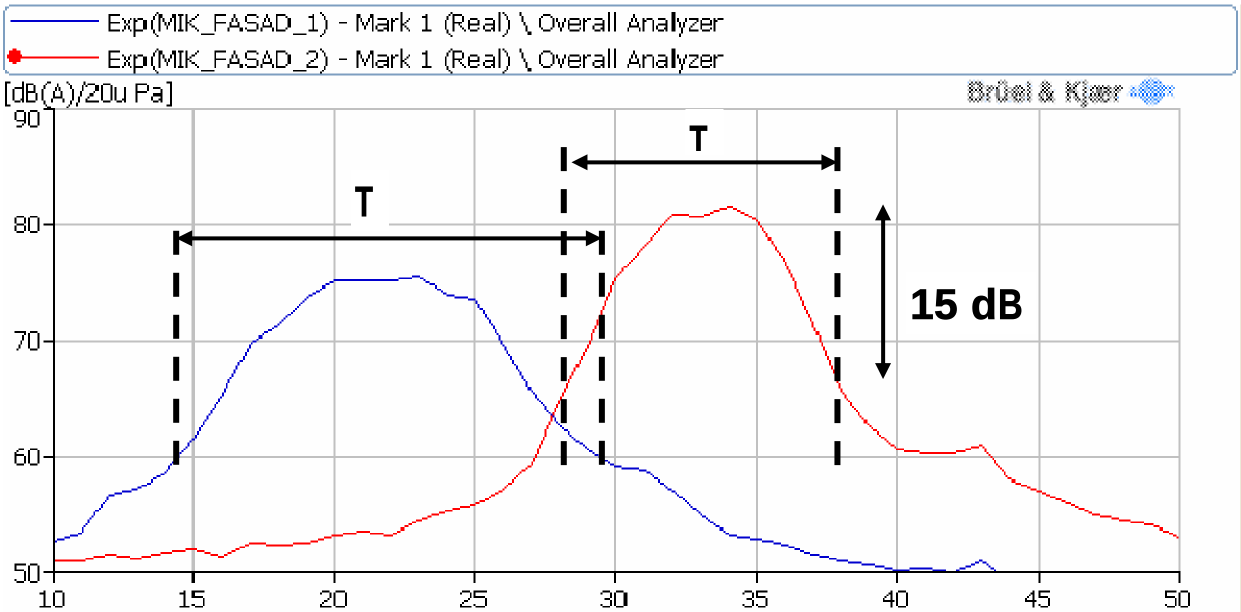


Figure 9. Measured sound pressure level as function oft time for one oft the tram passages used for evaluation of SEL-levels. The time interval T used for calculating the SEL-levels start and ends when the noise level is 15 dB less than the average passage level.

3.2 EVALUATION OF TWO NEW POROELASTIC ROAD PAVEMENTS IN GOTHENBURG

Two new poroelastic road surfaces have been tested at Flygfältsvägen in Gothenburg. The new road surfaces are of the type VIACOGRIP 8, with rubber granulates. The poroelastic pavements (40 mm and 60 mm thick) were repaved 1 October 2008 and are compared to a one year old standard ABT11 road surface. All sites are showed in Figure 10 below. The measurements were performed 17 October 2008. The temperature during the measurements was between 12-14 degrees.

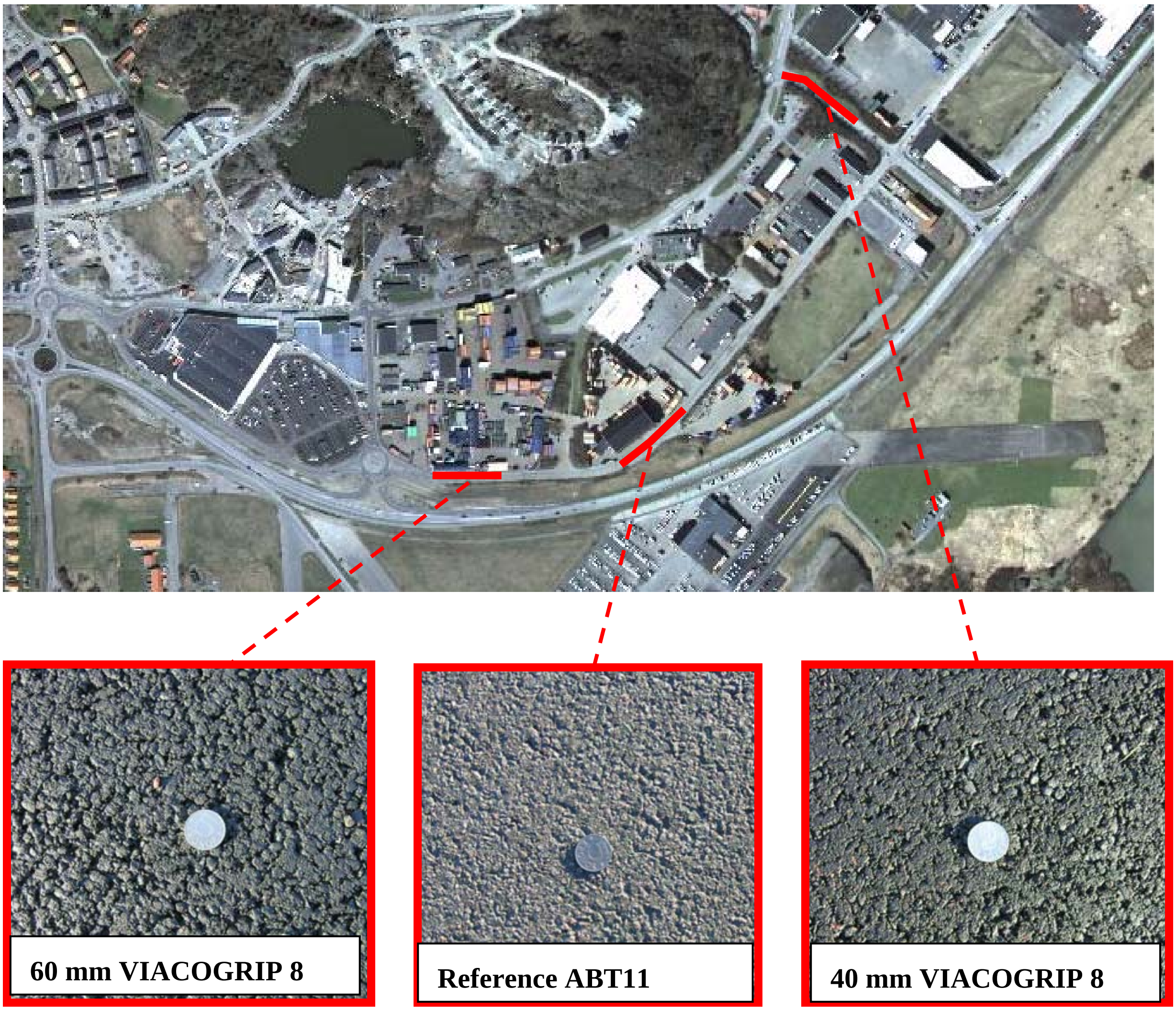


Figure 10. Tested road pavements at Flygfältsvägen, Gothenburg.

The recipe for tested road surfaces are similar to the VIACOGRIP 8 pavement, except that extra rubber granulates are added. The surfaces have about 6% rubber (saturated with bitumen) included in the mix. This corresponds to approximately 4.5% untreated rubber. The maximum stone size is 8 mm and the porosity of the pavements is about 10%.

3.2.1 Poroelastic road pavement, 60 mm

CPX measurements have been performed for the 60 mm thick VIACOGRIP 8 pavement at Flygfältsvägen. The measurements have been performed according to the setup described in chapter 2.1. In Figure 11 below the evaluated data points (from the least square curve fit functions) are presented as the broad band A-weighted Sound level vs. speed. The results are compared to the reference pavement of type ABT11.

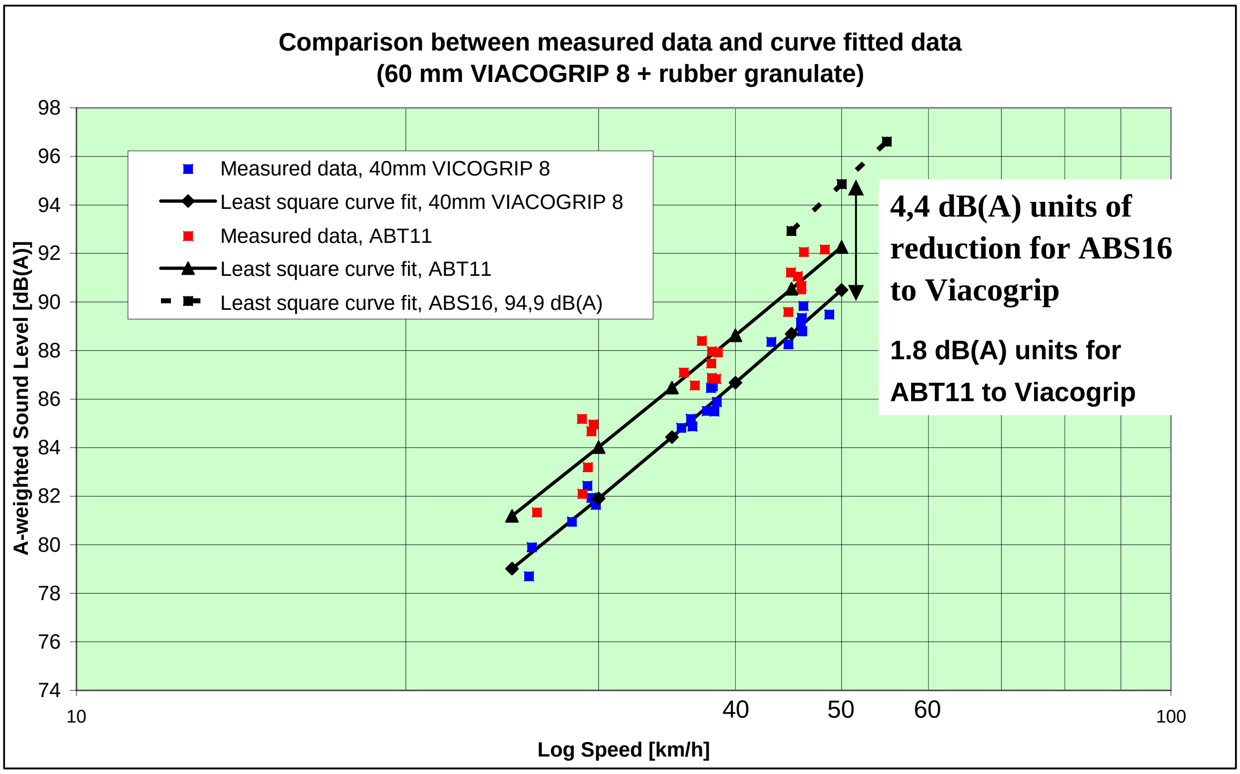


Figure 11. Evaluated data points (from the least square curve fit at each third octave band) for the poroelastic 60 mm VIACOGRIP 8 and the standard reference pavement ABT11.

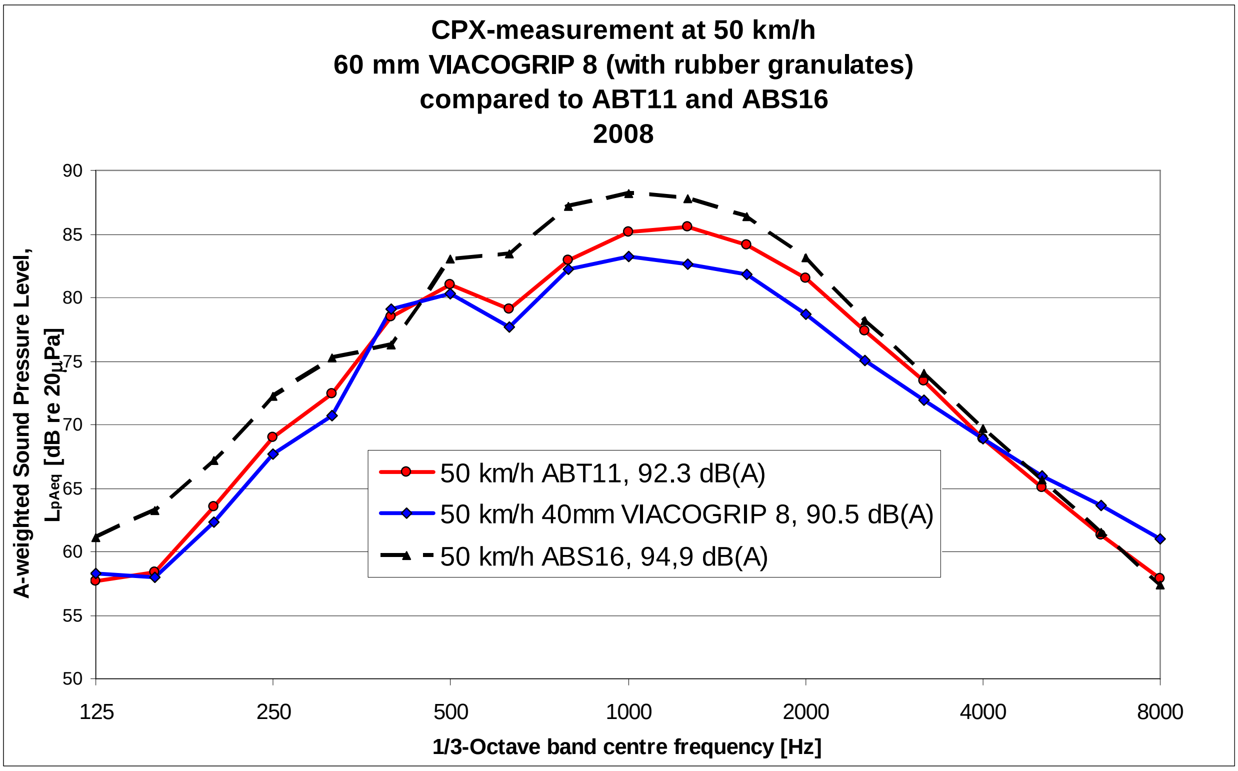


Figure 12. Measured tyre/road noise spectrum at 50 km/h for the poroelastic 60 mm VIACOGRIP 8 and the reference ABT11

3.2.2 Poroelastic road pavement, 40 mm

CPX measurements have been performed also for the poroelastic 40 mm thick VIACOGRIP 8 pavement at Flygfältsvägen. The measurements have been performed according to the setup described in chapter 2.1. In Figure 13 below the evaluated data points (from the least square curve fit functions) are presented as the broad band A-weighted Sound level vs. speed. The results are compared to the reference pavement of type ABT11. In the diagram is also plotted the sound level from a newly paved ABS16

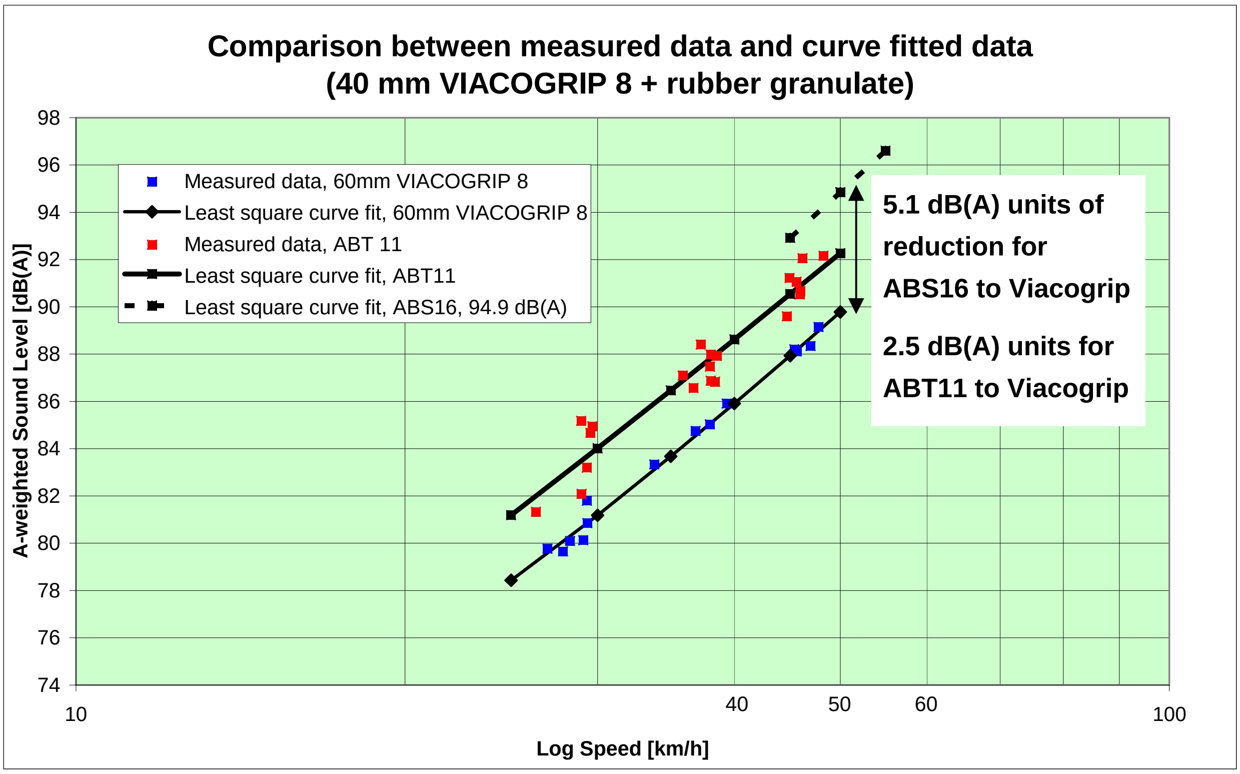


Figure 13. Evaluated data points (from the least square curve fit for each third octave band) for the poroelastic 40 mm VIACOGRIP 8 and the standard reference pavement ABT11 as well as for ABS16.

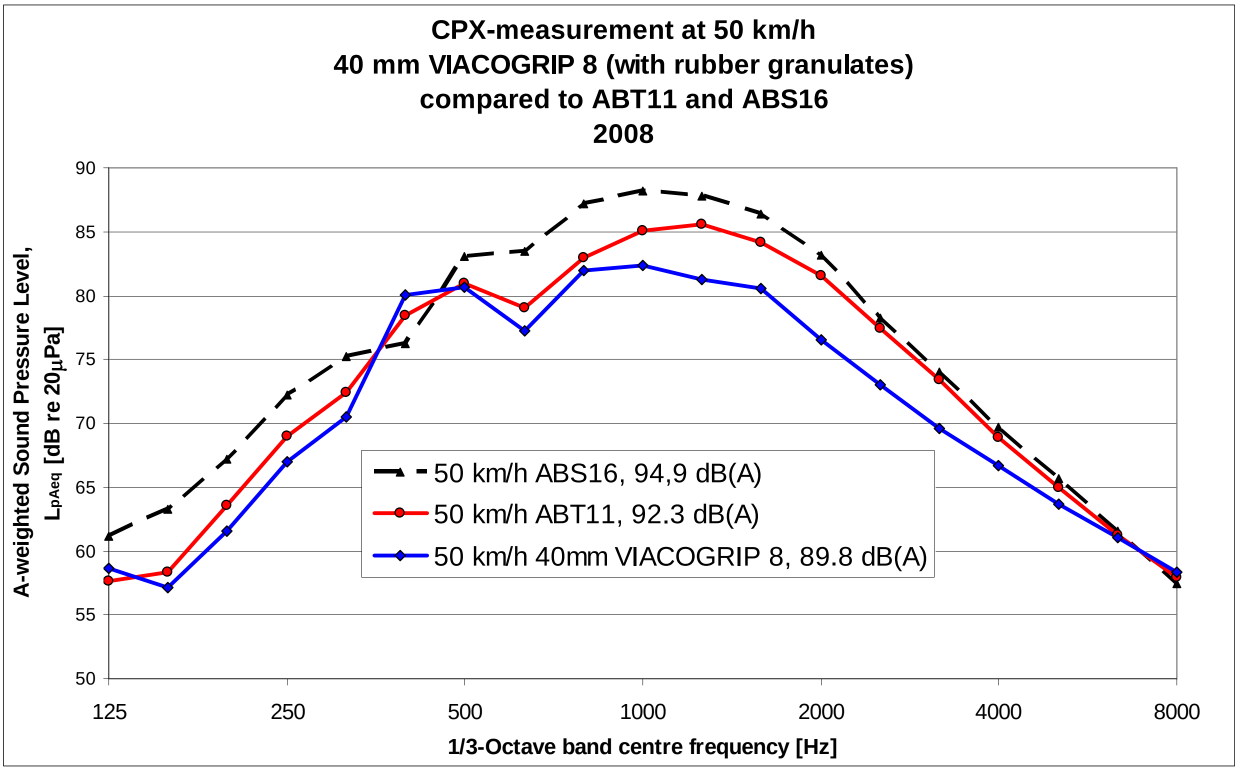


Figure 14. Measured tyre/road noise spectrum at 50 km/h for the poroelastic 40 mm VIACOGRIP 8 and the reference ABT11 and ABS16

3.3 DYNAMIC STIFFNESS MEASUREMENTS, 2007 AND 2008

Figure 15 presents the measured Dynamic Stiffness of the VIACOGRIP 8 at Blackebergsgatan in Stockholm compared to the VIACOGRIP 8 with 6% rubber granulates. The stiffness is also compared to a reference road surface of the type SMA11. It can be seen that the ordinary VIACOGRIP 8 has approximately the same Dynamic Stiffness as standard asphalt. With rubber in the pavement the dynamic stiffness is lowered by approximately 18 dB at 1000 Hz.

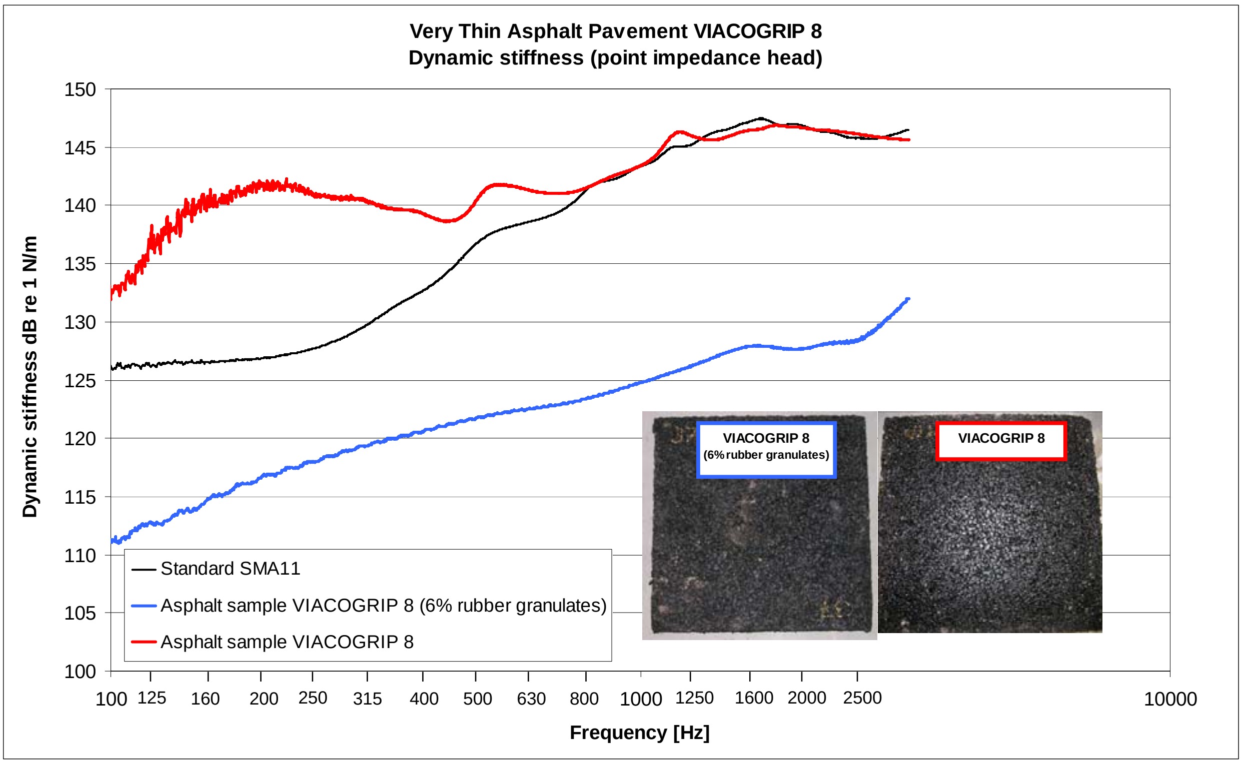


Figure 15. Measured dynamic stiffness for tested road surfaces.

4 DISCUSSION

Measurements have been performed in order to study the tyre/road noise reduction for a new poroelastic pavement relative standard ABT11 and ABS16 pavements. The measurements show that the tyre/road noise for a 40 mm thick Viacogrip pavement can be reduced by **up to 5.1 dB(A) units** relative ABS16 and 2.5 dB relative a one year old standard ABT11 pavement almost unworn and in good condition. The 60 mm thick pavement reduced the tyre/road noise by 1.8 dB relative the standard ABT11 pavement. It was believed that that the thicker pavement would give a slightly higher noise reduction. This did not however show up in the measurement results. The reasons can not yet be fully explained.

Measurements have also been performed in order to evaluate the noise reduction for the low Z-bloc platform screens mounted close to the tram tracks in Gothenburg. Microphone positions were chosen similar to those used when measuring drive-by noise for passenger cars. The gap between the screen rubber strip and the passing tram was approximately 5 cm. For the new M32 tram the screen insertion loss was measured to IL = 7 dB(A) units. For the older tram types the insertion loss was in average measured to IL = 6.4 dB(A) units. The M32 tram body has a smaller gap between the body and the ground. Therefore the screens become more effective for this tram type. The difference is though rather minor. It has been shown that the tested screen type is an effective solution for substantial reduction of tram noise. TRAF are now about to perform further studies regarding safety issues.