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Measurements of facade sound insulation using a loudspeaker or railbound vehicles as sources

Sigmund Olafsen
Brekke & Strand akustikk, P.O. Box 1024, NO-0218 Oslo, Norway, sigmund.olafsen@brekkestrand.no

Lunds Tekniska Högskola, Box 118, SE 22100 Lund, Sweden

The paper will describe the advantages and disadvantages of using a loudspeaker versus using railbound vehicles as signal sources for measurements of the sound insulation of a façade. It's based on measurements from five sites, one ordinary railway site, one site with the tram as source, and 3 sites with Oslo's metro as source. At mid-frequencies, typically 200 to 1000 Hz, the resulting sound insulation from measurements with loudspeaker or train is almost identical. At frequencies below 200 Hz, the loudspeaker appears to indicate a higher sound insulation than the railbound vehicles. This is also the case at frequencies above 1000 Hz. At low frequencies, the discrepancy could be due to a groundborne component from the railbound vehicle, resulting in a lower apparent sound insulation. At both high and low frequencies, the discrepancy could be due to an insufficient signal to noise ratio when the railbound vehicle is used as source. The paper will give recommendations for which cases should be measured using loudspeaker, railbound vehicles or both as a signal source for façade sound insulation measurements in houses close to railways or railbound urban transport lines like trams and metros.

1 Introduction

Indoor noise in residences from railbound vehicles will generally consist of two components. The first component is the airborne noise (L_{ia}), the second component is the groundborne noise (L_{ig}). It is important to determine as accurately as possible the relative influence of the two components. In existing houses it is often most practical to measure the sound insulation using both a loudspeaker and railbound vehicles as sound sources. For the presented measurements, the microphones have been in the same positions for both types of measurement. The loudspeaker has been placed in different positions in such a way as to simulate as well as possible the average direction of the path of the passing train.

The aim of this investigation has been to determine the difference between apparent sound insulation using the railbound vehicle and the loudspeaker as signal sources. Details about the microphone position are not critical for this difference.

2 Measurement method

2.1 Instrumentation

The measurements presented in this paper have been performed using a Norsonic 121 two-channel analyzer. The aritificial sound source used in the measurements have been made with a Norsonic 280 noise generator and power amplifier and a Norsonic 250 hemi-dodecahedron loudspeaker. The loudspeaker generates a sufficiently strong measurement signal in the frequency range 50 Hz to 5000 Hz to give a proper indoor level. Measurements have been made with a time resolution of 1 second and a frequency resolution of 1/3-octave bands.

2.2 Analysis of measurements

The analysis has been made on a basis of the overall Leq values for each of the measurements. The start and stop of each individual measurement has been made manually in all cases.

Analysis of the time profile shows that the indoor level in some 1/3-octave bands does not vary during the measurement when using the railbound vehicles as sound sources. This is probably due to background noise being higher than the signal. This phenomenon leads to an underestimation of the sound insulation of the façade at high frequencies. In the 5 presented cases, the frequency band where this effect becomes significant varies from 500 Hz to 2 kHz.

2.3 Sites

The measurement sites are all situated close to the tracks. A short description of the sites, details of the measurement methods and the results is given below. The microphone positions were always in front of the façade to be measured. There is no clear standard for measurements with the microphone placed in front of the façade [1,2]. However, there exists research into the merits of such measurements [3,4,5,6,7]. The ISO standard [2] is under revision. Some of the material presented in this paper may be used in that revision. The presented level differences are energy average attenuations for each site. A total of 5 sites are included in this study, called train 1, tram 1, metro 1, metro 2 and metro 3.

3 Details and results for each site

The sound insulation values measured using the railbound traffic as source are not correct for high frequencies. At these frequencies, the indoor level is due to background noise, and so the presented value is an underestimation. The values are shown in order to demonstrate how large the underestimation could be.

3.1 Site Train 1

The house in question is situated 30 meters from a railway line with 2 tracks. The measurements included in this presentation were made with 4 outdoor and indoor microphone positions. For each combination of outdoor and indoor microphone position, 1 measurement was made using train passages and one measurement with white noise from a loudspeaker. The loudspeaker was placed on top of the fence on a balcony approximately 2 meters in front of the façade.

In this site, there is little discrepancy between the apparent sound insulation at frequencies above 50 Hz, while the apparent discrepancy at high frequencies start at 500 Hz. This seems reasonable, as the sound levels from the railway are not particularly high at this site.

There is little influence of groundborne noise at this site.

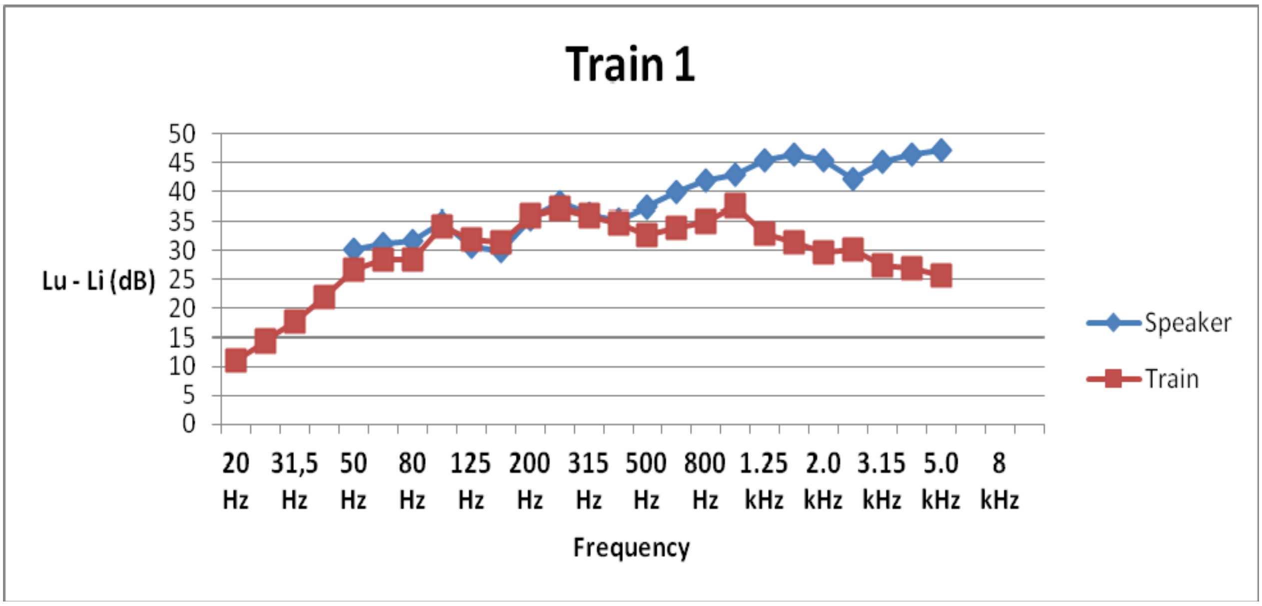

Figure 1: Level difference at site train 1

3.2 Site Tram 1

Site tram 1 is a house close to very close to a turning circle for the tram. The speeds are very low. The tram line is so close to the house that the inbound and outbound trams give different results, The level differences are based on microphone sweeps during loudspeaker test signals and tram passages. The distance to the outbound tram line from the façade is 13 m, to the inbound tram line 8 m. The presented values are averages of 4 measurements.

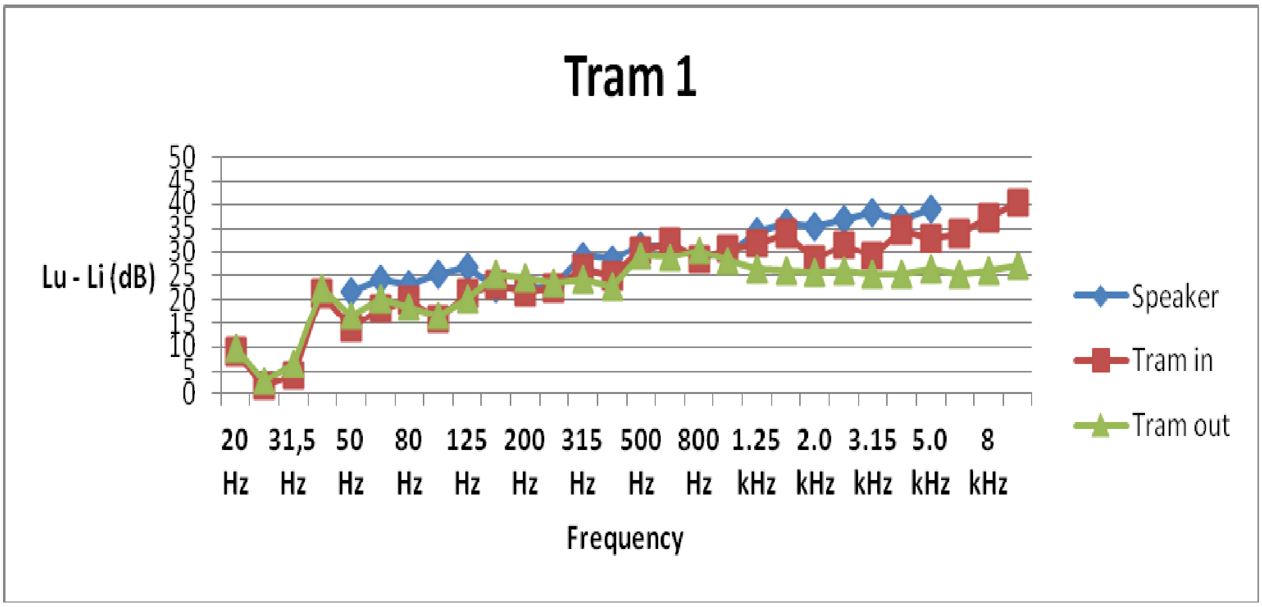

Figure 2: Level difference at site tram 1

At this site, there is a discrepancy between the sound insulation values at freqeuncies below 125 Hz. This is an indication that there might be a groundborne component in the indoor noise. At frequenices above 1000 Hz, there is a discrepancy between the sound insulaiton measured with the loudspeaker as source and the measured values with the tram as source.

3.3 Site metro 1

Site metro 1 is approximately 25 meters away from a new metro line. The measurements were made on a balcony faicng the metro line. Loudspeaker measurements were made with the source on top of the balcony fence approxiamately 3 meters away from the façade. 10 passing metro trains were used in the analysis. 2 loudspeaker positions with 6 microphone positions for each were used for the measurements with loudspeaker. Figure 3 shows the results from this site.

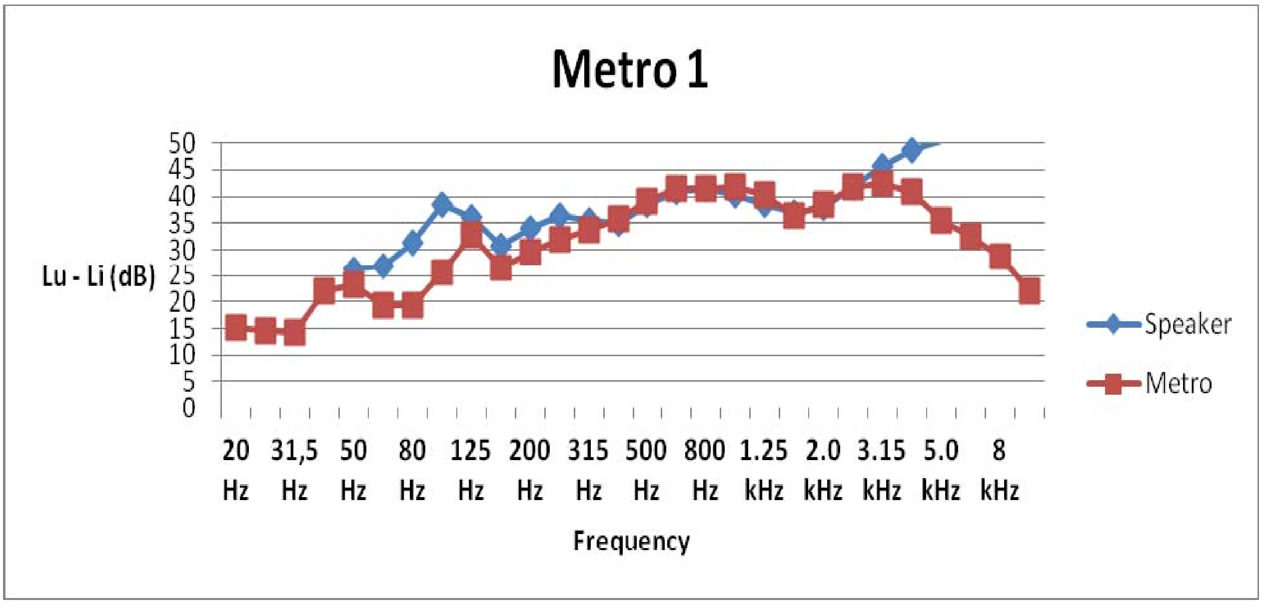

Figure 3: Level difference at site metro 1

At this site there's a discrepancy between loudspeaker and vehicle measurement up to 315 Hz, a higher frequency than in other cases. The discrepancy appears again at 3,15 kHz and upwards. There were no feelable vibrations nor audible structureborne sound in this case. In this case no vibration measurements were made, but it seems reasonable to assume that there is a contribution from groundborne noise anyway.

3.4 Site metro 2

The house where the measurements were made is 30 meters from the metro line. The presented levels are based on 10 metro train passages and 2 loudspeaker positions with each 5 microphone positions. The results are shown in figure 4.

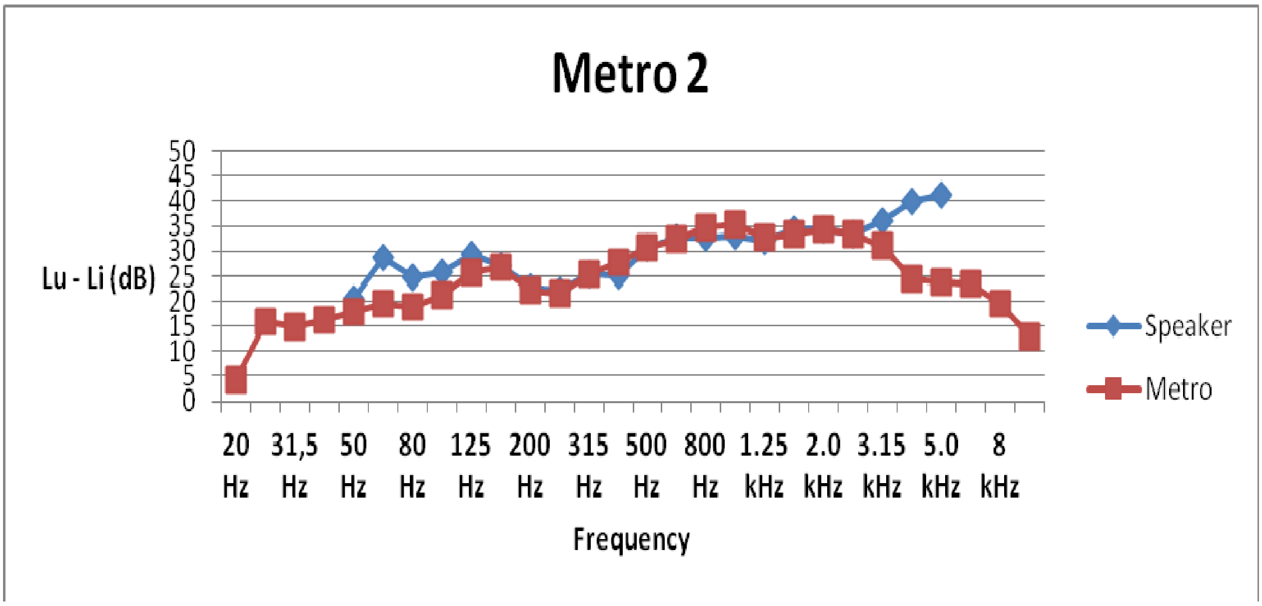

Figure 4: Level difference at site metro 2

In this case the discrepancy at low frequencies goes up to 125 Hz, and it starts again at 3,15 kHz.

3.5 Site metro 3

This site is at 17 meters from the metro tracks. The measurements were made with 10 passages of metro trains. Loudspeaker measurements were made using 2 microphone sweeps. The results are shown in figure 5.

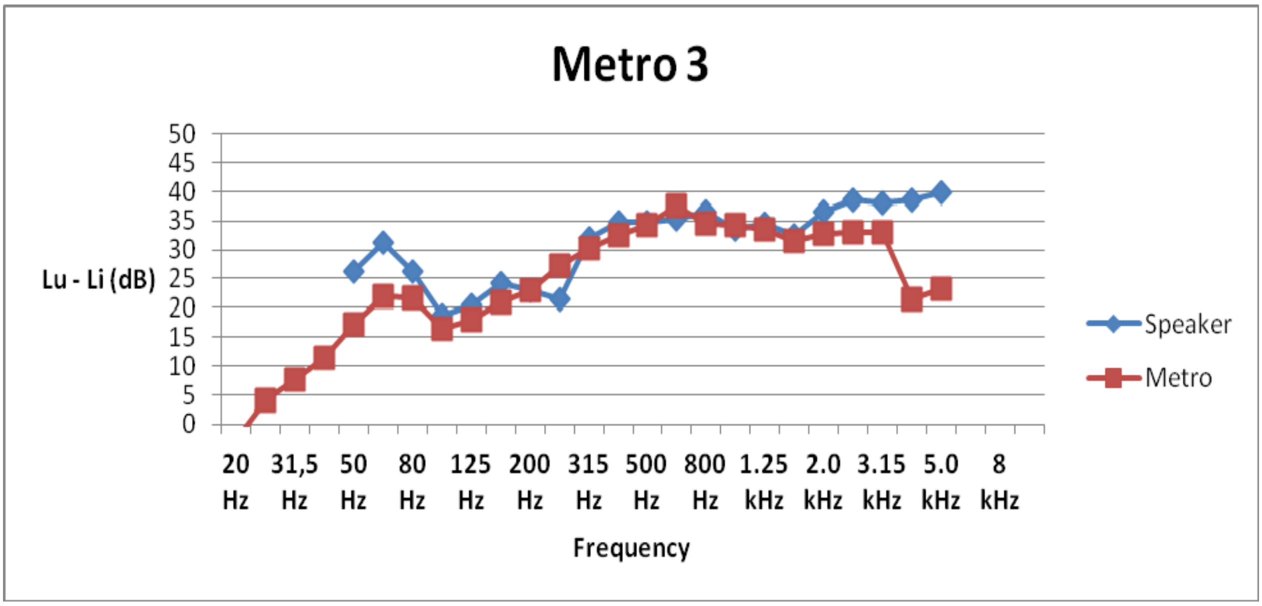

Figure 5: Level difference at site metro 3

There is a discrepancy at frequencies from 80 Hz downwards, and from 2,5 kHz upwards.

4 Further research

This paper is part of a project to acquire a better understanding of indoor noise from railbound vehicles. One question that comes naturally to mind, is whether the difference in measured insulation spectrum between the loudspeaker and the railbound vehicles has any practical significance. That is, will sounds at frequencies below 200 Hz or above 1000 Hz contribute to the total noise exposure? At low frequencies, groundborne noise is certainly a problem that cannot be solved using sound insulation measurements with a loudspeaker as source. The groundborne noise from railbound sources in residences is a particularly annoying type of noise. So in some cases there may be little difference in terms of overall weighted sound insulation index, but still the groundborne contribution is very important for the perceived noise situation.

More research into the sound field in front of the facade is required. In many practical cases it might be necessary to make the measurements using microphone positions in front of the facade. It would seem that the interference effects predicted by theory is not so critical in real field measurements.

Measurements of groundborne noise transmission is also required. The transmission of vibrations from the ground into buildings is not completely understood.

5 Acknowledgements

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6 Conclusions

There’s definitely a difference between the measured level difference using the railbound traffic or a loudspeaker as noise sources. In the frequency range 200 Hz – 1000 Hz the two sources give similar results, and both are acceptable. At lower frequencies than 200 Hz, the railbound vehicles will give an apparently lower sound insulation (and higher indoor level). It seems reasonable to assume that this is due to a groundborne contribution to the indoor noise level. At frequencies above 1000 Hz, there is insufficient noise energy in the railbound vehicle to give a good measurement of indoor noise level. The measured indoor values form railbound vehicles above 1000 Hz do not go above the background noise level, thus the sound reduction in the facade may be much better than indicated. It seems necessary to use both a loudspeaker and a railbound vehicle as noise sources in order to achieve a complete picture of the sound insulation.

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