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Field versus laboratory sound insulation of glass façades

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ABSTRACT

Office and residential buildings are sometimes placed at locations exposed to heavy traffic noise or other prominent noise sources. In order to achieve acceptable indoor sound levels, sufficient sound insulation in the façade is required. Recent measurements have shown a significant discrepancy between laboratory data and the measured sound insulation of the glass façades when mounted on site. The difference in gathered field versus laboratory values have been measured up to 15 dB. This introduces an uncertainty that creates a challenge for the building designers. The aim of this paper is to present measured results for various glass façades and examine some possible explanations to the observed differences between laboratory and field data.

1. INTRODUCTION

When designing building façades exposed to heavy traffic noise, sufficient sound insulation must be obtained to ensure acceptable indoor noise levels. Based on predicted or measured outdoor noise levels, necessary sound insulation qualities required from the glass façade are calculated. When ordering façade elements from the supplier, safety margins are often added, since the on site assembling process is usually performed in a less controlled environment than in the laboratory. The choice of the necessary safety margins naturally becomes a critical point in the design phase. Large safety margins may secure the resulting indoor levels, but may also lead to unnecessary high project costs. In Norway, the typical safety margin has traditionally been 2-3 dB, but measured façades presented in this paper reveal even greater discrepancies between field and laboratory results.

This paper will address these differences between field and laboratory sound insulation values, expressed as a single number rating $R'_w + C_{tr}$ and $R_w + C_{tr}$ respectively (as defined in ISO 717-1[1] and ISO 140-5[2]).

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2. CASE STUDIES

The graph below (figure 1) illustrates the difference between field ($R'_w + C_{tr}$) and laboratory ($R_w + C_{tr}$) measurements for 9 measured cases (office buildings). For every case and thus every construction type, the appurtenant laboratory value is known. Each measured case is a façade consisting of mainly glass panes and framework creating a smooth outer surface. The constructions were all handed over as completed. Measurements were performed using a loudspeaker as the noise source. .

The red line illustrates the situation where the field result equals the laboratory result. Values below the red line are glass façades where the field result ($R'_w+ C_{tr}$) had a lower value than the quoted laboratory result ($R_w+ C_{tr}$).

The result above the red line is the one case where the field measurement yielded better sound insulation than what was measured in the laboratory. As discussed in chapter 4 later on, the assembling precision in laboratories may also vary, and sometimes the mounting on site can be more accurate than in the laboratory. Another reason might be that the size of the test specimen in the laboratory often is different from the façade on site, which may also result in different sound insulation values.

The graph indicates that glass façades sometimes do not perform as well as should be expected, and as predicted in the laboratory. The differences between field and laboratory values in the 9 reported cases are as great as 15 dB, and the average difference is 8 dB. This is far more than the generally accepted safety margin of about 2-3 dB.

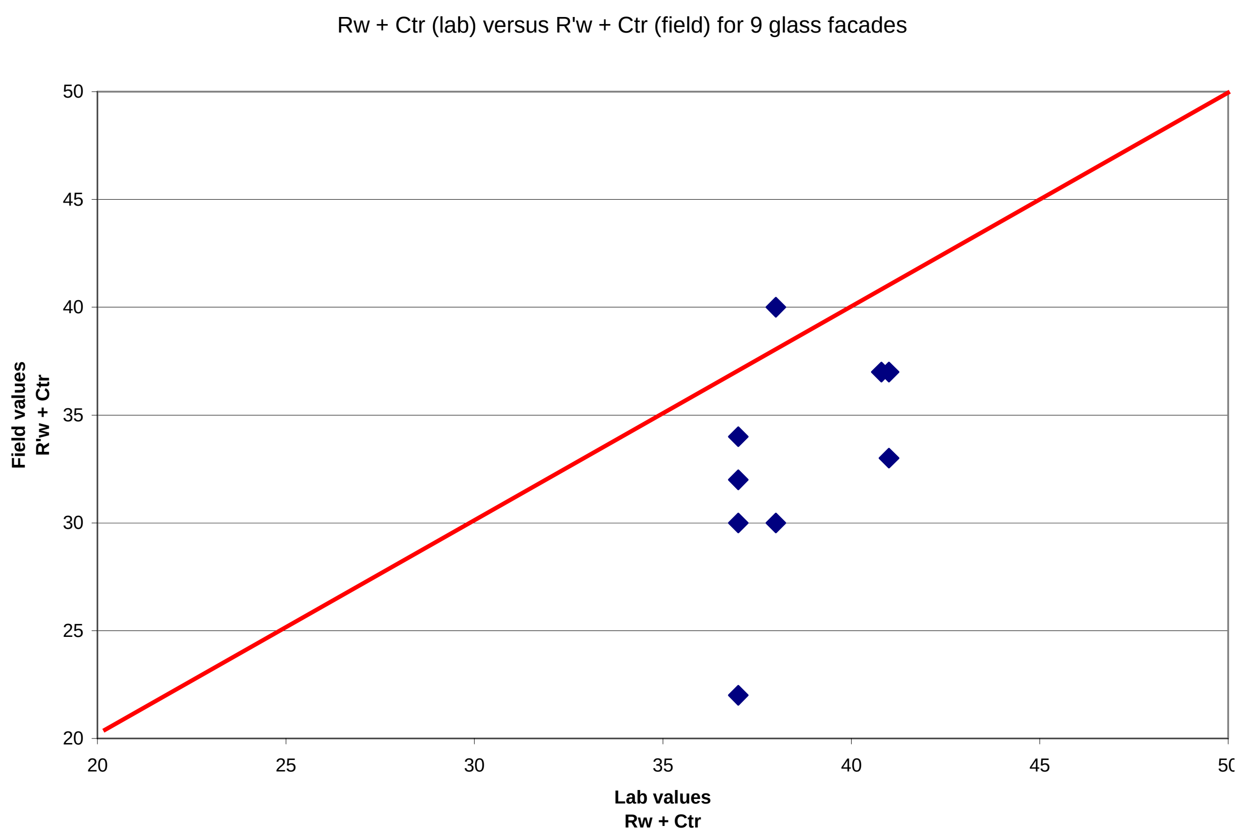

Figure 1: Measurements performed on 9 glass façades. Results are shown as the sound reduction index $R'_w + C_{tr}$.

Three possible reasons for these differences are explored:

- Quality of craftsmanship on site
- Mechanical properties of the window mounting
- Variability between laboratories

Even if the single number rating in field ($R'_w + C_{tr}$) corresponds well with the given rating from the laboratory ($R_w + C_{tr}$), the resulting indoor level may still be different from what is expected:

- The definition of R_w+C_{tr} assumes a smooth outdoor spectrum. Often the actual outdoor spectrum has a distinct peak in the low frequency region.
- The sound insulation capacities of a window or a glass façade are usually weaker at low frequencies, typically at a double wall resonance frequency between the glass panes.
- The sound field inside the window may be very different from the assumed diffuse field due to room acoustics.

The reasons for this and the consequences of the phenomenon have been thoroughly discussed and explained through a series of conference papers and M.Sc. theses. [3,4,5,6,7,8].

3. QUALITY OF CRAFTMANSHIP

Small deviations and inaccuracies in the construction of a building may lead to extensive variations in measured sound insulation. The bias may very well vary throughout the building. The challenge is to foresee this in respect to the degree of complexity in the detail drawings. The importance of precision must be understood both by the designers and the builders.

Figure 2 shows two measurements performed on the same building and on the same part of the façade construction. The red curve illustrates the initial measurement, executed when the façade was allegedly completed. The frequency curve indicates poor sound insulating values, with a pronounced weakness around 315 Hz, a weakness clearly audible indoors. The single value was measured to $R'_w+ C_{tr} = 30$ dB, whilst the stated laboratory value was $R_w+ C_{tr} = 38$ dB. The following construction examinations then revealed a lacking outer seal, i.e., the glass façade was not mounted with the required quality of craftsmanship. The inadequate sealing was corrected, and the sound insulation was measured again (blue curve). This seemingly minor detail led to an overall improvement of 10 dB, from $R'_w+ C_{tr} = 30$ dB to $R'_w+ C_{tr} = 40$ dB. In the 315 Hz 1/3-octave band the improvement was as great as 22 dB and in the 2500 Hz 1/3-octave band the improvement was 16 dB. In other words, the fitting of the glazing can have a significantly negative influence on the overall sound insulation capacity of the façade.

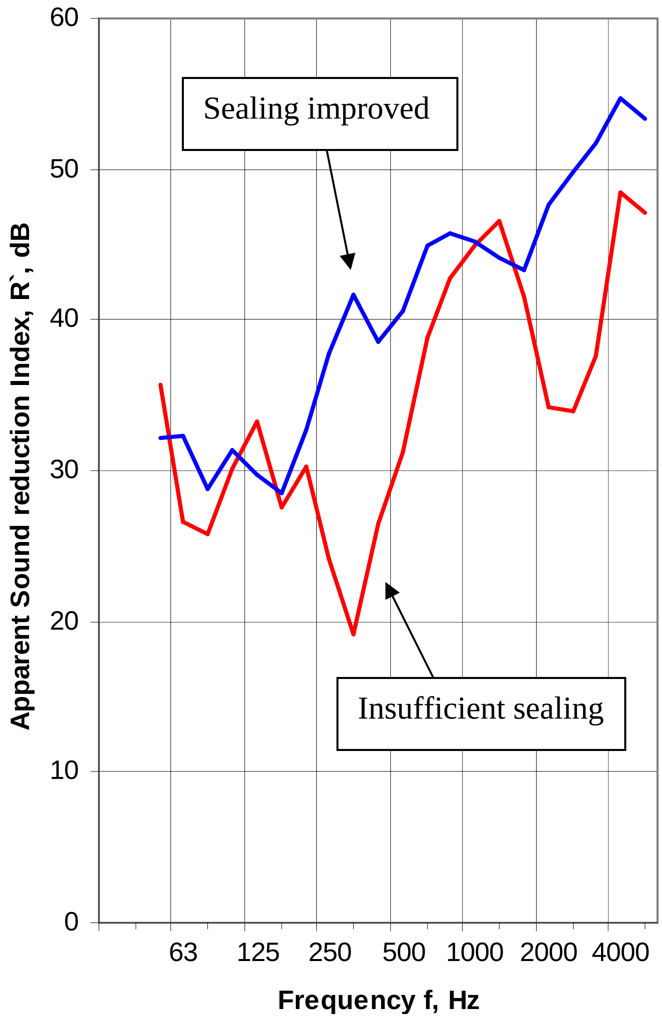

Figure 2: Measurement performed on the same glass façade before and after sealing improvements.

4. MECHANICAL PROPERTIES OF THE GLASS MOUNTING

Data considering the acoustic performance of the glazing it self is often quoted from the manufacturer, usually in terms of the sound reduction index R_w or $R_w + C_{tr}$. Using this value directly when designing a glass façade in a building should be avoided, or at least handled with care. The measurements listed above show that the framework and sealing of the complete façade also has a great effect on the resulting sound insulation. Using glass panes with high sound reduction index values (and ordinarily accompanying higher costs) could potentially be of waste if the framework is not up to the same standards as the glass.

The estimated acoustic performance of the joints and gaps must be taken into account as a part of the above mentioned safety margin. This corresponds with recommendations given in EN 12354-3[10].

The size of the test specimen may also be different in the laboratory. Smaller glass panes exhibit different sound insulation qualities than larger panes. The total weight of the glass pane may also influence the capacity of the framework.

The mounting of the glass pane can lead to different wave modes in the glazing. This might be important at single frequencies, but it is probably much less important for the overall sound insulation from a broadband noise source. As other factors mentioned in this paper seem to be more critical, this issue is not further discussed.

5. VARIABILITY BETWEEN LABORATORIES

It has been shown that the discrepancies in measured sound reduction values between different laboratories might be important. Saint Gobain Glass has performed a simplified round robin test between 6 different laboratories[10].

10 double glazings showed results for R_w+C_{tr} varying with up to 4 dB for glasses where the utmost care had been taken to ascertain that the laboratory tested identical samples. And so it seems a reasonable assumption that the variability in other cases will be at least as great as in this quoted case.

6. A MODEL TO DESCRIBE THE EFFECTS OF LEAKS

An air leakage in a façade construction will contribute to the overall sound insulation, depending on the size and shape of the leakage and the sound insulation qualities of the façade construction itself. Sound energy does not transmit easily through holes and slits with a diameter far less than the wavelength, and resonance phenomena will also influence the sound transmission. The sound reduction value of the leakage will therefore never be 0 dB and the sound transmission index $R_{leakage}$ is frequency dependent. The contribution to the total sound reduction must be included when the total acoustic qualities of the façade is evaluated.[10,11]

A simplified theory can illustrate the effect of inaccuracies (air leakages). Let`s assume various glass façades with sound insulation values ranging from $R_{\text{façade element}}$ = 20 dB to $R_{\text{façade element}}$ = 50 dB (laboratory measurements). How do these façades respond to air leakages of various sizes?

Figure 3 illustrates the theoretical total sound reduction R_{total} (dB) of the glass façade as a function of the laboratory value $R_{\text{façade element}}$ (dB) and the calculated effect of a leakage $R_{leakage}$ (dB) as a parameter. The curves show that for a façade with relatively low sound reduction index ($R_{\text{façade element}}$ = 20 dB), the effect of an air leakage of $R_{leakage}$ = 20 dB is of little consequence compared to the effect that the same leakage has on a façade with far better sound insulation. In other words, the better the expected sound insulation of the construction itself, the greater the influence of even a small leakage becomes. For a glass façade with an R value of 50 dB, even a minor leakage could substantially reduce the benefits of an expensive construction.

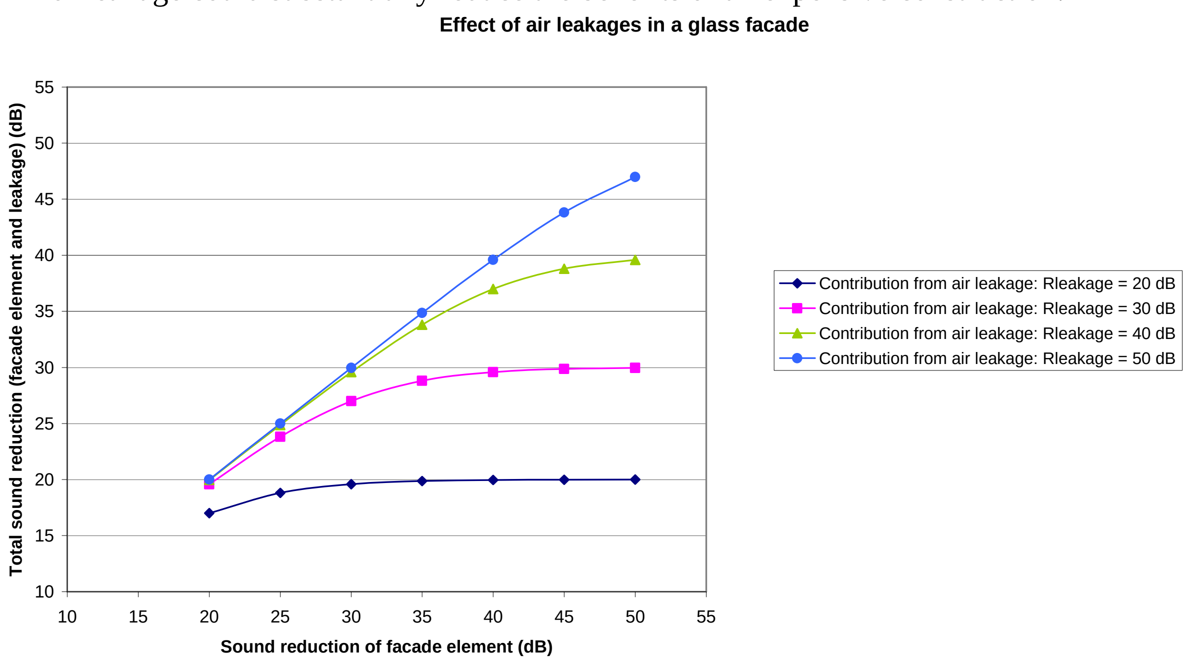

Figure 3: Simplified theory illustrating the effect of inaccuracies for various façade elements.

Figure 4 shows the effect of a leakage with sound reduction $R_{leakage}$ = 30 dB. The effect of such a leakage is much greater for a façade with high sound insulation values. In other words: a constant safety margin for façades with different sound insulating qualities may not be the best approach.

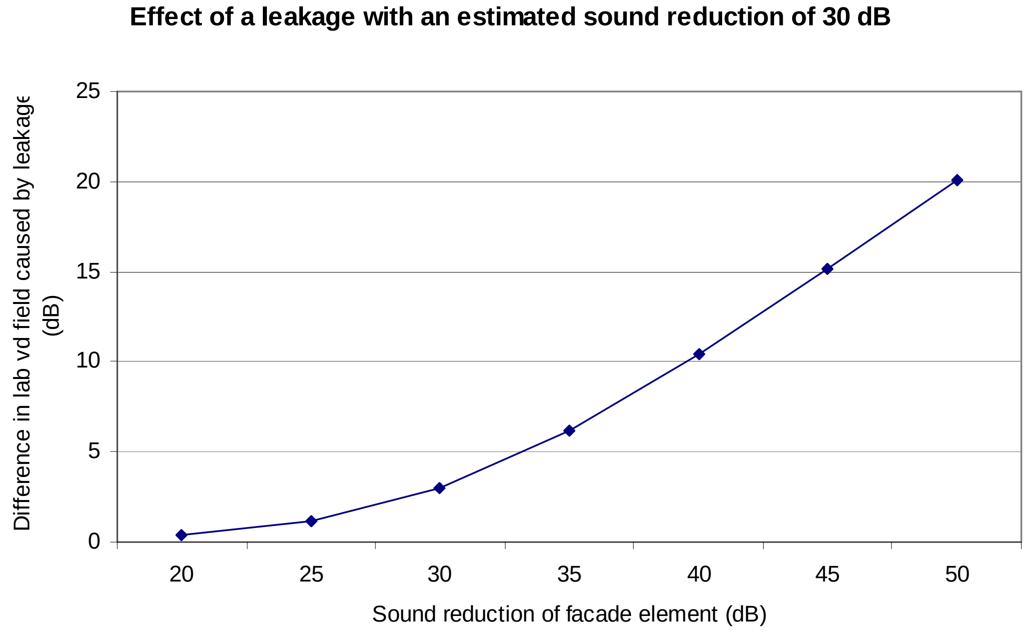

Figure 4: Calculated difference between the given laboratory value for the glass façade and the expected influence of a leakage with $R_{leakage}$ = 30 dB.

6. CONCLUSIONS AND FURTHER WORK

When designing buildings in noisy environments, sufficient information considering the acoustic properties of the glass façade must be acquired. Laboratory measurements of the complete construction should be performed, not just on the glazing, since the effect of the framework can have great influence on the total result. The safety margins used in the calculations must incorporate this factor if this is not included in the laboratory measurements.

The spectrum shape of the outdoor noise versus the frequency-dependent insulation qualities of the glass façade should also be taken into account.

Systems where the glazing is assembled to its framework on site should be avoided or at least minimized. Element solutions where mounting and sealing can be performed in advance could reduce the risk of inaccuracies and thus minimize the risk of reduced sound insulation.

The most critical factor from our experience is the quality of the craftsmanship. Visual inspections of sealing and spot checks of sound insulation are essential to ensure the final result for indoor noise in buildings with glass façades. More experience is needed to ascertain the optimal program for compliance checks of sound insulation in glass façades.

More measurements must be performed on finished glass façades to increase the statistical data on how these elements performs acoustically in the finished building. Substantial discrepancies should also be communicated back to the manufacturer, and possible causes should be explored.

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REFERENCES

[1] ISO 717-1: 1996 "*Acoustics - Rating of sound insulation in buildings and of building elements – Airborne sound insulation*"

[2] ISO 140-5: 1998 "*Acoustics – Field measurements of air borne sound insulation of façade elements and façades*"

[3] S. Olafsen & L.B. Hov , "*Considerations of room acoustics for traffic noise evaluation*", BNAM 2004, Mariehamn

[4] S. Olafsen, "*Accuracy of indoor traffic noise determination, part I, calculations, part II, measurements*", Uncertainty Noise Symposium, Le Mans 2005

[5] T. Killengreen & S. Olafsen," T*he shape of outdoor and indoor traffic noise spectra*", Internoise 2007, Istanbul

[6] T. Killengreen, M.Sc. thesis, "*Støyspektra fra veitrafikk – Gir glattere standardspektra et riktig bilde?*"Norwegian Universtiy of Tehcnology and Science, 2006 (in Norwegian)

[7]K. Haugen & S. Olafsen, "*Analysis of low-frequency resonances in façade sound insulation spectra*", Internoise 2008, Shanghai

[8]K. Haugen, M.Sc. thesis, "*Fasaders lydisolasjon mot støy fra vegtrafikk*", Norwegian Universtiy of Tehcnology and Science, 2007 (in Norwegian)

[9]NS-EN 12354-3 "*Building acousics. Estimation of acoustic performance of buildings from the performance of elements (annex B).*"

[10]M. Rehfeld, "*Dispersion of sound transmission loss of glazings*", Uncertainty Noise Symposium, Le Mans, 2005

[11]T.E. Vigran, "*Bygningsakustikk – et grunnlag*", Tapir akademisk forlag 2002 (in Norwegian)