Subjective Estimation of Airborne Sound Insulation in Buildings and How to Quantify the Real Acoustical Comfort of Dwellings.

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Summary

The quality of sound insulation in buildings is generally described as a single number rating of sound insulation. Many methods have been proposed for single number ratings of partition sound insulation performance. None has been robust enough to be completely satisfactory. The difference in sound levels from one side of a wall to the other indicates the sound transmitted loss through the wall. Acoustic tests relate sound loss through a wall at various frequencies then average the results to provide a single absolute value number. This rating system is necessary if one wishes to compare other wall systems with a specific wall design. However, these rating systems lack on the ability to quantify subjectively related disturbances between dwellings due to audible sounds perceived from neighbour's activities. Due to raised comfort demands concerning the airborne sound insulation in dwellings, as well as in flats and houses, it is not sufficient to avoid intelligibility listening through walls but to avoid recognition of transmitted sounds in general. A comparison of measured sound insulation with the absolute threshold of hearing endow with details judging the quality of the real acoustical comfort of dwellings. Since in most cases A-weighting is satisfactory for ranking noise in approximately the same way as it is subjectively heard, it is proposed to use the spectral corrected standardised sound level difference ($D_{nT,w}$ + *C) in decibel calculated in accordance with the EN ISO 717 for assessment reasons. A comparison between the standardised sound level difference and the hearing threshold depending upon background noise level is proposed. The results of this comparison will be discussed.*

1. Introduction

Since the early 1950s and 1960s, or even late as the 1970s where the main body of standards of sound insulation in dwellings are originated, there have been considerable improvements in living standards. One of the consequences of this is an increased use of home entertainment systems (with increased power output at low frequencies) and other domestic electrical appliances, and also an increase in the amount of noise that people are likely to make at home. Further, the trend towards home working, reduced contact with neighbours and rising expectations has meant that people are less tolerant of noise disturbance. The focus of the media on noise and neighbour disputes has also heightened public awareness of the problem. The wish after quiet and ease has therefore a high meaning for inhabitant and user of buildings. That is, why building acoustics is gaining more and more importance in our every day life. Due to the need having a quite atmosphere in our dwellings, flats or houses, noise from neighbours is becoming even more important than minimizing warmth losses, i.e. energy savings.

The problem to be considered is the transmission of noise from one dwelling unit to another. Due to raised comfort demands concerning the airborne sound insulation in dwellings, as well as in flats and houses, it is not sufficient to avoid intelligibility listening through walls but to avoid recognition of transmitted sounds in general.

In this paper a method is discussed which is based on the sound level difference across the partition and the loudness level, in the belief that loudness perception is a major factor in response to sound penetrating a partition.

2. The concept of rating

The quality of sound insulation in buildings is generally described as a single number rating of sound insulation. Many methods have been proposed for single number ratings of partition sound insulation performance. None has been robust enough to be completely satisfactory. The difference in sound levels from one side of a wall to the other indicates the sound transmitted loss through the wall: e.g., if the sound generated inside a room is 80 decibels (dB) and 30 dB is measured on the other side of the wall (adjoining room), then a reduction of 50 dB is achieved. Acoustic tests relate sound loss through a wall at various frequencies then average the results to provide a single absolute value number. This rating system is necessary if one wishes to compare other wall systems with a specific wall design. The methods for measuring the airborne sound insulation of building elements and in buildings have been standardised in the international standard EN ISO 140-4. The rating of the airborne sound insulation is regulated in the international standard EN ISO 717 [1]. The Weighted Standardised Level Difference ($D_{nT,w}$) and the Spectrum Adaptation Term (C) are determined on the basis of the A-weighted sound level differences and on the basis of a standardised spectrum for the sound level in the building interior (indoor noise) according to EN ISO 717.

The Weighted Sound Reduction Index (R_w) or the Sound Transmission Class (*STC*) etc., are single-figure rating schemes intended to rate the acoustical performance of a partition element under typical conditions involving dwelling separation. The higher the value of either rating, the better the sound insulation. Thus, the rating is intended to correlate with subjective impressions of the sound insulation provided against the sound of speech, radio, television, music and similar sources of noise characteristic of dwellings. In applications involving noise spectra that differ markedly from those referred to above (for example, heavy machinery, power transformers, aircraft noise, motor vehicle noise), the R_w and *STC* are of limited use. Generally, in such applications it is desirable to consider explicitly the noise spectra and the insulation requirements.

The absolute value used in this paper is the standardised sound level difference D_{nT} between two rooms. Since it is well known that a single number quantity is not able to specify an acoustic comfort in dwellings [2] [3] it is proposed to do a comparison on the basis of the spectral corrected standardised sound level difference ($D_{nT,w} + C$) and the absolute hearing threshold.

We do need some sort of subjective unit of loudness in order to judge the human reaction to loudness of sound more close to reality. The phon is the unit of loudness level that is tied to sound-pressure level at 1 kHz. The unit of subjective loudness, called sone, is generally accepted. One sone is defined as the loudness experienced by a person listening to a tone of 40-phon loudness level. A sound of 2 sones is twice as loud, and 0,5 sone half as loud [4]. A straight line can be drawn through these three points, which can then be extrapolated for sounds of higher and lower loudness. Figure 1 shows a graph for translating loudness level in phons to loudness in sones. One point on the graph is the very definition of the sone, the loudness experienced by a person hearing a 1 kHz tone at 40 dB sound-pressure level, or 40 phons. A loudness of 2 sones is then 10 dB higher; a loudness of 0,5 sones is 10 dB lower.

Although the crude way of deriving the linear graph, it is a simple way of getting at the subjective factor of loudness. It is worth realizing that a true subjective unit of loudness (sone) is related to loudness level (phone), which is in turn related by definition to what we can measure with a sound-level meter.

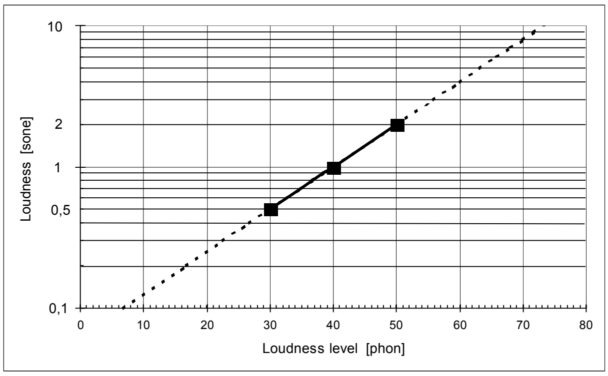

Figure 1. Graph for converting loudness levels in phon to loudness in sone

In an attempt to account for human hearing sensitivity in a standardised way the A-weighting characteristic is most widely used, and though originally intended for low-level sounds, it is commonly applied to higher sound levels as well.

3. Accounting for Audibility of Sounds

The problem of judging the human reaction to loudness of sound is complicated by the problem of measuring audibility of sounds due to the nonlinearity of human hearing. The frequency dependence of human hearing is described originally by the Fletcher-Munson Curves (1933) and later on by Robinson-Dadson (1956). Curves defining combinations of pure tones in terms of frequency and sound pressure level, which are perceived as equally loud, express a fundamental property of the human auditory system and are of basic importance in the field of psychoacoustics.

The threshold of hearing under free-field listening conditions were specified in ISO 226:2003(E) [5] and under diffuse-field listening conditions in ISO 389-7:2003(E) [6]. Figure 2 shows the hearing threshold under diffuse-field listening conditions as provided by the International Standard ISO 389-7: 2003(E).

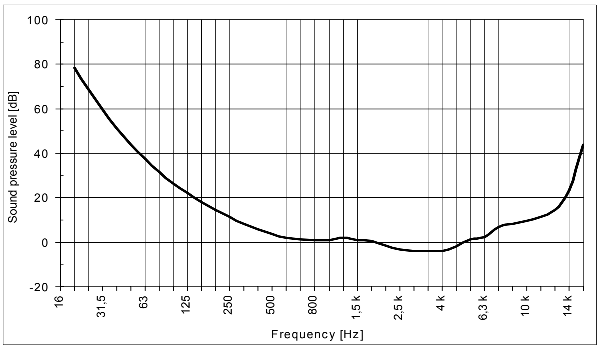

Figure 2. The Absolute Threshold of Hearing [6]

4. Case Study

To specify the sound insulation between dwellings it is generally accepted that a single figure index is not sufficient and is regularly misleading. Due to the single rating concept it is investigated a situation where a separating floor was complained of not having sufficient airborne sound insulation. Measurement tests of airborne sound insulation of the separating floor were carried out according to EN ISO 140-4. The tests result a weighted standardised level difference of $D_{nT,w}$ = 55 dB and an adaptation term of C = -1 dB. The sound insulation was improved step by step until a subjectively related satisfaction was achieved. The treatments were applied only to the flanking walls.

Case 1: The construction consists of a concrete floor base of thickness 180 mm with a floating floor. In the receiving room are 3 flanking plastered masonry wall and one internal framed plasterboard wall. Two external masonry walls have thickness of 365 mm and one internal masonry wall 240 mm. The volume density of the masonry walls is 650 kg/m^3.

Case 2: An additional independent free-standing panel consisting of 2 layers of plasterboard with staggered joints and mineral wool in the cavity were built on the inner side of the external and one internal walls in the source room to reduce flanking transmission.

Case 3: Same as Case 2 with additional independent panels at the two external walls in the receiving room.

Case 4: Same as Case 3, adding 2 independent panels, i.e. all 4 walls in the source room have independent panels.

Table I. Measured sound insulation and improvement

Case	Standardised sound level difference with $D_{nT,w} + C$	*Improvement* $\Delta D_{nT,w}$
1	55 – 1 dB	—
2	58 – 0 dB	3 dB
3	62 – 1 dB	4 dB
4	65 – 2 dB	3 dB

From Table I it is seen, that each treatment to the flanking walls provided higher sound insulation, at least $\Delta D_{nT,w} = 3$ dB.

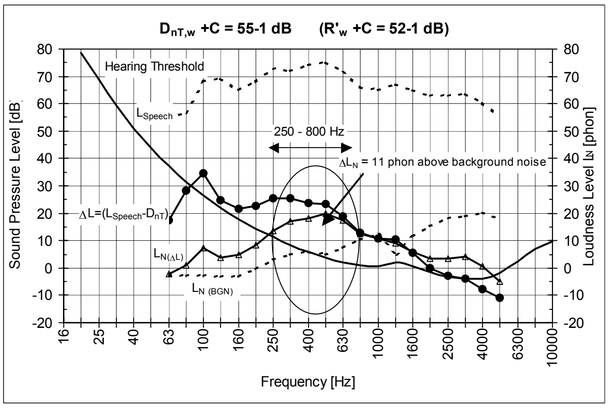

Figure 3. Loudness level vs. hearing threshold – Case 1

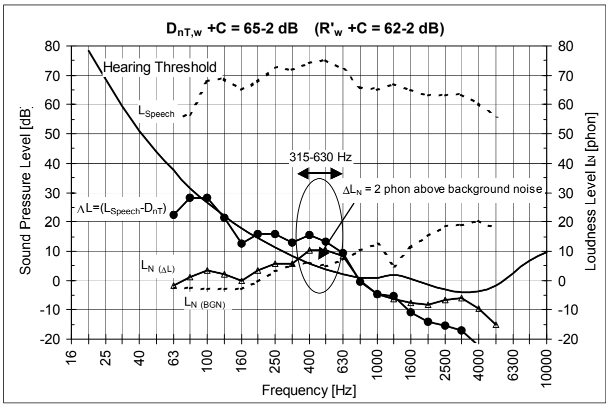

Figure 4. Loudness level vs. hearing threshold – Case 4

From comparison of Figure 3 and 4 it becomes clear how the subjective perception of the airborne sound insulation is related to the loudness level above background noise $L_{N(BGN)}$. In Table II the spectral corrected standardised sound level differences are shown and their subjectively assessments. The evaluation of the quality of the airborne sound insulation is depending on background noise and source sound level.

Table II. Subjective perception of airborne sound and its subjective assessment depending on source sound level.

Spectral corrected standardised sound level difference $D_{nT,w}+C$		Perception of airborne sound and its subjective assessment
Raised Voice 78 dB(A)	Loudness level difference ΔL_N	
Background noise 25 dB(A)		
63 dB	2 phon	hardly audibly
61 dB	5 phon	audibly, however not to understand
58 dB	8 phon	audibly and partially to understand
54 dB	11 phon	well audibly

4. Results

The field investigation revealed that the assessment of the real acoustical comfort subjectively correlates with a spectral corrected standardised sound level difference as presented in Table II. The comparison of the calculated loudness level and the threshold of hearing with respect to the background noise level yield the subjective assessment of the perceived sound level. A loudness level of 2 phon above background noise yield still an “audibly” transmitted sound level. It is proposed from subjective assessment a $D_{nT,w} + C \geq 58$ dB for reasonable acoustical comfort in dwellings. In order to summarise the results of the investigation it is proposed supporting the $D_{nT,w} + C$ rating due to the fact, that it markedly improves the strength of the relationship between subjective acceptability and the insulation rating.

References

[1] European Standard EN ISO 717-1: 1996, Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation.

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[4] Zwicker, E., Fastl, H., Psycho-acoustics. Facts and Models, 2nd Edition, Springer, Berlin 1999, pp. 203 - 205

[5] International Standard ISO 226: 2003, Acoustics – Normal equal-loudness-level contours.

[6] International Standard ISO 389-7: 2003 (E), Acoustics – Reference zero for the calibration of audiometric equipment – Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions.