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FIELD SOUND INSULATION MEASUREMENTS AT LOW FREQUENCIES

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1. Introduction

This paper investigates the spatial distribution of sound pressure level (SPL) inside rooms and its effect upon field sound insulation tests at low frequencies. Previous work[1] discussed the distribution of low frequency SPL inside a room and its effect upon environmental noise measurements. This work extends the previous analysis to the source room and discusses the repeatability of sound insulation tests in the field[2] with regards to the recently introduced spectrum adaptation terms[3] C and C_{tr}, which can include the 50Hz, 63Hz and 80Hz third octave bands.

Wright and Forthergill[4] have discussed and demonstrated the usefulness of the C_{tr} term. Good correlation was found between the level of acceptability of a piece of music with a heavy bass content and the single number rating, $D_{nT,w} + C_{tr,50\text{-}3150}$. In their case study, subjects were exposed to music radiating through different simulated floor types at different levels. Sweden[5] has introduced the $C_{50\text{-}3150}$ term with R'_w for the rating of lightweight (e.g. timber framed) constructions. This indicates the increasing importance of the spectrum adaptation term below 100Hz.

BS EN ISO140-4[2] Annex D currently provides guidelines for measurement at frequencies below 100Hz. It recommends an increase in the microphone spacing and microphone to boundary spacing, as well as an increase in the number of single microphone positions and source positions. This is clearly impractical for most dwellings in the UK, due to the conflict between the space required for measurement and that provided by small rooms with a volume less than 50m^3. It is therefore imperative that a reliable low frequency measurement method is devised before spectrum adaptation terms for low frequencies can be widely accepted.

2. Experimental method

The investigation was carried out in the BRE Flanking Laboratory. The construction consisted of a pair of ground floor rooms separated by a masonry cavity wall (figure 1). Two loudspeakers with pink noise excitation were placed in the source room and a three-dimensional grid was used for SPL measurement in both the source and receiving rooms. The three dimensional grid, which included measurement points at the room boundaries, had a spacing of 0.5m-0.6m, making a total of 360 points in the source room and 315 points in the receiving room. $L_{eq,30s}$ measurements were made at each point for third octave bands between 50Hz and 5kHz.

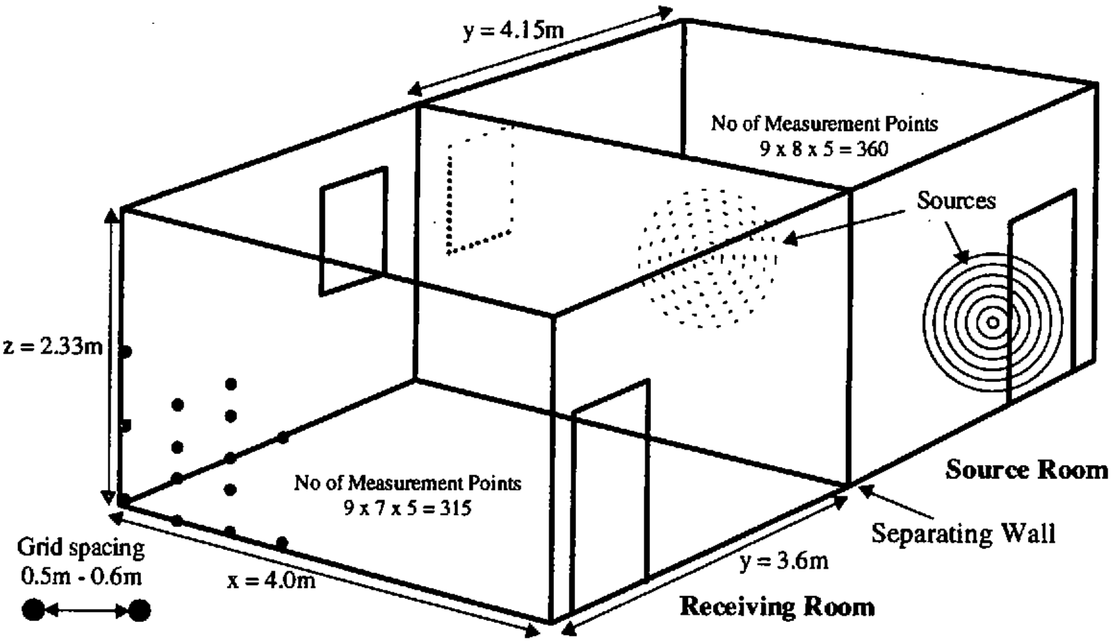


Figure 1: Experimental set-up

3. Analysis

3.1 SPL distribution at low frequencies

A selection of third octave band SPL distributions measured on horizontal and vertical planes that were approximately in the centre of each room are shown in figures 2 and 3. They show large variations (>20dB) between measurements near the centre of the room and those near the corners (0.5m from room boundaries). These distributions are influenced by room modes, which are one of the main factors governing poor repeatability in sound insulation and environmental tests below the Schroeder frequency, where the sound field in not diffuse.

3.2 Repeatability of sound insulation measurements

The Schroeder frequency, f_s was calculated and found to lie in the 500Hz third octave band. The repeatability of measurements below f_s was tested using data from the measurement grid. A total of 32 separate tests were simulated using criteria given by BS EN ISO140-4. Each test selected five random measurement positions in each room. Ranges and standard deviations of L_1 (measured source room level) and L_2 (measured receiving room level) in frequency bands 50 to 500Hz are shown in figure 4a(i) and 4a(ii). Figures 4b(i) and 4b(ii) show the range and standard deviation for D_{nT} and the single number ratings $D_{nT,w}$, $D_{nT,w}$ + C and $D_{nT,w}$ + C_{tr}. (Note that the same reverberation time measurements were used in each test)

The average sound pressure levels L_1 and L_2, varied considerably between each test [Figure 4a(i)]. L_1 varied by up to 9.5dB at 50Hz, whilst L_2 varied by up to 8dB at 63Hz and 6dB at 125Hz. D_{nT} results also varied considerably [Figure 4b(i)]. Ranges of up to 12dB occurred at 50Hz and 8dB at 63Hz and 125Hz. Ranges fell below 2dB in frequency bands 315Hz - 500Hz. However, $D_{nT,w}$ varied by only 1dB. The addition of $C_{100\text{-}3150}$ term increases the range to 2dB, whereas the addition of $C_{tr100\text{-}3150}$ and $C_{50\text{-}3150}$ did not increase the range but slightly increased the standard deviation. The addition of the $C_{tr,50\text{-}3150}$ term, however, increased the range of

Figure 2 Sound pressure level distributions on a horizontal plane in the source and receiving room

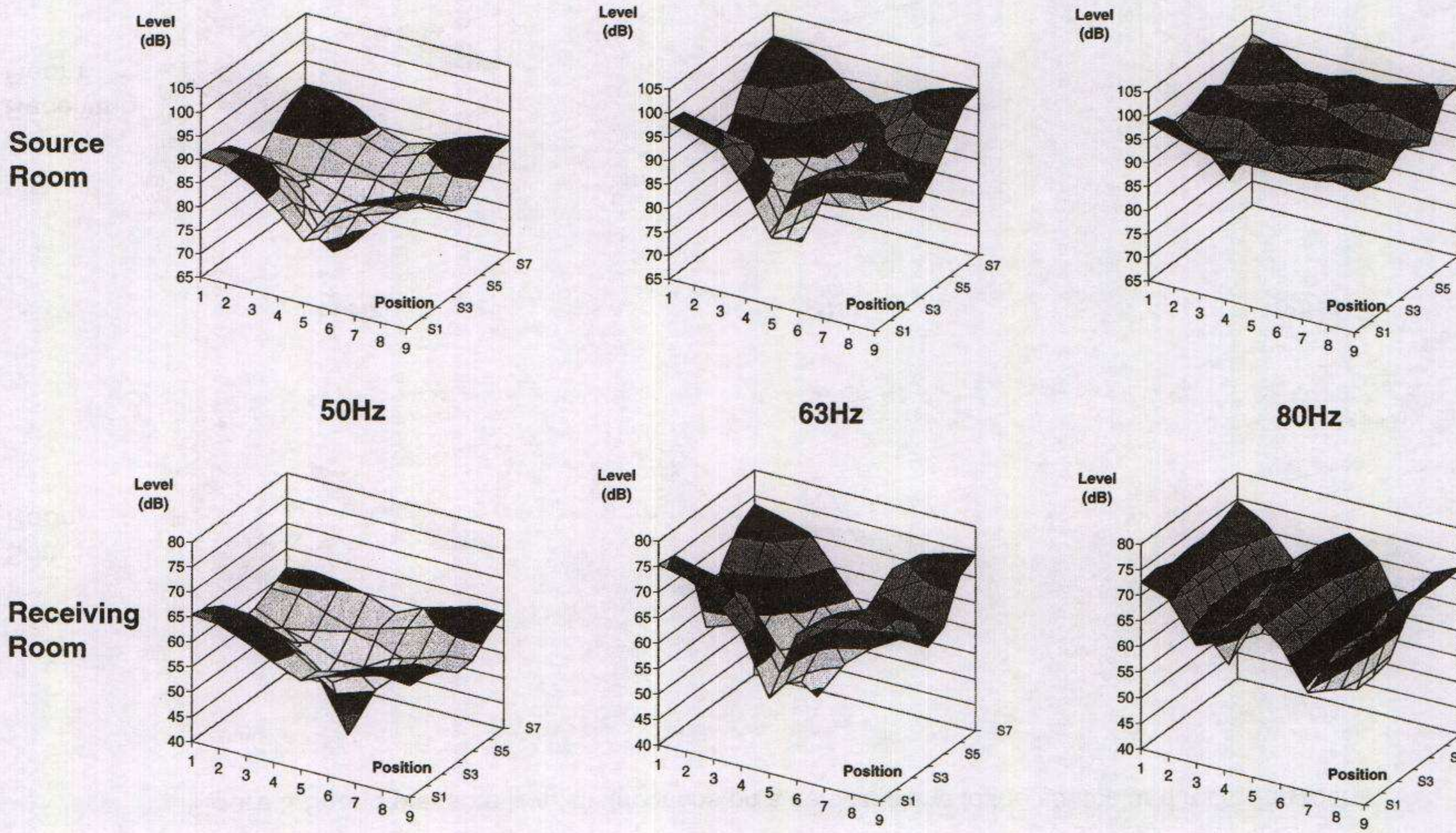
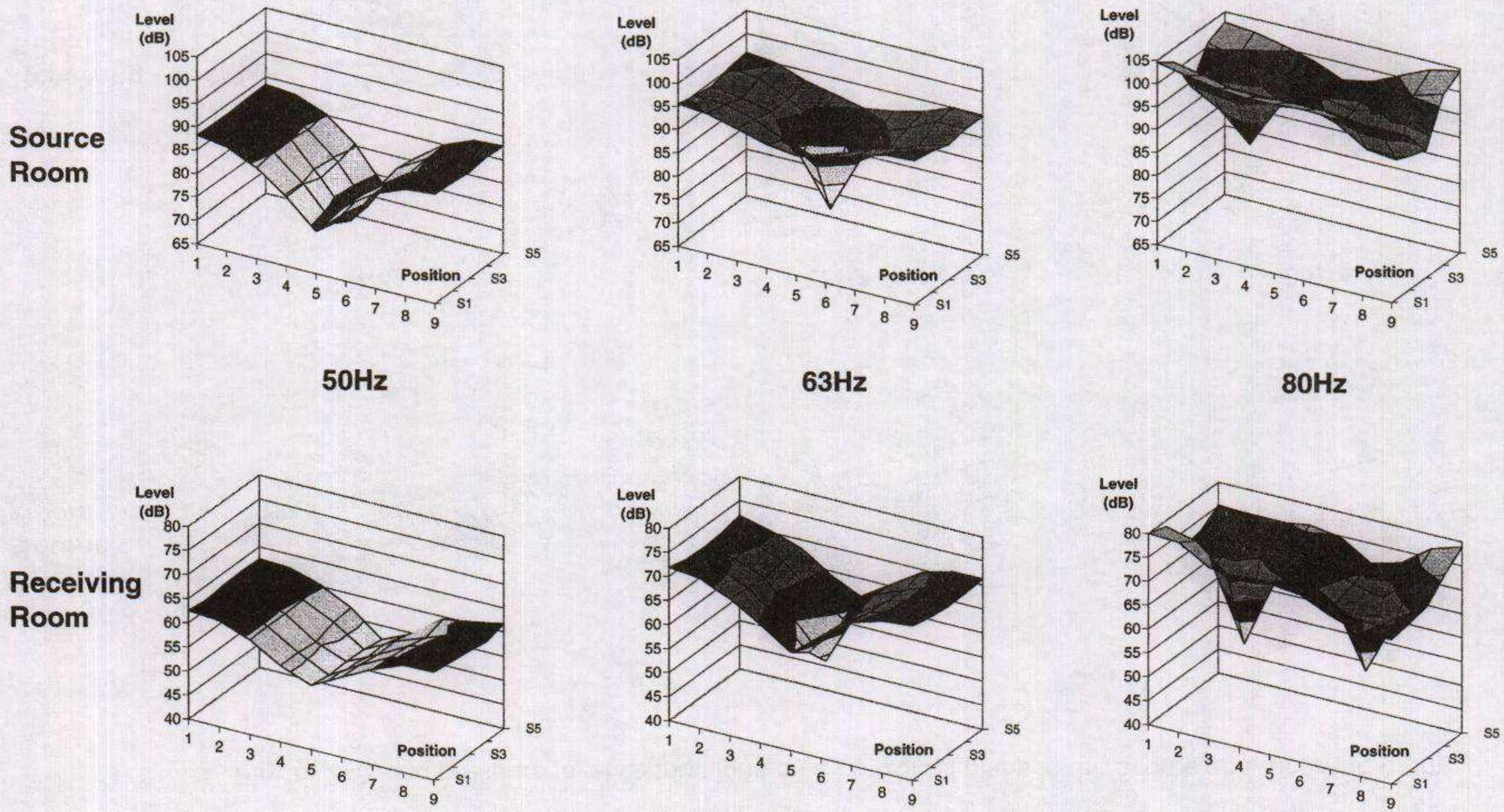


Figure 3 Sound pressure level distributions on a vertical plane in the source and receiving room



results by up to 4dB and the standard deviation from 0.3dB (for $D_{nT,w}$) to 1.2dB. One must therefore question the repeatability of tests that include $C_{tr,50\text{-}3150}$.

Figure 4a (i) (ii)

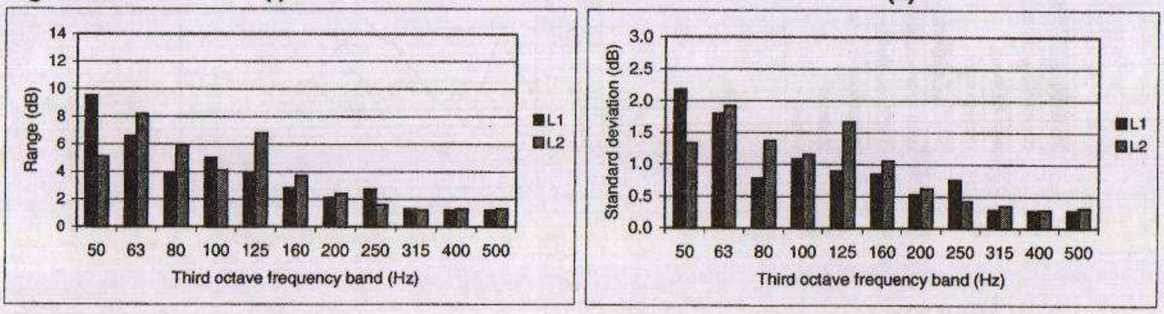
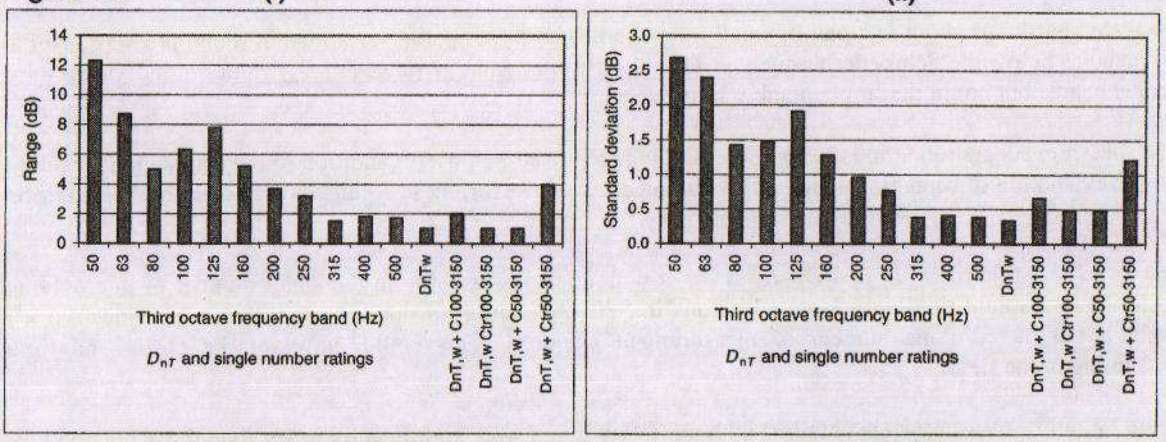


Figure 4b (i) (ii)



3.3 Comparison of single position and rotating boom SPL measurements

A single sound insulation test was also carried out using a pair of rotating booms placed in the centre of each room in accordance with BS EN ISO140-4. Figure 5a compares single number ratings obtained from the rotating boom measurements with those obtained from single position measurements. Figure 5b plots the difference in D_{nT} and the source and receive room levels, L_1 and L_2 between measurements obtained from rotating boom and those obtained by energetically averaging all grid measurements (approx. 100) that fit the criteria given by BS EN ISO140-4. (Note that the criterion of 0.5m from the boundaries is usually applicable to frequency bands of 100Hz and above. However, an increase in this distance would restrict measurement to the centre of the room, where the sound pressure level is at a minimum.)

Results from the rotating boom closely matched the average results obtained from single position measurement [Figure 5a]. It is possible to conclude at this stage that a rotating boom can estimate $D_{nT,w}$ and spectrum adaptation terms accurately. However, there was a discrepancy between the average sound pressure levels obtained using a rotating boom and those obtained by energetically averaging all measurements that passed BS EN ISO140-4 criteria. [Figure 5b]. Levels measured with the rotating boom were approximately 2dB less than those obtained for the whole room at frequencies below 125Hz. However, this discrepancy occurred in both rooms, hence the level difference and D_{nT} deviated about 0dB. Both methods therefore gave similar single number ratings. The two rooms had similar dimensions, hence they had similar sound fields. If the source or receiving rooms had been a different size or shape, their sound field would also have been different and the rotating boom results may have differed significantly from those obtained using single positions.

Figure 5a

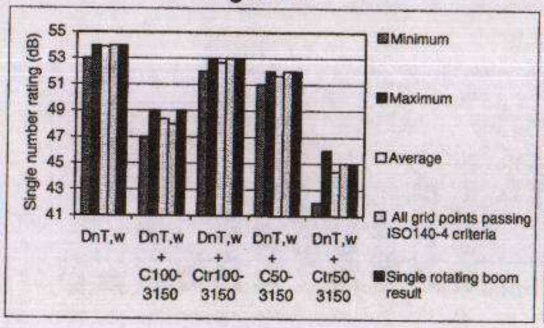
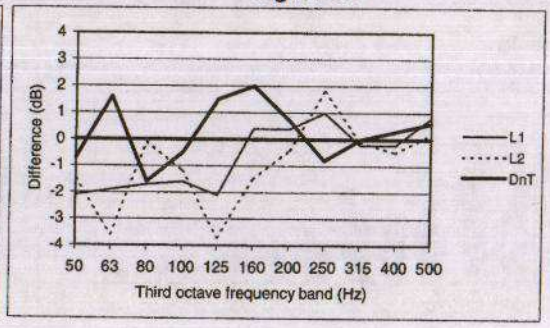


Figure 5b



4. Conclusions

Measurements carried out in a pair of small rooms indicated large spatial variations in sound pressure level at frequencies below the Schroeder frequency. This also resulted in large ranges of D_{nT} values in individual third octave bands, but not in the single number rating $D_{nT,,w}$.

The spectrum adaptation term is being increasingly recognised as a useful addition to the single number rating for the evaluation of sound insulation at low frequencies. However, these results have shown that the addition of the term $C_{tr,50\text{-}3150}$ may lead to poor repeatability.

The large variation in L_1, L_2 and D_{nT} results at low frequencies was due to the small number of microphone positions in a sound field with large variations in SPL. A solution to this (as suggested in previous work[1]) could be to increase the number of measurement positions. This could, however, be costly and time consuming in the field.

Some L_1 and L_2 measurements obtained with a rotating boom were significantly lower than those obtained by energetically averaging all grid measurements fitting the criteria of BS EN ISO140.

Reverberation times were constant for all the above tests. Reverberation time measurements are also highly variable at low frequencies, which could subsequently effect repeatability.

All measurements were carried out in a pair of empty rooms with acoustically hard surfaces. The large spatial variation in SPL could be improved by introducing diffusing and absorbing elements into the room. This would also lower the Schroeder frequency, f_s in each room. A reduction of the RT to 0.5 seconds would reduce f_s from the 500Hz to the 250Hz third octave band.

Further investigations are needed in order to optimise measurement positions and improve repeatability at low frequencies.

References

[1] **P. Turner, C. Hopkins & R. Vasudevan.** Sound pressure levels in dwellings at low frequencies. Proc. I.O.A. Vol 21 Part 7 (1999)
[2] **BS EN ISO140: 1998.** Acoustics - Measurement of sound insulation in buildings and of building elements. Part 4: Field measurements of airborne sound insulation between rooms
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[4] **P. Wright and L. Fothergill.** The spectrum adaptation terms in BS EN ISO717-1:1997. Acoustics Bulletin Nov/Dec 1998
[5] **K. Hagberg.** Extended frequency range for national sound insulation building regulations in Sweden. Internoise 98