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EXPERIMENTAL DETERMINATION OF REVERBERATION TIME FOR LOW FREQUENCIES IN AN IMPACT SOUND LABORATORY

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1. INTRODUCTION

The reverberation time is an important factor in assessing the acoustic quality of a room. It is also used in the determination of sound insulation, absorption and sound power.

Reverberation time for a given frequency band is defined as the time required for the average sound pressure level, originally in the steady state, to decrease 60 dB after the source is stopped. For measurement of sound insulation in buildings, airborne sound insulation as well as impact sound insulation, according to ISO 140/III and 140/VI [1,2] the absorption is a part of the correction term which is necessary to find out for assessment of the sound level in rooms. The correction term is given in decibels and at impact sound measurement, being ten times the common logarithm of the ratio between the measured equivalent absorption area of the receiving room and the reference equivalent absorption area. The sound pressure in the receiving room is depending on the total absorption of this room, which is normally determined by measuring the reverberation time.

The current standard for this kind of measurement gives a range of 100 Hz to 3150 Hz, but the recommendation would be to increase the lower frequency range to at least 50 Hz. However, in the frequency range below 100 Hz the sound field in living rooms of normal sizes consist of a few modes only, and the problem is then to decide upon a correct reverberation time, based on this low density of modes at these low frequencies.

For rooms with dimensions like the one that was studied in this case, a difference in reverberation time between 0-2 sek gives a difference in calculaton of sound index of 13 dB. This points out why it is very important that the reverberation time is measured as correct as possible. This study provides the results from various experimental studies that were carried out.

2. EXPERIMENTAL MEASUREMENTS - TEST PROCEDURES

The measurements were carried out in the impact sound lab of the Division of Physical Environment Technology. The used method for measurement of the reverberation time is the classical, where the sound pressure level decay is registered, still the most common and also standardised in ISO 354 [3] and SS 025264 [4].

According to the standards the reverberation time is determined from the slope of a line drawn on the decay curve between -5 dB and - 35 dB levels below the steady state level. To improve the accuracy an average value is determined from a large number of curves obtained with different microphone and source positions. The main reason for this investigation of the reververation time for very low frequencies was to find out - on the basis of measurements carried out as accurately as possible - the importance of the choise of microphone- and sound source position. All measurements were carried out with stationary source and microphone positions.

The investigated frequency range was from 31.5 Hz to 100 Hz. The dimension of the receiving room in the lab is 5.85 x 4.95 x 2.3m. For a rectangular room a simple relationship exist between the room dimensions, l_x,l_y and l_z and the frequencies corresponding to the normal modes of vibration of the room.

The relationship is

$$f = \frac{c}{2}\left[\left(\frac{n_x}{l_x}\right)^2 + \left(\frac{n_y}{l_y}\right)^2 + \left(\frac{n_z}{l_z}\right)^2\right]^{1/2} \text{ Hz} \qquad (1)$$

where c is the velocity of sound in m/s
l_x l_y an l_z are the dimensions of the room in m.
and n_x n_y and n_z are integers.

From eqn (1) the characteristic frequencies for 1/3 octave bands from 31.5Hz to 100 Hz have been calculated for the studied laboratory, where c is chosen to 340 m.s^{-1}. See table 1.

Traditional loudspeakers, used for this kind of sound measurement, do not have capacity enough to produce necessary sound level for frequencies down to 31.5 Hz. Instead, two loudspeaker with very strong bass, were used together with an equalizer for raising the sound level for these low frequencies. This provided a high sound level, at least 35 dB higher than the background noise level. Thereby, the decay curves were easy to estimate.

Table 1. Characteristic frequencies for 1/3 octave band up to 100 Hz as calculated for the studied receiving room.

nx	ny	nz	f (Hz)	1/3 octave band
0	1	0	29.1	31.5 Hz
1	0	0	34.4	
1	1	0	45	40/50 Hz
0	2	0	58.1	
1	2	0	67.5	63 Hz
2	0	0	68.7	
0	0	1	72.3	
2	1	1	74.6	
0	1	1	78	80 Hz
1	0	1	80.1	
1	1	1	85.2	
0	3	0	87.2	
2	2	0	90	
0	2	1	92.8	
1	3	0	93.7	
1	2	1	99	100 Hz
3	0	0	103	
2	1	1	104	
3	1	0	108	
2	3	0	111	

One of the investigations comprised 480 reverberation time measurements - spread at three horisontal layers in the room by 32 microphone positions for each layer and 5 times for each position. At another attemp, the two loudspeakers were placed in six different combinations. This times the microphone was placed in three positions, the same for all combinations. For comparison, measurements with a single loudspeaker, with the same high capacity, was also investigated. During the measurements only one person was in the room.

3. RESULTS AND DISCUSSION

The sound field in a room contains the forced direct field from the source and the reverberant field, consisting of all energy reflected one or more times from the room's walls.

The reverberation process for a frequency band is the result of the decays of the normal modes in the band, each mode decaying with its own time constant which depends essentially on the mean free path between reflections [5.6].

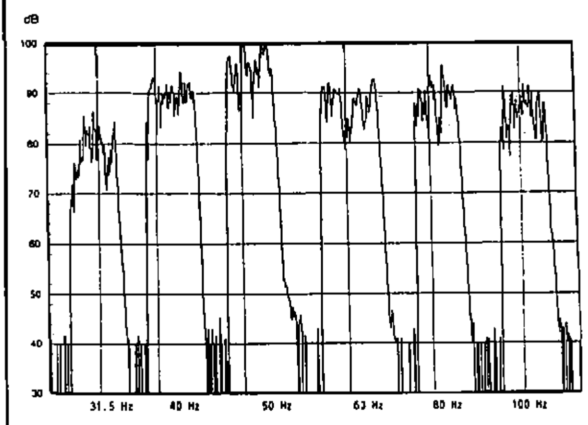

Fig. 1. Typical decay curves for 1/3 octave band

Figure 1 shows typical decay curves for 1/3 octave band center frequencies 31.5 Hz - 100 Hz. The curves traced out are practically linear over a large dynamic range, which make it easy to determine the decay. As the mode density at this frequency band is very low the reflections will be very few and consequently have little influence on the reverberation curve. On account of no interferences between the individual eigenmodes the curve traced out is smooth.

Figure 2 shows the measurement set up with two loudspeakers and measurement positions in three layers where the value of each position's is an average of 5 time. The loudspeakers were placed in the corner in order to must efficiently excite the room modes. The distance between the measurement positions is 0.8 m. The distance from walls, ceiling and floor is 0.55 m and it is 0.6 m between each layer. It can be seen from the figures, for 50 resp. 100 Hz, that most of the values are very similar. The same can be seen for the other investigated frequencies. The average value of these 480 measurements was for: 31.5 Hz = 0.7 s, 40 Hz = 0.8 s, 50 Hz = 0.8 s, 63 Hz = 0.6 s, 80 Hz = 0.8 s and 100 Hz = 0.9 s.

Very similar results could be seen from the other mesaurements. From the investigatings with different combinations of loudspeakers the value differ between 0.1 - 0.3 sec for different frequencies. Even for the measurement by the single loudspeaker, the average values were the same.

The very similar reverberation time value in the room show that it is mainly the forced direct field that influence. The curve is real steep and smoth, which depends of the few number of modes in the frequency band. The less number of room modes, the more important it is that the source gives high sound level in order to detect, the decay over the background noise.

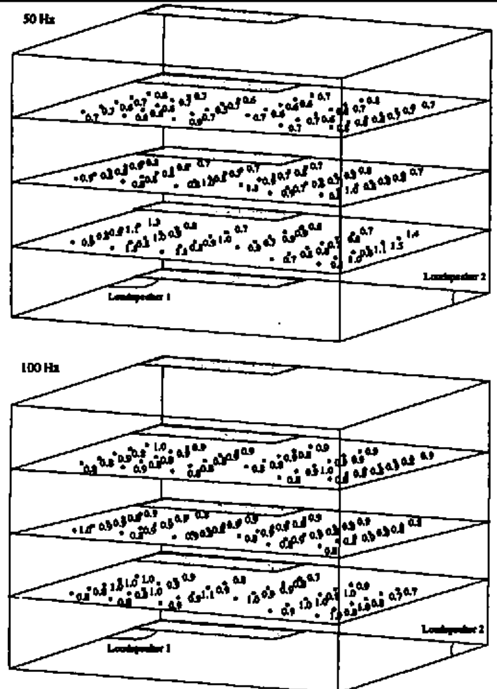

Fig. 2. Measurement set up and measured results

4. CONCLUSIONS

A diffuse field is usually defined as one in which, at any point in the room, reverberant sound waves are incident from all directions with equal intensity and random phase. In case with low frequencies with few modes the diffusiveness is low. The measured reverberation time is mainly from the forced direct field from the source and not depending of so many reflection from the wall's. The sound die away at the same rate overall in the room after the sound source has been stopped. The measurements have shown that the microphone position is not important for reverberation time measurements for these low frequencies. On the other hand it is important with high capacity of the sound sourse.

REFERENCES

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