Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
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Annals & Proceedings of DAAAM International 2011

THEORETICAL AND EXPERIMENTAL RESEARCH FOR DENSE CONCRETE AS A SOUND ABSORBING MATERIAL

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Abstract: *In this article are presented experimental and theoretical results for sound transmission loss through dense concrete partition are presented. The values measured under laboratory conditions are compared with the theoretical data. With the increase of outdoors noise levels the sound levels inside buildings are also increasing, focusing more and more attention on the need for better sound reduction of the building facades.*

Key words: *transmission loss, absorbing materials, reverberation room, sound pressure level, dense concrete*

1. INTRODUCTION

The data presented in this paper are expressed in terms of sound transmission loss, which is equivalent to sound reduction index. Sound transmission loss data are given in the one-third octave bands between 50 Hz and 5000 Hz.

A dense concrete material provides values of the sound transmission loss higher than other sound proofing materials of the same weight. Generally a partition will have better sound reduction with increasing frequency.

2. THEORETICAL ASPECTS

The sound transmission loss (R) of a partition depends on it`s mass, the stiffness and dimensions. If the stiffness can be ignored the transmission loss for an infinite partition for sound incident at an angle θ, is given by (Beranek & Vér, 1992):

$$R(\theta)=10\lg\left[1+\left(\frac{\omega\rho_s}{2\rho c}\cos\theta\right)^2\right]\ \ [\text{dB}] \qquad (1)$$

where ρ_s is the partition surface density [kg/m^2];
ω is the angular frequency [rad/s];
ρ=1.21 [kg/m^3], is the density of the air;
c=343[m/s^2] is the speed of sound in the air.

$$\rho_s=\rho_m h\ \ [\text{kg/m}^2] \qquad (2)$$

where ρ_m is the density of the partition material [kg/m^3] and h is the thickness of the partition [m].

The mass law equation predicts a 6 dB increase of the sound reduction index in case of doubling the thickness of the partition or of the frequency of the incident sound. The transmission loss will have the highest value for a normally incident sound, θ=0.

At a frequency rate lower than the critical frequency (f_c), relation (3), the transmission loss can be determined using the relation (1).

$$f_c=\frac{c^2}{2\pi h}\sqrt{\frac{12\rho(1-\nu^2)}{E}}\ \ [\text{Hz}] \qquad (3)$$

where ρ is the density of the material [kg/m^3]; ν is the Poisson coefficient and E is the Young’s modulus of elasticity [GPa].

At normal incidence relation (1) becomes:

$$R_0=10\lg\left[1+\left(\frac{\omega\rho_s}{2\rho c}\right)^2\right]\ \ [\text{dB}] \qquad (4)$$

With a perfectly diffuse sound field and R_0>15 dB, the argument of equation (1) may be averaged over a range of θ from 0 to 90° to yield the random incidence transmission loss at low frequency:

$$R_{random}=R_0-10\lg(0.23R_0)\ [\text{dB}] \qquad (5)$$

An expression for random incidence transmission loss at frequencies above the critical frequency was derived by Cremer (1942), (Fahy, 1993):

$$R_{random}=R_0+10\lg\left(\frac{f}{f_c}-1\right)+10\lg\eta-2\ \ [\text{dB}] \qquad (6)$$

The dominant influence of the coincidence transmission is seen in the presence of the loss factor therm, η, dimensionless.

3. LABORATORY MEASUREMENTS

Measurements were done in the acoustics laboratory of the Department of Engineering for Energy, Nuclear and Environmental Control, University of Bologna, Italy.

All measurement methods used in this study are standardized (ISO 140/3, 1995), (ISO 10140/2, 2010).

The sound transmission loss of a dense concrete partition has been measured in laboratory by placing the element under test in an opening between two adjacent reverberant rooms. Noise level is produced into one of the rooms, the source room. Part of the sound energy is transmitted through the dense concrete partition into the other room, the receiving room. The values of the transmission loss are calculated with the following relation (ISO 10140/2, 2010):

$$R=L_1-L_2+10\lg\frac{S}{A}\ \ [\text{dB}] \qquad (7)$$

where L_1 – is the average sound pressure level in the source room, [dB];
L_2 – is the average sound pressure level in the receiving room, [dB];
S =10.8 m^2, the area of the test specimen;
A – is the equivalent sound absorbtion area in the receiving room, in square metres.

The sound absorbtion area in the receiving room can be determinated with the Sabine relation (Kuttruff, 2009):

$$A=0.161\frac{V}{T_{rev}}\ [m^2] \qquad (8)$$

where V=66.91 m^3, is the receiving room volume and T is the measured reverberation time in the receiving room.

The dense concrete partition has as dimensions: 3.6 m length, 3 m width and 0.250 m thickness. The partition surface mass measured on 1 m^2 is 370 kg/m^2.

The parameteres of the dense concrete partition are presented in table 1(Cremer et al., 2005):

Replacing the values from table 1 in the relation (3) the critical frequency can be obtained 82 Hz.

At frequencies less than the critical frequency the transmission loss is obtained using the relations (4) and (5), and for frequency much higher than the critical frequency, the transmission loss is obtained by adapting relation (6) with the following equation:

$$R_{random}=R_0+6\lg\left(\frac{f}{f_c}-1\right)+6\lg\eta-2\ \ [dB] \qquad (9)$$

Table 2 contains the measured and theoretical transmission loss values as a function of frequency for the dense concrete partition:

Figure 2 illustrates the theroretical and measured values for the transmission loss. In the area of the critical frequency the difference between the measured and the theoretical values reaches it`s maximum distance.

Figure 2 illustrates the theroretical and measured values for the transmission loss. In the area of the critical frequency the difference between the measured and the theoretical values reaches it`s maximum distance. At high frequencies the measured values cannot go over 60 dB, due to practical limitations of the test facilities.

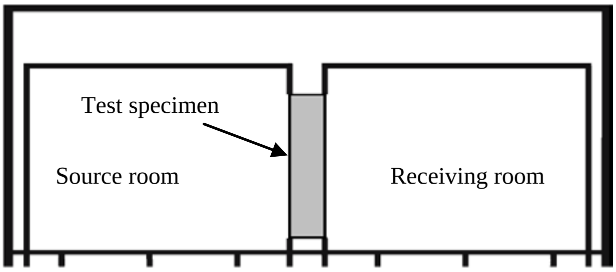

Fig. 1. Reverberation room for measurement transmission loss

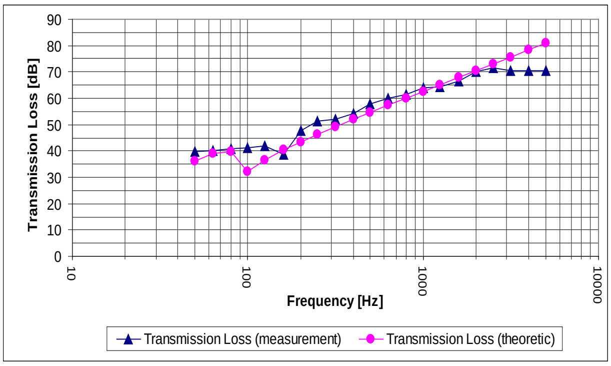

Fig. 2. Transmission loss measurements and theoretical values for the dense concrete partition.

Young's modulus of elasticity [N/m^2]	Poisson coefficient	Loss factor	Density [kg/m^3]
$22.8\cdot10^9$	0.15	0.004	2300

Tab. 1. Parameters values for the dense concrete partition.

Frequency [Hz]	Transmission loss (measurement) [dB]	Transmission loss (theoretic) [dB]
50	39.6	36.1
63	40.2	38.9
80	40.7	39.8
100	41.2	32.3
125	41.9	36.6
160	38.6	40.4
200	47.6	43.3
250	51.5	46.2
315	52.1	49
400	54.2	51.9
500	57.7	54.6
630	60.1	57.3
800	61.5	60.1
1000	64.1	62.7
1250	64.3	65.2
1600	66.4	68.1
2000	70.1	70.6
2500	71.5	73.1
3150	70.4	75.7
4000	70.4	78.4
5000	70.4	80.9

Tab. 2. Measured and theoretical transmission loss values for the dense concrete partition.

4. CONCLUSIONS

The analisys of the measurement data and the theoretical values shows a good correlation degree. The transmission loss values for a dense concrete partition increase as the frequency increases.

5. AKNOWLEDGEMENTS

The first author (Georgeta Todica) would like to thank the acoustics laboratory of the Department of Engineering for Energy, Nuclear and Environmental Control (DIENCA), University of Bologna, Italy for the support and help with the measurements.

This paper was supported by the project "PRODOC" contract no. POSDRU 6/1.5/S/5, project co-funded by the European Social Found through the Sectorial Operational Program Human Resources 2007-2013.

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