inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 51.3

PREDICTING IMPACT SOUND INSULATION OF THE WOODEN JOIST FLOORS - AN APPLICATION OF EUROPEAN MODELS

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INTRODUCTION

Multiple-resident wooden-constructed dwellings have a long tradition in Scandinavia. There are frequent complaints about low frequency impact sound from people in adjacent living areas. However, there has been little research or development relative to impact sound transmission through wooden flooring.

In recent years, consumer demand for better sound insulation of wooden floor in residences has greatly increased. For this reason, it is important for the house designer to predict, at the design stage, structure acoustic performance using knowledge of material properties. A prediction model is necessary for this purpose. CEN (the European standardisation organisation) has developed models for predicting sound transmission between rooms.

This study applies one of the CEN models in a new way to determine impact sound insulation of wooden joist floors that are assumed to be homogeneous. An equivalent method is used in this study to obtain basic floor parameter data e.g., floor thickness, material density and elasticity. Using the CEN model, the impact sound insulation of a wooden joist floor is calculated in one-third octave bands from 31.5 Hz to 3150 Hz, and is compared with measured data. Predicted and measured values are comparable.

CEN PREDICTION MODELS

There is no direct and simple relationship between acoustic performance of products from which a building is erected and measurable quantities in a completed building. The CEN model (CEN/TC126 prENxyz) links building materials to estimate sound transmission [1]. One of the CEN models (CEN/TC126 prENxyz-2) estimates impact sound insulation between rooms in buildings. This standard describes a detailed model that calculates sound transmission in a range of frequency bands; a single number rating can then be derived from the results [2].

With this model, for common monolithic floors, the normalized impact sound pressure level can be calculated accurately [3]. With the force level of a standard tapping machine, the following equation can be used at one-third octave bands for sound pressure level calculation [4]

$$L_n = L_F + 10\lg\frac{\mathrm{Re}(Y)\sigma}{m'} + 10\lg T_s + 10.6 \text{ dB}$$

$$L_n = 155 - 30\lg m' + 10\lg T_s + 10\lg\sigma + 10\lg\frac{f}{f_{ref}} \text{ dB}$$

where
L_F = force level of the tapping machine,
m' = mass per unit area,
$\mathrm{Re}(Y_i)$ = real part of the floor mobility
σ = radiation factor for free bending waves,
ρ = density of the floor,
T_s = structural reverberation time,
c_L = longitudinal velocity,
f_{ref} = the reference frequency.

APPLICATION WITH THE WOODEN JOIST FLOOR

Typical wood joist construction [5] is shown in Figure 1. The upper part consists of two layers of particle board, with a layer of cork granule board in between, and a layer of mineral wool resting on a layer of spaced panel. The supporting beams are of homogeneous wood. The lower part consists of two layers of plaster board suspended in a resilient steel section, inside which is a layer of mineral wool.

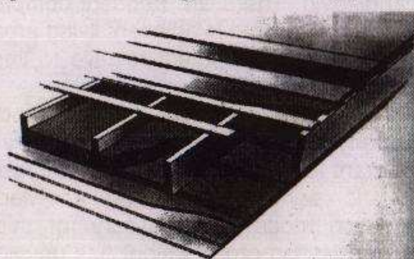

Fig. 1. Typical wooden joist construction.

The normalized impact sound pressure level of a wooden joist floor can be determined by first calculating the normalised impact sound pressure level from the supporting beam structure, and then figuring in the reduction level from the floating floor and soft covering.

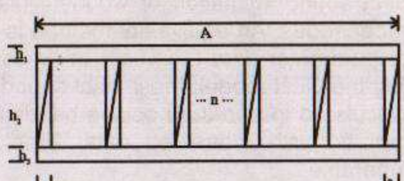

Fig. 2 Section of beam structure.

To calculate the impact sound pressure level from the supporting beam structure (Figure 2), the equivalent parameters, such as Young's modulus E', thickness h', and density ρ', of a composite structure are obtained by the following method.

A beam structure consists of a surface board, beams and a ceiling. The thickness of the surface board, beam and ceiling are described by h_1, h_2 and h_3 respectively, the length of the surface board short side is described by "A", the thickness of the beam are a_1, a_2, ···, a_n, respectively, as shown in Fig 2.

According to the bending wave theory, the geometrical moment of inertia of the total floor area about the neutral axis I is determined by [4]:

$I = \int_s y^2 ds$ then each section of geometrical moment I_1, I_2 and I_3 are obtained.

The beam structure equivalent parameter can be obtained by

$$E' = \frac{E_1 I_1 + E_2 I_2 + E_3 I_3}{I}$$

$$\rho' = \frac{\rho_1 h_1 A + \rho_2 h_2 \times a_1 \times n + \rho_3 h_3 A}{h_1 A + h_2 \times a_1 \times n + h_3 A}$$

$$h' = \sqrt[3]{\frac{12I}{A}}$$

where
E_1, E_2 and E_3 are Young's modulus of each section,
ρ_1, ρ_2 and ρ_3 are density of each section.
$a_1 = a_2 = \cdots = a_n$

According to Istvan L. Ver [6] the improvement in impact sound insulation achieved by the addition of the soft surface layer is defined in terms of the logarithmic ratio:

$$\Delta L_n = 20 \log \frac{F}{F'} \text{dB}$$

According to L. Cremer [4], the reduction in transmitted sound level in a locally reacting floating floor is

$$\Delta L_n = 20 \log \left[1 + \left(\frac{f}{f_0} \right)^2 \right] \cong 40 \log \frac{f}{f_0} \text{ dB}$$

According to Istvan L. Ver [6] the improvement in impact sound insulation in a resonantly reacting floating floor can be approximated by

$$\Delta L_n = 30 \log \frac{f}{f_0} \text{ dB}$$

where
F' and F = force acting on the floor with and without the resilient layer, respectively, N
$f_0 = \frac{1}{2\pi}\sqrt{\frac{s'}{m'}}$, Hz, is the resonance frequency of the floating floor
m' = mass per unit area of the floating floor, kg/m^2
s' = dynamic stiffness per unit area of the resilient layer, N/m^2

CALCULATION EXAMPLES

The normalized impact sound pressure level from wooden joist floor is calculated and compared with laboratory measurement results, as shown in Figure 3. Two samples of wooden joist floors were calculated. The input data follows:

Both samples have the same beam structure and ceiling, S = A*B = 3.19*3.79m^2, with six cross beams of 0.045m thickness

	h (m)	E (N/m)	ρ (kg/m³)
1	0.022	2E+09	520
2	0.22	4.5E+09	470
3	0.026	2.8E+09	923

Sandwiched floating floors: Sample 1 has a 22 mm and a 12 mm particle board with a 2 mm layer of cork granule board between, the particle board E = 4E+09 N/m and ρ = 710 kg/m³.

Sample 2 has a 30 mm and a 19 mm particle board with a 2 mm layer of cork granule board between, the particle board E = 4E+09 N/m and ρ = 710 kg/m³.

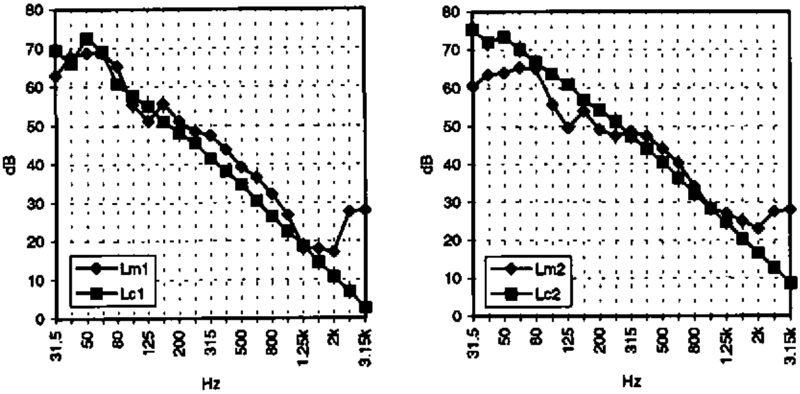

Fig. 3 calculation of impact sound pressure level and laboratory measurement results.

CONCLUSIONS

The advantage of this method is its simplicity and that it gives information on structure performance at design stage. This offers cost savings by permitting selection of the most efficient material available within budgeted limits. Further study is needed to consider other influences such as reduction of insulation by using suspended ceiling, influence of absorbing material, and field prediction, etc..

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