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COMPARISON OF IMPACT SOUND INSULATION MEASUREMENTS OF FLOOR COVERINGS USING DIFFERENT FLOOR TYPES AND EXCITATION SOURCES

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ABSTRACT
The reduction of transmitted impact noise by floor coverings has so far been determined on a standardized heavyweight floor using the standard tapping machine (ISO 140-8). It is generally known that correlation between the results obtained applying ISO 140-8 and the subjective impression is much worse on lightweight floor constructions, i.e. the values measured for these constructions are in general too favorable. Investigations carried out in Japan with alternative excitation by a rubber ball have shown better agreement. Since the relevant standard so far defines only a standardized heavyweight floor, a working group is now discussing the definition of a standard lightweight construction. Furthermore, the question is being discussed of whether an alternative excitation, in addition to the standard tapping machine, will be of advantage. It is, however, not yet known how the results obtained by the different excitation methods can be compared. The impact sound insulation was measured on different floor constructions provided with different floor coverings. Excitation was achieved by means of the standard tapping machine and the Japanese rubber ball, with different falling heights. The results of these measurements will be presented.

1 - INTRODUCTION
The measurement of the reduction of transmitted impact noise by floor coverings on heavy-weight floors is specified in ISO 140−8. Unfortunately the results obtained by this measuring method cannot be used for the estimation of the improvement of the sound insulation of floor coverings on light-weight constructions. As this problem is well known, an ISO working group, ISO TC 43/SC2/WG22, was established to standardize another method to measure the reduction of transmitted impact noise by floor coverings on light-weight constructions. In connection with this topic, two main problems are to be solved. The first problem is to define a standard light-weight floor or a set of standard floors which would be a world wide representative construction. The second problem is related to excitation. Especially when light-weight floors are used in real buildings, the low-frequency transmission for a typical excitation like walking people or jumping children is quite strong. Therefore Japanese acousticians proposed using a special rubber ball for low-frequency measurements on light-weight floors.

In order to perform systematic tests and to obtain representative and reliable results, a joint project of Fraunhofer Institut für Bauphysik, IBP, Stuttgart, and the Physikalisch-Technische Bundesanstalt, PTB, was established. The first part of the project, carried out by IBP, was to theoretically investigate the principle interaction between impact source, floor and floor covering. The results of this project part have already been published in [1] and will be briefly summarized in chapter 2. The second project step, performed by PTB, was to make practical measurements of the impact sound insulation on heavy-weight and light-weight floors using both the standard tapping machine and the rubber ball as excitation source. Furthermore, different types of floor coverings were used to investigate the reduction of the transmitted sound obtained in all cases. The results of the practical measurements and a first evaluation are presented in chapter 3.

2 - THEORETICAL BACKGROUND

The impact sound insulation of a floor construction is normally estimated by adding the insulation of the bare floor construction $L_{n,0}$ and the improvement ΔL of the floor covering. So the insulation of different combinations can be predicted when the relevant data are available. The entire measuring procedure for concrete floors is described in ISO 140 part 8.

The theoretical investigation by IBP for the interaction between source and floor was based on a relatively simple calculation [2] on the assumption that the system behaves linearly. The system of excitation is modeled as a resonant mass/spring/mass system with m_1 (the hammer), the (contact) stiffness s at the impact point and m_2 (the floor).

The force is given by the drop height of the hammer. Assuming a time spectrum of the force as half-sinusoidal, the first minimum in the frequency spectrum will be found at three times f_0 where f_0 is:

$$f_0 = \frac{1}{2\pi\sqrt{m_{eff}/S_{eff}}} \qquad \text{with} \qquad \frac{1}{m_{eff}} = \frac{1}{m_1} + \frac{1}{m_2} \qquad \text{and} \qquad \frac{1}{S_{eff}} = \frac{1}{S_1} + \frac{1}{S_2}$$

For a heavy concrete floor and a 500 g hammer, this minimum is outside the normal measurement range, i.e. the force spectrum is nearly constant and controlled only by the high contact stiffness at the impact point (Fig. 1 from [1]). For a light-weight floor the contact stiffness is much lower and brings down the minimum in the force spectrum to the building-acoustic frequency range. Covering the floors with additional "soft" layers reduces further the contact stiffness, so that a decreasing force spectrum results in the normal frequency range.

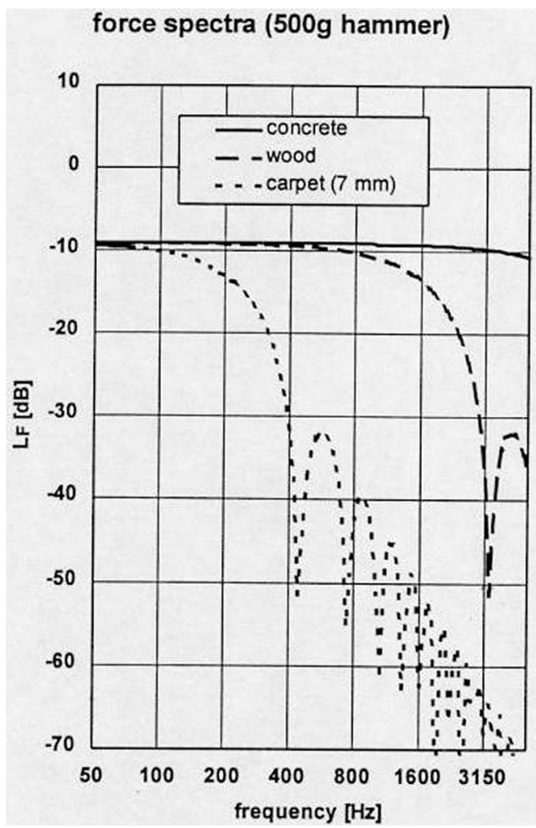

Figure 1: Impact force spectra of different floors [1].

The radiation of impact sound into the receiving room depends on the velocity of the excited floor which is proportional to the force acting on the floor. The difference of the force spectra without and with floor covering results in the impact sound improvement ΔL (Fig. 2 from [1]). Due to the different force spectra for higher frequencies, a carpet layer on a wooden floor gives lower results of the insulation improvement than on a concrete layer.

If a heavy impact source like a rubber foot of 20 kg mass is used the curves according Fig. 3 will be obtained. The stiffness of the rubber impact source determines the resonant frequency so that there is nearly no difference between the impact force on concrete floors and wooden floors. Therefore the

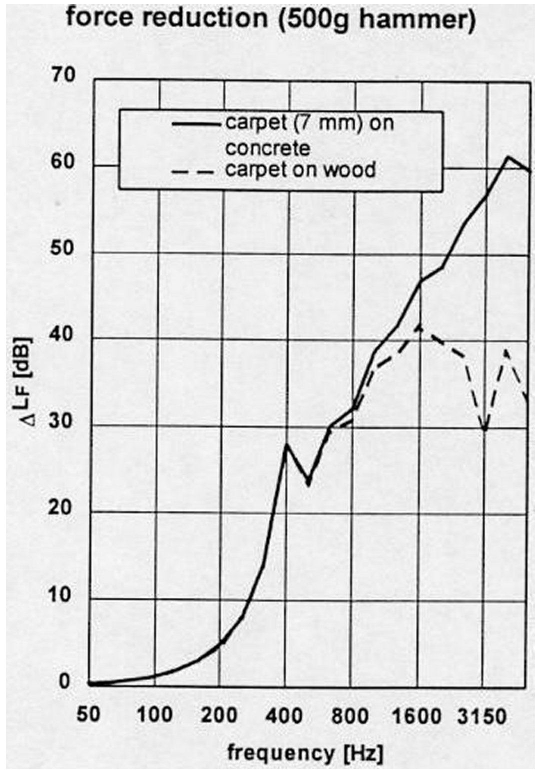

Figure 2: Impact sound improvement due to floor construction [1].

reduction of the transmitted impact sound of an additional layer like a carpet is also similar in the two cases.

3 - MEASUREMENTS AND OBJECTS

The practical measurements were performed on a standard concrete floor 14 cm thick and on a light-weight wooden floor construction as shown in Fig. 4.
This is one of the constructions proposed in the latest draft of ISO 140-11. As additional layer five different floor coverings were used. Two coverings were made of gum, one 6 mm in thickness and relatively stiff (gum_A) and the second softer one 10 mm in thickness (gum_B). The third covering is sold as 'artificial lawn' for balconies etc., 8 mm in thickness. Finally two carpet floor coverings of different structure were used. One was about 12 mm thick including a felt back 3 mm thick (carpet_A) and the other had a thickness of 10 mm including a 4 mm back of plastic foam (carpet_B). The measuring program was as follows:
All measurements were performed on the concrete and on the wooden floor

- Excitation by standard tapping machine
  - impact sound insulation
  - reduction of transmitted impact noise
  - transient acceleration pattern of the hammer impact
- Excitation by rubber ball
  - impact sound insulation
  - reduction of transmitted impact noise

The transient acceleration pattern was measured by a laser vibrometer technique. The results obtained should show the correspondence of the actual hammer acceleration during impact with the half-sinusoidal impact assumed by the simple theory. Due to difficulties concerning the measuring setup, only measurements of the acceleration of the tapping machine are available yet.

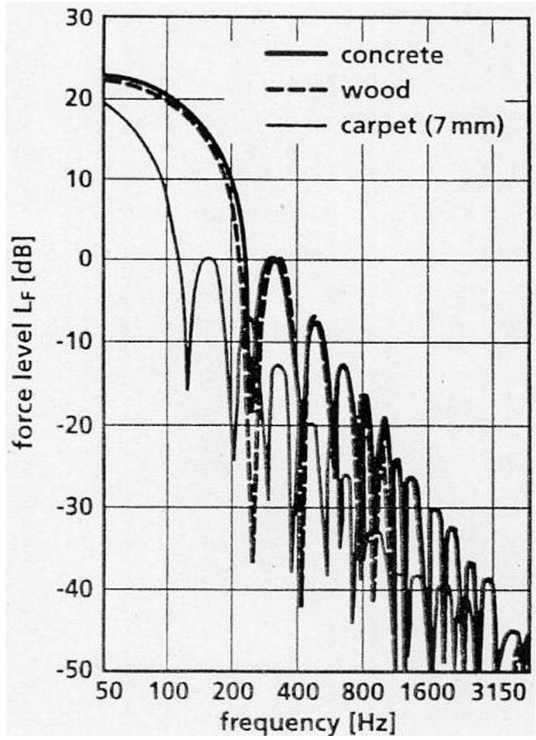

Figure 3: Force spectrum of a heavy impact source (theoretical [1]).

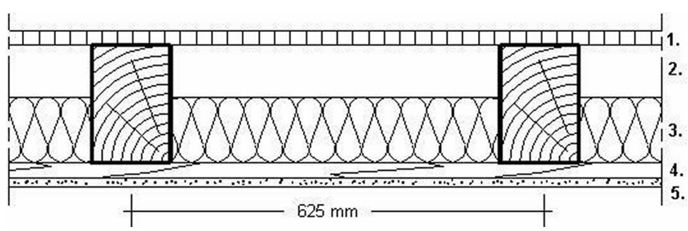

Figure 4: Construction of the light-weight wooden floor; layer structure (from top to below): 1 - 22 mm wooden chipboard, screwed to the joists; 2 - wooden joists; 3 - 100 mm mineral wool; 4 - 24 mm wooden ceiling battens, crewed to joists; 5 - 12,5 mm gypsum board, screwed.

4 - RESULTS

Fig. 5 shows the impact sound pressure levels measured on both bare floor types using the tapping machine as excitation source. The results obtained basically agree with the behavior predicted by the simple theory.

In Fig. 6 the frequency response of the measured (!) impact force level can be seen (see also Fig. 1). If in the concrete case a constant impact force level can be assumed, for the light-weight floor the contact stiffness determines the decrease at higher frequencies, which also leads to the impact sound level shown in Fig. 5 being reduced.

Fig. 7 shows the measurements of the impact sound pressure level when the rubber ball is used for excitation. The stiffness of the rubber ball itself, which is much lower than the contact stiffness of both concrete and wooden floor, determines the decreasing slope of the curve obtained. Differences occur only in the 3000 Hz range where the contact stiffness of the light weight floor is no longer small compared to the rubber ball stiffness.

More interesting are the consequences for the measurements of the reduction of impact sound if the floor is covered with additional layers. Fig. 8 shows the results for the measured impact sound reduction for the five layers applied to the concrete floor.

Fig. 9 shows the same results but for the wooden floor.

In Fig. 10 and Fig. 11 the impact sound improvements for two layers are shown calculated from the measured impact force level of the hammer. The results obtained by the two methods are in good

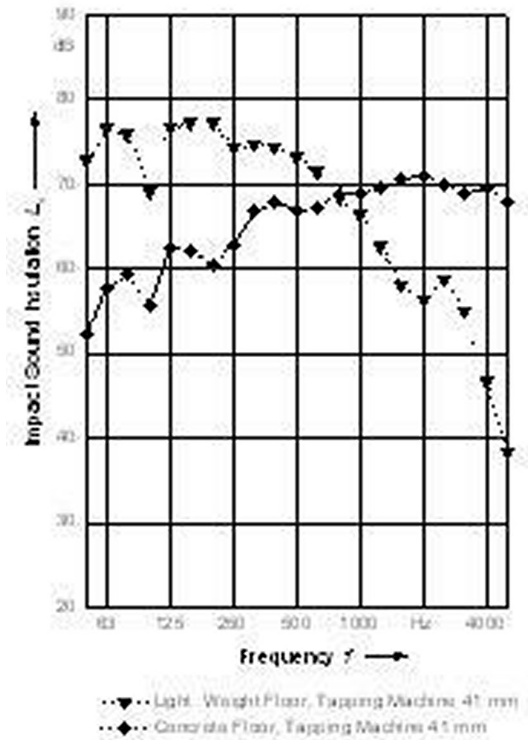

Figure 5: Impact sound pressure levels measured with the tapping machine on bare floors.

agreement considering, that the force level was measured only during one hammer drop and not averaged over several drops and over various floor positions.

The behavior of the improvement curves can generally be explained as follows: The impact sound reduction is caused by the different impact force level obtained due to different contact stiffnesses. For lower frequencies (e.g. 63 Hz) the improvement of the sound insulation is about 0 dB, because the force spectra for all cases treated are nearly equal. The increase in the improvement curves starts at the frequencies at which the resulting contact stiffness of the floor with layer leads to the force level decreasing. The increase in the improvement curves ends and changes to a more or less constant value when the force level of the bare floor itself begins to decrease. Then the constant value of the impact sound reduction is the difference between the two decreasing curves.

For a harder layer like gum_A the resulting stiffness in Fig. 8 and Fig. 10 is still quite high. Therefore the improvement of the sound insulation is smaller than when the other layers are used. In the case of the wooden floor (see Fig. 9 and Fig. 11) the increase stops when the decrease of the force level of the bare floor begins (see also Fig. 6).

If the rubber ball is used for excitation, the relatively low stiffness of the ball itself determines the shape of the impact force spectrum. Therefore the improvement of the impact sound insulation by the floor coverings is very small. For the light-weight floor the improvement is nearly zero dB at higher frequencies and does not exceed 10 dB at all (Fig. 12). The improvement curve for concrete floors shows a small increase up to 1 to 2 kHz. A maximum value of about 18 dB for carpet_B is observed before going down to zero at the highest frequencies (Fig. 11).

The interpretation of the results given above is based on a simple model and on a linear theory (!). For practical layers like carpets or rubber and for the rubber ball itself, a linear behavior, especially as regards the stiffness, cannot be generally assumed.

5 - CONCLUSIONS AND OUTLOOK

The measurement of the improvement of the sound insulation can be easily measured using a concrete floor and a tapping machine for excitation. Then the force impact spectrum of the bare floor can be assumed as constant in frequency. The improvement of additional layers is directly linked with the lower contact stiffness. The results obtained are valid only for a hammer excitation where the mass of the hammer and the contact stiffness of the floor determine the behavior. The results are not suitable to represent real conditions with a walking or jumping person exciting the floor. The mass and the

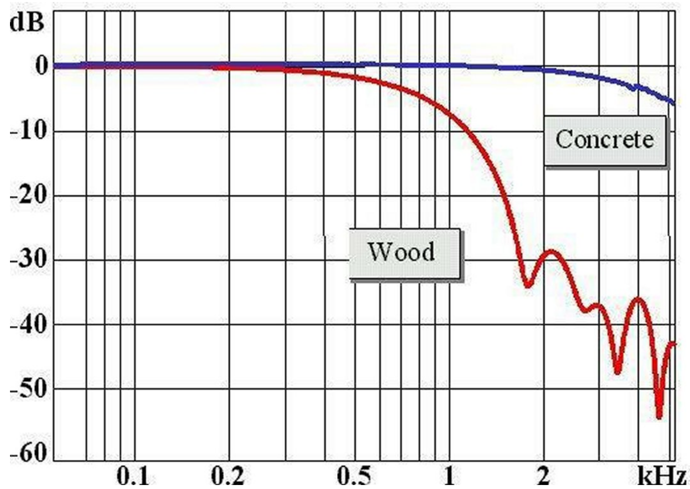

Figure 6: Frequency response of measured impact force levels (tapping machine).

stiffness of the excitation source are completely different and lead to completely different results for the improvement of the sound insulation. Measurements of the sound insulation improvement on light-weight floors are highly dependent on the contact stiffness of the basic floor type, at least for hammer excitation. It is discussed in the ISO working group whether it is reasonable to standardize a bare wooden floor with the tapping machine as excitation source when the results obtained are valid only in this specific case and are not representative of various types of wooden floors and somehow related to a natural excitation like a walking person. Furthermore, it is still not clear whether the results of the impact sound reduction measurements can be converted from rubber ball excitation into hammer excitation and vice versa. Therefore all the data of material properties and of the influence of non-linearity must be available.

REFERENCES

1. **W. Scholl, W. Maysenhölder** , Impact Sound Insulation of Timber Floors: Interaction Between Source, Floor Coverings And Load Bearing Floor, *Building Acoustics*, Vol. 6 (1), pp. 43-61, 1999

2. **L. Cremer, M. Heckl**, *Körperschall* , Springer Verlag, Heidelberg, New York, 1982

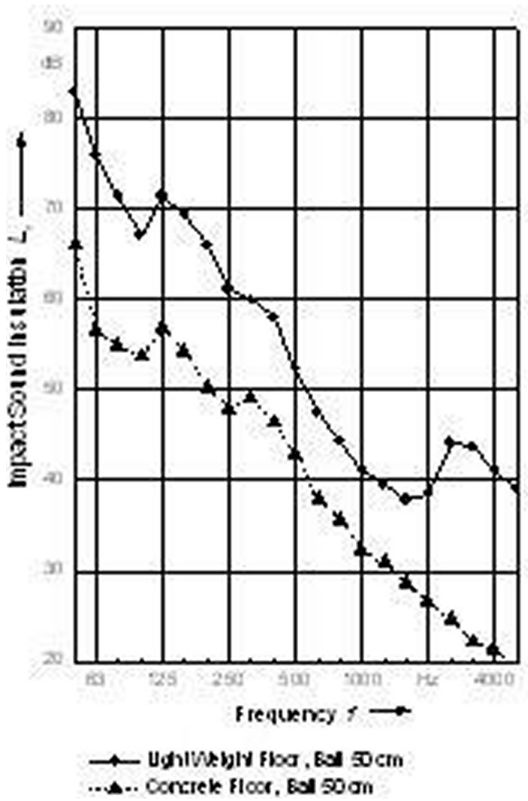

Figure 7: Impact sound pressure levels measured with the rubber ball on bare floors.

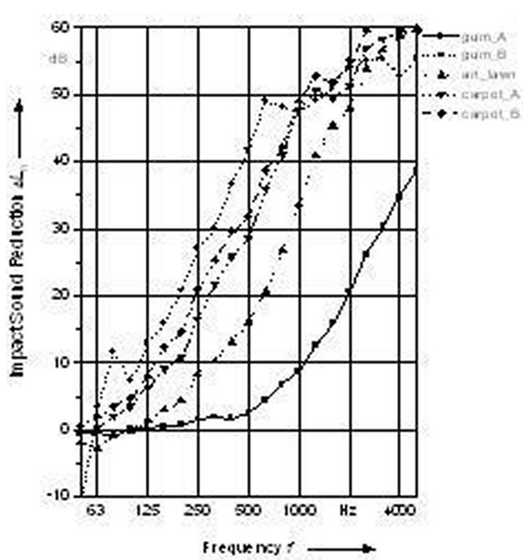

Figure 8: Measured improvement of the impact sound insulation on the concrete floor.

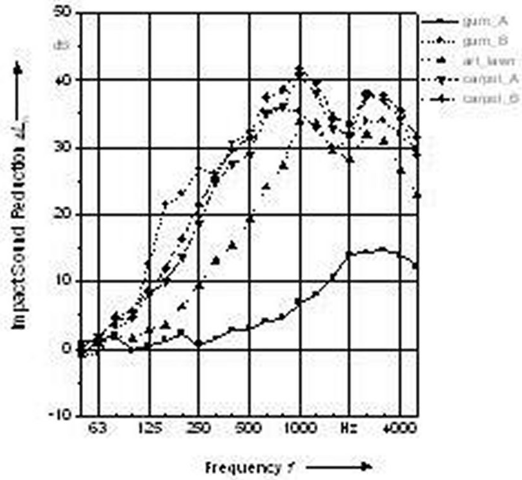

Figure 9: Measured improvement of the impact sound insulation on the light-weight floor.

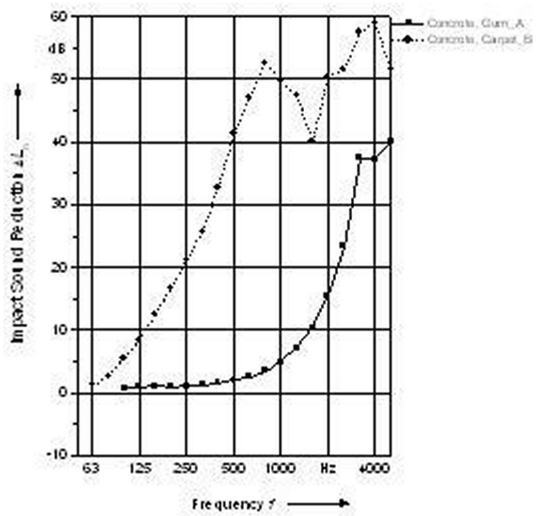

Figure 10: Improvement of the impact sound insulation on the concrete floor calculated from measured force spectra.

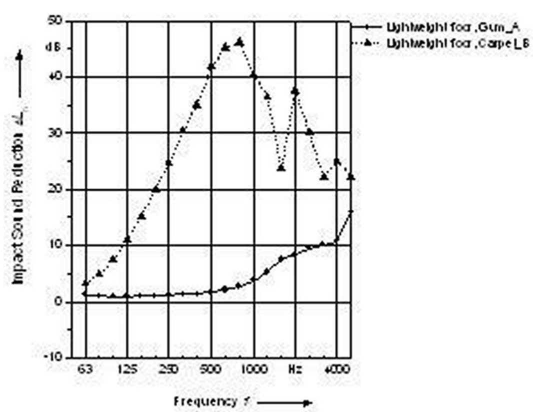

Figure 11: Improvement of the impact sound insulation on the light-weight floor calculated from measured force spectra.

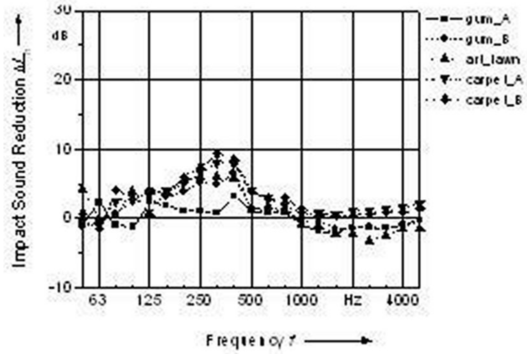

Figure 12: Improvement of the sound insulation on the light weight floor, ball excitation.

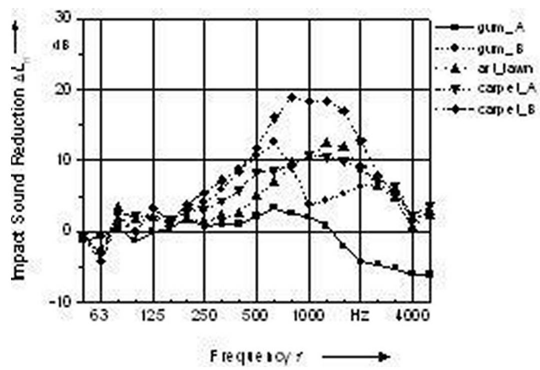

Figure 13: Improvement of the sound insulation on the concrete floor, ball excitation.