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SOUND INTENSITY: STATE-OF-THE ART IN NOISE CONTROL OF BUILDINGS

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This paper summarizes the progress that has been made in the application of sound intensity techniques related to the research of sound transmission loss in building acoustics. The modern development of sound intensity instruments began with the discovery of the fast Fourier transform and with the develpoment of techniques for filtering electrical signals using digital techniques. It was only after these techniques became well established, that instruments and procedures for the determination of sound intensity became available for laboratory and in situ measurements. Applications for these instruments and procedures quickly followed and are still pursued today. In this paper some of these developments are discussed, with emphasis on those directly related to sound transmission loss in buildings.

1. Introduction

Trends in developing new room acoustic predictions and design techniques consist in utilizing mathematical modelling and computer calculations. The process requires an extensive knowledge of the acoustic parameters related to the sound field generated from the source side, the propagation path and the sound field at the receiver side. This can be obtained by theoretical modelling, but in many cases it is more significant to obtain this information experimentally and, therefore, precision measurement techniques have become a crucial component of the design and prediction process.

Until recently the only acoustical quantity that could be measured accurately was the sound pressure, and from this, other acoustical quantities could be calculated. The scientific interest to get more accurate information on sound insulation for example by scanning overall surfaces, required that other acoustical quantities needed to be measured. The development of the Fast Fourier Transform analyzer, the introduction and perfection of digital electronic technology and the improvement of acoustic transducers permitted the construction of reliable sound intensity meters and other valuable equipment for laboratory and in situ measurements.

The ability to obtain acoustic power flow from nearfield measurements in receiving rooms, substantially expands our capability to study all details of the sound radiation from complex building structures, in order to study the details of sound propagation in spaces with complex boundaries and to perfect the measurement of the acoustical properties of structures. Using computational technique, sound field maps of acoustic intensity vectors and waveforms, as well as acoustic holography repesentations, can be obtained.

2. Sound intensity

The sound intensity, its measurements and applications, has been the common factor in one of the most remarkable progresses in acoustical engineering in the last 15 years. This has also been the case in building acoustics research, and that for several reasons.

First the increased availability of computing power together with advanced graphic representation have enabled us to show sound intensity fields. Examples of the flow pattern of the sound power radiated from a violoncello measured by the sound intensity technique and from iso-normal intensity contour distributions in the

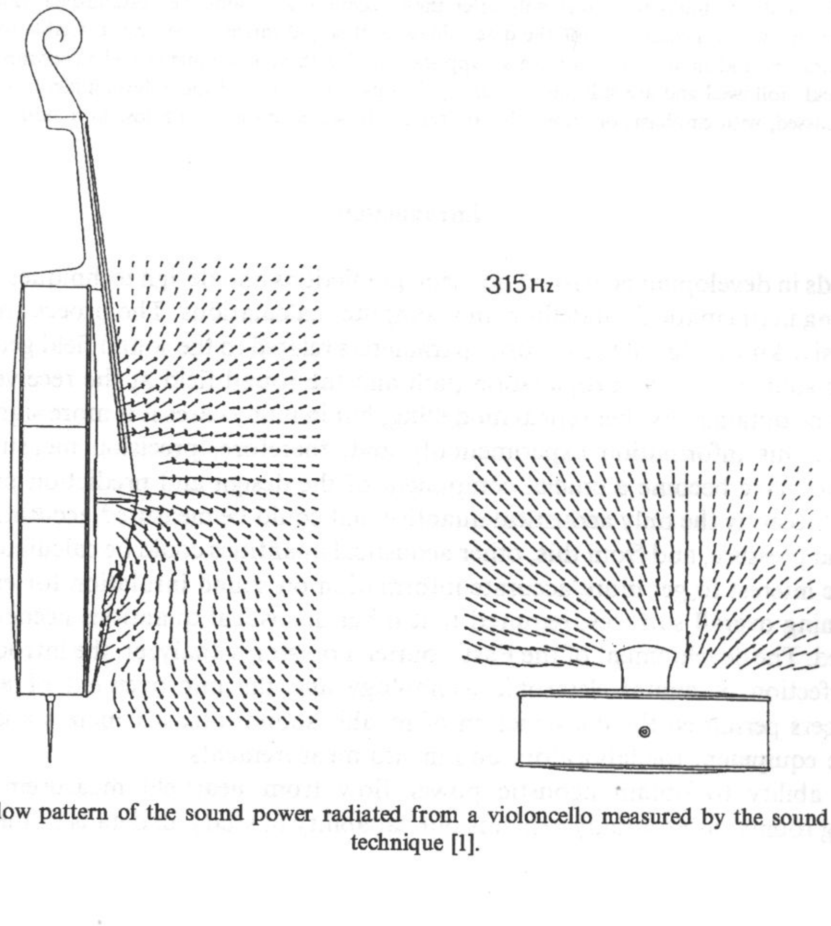

Fig. 1. Flow pattern of the sound power radiated from a violoncello measured by the sound intensity technique [1].

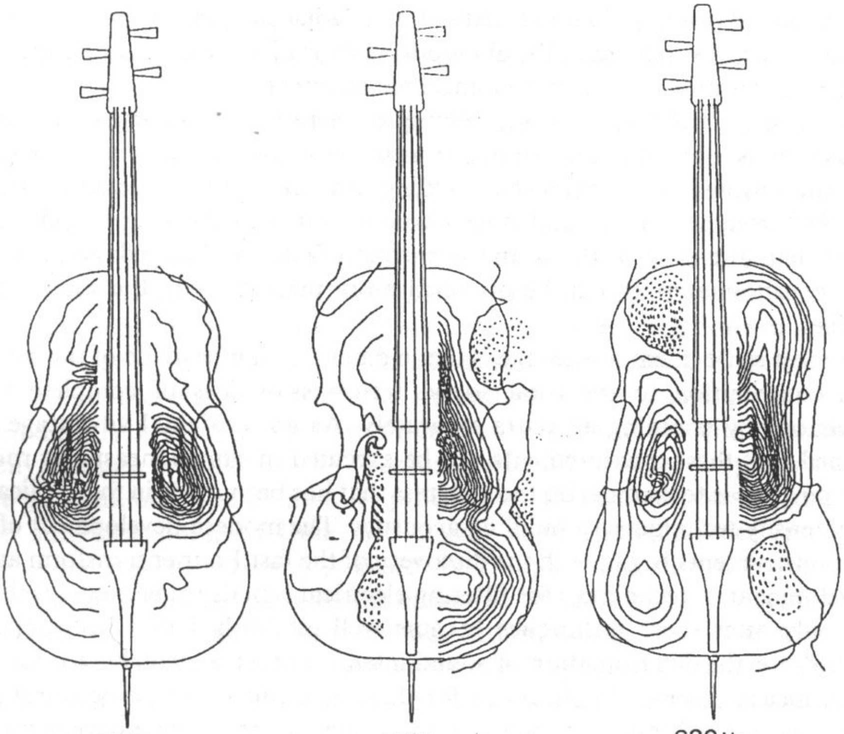

Fig. 2. Iso-normal intensity contour distributions in the field of a violoncello (Full lines: positive, broken lines: negative) [1].

field of a violoncello are given in Fig. 1 and Fig. 2 [1]. This has led to a better understanding of the sound field radiated from constructions such as walls and plates and the reflection from and diffraction around surfaces such as absorbing materials.

Second, the instruments available for the direct measurement of sound intensity have led to new techniques for the determination of the properties of noise reducing elements such as sound transmission loss of structures and impedance characteristics of acoustic materials.

The existing techniques and methods, which are used for standard measurements in acoustic research, were very complicated and required moreover expensive measuring laboratory facilities. The conventionally used sound pressure level measurements did not gave immediately the desired results as the microphone measures the total sound pressure, which can be influenced by the close sound field, multi-direction transmission paths, and directivity sensitiveness or reverberation effects. The sound pressure is a scalar quantity and will give insufficient information about the direction and the size of the sound energy flux of a radiating field. In order to identify sound sources and sound transmission paths, selective enclosures with lead and screens and anechoic rooms were necessary. Measurements of sound transmission loss of building structures in laboratory facilities require two adjacent perfect diffuse measuring rooms and the measurement of the absorption factor of acoustic materials needs to be done in reverberation rooms and in anechoic chambers.

The advantage of the mesuring technique where the sound intensity vector can be measured is obvious. The sound transmission loss of the most complicated single, multilayered and composed building elements and the ordering transmission ways through building and other structures due to flanking sound transmission, the determination of the sound absorption factor and impedance characteristics of acoustic materials, can be obtained more precisely with the sound intensity technique.

The most self-evident advantage is that a diagnosis can be made of the weak links and its contribution to the total sound transmission loss of complete building constructions by scanning all parts separately. As an incidental advantage can be mentioned that these measurements can be executed in simple measuring rooms.

The purpose is to summarize the progress that has been made in the application of sound intensity techniques to buidling acoustics. The modern development of sound intensity instruments began with the discovery of the fast Fourier transform and with the development of techniques for filtering electrical signals using digital techniques. It was only after these techniques became well established that instruments and procedures for the determination of sound intensity became available for laboratory and field measurements. Applications for these instruments and procedures quickly followed and are still pursued today. In this paper, some of these developments are discussed, with emphasis on those applications directly related to building acoustics. The papers that have appeared in literature are so numerous that it would be impossible to mention them all. Therefore, it has been necessary to be selective in the choice of the presented material. Many of the references are to papers which appeared in International Journals on Acoustics and Noise Control Engineering, in Proceeding of Inter-Noise Congresses, in Proceedings of specialized Symposia on Sound Intensity held at CETIM in Senlis, France [2, 3] and from the book of F. Fahy, titled *Sound intensity* [4].

Widespread use of sound intensity techniques in building acoustics will depend on future standardization. Examples of the importance of standardization include the development of standards for the determination of sound transmission loss properties of building acoustics structures such as walls, floors, ceilings, roofs and facade elements and the determination of sound absorptive properties of acoustical materials, both for normally-incident and oblique and randomly-incident sound waves. It appears that widespread acceptance of methods will only occur after standardization has been done. A first step is the development of instrument standards and standardization techniques for the calibration of instruments. This work is done by IEC-TC 29. Because of widespread interest in the determination of sound absorption and impedance characteristics of acoustic materials, manufacturers of acoustic equipment have already developed the two-micrphone measurement tube equipment, and ISO/TC 43/SC 2 WG 14 is asked to prepare a standard on the two-microphone method with the tube technique. But up to now no standardization related to the use of a measuring method with the two-microphone technique, at oblique or random sound incidence is under way.

There is also widespread interest in the determination of sound transmission loss of buildings and building elements. At the moment ISO/TC 43/SC 2/WG 18 is revising the different parts of ISO 140. This revision is done in narrow co-operation with CEN/TC 126-"Acoustic properties of building products and buildings". Up to now only in part 5: "Field measurements of airborne sound insulation of façade elements and facades" of ISO/TC 43/SC2/WG 18, the sound intensity measuring technique has been restrained as an informative measuring technique in Annex 2.

Acoustic intensity can be obtained from the sound pressure and particle velocity amplitudes and the phase between the quantities. While sound pressure can be measured directly by small and precise mircophones, there are no suitable transducers to directly measure particle velocity. Because particle velocity is proportional to the pressure gradient, one type of intensity probe approximates the pressure gradient by pressure difference obtained from two closely spaced mircophones (p-p probe). Another probe type (p-u probe) is based on Doppler shift caused by modulating a high frequency ultrasonic wave by the measured acoustic wave. The techniques for the determination of sound intensity are not without errors. A discussion of factors which affect the accuracy of the measurements is beyond the scope of this paper. Some of the papers who discussed problems related to accuracy are listed in references [5 to 12].

The number of papers on sound intensity measurements and applications in the field of building acoustics has grown very rapidly in the last decade, and it is difficult to summarize them all. Therefore, it seems appropriate to select papers on sound transmission loss only and to present a few of the results with emphasis on practical applications. A lot of research has also been done on absorption and impedance characterization of acoustic materials performed by the two-mircophone technique [13]. The results obtained will not be treated in this paper.

3. Sound Transmission Loss Measurements

Sound transmission loss measurements (STL) are based on measurements of the sound power which incidents on the tested partition and which is radiated from the other side. The transmission loss of structures such as walls, panels, facades, floors and ceilings is usually measured between reverberation rooms. By definition the sound transmission loss of a structure is given by:

$$R = 10\log(P_1/P_2) \qquad \text{(dB)}, \tag{3.1}$$

where P_1 and P_2 are the incident and transmitted sound powers. A proportion of the sound power which enters the structure may be transmitted to, and radiated by the adjoining structures, this process is called "flanking transmission". The source room is supposed to create a diffuse sound field so that the direction of the waves incident on the measured partition would be distributed uniformly. For the determination of the incident sound power, the intensity method is identical to the classic two-room method and P_i is determined by the sound pressure measurement in the diffuse field of the source room. In standard form the incident sound power is based on:

$$P_1 = (p_1^2/4\rho_0 c)S \tag{3.2}$$

with p_1 the sound pressure in the source room, ρ_0 the static density of air, c the velocity of sound in air and S the structure surface. The transmitted sound power for the classic two-room method is determined from the sound pressure in the diffuse receiving room based on the relationship:

$$P_2 = (p_2^2/4\rho_0 c)A_2, \tag{3.3}$$

where A_2 is the equivalent sound absorption in the receiving room and p_2 the sound pressure in the receiving room. Substitution of equations (3.2) and (3.3) into equation (3.1) and conversion to the decibel scale yields the standardized formulation for the two-room method (ISO 140-3):

$$R = L_{p1} - L_{p2} + 10\log(S/A_2) \quad \text{(dB)} \tag{3.4}$$

where L_{p1} and L_{p2} are the time and space-averaged sound pressure levels in the source and receiving room.

For the intensity method the transmitted power is determined from the surface averaged sound intensity I_2 as:

$$P_2 = I_2 S \tag{3.5}$$

Substituting equations (3.2) and (3.5) into equation (3.1) yields the formulation for the intensity method:

$$R_1 = L_{p1} - L_{I2} - 6 \quad \text{(dB)} \tag{3.6}$$

where L_{p1} is the spacial average of the sound pressure level in the source room, and L_{I2} is the averaged normal intensity level measurement on the enveloping surface. The standard formula albeit adequate for general-purpose applications, does not give full account of all the factors which may affect the test results, such as the influence of boundary interference fields near the radiating structure, the composition of the structure, and calibration and absorption errors. The calibration and absorption erros are treated more elaborate elesewhere [14, 15, 16, 17, 18].

The standard procedure for estimating energy density in reverberation rooms involves spatial averaging of the sound pressure level in the central part of the room. WATERHOUSE [19] pointed out that in reverberation rooms there is an increase in energy density at the boundaries. Thus estimates of the total room sound energy based on measurements of the sound pressure level in the central portion of reverberant rooms will be too low with the result that the sound reduction indices obtained by the intensity method will be underestimated. This phenomenon which is particularly significant at low frequencies is believed to be at least partly responsible for the small, though consistent, discrepancies between intensity and conventional two-room method results which have been published [15, 20, 21, 22, 23, 24, 25].

Taking into account the Waterhouse correction, the extended formulation of the STL is:

$$R_1 = L_{p1} - L_{I2} - 6 + 10\log(1 + \lambda S_1/8V_1) \qquad \text{(dB)} \tag{3.7}$$

where λ is the wavelength, and S_1 and V_1 are the internal surface area and the volume of the source room, respectively. The Waterhouse correction is only applicable at low frequencies. For a room with volume 100 m^3 the correction is 0.5 dB at 500 Hz, 1.0 dB at 200 Hz, 2 dB at 100 Hz and 3 dB at 50 Hz.

In practice, the assumption of equal measurement and test object surface area is justified only in the case of short distance measurements with the intensity probe in relation to the radiating structure, as is shown in Fig. 3, where is presented a vertical section of the sound tranmission rooms together with the used measuring equipment. The transmitted sound intensity distribution is normally measured on a surface parallel to the partition. Measurements on the peripherical faces of the enclosing surface must not be neglected: a significant proportion of the transmitted power may be transported through these faces, especially at frequencies in the neighbourhood of the critical frequency of the panel structure. Some systematic investigations have been made on the influence of measuring distance and sample point density on the accuracy of estimated loss, for example by Minten, Cops and Wijnants [16] and Guy and De Mey [26]. In the case the measurement surface S_m, completely enveloping the test object is larger than the object surface S, the sound transmission loss can be inferred by the formulation:

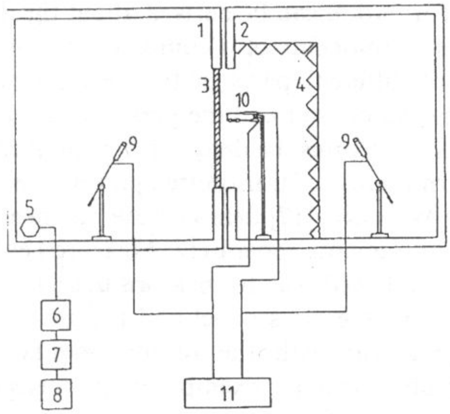

Fig. 3. Laboratory facility to measure the STL of test structures. *1.* Transmitting room, *2.* Receiving room, *3.* Structure, *4.* Absorbing material, *5.* Loudspeaker system, *6.* Amplifier, *7.* Filter, *8.* White noise geneator, *9.* Microphones, *10.* Sound intensity probe, *11.* Sound intensity analyser [23, 30].

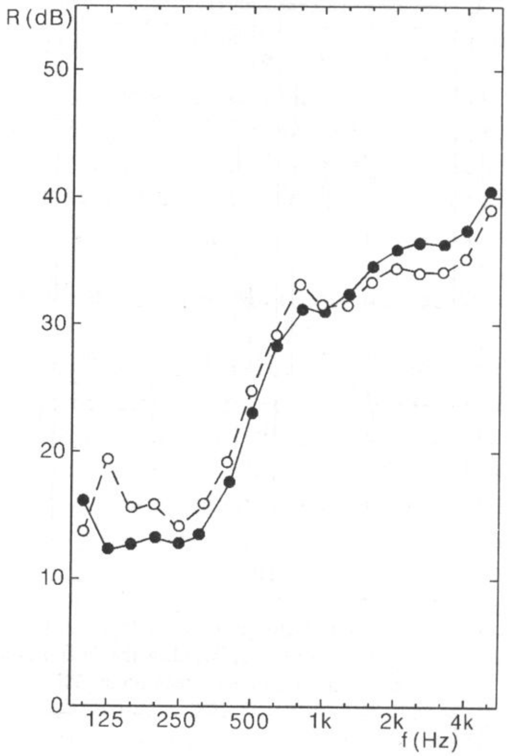

Fig. 6. STL of the complete facade element determined following both measuring techniques. ●——● Intensity method; ○ – – – ○ Conventional method.

together with the results of the overall facade element, are given in Fig. 5. The weakest point in the facade, namely the ventilation clearly shows the lowest results. Figure 6 shows a comparison of the measuring results of the STL of the complete facade element according to the conventional method and the intensity method. The agreement is very satisfying over the whole frequency range.

4.2. Visualization of sound intensity and design

An example of the distribution of sound intensity over a window at 250 Hz and 2 KHz and published by Tachibana [31] is given in Fig. 7. In this measurement, the sound was located inside the room and the sound intensity normal to the window was measured outside, at a lot of discrete points. The sound power uniformly transmits through the window at low frequencies, as shown in (a): 250 Hz, whereas sound power transmits dominantly through the edge parts of the window in the case of high frequencies as shown in (b): 2 kHz. Gerretsen [32] investigated the influence of window frames, the dimensions of window panes and the position of ventilation openings on the STL.

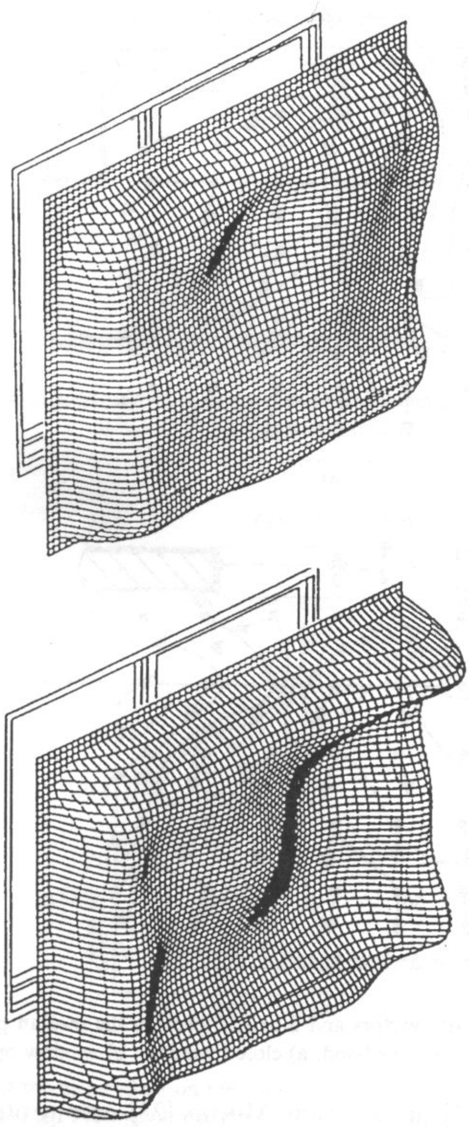

Fig. 7. Sound intensity transmission through a window: a) 250 Hz octave band; b) 2 kHz octave band [31].

Among the many applications of sound intensity measurements to determine the sound properties of building structures are a number which address specific aspects of design, operation and installation. The effects of window opening were investigated by MIGNERON and ASSELINEAU [28] and examples of the sound intensity field are shown in Fig. 8. GUY and DE MEY [26] investigated the effect of absorbent aperture surfaces in the measuring opening on the STL of glazing. They observed significant increases in STL, and concluded the mechanism was not the reduction of sound power radiated by the partition but the subsequent absorption by the reveal.

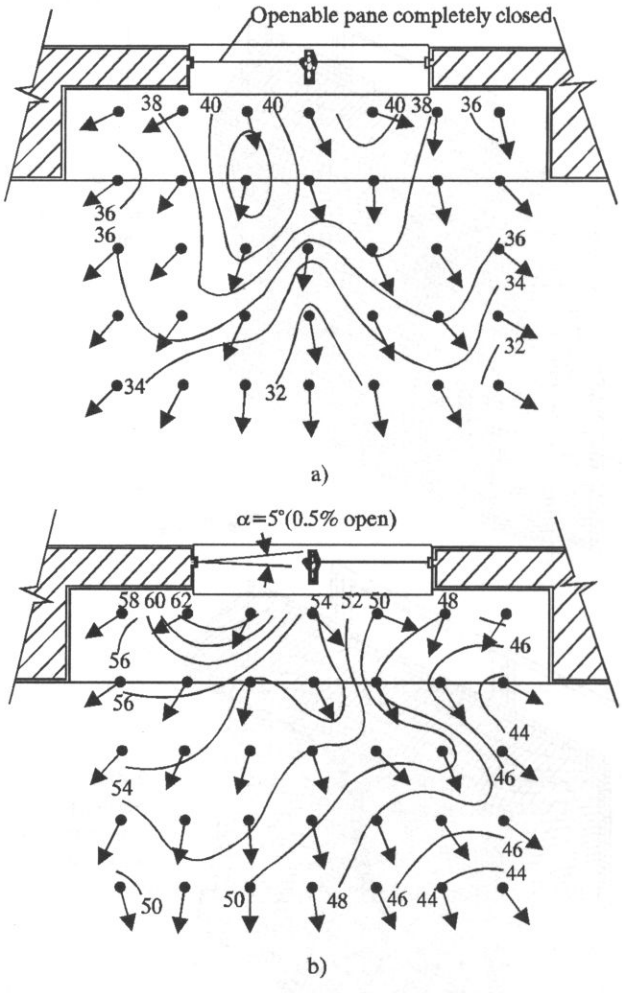

Fig. 8. Distribution of the mean intensity vectors and intensity levels in the median plane of a window transmitting noise in the 1 kHz 1/3 octave band: a) closed window; b) window opened 5° [27].

Halliwell and Warnock [24] and Cops and Minten [23], among others, have used the intensity method to investigate the influence on the STL of the placement of partitions within the thickness of an aperture between two reverberation rooms — the so called "niche effect". Figure 9 shows a vertical section of a two-room measurement facility with an extremely (I) and a centrally placed partition within the niche opening. Figure 10 shows the influence of the niche effect on the STL measurement results obtained with the sound intensity method for a laminated glass panel, together with the standard deviation on the measurement results. Cops, Minten and Myncke [30] investigated other design parameters such as the influence on the STL of the room volumes, the dimensions and the depth of the opening, the influence of diffusors, loudspeakers and microphones.

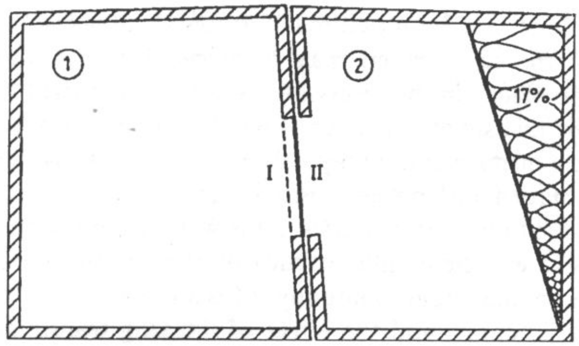

Fig. 9. Horizontal cross section of a two-room measurement facility in order to measure the influence of the niche effect on the sound transmission loss [23].

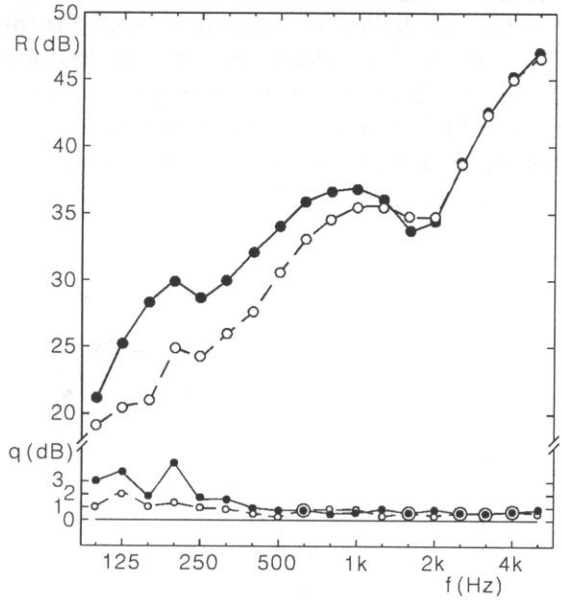

Fig. 10. Influence of the niche effect on the sound transmission loss measurement results for a laminated glass panel [23]. Placement: extremely (●——●); Placement: centrally (○ – – – ○).

4.3. Flanking transmission

Many investigations have been performed on the influence on the STL of flanking effects as well in laboratory facilities as in practice [14, 30, 33, 34, 35, 36, 37]. While carrying out these investigations it was found that problems could arise when attempting to measure the mean intensity from the weakly radiating surface. The instrumentation is not suitable for the use in sound fields where the pressure-intensity index is greater than 13 dB. In practice this may mean that sound intensity from a separating wall/floor can be measured but sound intensity measurements from a flanking wall in the same room may be unreliable. For this reason acoustic absorbent should be placed in the receiving room to reduce the P-I index as much as possible. Even if the measured P-I index is within the limitations of the instrument, calculated mean intensity values may be misleading if the individual intensity measurements fluctuate a lot between positive and negative values which can happen at low frequencies due to vibration modes in the wall. If there is much variation in the individual intensity levels, the number of measurement positions should be increased to avoid errors due to inadequate sampling. Measurements have been performed on different wall/floor junctions and the effect of flanking transmission on the sound insulation of a timber floor as well as the flanking sound transmission within facade structures. In all these investigations the technique identified the most important sound paths. Disadvantages of the technique are that it requires large quantities of acoustic absorbent, which is bulky to transport, and the procedure is fairly time-consuming which can be a problem in field investigations when time is frequently very limited. At least this technique gives a lot of supplementary information which can not be obtained with the conventional standardized method. In order to prove this, measurements performed on a plastered heavy stone wall,

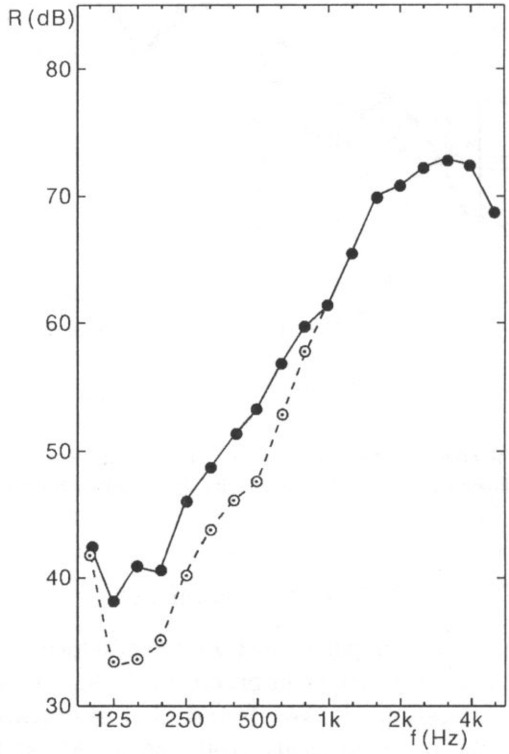

Fig. 11. STL of the plastered heavy stone wall measured with the sound intensity technique. ●——● room 2 to 1 (without correction); O – – – O room 2 to 1 (with correction).

nearly of the same thickness as the surrounding room walls, and measured in the laboratory facility (Fig. 9) are discussed [30]. The plastered heavy wall, with high sound insulation was fixed in room 1, and measurements with the sound intensity technique where performed in both direction from room 1 to 2 and vice versa in order to observe eventual flanking effects. During the measurements of the STL from room 1 to 2 the radiated sound intensity was determined by scanning the wall in the receiving room. During the measurements of the sound transmission loss in the opposite direction from room 2 to 1, the wall in the receiving room was scanned as well as the flanking walls.

In Fig. 11 the STL results as a function of frequency are shown according to the measurement direction 2 to 1. The full curve shows the results of the STL calculated from the direct radiation of the sound from the wall without any correction for flanking. The dashed curve shows the results taking into account the correction for flanking radiation through the connecting walls. An important flanking transmission occurs at low and medium frequencies. In Fig. 12 the corrected STL according to the measurement direction 2 to 1 is compared with the results in the opposite direction. There is a remarkable good agreement between the STL results.

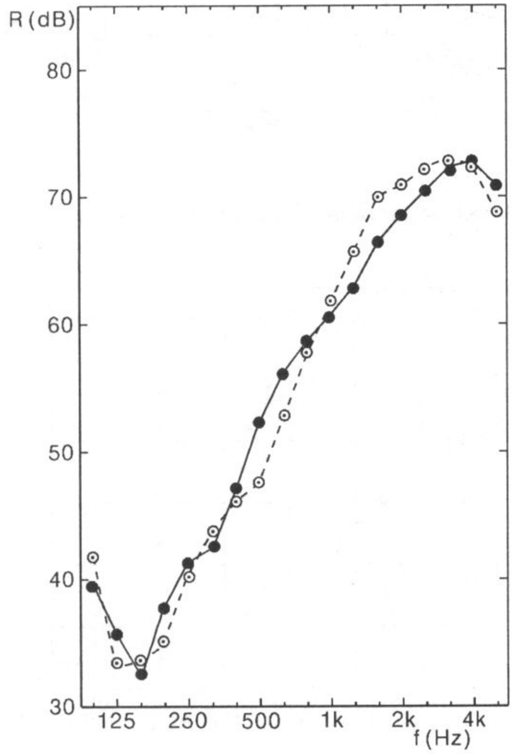

Fig. 12. STL of the plastered heavy stone wall measured with te sound intensity technique in both directions. ●——●: room 1 to 2; ○ – – – ○ room 2 to 1 (with correction for flanking).

4.4. *Saddle roof construction*

The intensity-based technique has also been successfully applied to the field investigation of the in-situ transmission loss of saddle constructions in Fig. 13 [38]. Measurements are performed on the roof surface and the side facade before and after additional sound insulation elements have been placed, in order to increase the sound insulation against aircarft noise. The different parts were separately scanned and out of this measurements the weak points could be fixed, and improvement of the sound transmission loss could be suggested. Figure 14 shows the STL values obtained with the sound intensity technique for the side facade of the roof construction and clearly presents the weaker points.

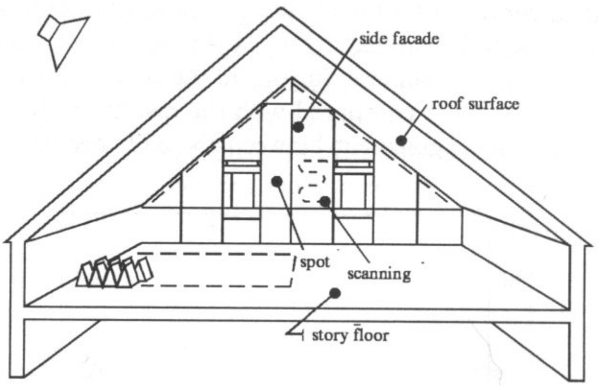

Fig. 13. Detailed drawing of the saddle roof construction [38].

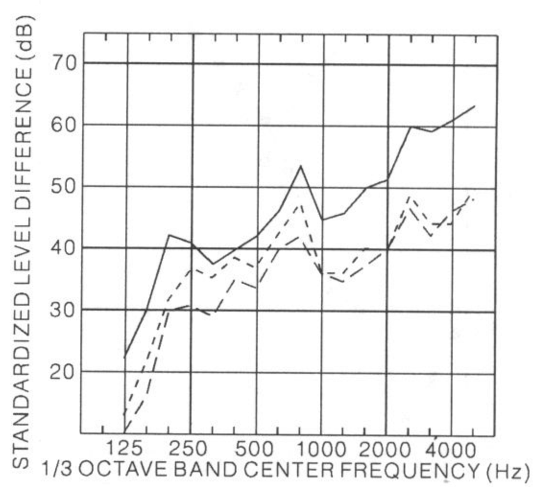

Fig. 14. STL results obtained with the sound intensity technique of the side facade of the saddle roof construction [38]. ——— brickwork; .... glazing; – – – – – silence box.

4.5. *Other applications*

The effect of reverberation time in the receiving room, in a laboratory facility, on the STL using sound intensity has been investigated for different reverberant conditions by J. Lai and D. Qi [39]. Results indicate that the sound intensity measurements are virtually independent of the reverberant conditons, provided that the pressure-intensity index of the measurements does not exceed the dynamic capability of the measuring system.

J. Lai and M. Burgers [40] investigated the STL for different field conditions of composite partitions and discussed the importance of the experimental procedure. M. Lim [41] investigated the structural damping of panels by using a sound intensity technique. The panel was mounted at the opening of a box structure or onto a window separating two rooms and was subjected at the opening of a box structure or onto a window separating two rooms and was subjected to an excitation by broad-band white noise. The sound pressure behind the panel, the vibratory velocity of the panel and the radiated sound intensity in front of the panel are used to calculate the panel's structural loss factor.

4.6. *Round Robin Test measurements*

During a Round Robin Test performed in different Scandinavian laboratories [25, 42] about 30 different measurements have been carried out to estimate the precision of

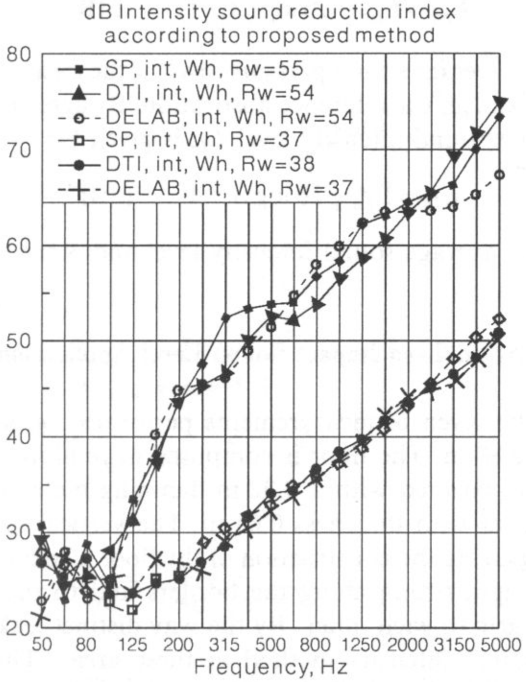

Fig. 15. Intensity sound reduction index of a Scandinavian Round Robin Test for a single metal leaf window (lower curve) and a double metal leaf window (upper curve) [25, 42].

the intensity mehtod when compared with the conventional standardized method. Figure 15 shows the results of intensity sound reduction index for the interlaboratory comparison for a single metal leaf window (lower curve) and a double metal leaf window (upper curve) obtained during the Scandinavian RRT. The results show an excellent agreement. The small differences between the laboratories seem to be the same for the intensity and conventional method.

General conclusions from all the measurements discussed are: the direct measurements of the transmitted sound intensity offers a number of substantial advantages compared to the conventional method: 1. The receiving room does not have to be calibrated for its acoustic absorption, nor is such room actually necessary, 2. The sound power radiated by composite partitions, such as dividing walls between rooms and facades in buildings, may be separately determined, thereby allowing detection and precise quantification of flanking sound transmission; 3. The distribution of transmitted intensity over the surface of the partition may be determined, thereby revealing the presence of weak areas, or leaks.

5. Normalized Impact Sound Level Measurements

The normalized impact sound pressure level L_{pn} is given by:

$$L_{pn}=L_{pm}-10\log(A_0/A) \qquad \text{(dB)} \tag{5.1}$$

with L_{pm} the measured average sound pressure level, A the measured absorption in m^2 in the receiving room and A_0 the reference absorption. By agreement A_0 equals 10 m^2. The normalized impact sound intensity level L_{In} is given by:

$$L_{In}=L_{Im}-10\log S-4 \qquad \text{(dB)} \tag{5.2}$$

with L_{Im} the measured average sound intensity level and S the surface of the floor.

6. Normalized Impact Sound Level Applications

An example will be given of measurements performed on a floating floor with dimensions 2.80 m × 2.80 m. The floor is composed of reinforced concrete elements with thickness 0.12 m, covered with a 0.02 m damping material "antison" and an upper floating slab layer with thickness 0.05 m. The vertical section of the floor is presented in Fig. 16. During the construction of the floor a lack of attention has been given to the correct tight fitting along the borders and to the tight fitting of the reinforced concrete parts to each other. By the way distinct leaks of noise could be measured with the sound intensity method at these areas. This was most clearly perceptible from the measurements of the air-borne sound transmission loss measurement but also from the impact sound level measurements.

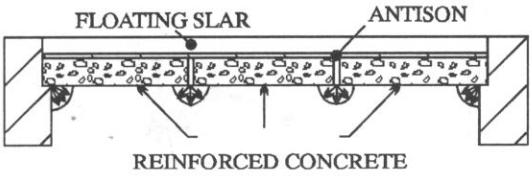

Fig. 16. Vertical section of the floating floor. Dimensions: 2.80 m × 2.80 m
Thickness: Floating slab: 0.05 m; Damping layer antison: 0.02 m; Reinforced concrete: 0.12 m.

Measurements of the sound transmission loss, carried out with the sound intensity method are represented in Fig. 17. Successively the sound transmission loss of the concrete elements of the floor, the leaks at the borders and the leaks between the concrete elements have been scanned and measured. From these measurement data the total sound transmission loss of the floating floor is calculated. The unfavourable influence of the leaks on the total sound transmission of the floor is remarkable. This is clearly shown in Fig. 18, where the sound transmission loss results of the floor were scanned in the same way as before. Almost no difference is observed between the measurement results, as shown in the figure. The total sound transmission loss,

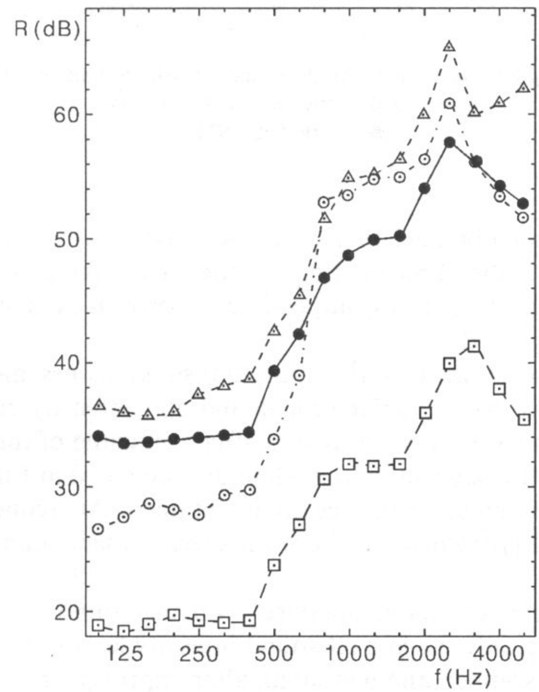

Fig. 17. STL of the floating floor measured with the sound intensity technique. Inaccurate fitting of leaks. □ – – – □: Border leaks; ○ – – – ○ Leaks between concrete elements; △ – – – △ Concrete elements; ●——● Total STL.

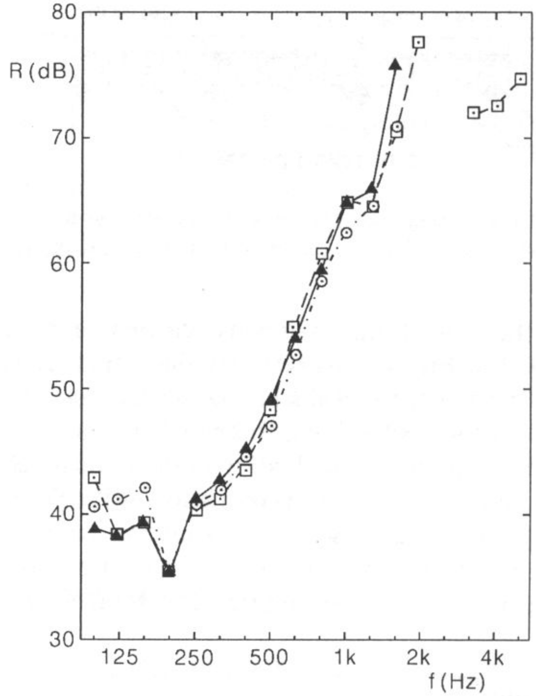

Fig. 18. STL of the floating floor measured with the sound intensity technique, after tight fitting of leaks. □ – – – □: Border leaks; ○ – – – ○ Leaks between concrete elements; △ – – – △ Concrete elements; ●——● Total STL.

compared to the result obtained in Fig. 17, increases strongly over the frequency region of interest. With the tightened floor, at the higher frequencies, due to the high sound insulation of the floor, it was impossible to perform exact measurements with the sound intensity method.

Parallel to the measurements of the sound transmission loss, measurements of the impact sound level with the conventional and the intensity method have been performed. Measurement results before and after tightening of the leaks of the floor and determined with the conventional method are presented in Fig. 19. At the lower frequencies no improvement of the results is obtained. At frequencies higher than 1000 Hz a distinct improvement of the normalized impact sound pressure level is obtained.

In Fig. 20 measurement data, obtained with the sound intensity method, are presented. In this case only the impact sound intensity level of the different parts of the floating floor are scanned and measured, after improvement of the quality of the floor by tightening. From these results the total value of the impact sound intensity level is determined. A comparison of the results, obtained with the conventional and sound intensity technique, is shown in Fig. 21. The agreement is very convincing.

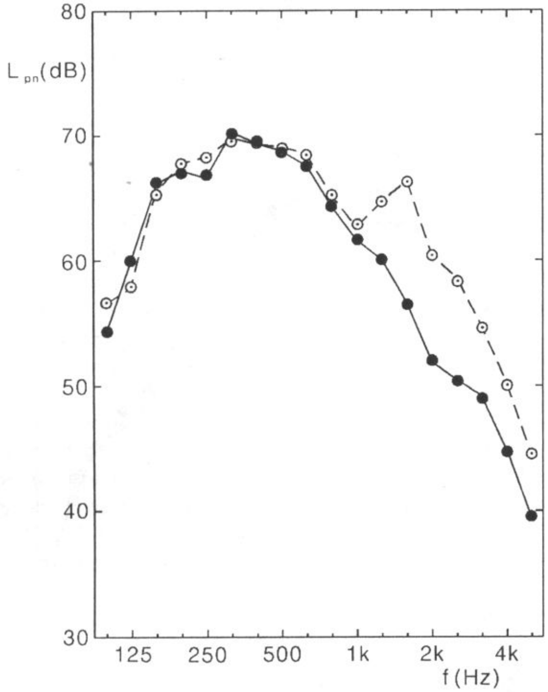

Fig. 19. Normalized impact spind pressure level of the floating floor. ○ — — — — — ○ before tight fitting of leaks; ●———● after tight fitting of leaks.

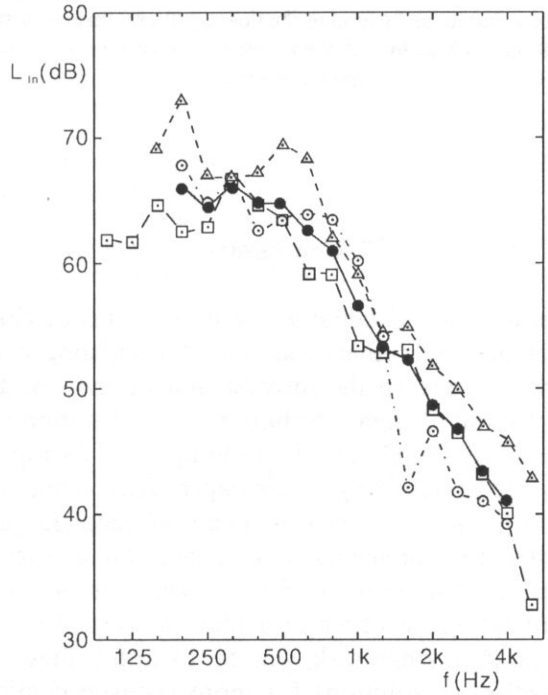

Fig. 20. Normalized impact sound intensity level of the floating floor after tight fitting of the leaks. △ — — — △: center central concrete element; ○ — — — ○ sides central concrete element; □ — — — □ side concrete elements; ●——● Total impact sound intensity level.

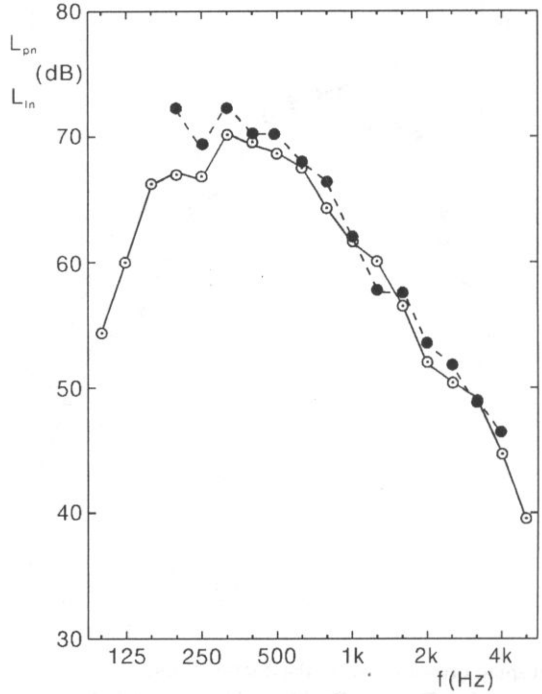

Fig. 21. Normalized impact sound intensity level of the floating floor measured with the conventional and intensity method. ●– – ●: normalized impact sound intensity level; O——O: normalized impact sound pressure level.

7. Conclusions

During the last decade a lot of valuable new measurement techniques, to perform the sound transmission loss and impact sound level of building structures, have been developed. This is mainly due to the introduction of the fast Fourier transform analyzers and the perfection of digital technology and the improvement of acoustic transducers. One of this, the sound intensity technique and its application to building acoustics, has been treated extensively in this paper. This technique has contributed, in a large sense, to more accurate measurements of acoustic parameters, such as sound transmission loss measurements and impact sound level measurements of complicated building constructions. A future task will be the development of international standardization, in order to achieve a widespread acceptance of the measurement methods. A further task will be to apply these technique for the development of cost-effective solutions for more acoustic comfort in the field of building acoustics.

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