# LABORATORY FOR FLANKING SOUND TRANSMISSION OF LIGHTWEIGHT CONSTRUCTIONS

By

J. P. NAGY

Institute for Building Constructions and Equipment, Technical University, Budapest

Received February 20, 1974

Presented by Prof. Dr. L. GÁBOR

## 1. Purpose of the laboratory

A laboratory for flanking sound transmission has been established in the central hall of the new Building Laboratory, destined to improve teaching work at the Institute for Building Constructions and Equipment, as well as to facilitate building acoustics research on lightweight constructions. This laboratory differs by the program to be realized from the standardized laboratories designed on the basis of decades of experience [11, 12]. First, these differences will be expounded, pointing out that this laboratory established within a limited volume and expanse with modest means will by no means compete with traditional acoustic laboratories, does not overlap neither replace the planned acoustic laboratory of the Technical University.

This laboratory has been planned for testing the main sound transmission paths one by one and combined (Fig. 1). To this aim, a high degree of flexibility has been aimed at. Two spaces of the laboratory can be divided by means of mobile sound insulating walls into five measuring rooms to cope with the given program (Fig. 2). Thereby program varieties outlined in Fig. 3 can be realized to test the direct and the flanking sound transmission loss primarily of suspended ceilings, curtain walls and mobile partition walls, a way open to "double" or "triple" additive tests (arrangements *c*, *e* and *f* in Fig. 3).

To simulate lightweight constructions, the tested elements are "dry" mounted, of advantage for both the versatility of the laboratory and for the measurements of different boundary conditions on sound reduction.

From education aspects, it is of primary importance that students become acquainted both with the measuring methods and test results and the building process of the elements to be tested. During measurements, the different acoustic effects can be observed and compared. Take e.g. simultaneous tests on a suspended ceiling between rooms 02 and 03, and on a curtain wall between rooms 04 and 05, the two results can immediately be compared instrumentally and subjectively. The same arrangement permits to test the airborne sound reduction of the curtain wall against outside noises according to program *i* in Fig. 3, giving another "fresh information".

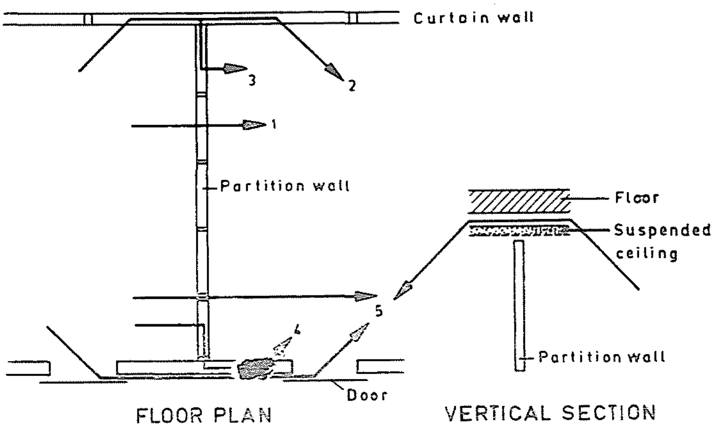

*Fig. 1.* Sound transmission paths in lightweight buildings. 1 — Direct sound transmission path; 2,3,4 — flanking paths with structure-borne sound transmission; 5 — flanking path without structure-borne sound transmission

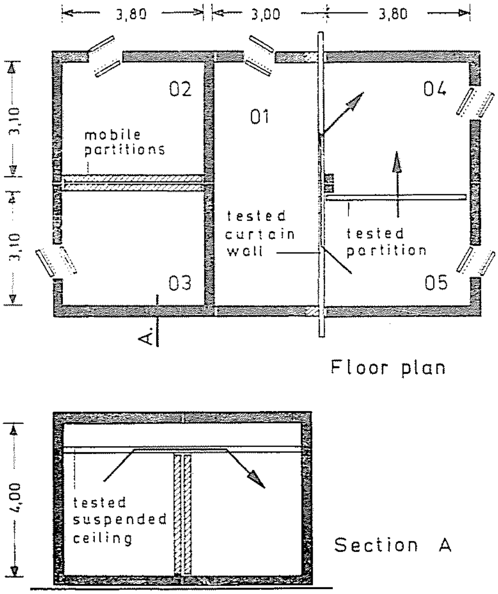

*Fig. 2.* Sketch of laboratory measuring rooms

Means to realize the outlined program are rather restricted both in volume and in financial means, thus, large measuring rooms and "heavy" walls and floors had to be renounced of. Nevertheless, the error due to the influence of insufficient diffusivity of rooms seems to be negligible compared with differences of sound transmission losses of real lightweight structures (curves 5 and 6 in Fig. 5). On the other hand, "similarity" of sizes and boundary

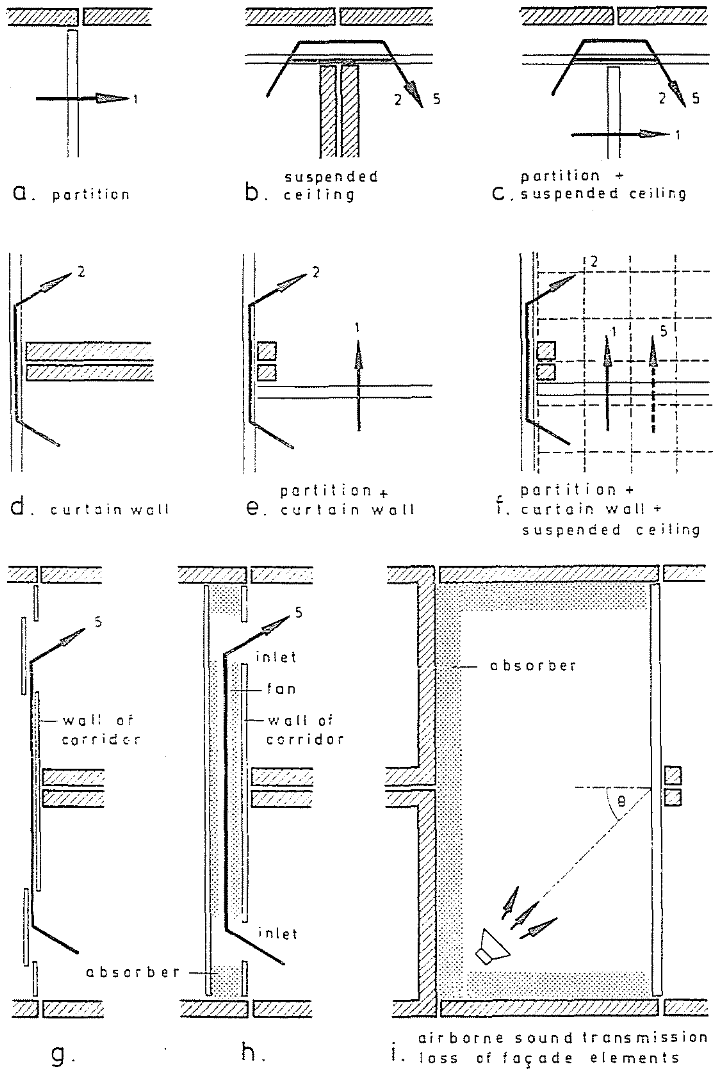

*Fig. 3.* Programs for measuring the direct and flanking sound transmission loss of lightweight constructions and façade elements

conditions in the field and in the laboratory for flanking transmission permits to directly apply the measurement results to practice against those obtained in traditional laboratories.

To our information, a complete laboratory for flanking sound transmission — described in this paper — seems to be a new idea. Laboratories belonging to well-know research institutes[1] have been designed for testing

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[1] Technical University, Berlin; Technical University, Braunschweig; Technical University, Copenhagen; "Bundesanstalt für Materialprüfung" Berlin.

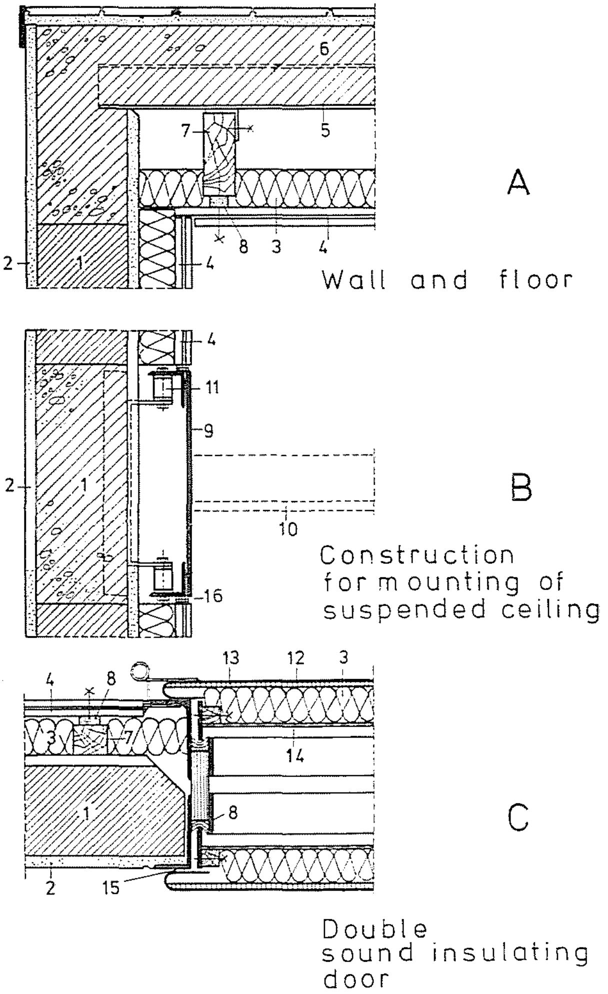

*Fig. 4.* Details of construction. 1 — Solid brick wall; 2 — plaster; 3 — slag wool; 4 — 2×9,5 mm gypsum plaster board; 5 — corrugated steel plate; 6 — concrete; 7 — timber beam; 8 — rubber; 9 — steel plate cornice; 10 — suspended ceiling under test; 11 — rubber spring; 12 — steel plate 2 mm thick; 13 — vibration damping material; 14 — perforated plate; 15 — felt; 16 — plastic joint

flanking sound transmission primarily of conventional constructions. There are several laboratories abroad for flanking sound transmission of suspended ceilings[2]; others are in the stage of planning, as stated by ISO/TC 43 "Subcommittee of Building Acoustics".

The available data and experience have been taken into consideration in planning the suspended ceiling tester.

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[2] "Gieger and Hamme Laboratories" U.S.A.; Acoustics Laboratories of "British Gypsum Ltd.," East Lake, England; of "Institut für Bauphysik" Stuttgart, F.R.G.; Building Acoustics Laboratory, Kungl Tekniska Hogskolan, Stockholm.

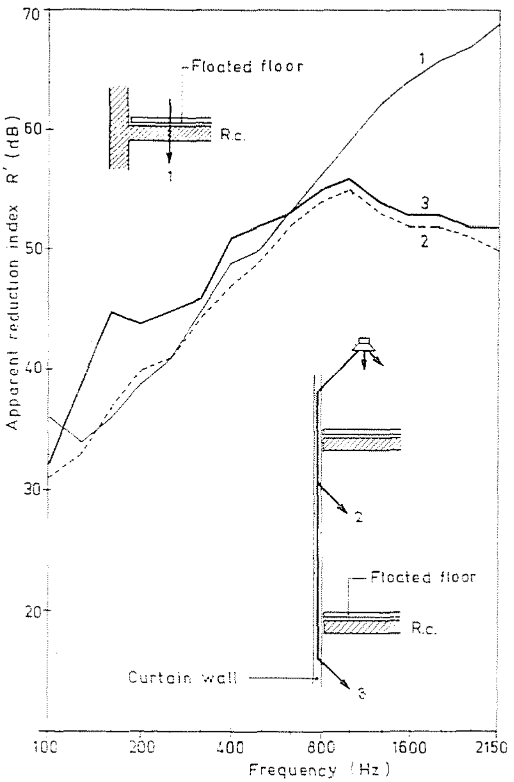

*Fig. 5.* Sound reduction between rooms separated by identical floors in buildings of heavy and lightweight construction. 1 — Adjacent rooms in a heavy-structured building; 2 — as 1 but in a curtain-walled building; 3 — source and receiving rooms intercept another room in a curtain-walled building

## 2. Constructional and acoustical design of the laboratory

The construction kept in mind the acoustic principle "house in a house". Rooms 02, 03, 04 and 05 are independently placed on "floated" stiff reinforced concrete slabs. The structure-borne sound transmission loss between the measuring rooms is considerable.

Design of the external walls and floors of the laboratory kept in mind the protection to the noise of the hall (airborne sound reduction); the elimination of flanking sound transmission through laboratory walls and floors; and structural aspects. The solid brick wall 51 cm thick, both sides plastered, is internally lined by two layers of plaster gypsum board, with slag wool filling.

Acoustically the floor is essentially identical with the wall construction, as shown by detail A in Fig. 4.

Mounting systems for the test constructions will be developed in the research program to be realized. Built-in steel structural members (e.g. a steel plate cornice to hold bracings of the tested suspended ceiling, detail B in Fig. 4) permit a great variety of mountings.

A double steel door has been applied (C in Fig. 4).

## 3. Effect of flanking sound transmission on sound reduction between rooms

In conventional, "heavy-structured" buildings where both direct and flanking sound paths (types 1, and 2, 3, 4, resp.) are due to large masses, stiff structures and connections, greatest part of the sound energy is transmitted to the adjacent room through the partition. According to **Fasold** and **Sonntag** [17], in such cases about 50% of the sound energy is transmitted by the direct path No. 1, while about 25% by flanking paths 2 and 3, both vertically and horizontally according to the following relationships for the mean sound reduction index $R$:

$$R_2 \approx R_1 + 6 \text{ dB} \tag{1}$$

$$R_{34} \approx R_1 + 6 \text{ dB} \tag{2}$$

$$R_{234} \approx R_1 + 3 \text{ dB} \tag{3}$$

Considering the $R_1$ value as requirement for sound reduction between adjacent rooms (this method is applied by several foreign standards such as DIN 4109 [8] and TGL 10687 [9] with certain restrictions), Eqs (1), (2) and (3) lead to utmost important conclusions on the minimum sound reduction of flanking sound transmission paths in "heavy" construction systems. For instance, according to Eq. (1) the flanking sound reduction $R_2$ must be at least 6 dB higher than the required sound reduction value. For conventional, heavy constructions, the possible maximum sound reduction of about 54 to 57 dB can be achieved by improving the partition quality between adjacent rooms.

To our observations [16], conditions (1), (2) and (3) are not met by recent-type buildings, especially by lightweight structures, what is more, often the flanking transmission loss (e.g. $R_2$) is by far less than the direct transmission loss of the partition. Accordingly, the new Hungarian standard specifications for sound insulation [13] specify "sound reduction between rooms", as against foreign and international standards for "sound transmission loss requirements of walls and floors". In the following, the harmful effect of flanking sound transmission paths will be illustrated.

Sound reduction between rooms has been tested in two buildings of different construction systems. In both cases, a reinforced concrete floor type "Sim-Kar", with circular holes, covered with floated flooring, has been applied. In one case the floor was supported on heavy reinforced concrete wall slabs ("heavy building system"), the other building was of "mixed" system with reinforced concrete framework and curtain walls. The latter type exhibited significantly lower sound transmission losses for frequencies over 800 Hz (curves 1 and 2 in Fig. 5). The deviation is likely to be due to the harmful effect of flanking transmission path type 2 created by the curtain wall, both by its acoustically imperfect joints and by structure-borne sound transmission. This assumption has been tested by a measurement according to scheme 3 in Fig. 5, plotted in curve 3, with non-adjacent source and receiving rooms separated by a third room. Sound reduction according to curve 3 in Fig. 5 is obviously determined by the flanking sound transmission path created by the curtain wall, namely possibility of direct sound transmission is excluded by the intercepted room, with the two floors.

The next example also refers to a "mixed" building system presented in Fig. 6. Curves 1, 2, 3 and 4 in Fig. 6 correspond to airborne sound reduction featured by four prefabricated lightweight walls of different sandwich systems built from floor to floor. These walls are a priori acoustical misconstructions, namely the "coincidence effect" is manifest in the frequency range 200 to 1600 Hz, primordial from noise control aspects. What is more, imperfect joints (flanking sound transmission path type 5) eliminate the sound transmission loss of poor walls. Hence, these measurement results are typical of the building or mounting methods rather than of the walls.

Curves 5 and 6 in Fig. 6 refer to a lightweight-structure building erected in Hungary from foreign-made units. The double steel partition wall touches the lower plane of the "sound-absorbent" suspended ceiling of poor sound transmission loss, overrun by the flanking sound transmission path type 6, causing the sound reduction between adjacent rooms to follow curve 6, while the rather high direct sound transmission loss (type 1) of the partition itself is about that of curve 5. The coarse acoustic error is manifest by the flanking sound transmission loss, by orders of magnitude (20 to 30 dB) lower than the direct one.

Part of acoustic deficiencies due to flanking sound transmission paths (especially, direct transmission of airborne sounds) are due to causes recognizable and corrigible to the commonsense, without special acoustic knowledge. By now, analysis and elimination of the effect of flanking sound transmission paths types 2, 3 and 4, related to structure-borne sound transmission are only facilitated by measurements in laboratory for flanking sound transmission as presented in item 1. Because of the complexity of circumstances and influences, to now, no theory suiting real computations has been established. The available results refer to single-layer, rigid structures and simple connections (1 through 7). The inherent difficulty will be illustrated by our test results on a lightweight-structure building, instructive by demonstrating the effect of flanking sound transmission paths to depend on the spatial and other conditions recapitulated as "features", rather than on the building system alone.

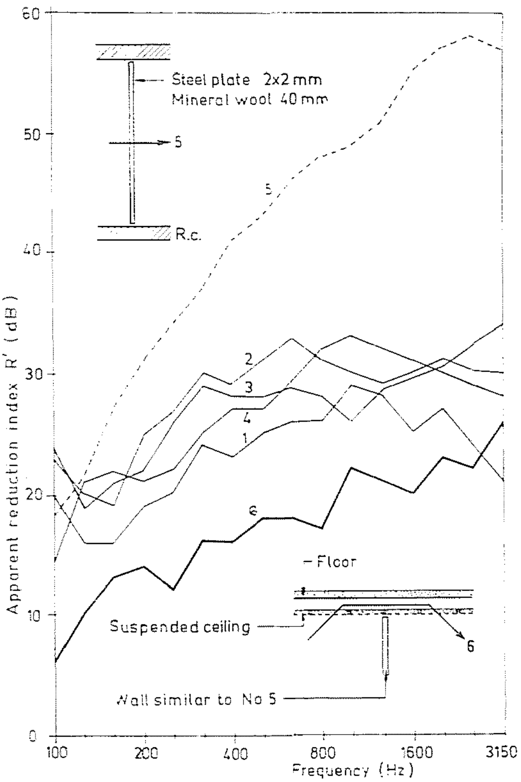

*Fig. 6.* Effect of flanking path on the sound reduction between rooms separated by lightweight partitions. 1, 2, 3, 4 — Acoustically stiff double partitions in field conditions in a heavy-structured building; 5 — double 2 mm steel plate wall with 40 mm slag wool fill in laboratory without flanking path; 6 — partition as under 5 but in field conditions

Sound reduction between adjacent and non-adjacent rooms open to a common gallery in a lightweight-structured building has been tested. The spatial arrangement and the main technical data and test set-up are presented in Fig. 7. For the sake of comparison, the noise level differences $D$ have been determined (curves 1, 2, 3 and 4 in Fig. 7). Unexpected differences in measurement results need further research to be explained. Let us point out differences and some typical features of measurement results.

— Curves 1 and 2 refer to sound reduction between adjacent rooms in different spatial positions. Course (mild slope) of curve 1 shows flanking sound transmission path type 5 to exist. For curve 2 — probably due to the greater distance between the source and the receiving room — the effect of airborne sounds by flanking transmission is reduced and sound reduction achieved (curve 2 in Fig. 7).

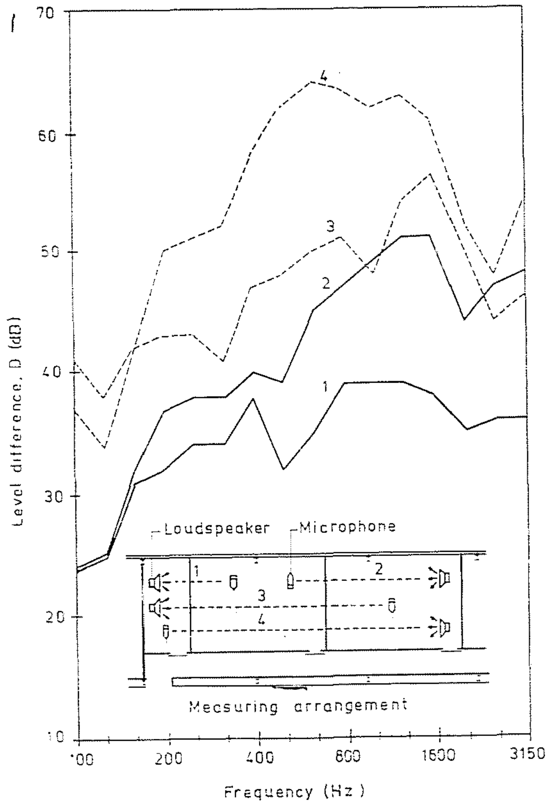

*Fig. 7.* Effect of spatial position on the sound reduction between rooms in a lightweight-structured building. 1, 2 — Adjacent rooms; 3, 4 — source and receiving rooms intercept a third room

— Curves 3 and 4 demonstrate arrangements 3 and 4 not to obey the acoustic reciprocity theorem in the 200 to 1600 Hz frequency range, evidently because of the different development of structure-borne sound excitation, propagation and radiation conditions. On the other hand, in the 1600 to 2500 Hz frequency range, the reciprocity theorem prevails, while in this range airborne sound transmission prevails due to "aperture resonance" and the "source—path—receiving" track is invertible.

The presented examples convincingly demonstrate that the flanking sound transmission paths between rooms of lightweight constructions are decisive for the airborne sound transmission loss, and may offset the possible acoustic advantages of walls and floors. Actually, intricacy of conditions and physical phenomena prevents sound reduction in lightweight constructions from being pre-estimated. Acoustically correct structures and building systems can only be developed on the basis of laboratory analysis of flanking sound transmission paths, permitting at the same time to clear theoretical relations.

## Summary

Concrete evidence is given of the decisive effect of flanking sound transmission paths on the sound reduction between rooms in lightweight construction in Hungary as against heavy buildings where sound reduction between adjacent rooms is determined by the partition quality. Actual knowledge is not at the stage to permit pre-assessment of the flanking sound transmission losses. Acoustic problems cannot be solved without laboratory analysis of flanking sound transmission paths. Description is given of the special laboratory to be realized with modest means at the Technical University, Budapest.

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Ass. Prof. Dr. József P. NAGY, 1111 Budapest, Műegyetem rkp. 3. Hungary

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* In Hungarian.