SOME ACOUSTIC PROBLEMS IN SYSTEM-BUILDING*

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1. Airborne sound insulation in public buildings

Acoustic problems will be restricted in the following to airborne sound insulation, on the other hand, to public buildings. Protection against impact sounds is much simpler, as seen in Fig. 1. The figure shows a mechanical solution [1] developed about 50 years ago. Among architectural solutions the wall to wall carpet floor is pointed out.

In 1979/80 our Department carried out investigation to have a survey of sound insulation in public buildings constructed in recent years mainly by system-building. Unfortunately, the greater part of them did not meet even minimum requirements for airborne sound insulation. Figure 2 demonstrates the airborne sound insulation properties of school buildings. Sound insulation

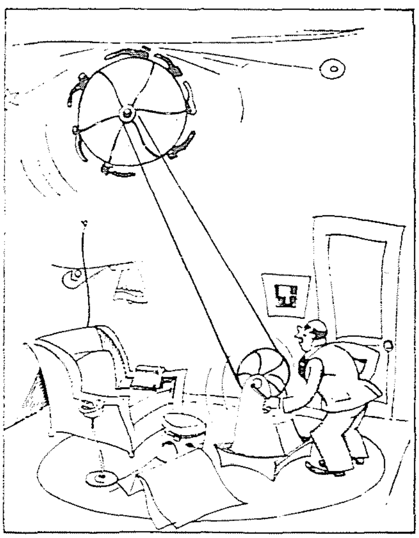

Fig. 1. A brilliant method of protection against impact sounds [1]

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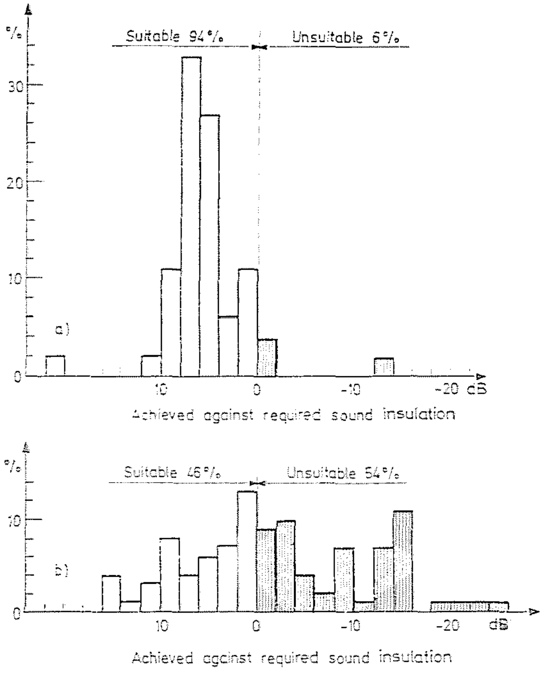


Fig. 2. Adequacy of airborne sound insulation between classrooms. *a)* Vertical; *b)* horizontal

between classrooms separated by floors is in general satisfactory, however, in 54% of the cases sound insulation between rooms separated by partitions had to be qualified "inadequate". Also the great difference between the results is striking. The performance of the worst solution was by 24 dB behind the requirements, and by 40 dB behind the best solution. Though, designers and researchers did their best to solve acoustic problems.

Failure of sound insulation between rooms separated by a wall partly arises from the custom of designers of "thinking in terms of the dividing structure alone". This thinking has evolved in the period of massive building systems with load-bearing structural walls, and was at its time modern, because in these systems the partition and the floor were determinant for sound insulation between adjacent rooms. In actual building systems the partition is not determinant any more, especially because of flanking sound propagation through suspended ceilings, outer walls and other structures.

2. Examples for dominant flanking sound transmission

Flanking transmission has already been mentioned in old reference books. As an example, Figure 3 in the book of the Society of German Engineers (VDI), published in 1934, is referred to [1]. The presented mistake is characteristic of many lightweight buildings. In case of a lightweight building system the designer applied an excellent partition, but was oblivious of the flanking path through the sound-absorbent suspended ceiling, a mistake very difficult to correct as seen from the comparison of curves *a* and *c* in Fig. 4.

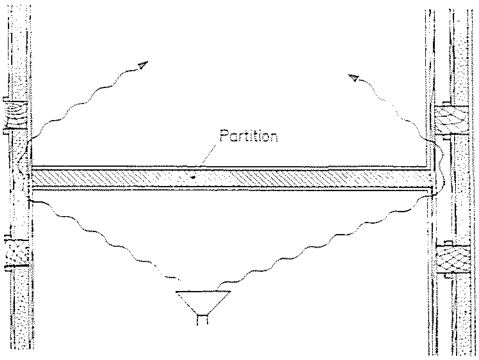


Fig. 3. Illustration of the flanking effect in 1934 [1]

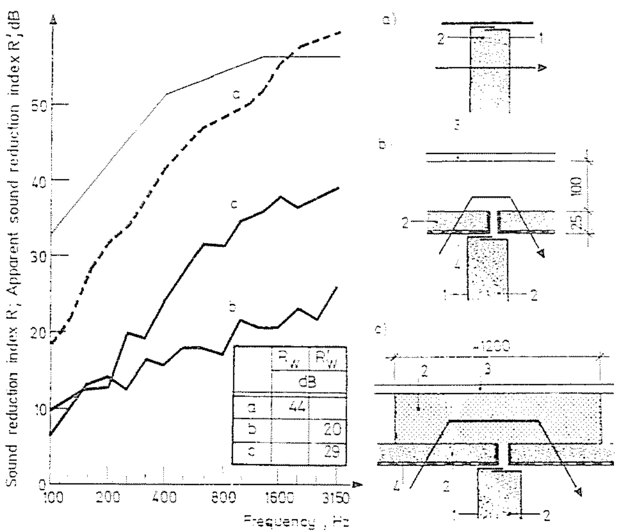


Fig. 4. Flanking effect caused by a sound-absorbent suspended ceiling: *a)* Sound reduction index of the partition in a flanking-free laboratory; *b)* and *c)* Apparent sound reduction index in situ. 1. steel sheet; 2. glass wool; 3. gypsum board; 4. perforated aluminium plate

Figure 5 illustrates the flanking effect of the corridor wall. The double stud partition was tested in a reinforced concrete building and certified to be suitable for school buildings (see curve *a* in Fig. 5). This wall system was applied in school buildings combined with an 8 cm thick gypsum-perlite corridor wall. The standard test result is represented by curve *b*. The flanking effect is obvious. Results in Fig. 5 point out the field test result to be typical of the entire system and other factors involved, rather than of the partition as a subsystem, thus, sound insulation of each subsystem (e.g. partition) must not be tested under field conditions, nor talked about, and the subsystem must not be certified "acoustically suitable" — contrary to practice in this country.

Flanking sound paths may also occur in other than lightweight buildings, as seen from the example in Fig. 6. In a school building designed with reinforced concrete framework, double partitions of solid brick, 12 cm thick each, separated the classrooms. Sound reduction index of such a wall tested in a flanking-free laboratory is presented by curve *a* in Fig. 6. Result of the field test was by about 20 dB worse (see curve *b*). Obviously this result is determined by flanking paths such as exists in the 6 cm hollow brick partition between the classrooms and the corridor.

Also the flanking sound transmission through the outer wall can be determinant for the sound insulation between adjacent rooms, as seen in Fig. 7. In two r.c. structured school buildings the same partition system was used (see junctions *a* and *b* in Fig. 7) but junctions between the outer wall and the partition much differed. In case *a*, the wall was discontinuous at the reinforced concrete column where much of the structure-borne sound energy

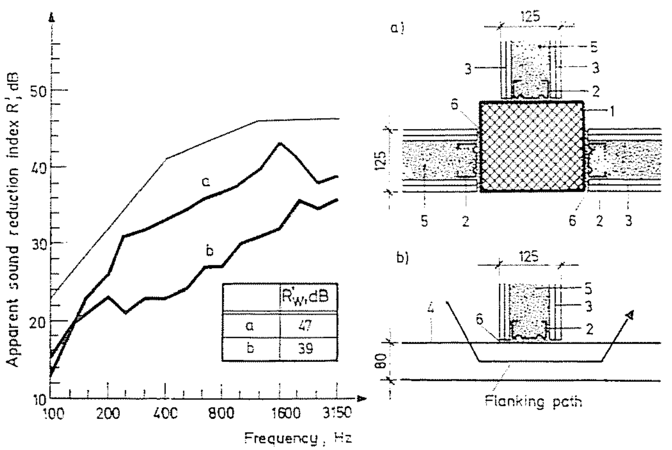


Fig. 5. Flanking effect due to a lightweight corridor wall: 1. Reinforced concrete column: 2. steel stud: 3. 2 leaves of 12,5 mm gypsum board: 4. 8 cm gypsum-perlite block wall: 5. mineral wool: 6. gypsum jointing

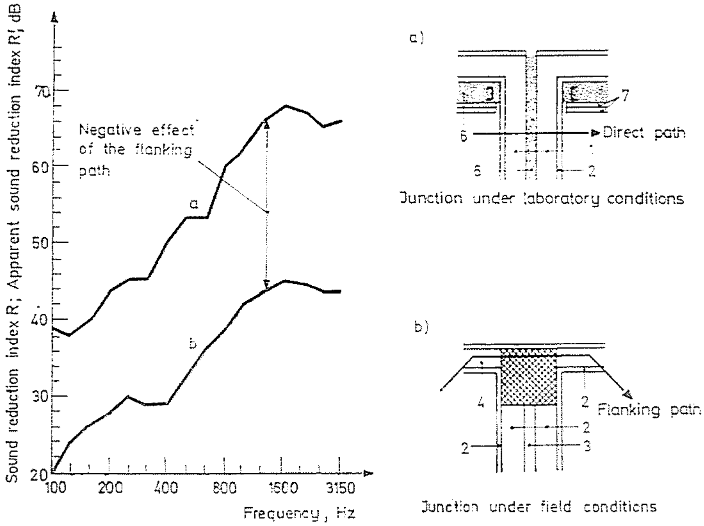
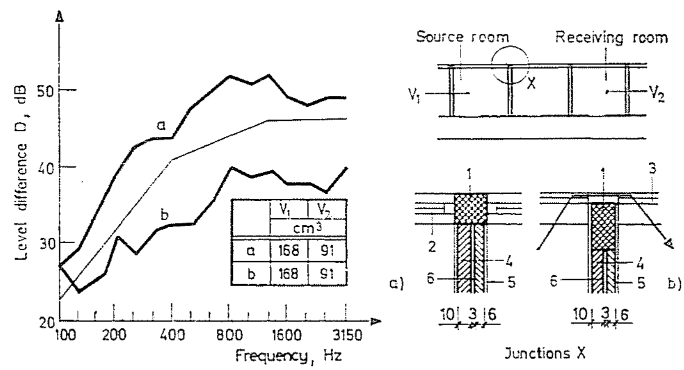


Fig. 6. Flanking effect due to a hollow brick corridor wall 1. 12 cm solid brick; 2. plastering; 3. continuous air gap; 4. 6 cm hollow brick; 5. reinforced concrete column; 6. mineral wool; 7. 2 leaves of 12.5 mm gypsum board



	V_1	V_2
	cm³	
a	168	91
b	168	91

Fig. 7. Flanking effect due to a strip window (the source and receiving rooms are apart): 1. Reinforced concrete column; 2. windows between columns; 3. strip window; 4. hollow brick; 5. plastering; 6. air gap

is reflected. In case *b*, strip windows were applied, probably because of aesthetic reasons. Here the designer — unaware — gave up the structure-borne sound insulation at the r.c. column and created a flanking path. The effect of this path can be proved by a measurement according to the arrangement in Fig. 7. (A third room has been inserted between the source and the receiving rooms.) In case *b* the sound insulation between rooms is in general by 10 dB lower than in case *a*.

3. Effect of junctions between subsystems

There are complicated cases with several flanking paths, nevertheless not these but trivial design or construction defects cause the problem. Such a complex case is exemplified in Fig. 8. In a combined building system, a r.c. framework, hollow brick and glass concrete partitions, as well as curtain walls were used. In Fig. 8. the following sound paths are seen:

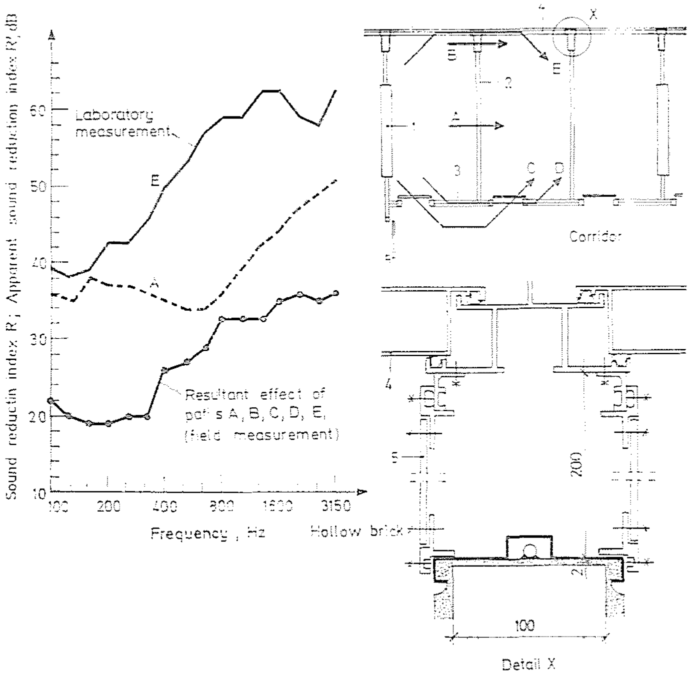


Fig. 8. Flanking paths and their effects in a building of mixed construction: 1. Reinforced concrete wall; 2. plastered hollow brick wall 10 cm thick; 3. glass-concrete wall; 4. curtain wall; 5. 4 mm fibre board lining

— Direct path A across the 10 cm thick lightweight block partition wall (with a sound reduction index illustrated by curve A);
— direct path B, through the jointing element between the partition and the curtain wall (of its effect no concrete information is available);
— flanking path D through the glass concrete corridor wall;
— flanking path C through the doors opening to the common corridor;
— flanking path E through the curtain wall characterized by curve E, determined in the laboratory of this Department.

Sound insulation between adjacent rooms is extraordinarily low and in average by 10 dB lower than the sound insulation of the hollow brick partition (see curve A) indicating that the critical element of sound transmission is not the partition. According to curve E, also the curtain wall has to be excluded. The doors and the glass concrete (paths C and D) can be exonerated on the basis of experience. Accordingly, the defect can be attributed — according to the drawing *x* in Fig. 8 — to the junction between the curtain wall and the partition (path B).

Junction between the curtain wall and the partition is often acoustically imperfect. Unsealed gaps or "pottered" joint elements alien to system-building

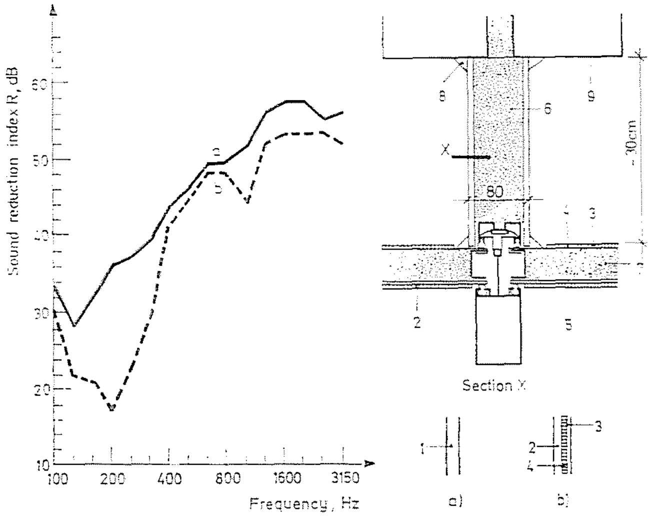


Fig. 9. Sound insulation of two types of jointing elements between the partition and the curtain wall 1. 10 mm gypsum board: 2. 6 mm asbestos cement; 3. 1.5 mm steel plate; 4. damping material BARY-X. 8 kg/m^2; 5. as 4 but 12 kg/m^2; 6. mineral wool 110 kg/m^2; 7. curtain wall with high flanking sound insulation; 8. silicon paste; 9. separation wall of the laboratory

are rather frequent. For a sealing band wide enough, the order of layers in the joint structure may be wrong, although it is not too difficult to make a jointing element with a high sound insulation, as shown in Fig. 9.

Often also connections between curtain wall and floor raise problems. In Fig. 10, different types of connections between curtain walls and floors are compared. In case *a*, both the floor and the suspended ceiling are tightly joined to the curtain wall, the connection can be considered as accomplished. Curve *a* attests the excellent acoustic properties of floors with suspended ceiling — properly carried out. The much worse result for solution *b* in Fig. 10 arises from the use of perforated suspended ceiling. Effect of the poor joint between curtain wall and floor appears from the great difference between curves *c* and *a* in Fig. 10.

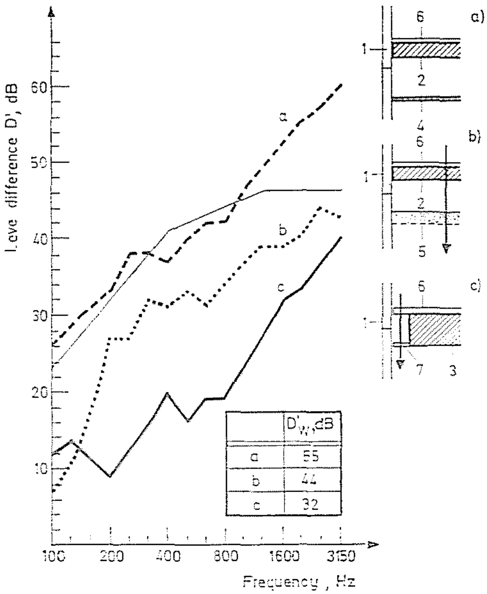


Fig. 10. Effect of the joint between curtain wall and floor on the sound insulation between vertically adjacent rooms. 1. Curtain wall; 2. fluted steel floor with 8 cm concrete topping; 3. solid concrete slab 20 cm thick; 4. suspended ceiling without perforation, 8 kg/m²; 5. perforated aluminium plate suspended ceiling with glass wool blanket; 6. floor finish; 7. fibre board lining

4. Problems of designing and evaluating sound insulation

Within this very complicated and ramified matter, some ideas have to be presented on the relation between subsystem properties and system characteristics (more exactly, sound insulation between rooms in an erected building).

In system-building the designer is concerned above all with the requirements for each of the subsystems. As referred to above, the resultant sound insulation is the common feature of the subsystems and their joints. The requirement refers to this final result, permitting, in turn, to establish by mathematical methods the set of requirements for each subsystem [3]. Of this set the most suitable one has to be chosen. As a simple example, let us suppose that the system selected for the construction of a school building features two flanking paths through walls and floors. Requirements for the subsystems may be determined according to the following varieties.

Variety	Field requirement according to Hungarian standard MSz 04.601-80 R'_w	Requirements for subsystems		
		Partition $R'_{1,w}$	Suspended ceiling $R'_{2,w}$	External wall $R'_{3,w}$
1.	47	55	48	62
2.	47	52	52	52
3.	47	47	62	62

Demands and possibilities determined in the above varieties may be formulated as follows:

Case 1. In possession of a highly sound insulating partition and a poor suspended ceiling, practically no flanking path is permitted in the external wall.

Case 2. For an identity between the effects of direct and flanking paths arising from the subsystems and their joints (relatively easy to realize), the requirement for the subsystems is by 5 dB higher than that for the entire system.

Case 3. The requirement for the partition is the same as that for the complete system if there is no flanking path at all (conceivable only for traditional building systems).

A very important rule is valid in every case: if the system comprises a flanking path, the requirement for the subsystem of walls and floors is always more rigorous than that for the complete system.

In this spirit, suggestions have been made for the design of partitions and two types of suspended ceilings in the ALBA—CLASP system (see curve *a* in Fig. 11). The flanking sound insulation of the unperforated gypsum suspended ceiling was found to be satisfactory (see curve *b* in Fig. 12) but the perforated variety proved to be rather inadequate from this point of view (curve *c* in Fig. 12). To improve the flanking sound insulation, a design according to joint *a* in Fig. 12, i.e. a double wall in the plenum above the partition was suggested, resulting in an improvement by 14 dB over the unperforated suspended ceiling (compare curves *a* and *b* in Fig. 12). The two varieties were also tested under field conditions, the partition and all other factors being identical. Laboratory tests suggested superiority of variety *a* also under field conditions. Our subjective personal observations confirmed this supposition. The tests, however, made according to Hungarian standard MSz 18154—72, belied our hopes, namely both varieties got the same qualification: neither of them met the standard requirements. The final conclusion is that standard test and evaluation results do not express the real acoustic performance, especially:

— if the effects of flanking paths are not negligible;
— if sound absorbent linings are in the rooms;
— if the rooms are spacious.

In case of new building systems applied especially for public buildings, at least one of the items above prevails, thus, in such instances the standard evaluation would lead to erroneous conclusions. Fundamentals of a new evaluation system are found in [4].

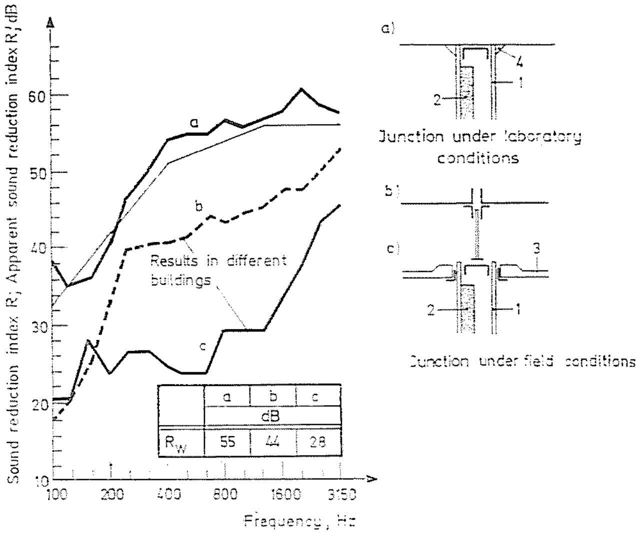


Fig. 11. Comparison of the results of laboratory and field measurements on a partition of a lightweight building system. 1. 12 mm cemesto board BETONYP; 2. 40 mm mineral wool 110 kg/m^3; 3. unperforated gypsum suspended ceiling; 4. silicon paste sealing

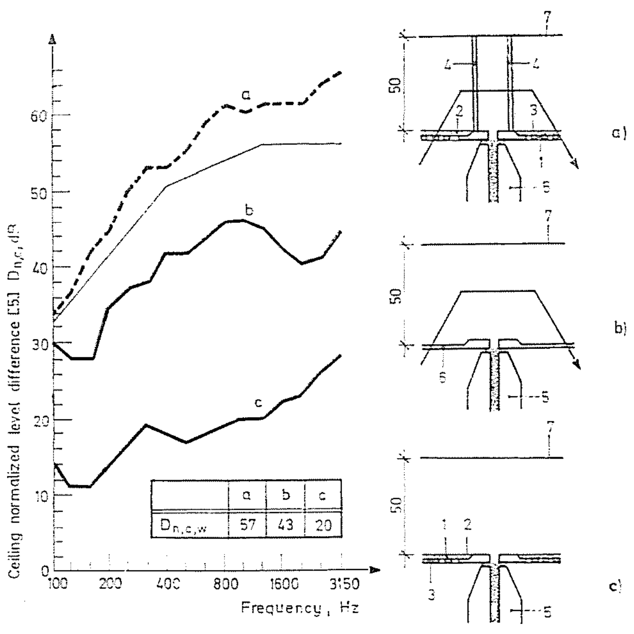


Fig. 12. Example for improving the flanking sound transmission loss through perforated suspended ceiling. 1. Perforated gypsum; 2. glass wool; 3. aluminium foil paper; 4. gypsum plaster on metal lath; 5. separation wall in the laboratory; 6. unperforated gypsum

5. Conclusions

In new building systems, sound insulation between the rooms is mainly determined by the direct sound insulation of the dividing subsystem, as well as by the flanking sound insulation, defined by the other subsystems and their joints. The requirement depending on the intended use of the building — to be checked by field measurement — refers to the resultant of direct and flanking sound insulation.

The sound insulation requirements for subsystems have to be interpreted as components of the resultant above, and determined by mathematical methods. Since many varieties of the possibilities may suit a given purpose, suitability of single subsystems — detached from the other factors — cannot be spoken of.

Acoustic requirements valid at present cannot be directly applied to judge the subsystems and establishments in system-building. Neither do these requirements provide an adequate basis for the design.

Acknowledgement

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Summary

Sound insulation between rooms separated by walls in public buildings in some new building systems is generally unsatisfactory. In most cases, however, not the partition is "guilty" but the acoustically ignored joints between subsystems, and the so-called flanking sound propagation in structures joining the partition (e.g. suspended ceiling, external wall). Sound insulation found in field tests is the resultant of acoustic properties of the subsystems and their joints.

Specifications concern the resultant sound insulation, deduction of the requirements for subsystems relies on.

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* In Hungarian.