INTERCOMPARISON OF LABORATORY MEASUREMENTS OF AIRBORNE SOUND INSULATION OF PARTITIONS FOR THE DETERMINATION OF REPEATABILITY AND REPRODUCIBILITY VALUES

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SUMMARY

With the aim of determining repeatability and reproducibility values for the sound reduction index of partitions, an interlaboratory test was organized among nine Italian laboratories. Two different gypsum board partitions were tested in each laboratory. The specimens were supplied free by BPB Italia, which also provided for the installation of the material in all the laboratories. The measurements started at the end of 1993 and ended at the beginning of 1995. The laboratories followed the procedures specified in the international standard ISO 140-3. The results have been computed according to the international standards ISO 140-2 and ISO 5725. This paper describes the organization and the results of this interlaboratory test.

INTRODUCTION

Since it is not possible to specify completely the construction of laboratory test facilities or the sound field conditions obtained, some details of the test facilities and procedures are left to the choice of the operator. This, together with the statistical character of sound fields within rooms, leads to uncertainties in the results due to non-systematic and systematic influences. In agreement with modern statistical methods, the concepts of repeatability "r" and reproducibility "R" have been used in ISO 140-2 to state the precision of the measurements carried out according to a test method. The determination of the repeatability and reproducibility values of a test method is obtained by an interlaboratory test taking into account the procedures given in the international standards ISO 140-2 and ISO 5725. Tentative values of "r" and "R" are given in Annex A of ISO 140-2.
With the aim to determine the values of "r" and "R" for the sound reduction index of walls, the Engineering Institute of the University of Ferrara, with the support of SINAL (National System for Laboratory Accreditation) and the GAA (Environmental Acoustic Group) of the Italian Acoustic Association organized an interlaboratory test among nine Italian laboratories.

REPEATABILITY AND REPRODUCIBILITY

The concepts of repeatability and reproducibility applied in the field of sound insulation are described in the international standard ISO 140-2 (1991) [1].

Repeatability “r” shows the closeness of agreement between mutually independent test results obtained with the same method on identical test material in the same laboratory with the same equipment by the same operator within short intervals of time.
Reproducibility “R” shows the closeness of agreement between test results obtained with the same method on identical test material in different laboratories with different operators using different equipment.
The knowledge of “r” and “R” values for a specific test method makes it possible to evaluate the precision of measurements carried out under repeatability and reproducibility conditions. The following cases are of special interest.
a) When, in a single laboratory, only one determination “y” is made of the quantity being tested, the confidence interval, with a probability of 95%, for the true value “μ” is:

$$y - \frac{R}{\sqrt{2}} < \mu < y + \frac{R}{\sqrt{2}}$$

b) When, in a single laboratory, “n” determinations are made of the quantity being tested with the mean value “$\bar{y}_{r,n}$”, the confidence interval, with a probability of 95%, for the true value “μ” is:

$$\bar{y}_{r,n} - \frac{1}{\sqrt{2}}\sqrt{R^2 - r^2\left(1-\frac{1}{n}\right)} < \mu < \bar{y}_{r,n} + \frac{1}{\sqrt{2}}\sqrt{R^2 - r^2\left(1-\frac{1}{n}\right)}$$

c) If each of “p” laboratories performs a single determination of the quantity being tested with a mean value “$\bar{y}_{R,n}$”, the confidence interval, with a probability of 95%, for the true value “μ” is:

$$\bar{y}_{R,n} - \frac{R}{\sqrt{2p}} < \mu < \bar{y}_{R,n} + \frac{R}{\sqrt{2p}}$$

The “r” and “R” values may also be used to verify the proper operation of test procedures of a laboratory which has not taken part in the interlaboratory test. Furthermore it is recommended that laboratories verify, from time to time, their measurement procedures.

PARTICIPANT LABORATORIES

Nine Italian laboratories took part in this intercomparison: “C.S.I.” in Bollate (MI), “C.S.R. - Consorzio Studi e Ricerche della SCM” in Rimini, “I.C.I.T.E. - Istituto Centrale Industrializzazione e Tecnologia Edilizia” in S.Giuliano Milanese (MI), “Istituto di Acustica O.M.CORBINO” in Rome, “I.E.N.G.F. - Istituto Elettrotecnico Nazionale G. Ferraris” in Turin, “ISTITUTO GIORDANO - Centro Studi e Ricerche di Fisica Tecnica” in Bellaria (RN), “ISTEDIL - Istituto Sperimentale per l'Edilizia” in Guidonia Montecelio (ROME), “MODULO UNO - Acoustical Engineers and Consultants” in Turin, “SIMPA” in Ferentino (FR). Seven of these laboratories certify the sound insulation performance of walls for external customers, two of them use the laboratory for the qualification of their own products or for research activities. It seems important to note that the laboratories which took part in this intercomparison were not chosen after veriries which took part in this intercomparison were not chosen after verifying the conformity of their test facilities with ISO 140-1, but simply because they were available and interested in participating in these tests. Table 1 shows the main features of these nine laboratories.

Table 1: Main features of the nine laboratories

Laboratories	*Corbino*	*Csi*	*Csr*	*Icite*	*Iengf*	*Istedil*	*Istituto Giordano*	*Modulo Uno*	*Simpa*
Dimensions room 1 (m)	4.8x 5.84x 3.05	3.7x 4.05x 3.35	4.45x 5.7x 3.06	4.4x 4.4x 3.20	3.97x 4.3x 3.46	4.12x 5.0x 3.18	3.62x 4.4x 3.50	variable	3.8x 2.9x 4.71
Volume room 1 (m^3)	85.5	50.2	74	53.6	59	65.5	56	76	52
Dimensions room 2 (m)	4.8x 5.84x 3.05	6.0x 4.05x 3.35	4.15x 5.0x 3.25	4.85x 4.0x 3.70	4.1x 4.3x 3.46	4.12x 5.0x 3.45	4.7x 4.4x 3.50	variable	3.8x 2.9x 4.95
Volume room 2 (m^3)	85.5	81.4	67.5	59.3	65	71.1	72	222	54.5
Test opening (m)	2.5x 2.54	4.05x 2.7	2.0x 2.2	3.31x 3.0	3.6x 2.8	3.1x 2.96	3.6x 3.0		3.6x 2.74
Area test opening (m^2)	6.3	10.9	4.4	10	10.08	9.23	10.8	9.2	9.86
Diffusing elements	NO	NO	SI	NO	SI	SI	SI	SI	NO
Rw max (ISO 717)			56.5		61	60		58	56

STANDARD REFERENCES

All the measurements were carried out according to the international standard ISO 140-3 (1995) [2]. This standard introduces many changes with respect to the previous version of ISO 140-3 (1978) and its amendment (1990). It gives more details for the installation of partitions, doors, windows, glazing and facade elements. The generation of the sound field in the source room has to comply with stricter conditions. Special procedures have to be followed for the qualification of the loudspeakers and of the loudspeaker positions. The frequency range of measurements has been extended to the centre frequency of 5000 Hz and additional information in the low frequency range (50, 63, 80 Hz) is also required.
The determination of “r” and “R” values has been carried out according to international standards ISO 140-2 (1991) [1] and ISO 5725 (1986) [3].

THE SPECIMENS

Two different gypsum board partitions were tested in each laboratory. The first wall (fig.1) had one single plate of gypsum board, with a thickness of 12,5 mm, on each side. The plates were mounted on a metal frame made by studs and guides 75 mm thick. Glass wool was inserted inside the wall - 50 mm thick, and with a density of 40 kg/m^3. The second specimen was a wall with two gypsum boards on each side (fig.2). The frame was as described for the first specimen. The two specimens were supplied free by BPB Italia, which also provided a single team of workers for mounting the walls in all the laboratories. The material came from one single stock of production and the mounting was performed according to a well defined procedure.

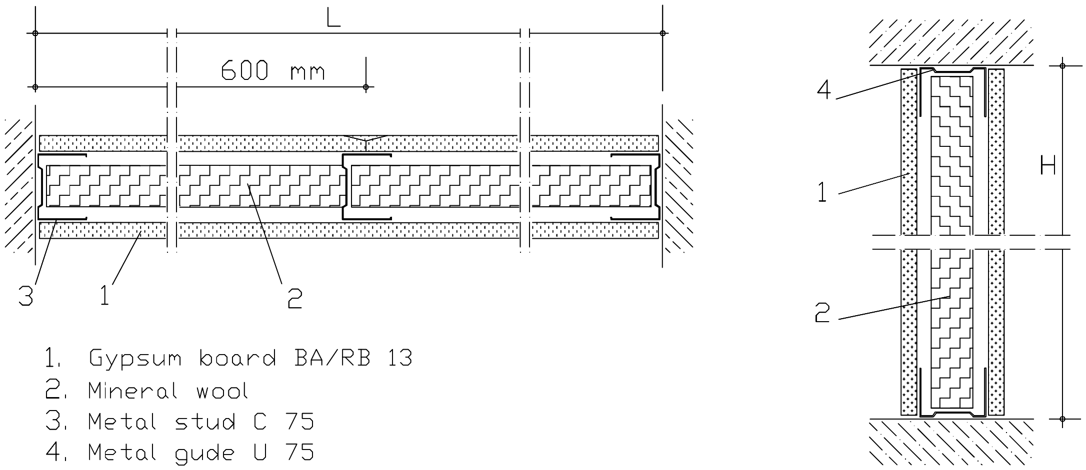


Figure 1: Horizontal and vertical sections of test specimen 1.

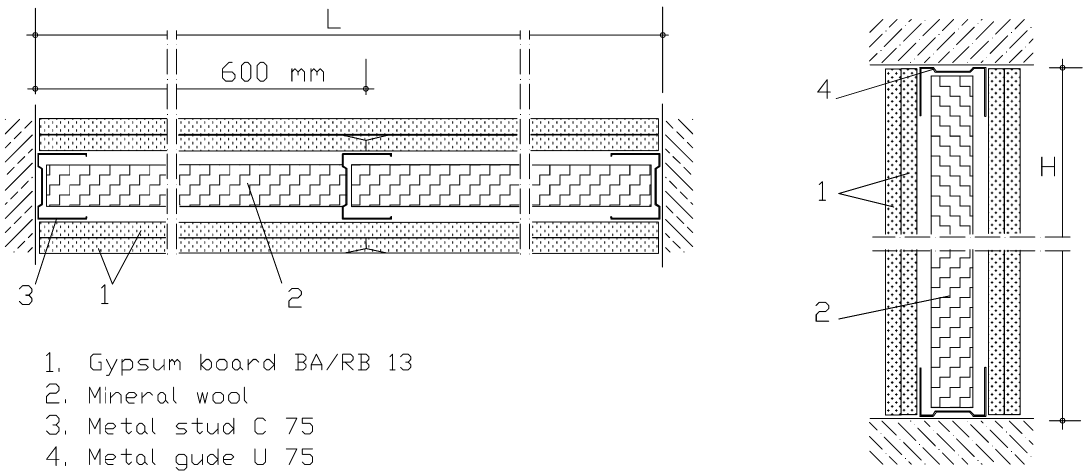


Figure 2: Horizontal and vertical sections of test specimen 2.

RESULTS

The tests started at the end of 1993 and finished at the beginning of 1995. Each laboratory was indicated with a letter (A-I) in order to ensure anonymity. Not all the laboratories could supply the 5 independent tests required by ISO140 -2: in this case the values of the simple variance “sr” were assigned on the basis of previous measurements taken in the same laboratory with other specimens.
From the analysis of all the data, laboratory “I” came out as anomalous and therefore its measurements were not used for computing the “r” and “R” values.

Figure 3 shows, for the two specimens, the sound reduction index as a function of the frequency in the range 100 Hz - 3150 Hz supplied by all the laboratories. The frequency range was limited to 3150 Hz as laboratory “H” did not give results at frequencies higher than this value. The values shown in this figure are the mean values of the results obtained in each laboratory when more than one measurement were made. Figure 4 shows, for the two specimens, the values of the single number of the sound reduction index Rw (dB) computed as required by ISO 717 [4]. The first specimen gave Rw=46 dB; the second specimen gave Rw=51 dB. The same figure 4 shows two more single numbers of the sound reduction index indicated as dB(A) pink and dB(A) traffic obtained according to the last revision of ISO 717.

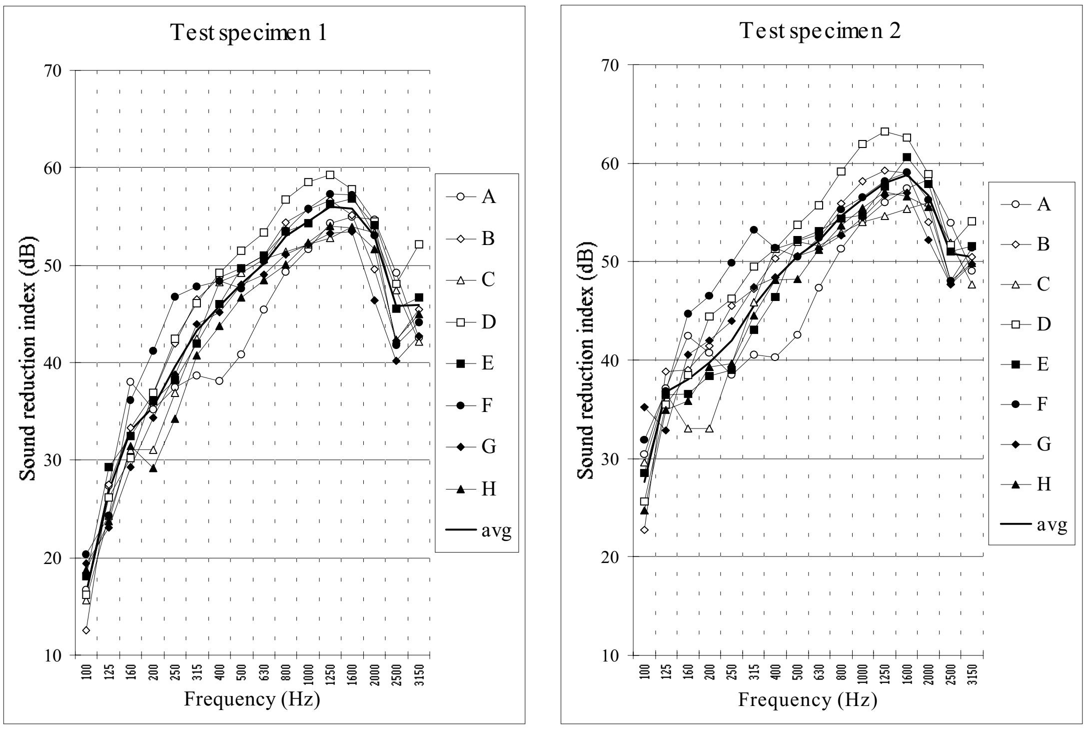


Figure 3: Sound reduction index of specimen 1 and 2 obtained from all the measurements.

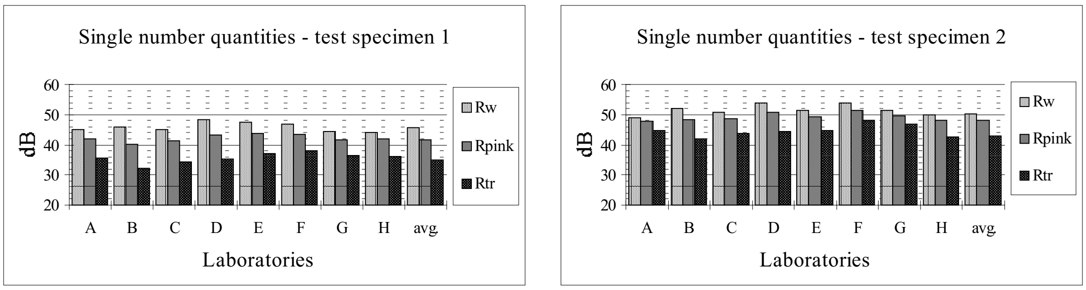
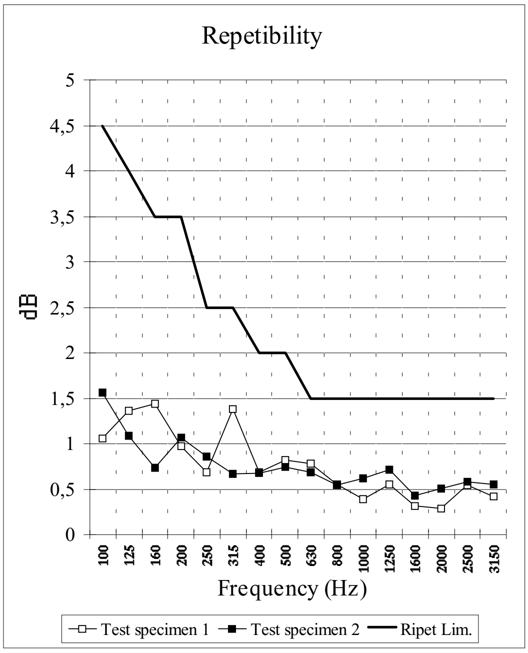


Figure 4: Single-numbers quantities of sound reduction index of specimens 1 and 2: Rw, Rpink, Rtraffic.

Figure 5 shows, for each specimen, the values of “r” and “R” obtained from this interlaboratory test. These values are compared with the tentative values given in Annex A of ISO 140-2. Figure 6 shows the reverbaration time values in each of the laboratories and the correction term to determine the sound reduction index.



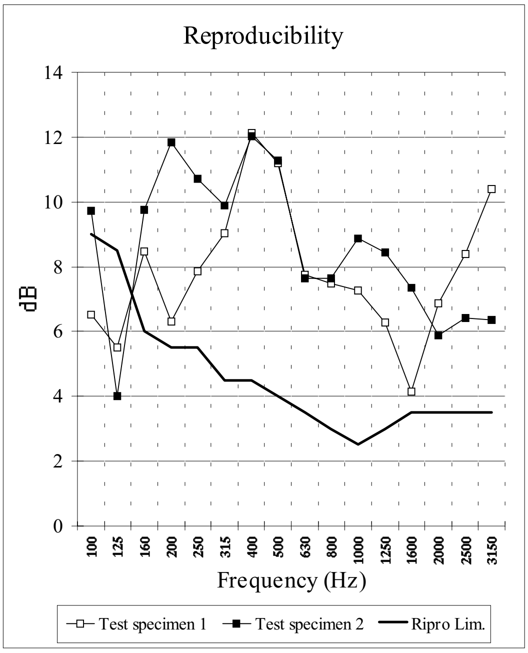
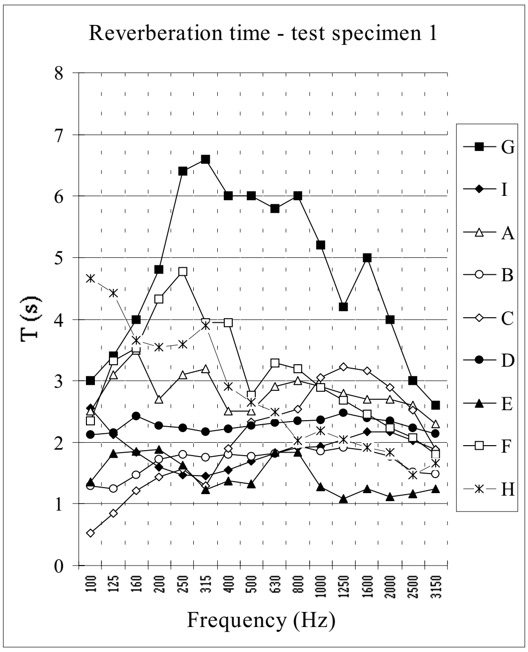


Figure 5: Repeatability “r” and reproducibility “R” values obtained from this interlaboratory test: comparison with the tentative values given in ISO 140-2.



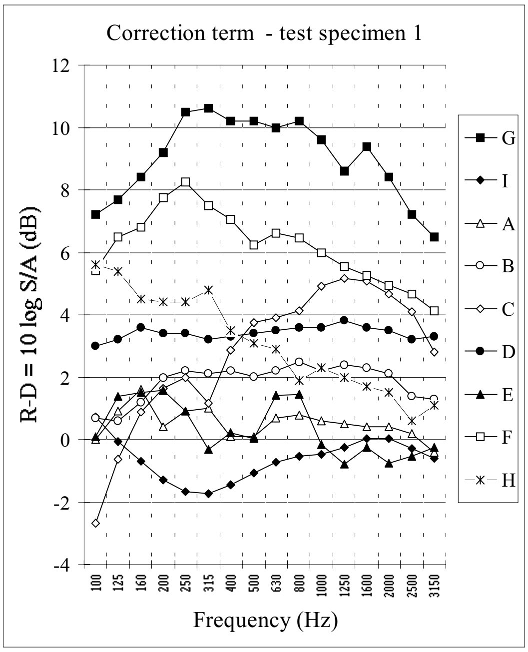


Figure 6: Reverbaration time values measured in each of the laboratories and correction term calculated to determine the sound reduction index.

CONSIDERATIONS

The repeatability values obtained in this interlaboratory test (see figure 5) are lower than the values of Annex A. This result is probably due to the automatic measurement procedures made possible by modern instrumentation, which reduce the causes of variabilitiy for results obtained in a laboratory which operates under repeatability conditions. On the contrary, the reproducibility values are higher than the values of Annex A (see fig.5). It seems important to note that these “R” values, quoted in Annex A of ISO 140-2, are tentative and represent an average of “R” values obtained from three different interlaboratory tests. One was carried out among 5 laboratories in Germany in 1983, using as test specimen a glazing in a staggered test opening; the second was an interlaboratory test conducted from 1982 to 1985 involving seven laboratories in Belgium and in the Netherlands using a lightweight partition and two brick walls; the third was an interlaboratory test conducted in 1985/86, a BCR project involving eight laboratories using double-glazing. ISO 140-2 does not give the dispersion of the data used for the R values shown in Annex A. The lack of sufficient data and the difference in these experiences do not make it possible to draw a significant comparison with the results obtained under this interlaboratory test. A critical analysis of all the results has not yet been done. However, some observations are possible and some hypotheses may be formulated to interpret the data.
The distribution of “R” with the frequency is irregular, and shows evident maxima and minima (fig.5). Specimen 1, the less insulating, shows a maximum value at 400 Hz (R =12 dB) and a minimum at 1600 Hz (R =4 dB); in the low frequency range, the R values are lower than the ones in Annex A. The reproducibility value of Rw is 4 dB. Specimen 2, more insulating, shows two maxima at 200 Hz and at 400 Hz with R =12 dB, and a minimum at 2000 Hz with R = 6 dB. Generally, the “R” values are higher than those of specimen 1, as is also evident from the reproducibility value of R_w which is 4,5 dB. The increase in the reproducibility values with the sound insulation performance of the specimens shows a possible effect of flanking transmission between the test rooms in the laboratories which took part in this intercomparison. There are also other factors which may have produced high reproducibility values: the differences among the specimens mounted in the laboratories due to the different test opening dimensions (see table 1) and to the unavoidable differences in the mounting, even if this was done by one single team of workers operating under precise guidelines. The conditions of sound diffusion in the test rooms are different between the laboratories, as is evident from the significant variations of the reverbaration time values (see figure 6). In some laboratories the reverbaration times were much higher than the values suggested by the international standard ISO 140-1 which gives the requirements for the laboratory test facilities.

CONCLUSIONS AND FUTURE PROJECTS

These results show that measurements can be influenced by many factors, like mounting and the characteristics of the test specimen, the dimension and

shape of the laboratories and test openings, flanking transmission, diffusion of sound field, reverberation time, measurements procedures and instrumentation. The limited number of laboratories did not make it possible to carry out a comparison between laboratories with similar acoustic and geometric characteristics. However, the comparison was useful in order to determine the parameters which need to be strictly controlled and to provide information for the future revision of the national and international standards.
On the basis of the experience acquired with this interlaboratory test, a comparison between European laboratories, financially supprted by the European Community (Measurements and Testing Programme 1990-94) was organized. The intercomparison started in 1995 and will be finished in the spring of 1997. Twenty-four laboratory from eleven different countries are taking part in the project.

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REFERENCES

[1] ISO 140/2 (1991), “Measurement of sound insulation in buildings and of building elements - Part 2: Determination, verification and application of precision data”, UNI EN 20140-2 (1994).
[2] ISO 140/3 (1995), “Measurement of sound insulation in buildings and of building elements - Part 3: Laboratory measurements of airborne sound insulation of building elements”.
[3] ISO 5725 (1986), “Precision of test methods - Determination of repeatability and reproducibility for a standard test method by inter-laboratory tests”.
[4] ISO/DIS 717/1-2 (1994), “Rating of sound insulation in buildings and of buildings elements. Part 1: Airborne sound insulation in buildings and of interior building elements. Part 2: Impact sound insulation”.
[5] ISO/DIS 140/1 (1994), “Measurement of sound insulation in buildings and of building elements - Part 1: Requirements for laboratory test facilities with suppressed flanking transmission”.