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MEASUREMENT OF SOUND INSULATION IN BUILDINGS AND OF BUILDING ELEMENTS

PART 9 LABORATORY MEASUREMENT OF ROOM-TO-ROOM AIRBORNE SOUND INSULATION OF A SUSPENDED CEILING WITH A PLENUM ABOVE IT

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0. FOREWORD

0.1 This Indian Standard (Part 9) was adopted by the Indian Standards Institution on 9 April 1986, after the draft finalized by the Acoustics Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This method utilizes a laboratory space so arranged that it simulates a pair of horizontally adjacent typical offices or rooms sharing a common suspended ceiling system, plenum space and a dividing wall. The dividing wall extends to the underside of the ceiling system which at the junction is either continuous or discontinuous.

0.3 The quantity being measured is the ceiling normalized level difference. Measurements are considered to be valid only when the sound transmitted by paths other than the suspended ceiling and common plenum space is negligible.

0.4 The method may be extended to include the study of composite ceiling systems comprising the ceiling material and other components such as luminaires and ventilating systems.

0.5 The method may also be extended to the study of the additional sound insulation that may be achieved by auxiliary systems such as material used either as plenum barriers, or as backing for all of, or part of, the ceiling.

0.6 While preparing this standard assistance has been derived from ISO/DIS 140/9 'Measurements of sound insulation in buildings and of building Elements — Part 9 : Laboratory measurement of room-to-room airborne sound insulation of a suspended ceiling with a plenum above it', issued by the International Organization for Standardization (ISO).

0.7 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part 9) specifies a laboratory method of measuring airborne sound insulation of a suspended ceiling with a plenum of defined height mounted above an acoustical barrier which separates two rooms in a standardized laboratory.

2. TERMINOLOGY

2.0 For the purpose of this standard, the terms and definitions given in IS : 1885 (Part 3/Sec 8)-1974† shall apply in addition to the following.

2.1 Average Sound Pressure Level in a Room — Ten times the common logarithm of the ratio of the space and time average of the sound pressure squared to the square of the reference sound pressure, the space average being taken over the entire room with the exception of those parts where the direct radiation of a sound source or the near field of the boundaries (wall, etc) is of significant influence. This quantity is denoted by L and is expressed in decibels.

$$L = 10 \log \frac{p_1^2 + p_2^2 \ldots + p_n^2}{n p_0^2} \qquad \ldots(1)$$

where

$p_1, p_2, \ldots p_n$ are the rms sound pressures at n different positions in the room; and

$p_0 = 20\ \mu$Pa is the reference sound pressure.

2.2 Level Difference — The difference in the space and time average sound pressure levels produced in two rooms by a sound source in one of the rooms. This quantity is denoted by D, and is expressed in decibels.

$$D = L_1 - L_2 \qquad \ldots(2)$$

where

L_1 = average sound pressure level in the sound source room; and

L_2 = average sound pressure level in the receiving room.

*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part 3 Acoustics, Section 8 Architectural acoustics.

2.3 Ceiling Normalized Level Difference — The level difference corresponding to a reference value of absorption area in the receiving room. This quantity is denoted by $D_{n,c}$ and is expressed in decibels.

$$D_{n,c} = D - 10 \log \frac{A}{A_0} \quad \ldots (3)$$

where

D = level difference,

A = equivalent absorption area in the receiving room, and

A_0 = reference absorption area.

For the laboratory, $A_0 = 10$ m^2.

2.4 Plenum Space — The whole of the void above the suspended ceilings in both rooms in the test facility.

Its dimensions are to be measured discounting the thickness of any sound absorbing material adhered to the walls or laid on the back of the test ceiling.

3. MEASURING EQUIPMENT

3.1 The measuring equipment shall be suitable for meeting the requirements of **5.**

4. TEST ARRANGEMENT

4.1 Requirements for the Laboratory

4.1.1 The laboratory test facility is divided into two rooms of approximately equal volumes by a wall. The essential features of the test facility are listed below and are shown schematically in Fig. 1.

4.1.1.1 *Construction of the test facility* — The test facility shall be rectangular parallelepiped. It is recommended that a vibration break be provided in the outer walls, floor and roof of the facility in order to esnure that flanking sounds transmitted by paths other than the suspended ceiling and common plenum space are negligible.

The level of the background noise shall be sufficiently low to permit a measurement of the sound transmitted from the source room taking into consideration the power output of the source room and the isolating properties of the specimens for which the laboratory is intended. The reverberation time in each room should be greater than 1 s at all one-third octave bands of measurement with no plenum lining and no test specimen in place.

NOTE — For the purpose of determining the reverberation time of both rooms, a suitable impervious plenum barrier should be installed between the top of the dividing wall and the roof.

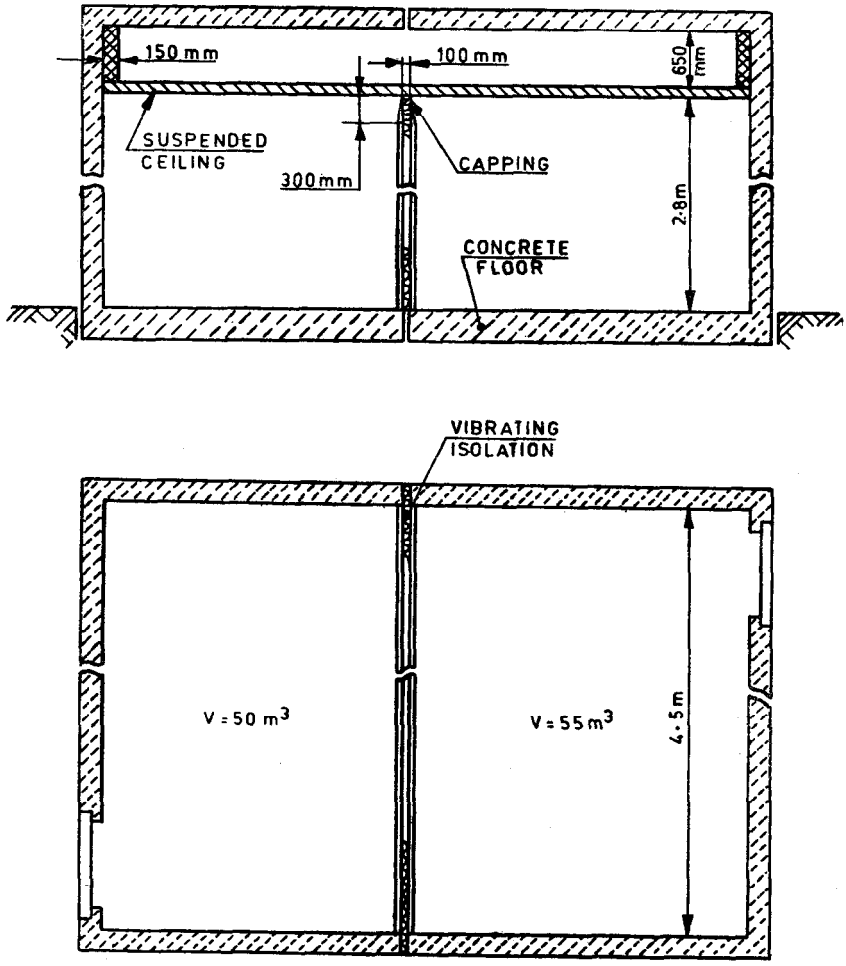

FIG. 1 CROSS-SECTION AND PLAN OF THE TEST FACILITY

4.1.1.2 *Dimensions of the test facility* — The width of the test facility shall be 4·5 ± 0·5 m and the height from the ground to the underside of the face of the suspended ceiling shall be 2·8 ± 0·2 m when all dimensions are measured internally. The volume V of each room should be at least 50 m^3 and the dividing wall should be positioned such that the two room volumes will differ by at least 10 percent when the ceiling is in position.

NOTE 1 — It is realized that existing facilities may have room volumes less than 50 m^3, as low as 40 m^3. Such facilities will be allowable in accordance with this standard in cases where diffusing elements are employed.

NOTE 2 — The limitations and room dimensions as stated above are intended to improve reproducibility between measurements made by different organizations on similar materials.

4.1.1.3 *Dividing wall* — This is defined as the ceiling height acoustical barrier which divides the test facility into two rooms. The wall should be tapered at its upper extremity so that its overall thickness at the capping is not greater than 100 mm. The tapering between the widest part of the wall and the capping will be achieved by means of an angle not exceeding 30° from the vertical. The construction of the dividing wall shall be of such materials that its sound insulation is 10 dB more than that of any ceiling which is likely to be tested.

NOTE — For checking the sound insulation of the facility, a suitable plenum barrier of construction similar to the dividing wall can be installed between the top of the dividing wall and the roof.

4.1.1.4 *Plenum depth* — The plenum depth should be between 650 mm and 760 mm as measured from the upper face of the suspended ceiling to the underside of the roof of the test facility. This dimension also applies to the gap between the top of the dividing wall and the roof.

4.1.1.5 *Plenum lining* — One side wall and both end walls of the plenum should be lined with suitable sound absorbing material. This material is to have such properties that when tested as a plain absorber in accordance with IS : 8225-1976*, it will have absorption coefficients not less than those shown below:

Centre frequency, Hz	125	250	500	1 000	2 000	4 000
Absorption coefficient, α_s	0·65	0·80	0·80	0·80	0·80	0·80

*Method of measurement of absorption coefficients in a reverberation room.

For the other side wall and the roof, the absorption coefficient should be less than 0·10 at all the above frequencies.

NOTE — For practical purposes, the thickness of the lining should not exceed 150 mm.

4.1.1.6 *Diffusers* — If necessary, diffuser elements may be installed in the rooms so as to improve the diffusion conditions.

4.2 Installation of the Test Ceiling

4.2.1 The detail of joining the ceiling to the top of the dividing wall is of critical importance and care shall be taken to simulate actual field conditions.

4.2.2 The area of a continuous ceiling shall be equal to the area denoted by length and width of the test facility.

4.2.3 For a discontinuous ceiling, it may be necessary to add additional capping to the top of the dividing wall to complete the junction. The area of a discontinuous ceiling shall then be equal to the area denoted by the length and width of the test facility less the area of the adapter cap on the top of the dividing wall.

4.2.4 The ceiling components shall be selected to represent those which would be used in actual field installations. The ceiling shall be installed in accordance with the recommended practice of the manufacturer or with the recommended practice of an installation standard.

5. TEST PROCEDURE AND EVALUATION

5.1 Generation of Sound Field in the Source Room

5.1.1 The sound generated in the source room should be steady and should have a continuous spectrum in the frequency range considered. Filters with a band width of at least one-third octave may used.

5.1.2 The sound power should be sufficiently high for the sound pressure level in receiving room to be at least 10 dB higher than the background level in any frequency band.

5.1.3 If the sound source contains more than one loudspeaker operating simultaneously, the loudspeakers should be contained in one enclosure, the maximum dimension of which should not exceed 0·7 m. The loudspeakers should be driven in phase.

5.1.4 The loudspeaker enclosure should be placed in each room to give as diffuse a sound field as possible and at such a distance from the test specimen that the direct radiation upon it is not dominant.

5.2 Measurement of the Average Sound Pressure Level

5.2.1 The average sound pressure level may be obtained by using a number of fixed microphone positions or a continuously moving microphone with an integration of p^2.

5.3 Frequency Range of Measurements

5.3.1 The sound pressure level should be measured using one-third octave band filters. The discrimination characteristics of the filters should be in accordance with IS : 6964-1973*.

One-third octave band filters having at least the following centre frequencies, in hertz, should be used:

100, 125, 160, 200, 250, 315, 400, 500, 630, 800,
1 000, 1 250, 1 600, 2 000, 2 500, 3 150, 4 000.

5.4 Measurement and Evaluation of the Equivalent Absorption Area

5.4.1 The correction term of equation (3) containing the equivalent absorption area shall be evaluated from the reverberation time measured according to IS : 8225-1976† using Sabine's formula:

$$A = \frac{0{\cdot}163\ V}{T} \qquad \ldots (4)$$

where

A = equivalent absorption area, in square metres;

V = receiving room volume, in cubic metres, with the test ceiling in place; and

T = reverberation time, in seconds.

5.5 Measurement Procedure

5.5.1 Each organization should determine a normal test procedure which complies with this standard.

5.5.2 The necessary criteria which affect the repeatability of the measurements are shown below:

a) Number, type and size of diffusing elements (if any);

b) Position of the sound source;

c) Minimum distances between microphone and sound source and microphone and room boundaries with regard to near fields;

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*Octave, half-octave and third-octave band filters for analysis of sound and vibrations.

†Method of measurement of absorption coefficients in a reverberation room.

d) Number of microphone positions or, in the case of a moving microphone, the microphone path;

e) Averaging time of the sound pressure levels; and

f) Method for determining the equivalent absorption area, which involves a number of repeated readings in each position.

An example of typical test conditions is given in Appendix A.

5.6 Evaluation of Ceiling Normalized Level Difference

5.6.1 The test procedure shall be repeated reversing the source and receiving rooms. The reported value $D_{n,c}$ shall be the arithmetic average of the two results.

6. PRECISION

6.1 It is required that the measurement procedure should give satisfactory repeatability. For the instrumentation and, in specific cases, for the complete measurement condition, this can be determined in accordance with the method described in IS : 9901 (Part 2)-1981*.

6.2 It is recommended that different organizations in the same country should periodically perform comparison measurements on the same test specimen to check repeatability and reproducibility of their test procedures.

7. STATEMENT OF RESULTS

7.1 For the statement of results, the ceiling normalized level difference of the test specimen should be given at all frequencies of measurement, in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the length for 10 : 1 frequency ratio should be equal to the length for 10 dB, 25 dB or 50 dB on the ordinate scale.

8. TEST REPORT

8.1 The test report shall make reference to this Indian Standard and shall include the following information:

a) Name of organization which performed the measurements;

b) Date of test;

c) Detailed description of test ceiling with sectional drawing and mounting conditions, including size, thickness, mass per unit area, number of suspension hangers and whether the ceiling is continuous or discontinuous at the partition capping, together with details of any luminaires, ventilating elements or other openings;

*Measurement of sound insulation in buildings and of building elements: Part 2 Statement of precision requirements.

d) Ceiling test material, for example, acoustic tile. This information should include the origin of manufacture and the manufacturer's descriptive code number;

e) Dimensions of actual rooms used including volume of rooms and plenum height of test facility;

f) Cross-sectional area above the dividing wall and constructions (if any);

g) Specification (and thickness) of any materials used in the plenum either as a barrier or a lining on the back of the specimen (or both);

h) Description of the junction of the dividing wall and the ceiling;

j) Type of noise and of filters used;

k) Brief description of details of procedure and equipment (*see* **5.5**);

m) Ceiling normalized level difference as a function of frequency;

n) Equivalent absorption area measured in both rooms as function of frequency;

p) Limit of measurement in case the sound pressure level in any band is not measurable on account of background noise (acoustical or electrical); and

q) Any deviations from the procedure specified.

APPENDIX A

(*Clause* 5.5.2)

EXAMPLE OF TEST PROCEDURE

An example of a test procedure which will normally be expected to give repeatability as indicated in IS : 9901 (Part 2)-1981* is given below.

The dimensions and shape of the test facility are shown in the figure. The walls, floor and roof of this structure are preferably constructed from heavy masonry.

The measurement is carried out in both directions with a loudspeaker installed in each room during the entire test. The ceiling normalized level difference is measured separately for each direction of test; the value reported is the arithmetic average of the two results.

*Measurement of sound insulation in buildings and of building elements: Part 2 Statement of precision requirements.

The loudspeaker is placed facing one corner of each room and the sound field in each room sampled with six randomly distributed microphone positions. No microphone should approach closer than 0·7 m to any surface and microphone positions should be separated by a distance of at least 0·5 m. Sound pressure level readings are taken at each microphone position using an averaging time of at least 5 s in each frequency band at each position. One-third octave band filters are used.

The equivalent absorption area is determined from decay curves measured using six microphone positions with one reverberation time analysis at each position. The reverberation time is evaluated from the averaged slope over a convenient range beginning about one-tenth second or a few decibels down from the beginning of the decay, the range used being not less than 20 dB, nor so large that the slope changes by 20 percent, nor so that background noise interferes with the results.