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BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE INDIA

SOUND ABSORBING MATERIALS AND THEIR UTILITY IN ACOUSTICS AND NOISE CONTROL

Introduction

Sound absorbing materials are employed for the reduction of noise in factories, offices, schools, hospitals restaurants, workshops etc. They are also employed to reduce the reverberation time and to avoid distant reflections from the walls, ceiling and other surfaces in an enclosure, thus improving hearing conditions or speech intelligibility. Acoustical materials can also be used as lining on barriers and enclosures with a view to confining noise from speçific sources and to reduce transmission of sound through ducts.

Performance

The performance of an acoustical material is judged by its sound absorption coefficient, i.e. the fraction of the incident sound energy absorbed under reverberent conditions. (Reverberation is the persistance of sound energy inside a room and Reverberation Time is the time taken by a sound to decay through 60 db or to 1 millionth of its original strength, after the source has ceased emitting sound). Any acoustical material must absorb at least 20 percent of the incident sound energy. The absorption coefficient of the material depends on the frequency of sound and hence it is measured and reported at six standard test frequencies in the audible range. For an overall functional behaviour, an average value of the coefficients at four frequencies of 250, 500, 1000 and 2000 c/s is taken. This is called the Noise Reduction Coefficient of the material.

Application

The sound absorption coefficient of a material is generally measured in the laboratory by two methods : (i) Reverberation Chamber Method; and (ii) Standing Wave Apparatus or Tube Method. Chamber coefficients are used in the acoustical design of rooms and these are always higher than those obtained from the tube method. The tube method is useful for research and for studies on acoustical behaviour of materials. For the purpose of the designing of different halls, values of absorption coefficient should always be the values obtained in the Reverberation Chamber which are given in Table 1. A list of sound absorption coefficients of different indigenous and commonly used acoustical materials measured at the C. B R. I. by the Reverberation Chamber and the Standing Wave Methods are given in the Tables I and II. From these Tables it is easy for the designers to choose the proper acoustical treatment for any enclosure.

In practice, besides sound absorption coefficient, there are other equally important considerations e. g. distribution of the material and the form in which the material is to be used*. These are to be carefully weighed in order to obtain the optimum acoustical performance. The performance of an acoustical material as well as the experience and skill of the designer therefore plays a very significant part in achieving the desired result.

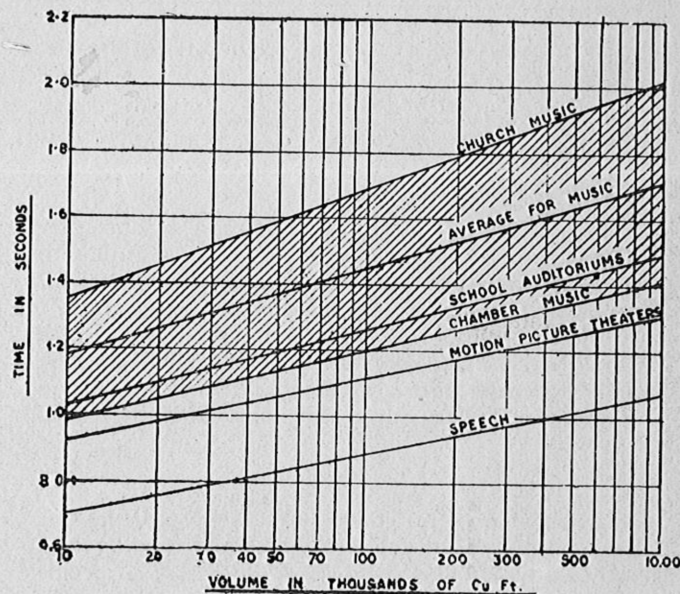

Fig. 1 Optimum reverberation time at 512 Cycles for different types of Rooms as a function of room Volume.

Problems concerning speech communication in large halls arise out of their long reverberation time. There is an optimum value of the reverberation time for each hall. Fig. 1 shows the relation between the volume of the hall and the optimum reverberation time for various purposes for which the hall will be used. It can be seen that the optimum reverberation time of halls used for music should be more than those used for speech only. The desired value of the reverberation time can be achieved by introducing the required quantity of additional absorption.

*The distribution of the acoustical material should be such that it covers mostly the distant surfaces of an enclosure from the speaker i.e. the rear wall, and ceiling etc.

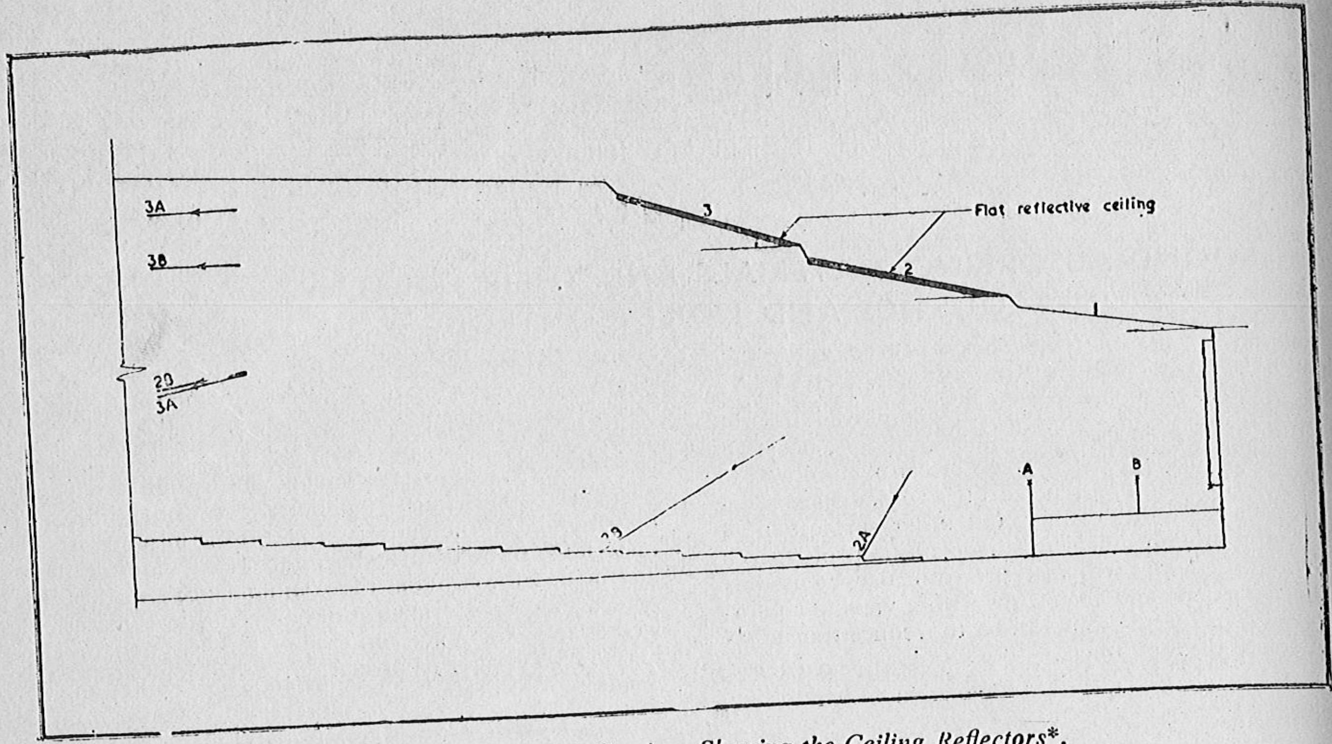

Fig. 2 Section of an Auditorium Showing the Ceiling Reflectors.*

The next consideration is the amount of absorptive treatment required. There are some rules governing the extent of treatment so as to keep it within practical and economical limits. The total absorption, in Sabins, in any room should be between 20 and 50 percent of the total internal surface area of the room, and the lower value is generally more applicable to rooms having floor dimensions large in comparison with the ceiling height.

The absence of reflective surfaces close to the stage is a serious defect in such enclosures. It results in the arrival of a weak, ill-defined direct sound at a specified location in the hall often accompanied by delayed first order reflections. When such reflections arrive at a point within 40 milliseconds of the direct sound, these may be considered as part of the useful signal and may contribute to the intelligibility of speech, but later arrivals tend to mask the subsequent speech syllables.

To further increase the intelligibility as well as the speech communication in a hall, it is essential to increase the strength of the direct sound as compared to the reverberant sound. This is achieved by introducing: (i) A flat reflective ceiling in front of the proscenium (Fig. 2), (ii) Side reflectors in the stage (Fig 3). The ceiling reflectors are inclined from the horizontal so as to direct the sound towards the audience in the hall (Fig. 2 and Fig. 3) Sometimes a column loudspeaker is very useful in such situations.

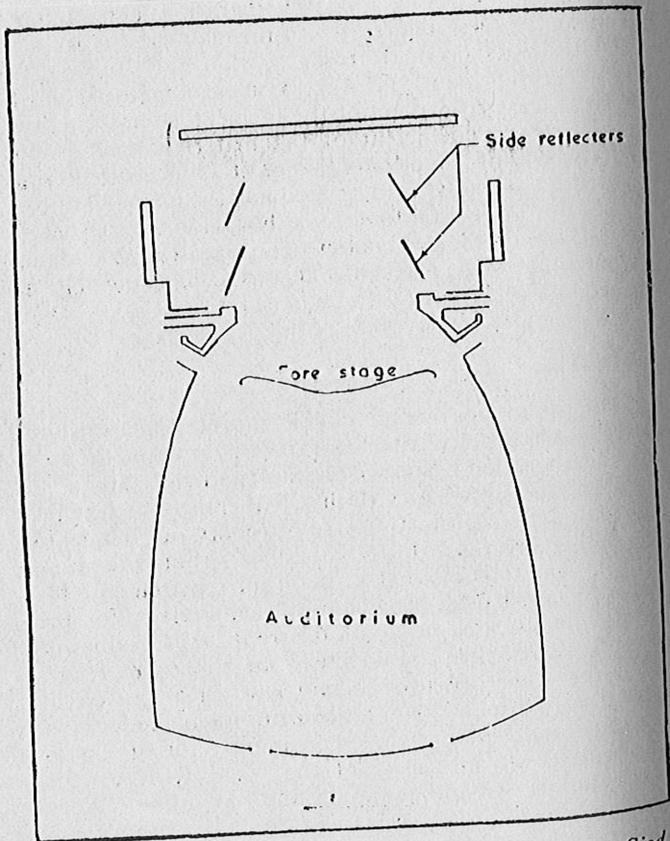

Fig. 3. Plan of an Auditorium Showing the Sied Reflectors.

Absorptive Material for Acoustical Design

The procedure which is generally adopted to provide good acoustical conditions in a hall has been described in an earlier digest*. It is important for architects and engineers to consider all the aspects mentioned above along with the procedure given in the earlier digest.

In every hall, the rear wall should always be treated with an absorptive material. Care should be taken that the total distance travelled by the reflections from the untreated ceiling to a point in the hall do not exceed by more than 60 ft. the direct distance of that point from the source. For a medium size of hall, having a capacity of 400 to 700 seats, 25 ft. of the side walls and ceiling from the stage should be left untreated. For a given volume of the hall, one may find from Fig. I the value of the required reverberation time (T). If V is the volume of the hall in cu. ft., the required total absorption (A) is given by Sabine's formula:

$$A = \frac{V}{20T} \text{ sq. ft.}$$

the major contribution being due to the audience (N). The normal practice is to take 2/3 of the seating capacity in the hall in calculating the total absorption due to the audience.

Thus the contribution of occupied seats (upholstered chairs) $= 2/3 \text{ N } 4$

$$= \frac{8\text{ N}}{3} \text{ sq ft.}$$

where the audience absorption is taken to be 4 Sabin *(Sabin is the unit of the absorption which is defined as the total absorption of sound by 1 sq. ft. of an open window).*

Contribution of sound absorption by unoccupied seats $= 1/3 \text{ N. } 2 = \frac{2\text{ N}}{3}$ sq. ft.

The absorption of unoccupied upholstered seat is taken as 2 units per seat.

Therefore, total absorption due to audience

$$= \frac{8\text{ N}}{3} + \frac{2\text{ N}}{3} = \frac{10\text{ N}}{3} \text{ sq. ft.}$$

If "a" is the total absorption due to curtains, furniture and other articles etc. in the hall, then

Total absorption in the hall $= \left[\frac{10\text{ N}}{3} + a\right]$ sq. ft.

Additional absorption required in the hall

$$= \frac{V}{20\text{ T}} - \left(\frac{10\text{ N}}{3} + a\right) = A_1 \text{ (say)}$$

If the total area of different surfaces in the hall available for treatment with acoustical materials be S sq. ft. and if the noise reduction coefficient of the material (From data in Table 3) used is α then S and α shold be so chosen that the required absorption of A_1 is obtained. It is clearly illustrated by the wroked out example given below.

Suppose the volume of the hall be 82,000 cu.ft.

1. From Fig.1 the optimum reverberation time is found out to be 0.9 seconds.

2. The total absorption by the Sabine's formula,

$$= \frac{82{,}000}{20} \times \frac{10}{9} = 4555 \text{ sq.ft. units}$$

3. (i) Absorption contribution due to 2/3 audience (600 people) $= 400 \times 4 = 1600$ sq.ft. units

   (ii) Absorption due to unoccupied seats $= 200 \times 2 =$ 400 sq ft Units Therefore total absorption due to audience $= 2000$ sq.ft. units

   Hence extra absorption needed $= 2555$ sq.ft. units

   The following treatments are suggested.

4. (i) Ceiling area: 40 ft. $\times$ 55 ft. $= 2200$ sq.ft. units
   Sound absorption coefficient of the material $= 0{\cdot}6$
   Hence absorption due to ceiling
   $2200 \times 0{\cdot}6 = 1320$ sq ft units

   (ii) Area of the side walls provided with sound absorbing material
   (50 ft $\times$ 10 ft $\times$ 2) $= 1000$ sq.ft. units

   Absorption due to side walls $= 1000 \times 0{\cdot}6 = 600$ sq.ft. units

   Area of the rear wall treated $= 9{\cdot}5\text{ft} \times 55\text{ft.} =$ 523. sq. ft.

   Absorption due to rear wall $= 523 \times 0.6 = 314$ sq ft. units

   (iii) Absorption due to curtains $= 500 \times 0{\cdot}4 = 200$ units (Where 0·4 is taken to be the absorption coeffcient of the heavy curtains).

   (iv) other absorptions (say) $= 150$ sq ft. units

   Hence the total absorption provided is 2584 sq.ft. units, which is nearly the extra absorption required in the hall

*Acoustic Design of Auditoria, Halls and Theatres, Building Digest No. 6, Central Building Research Institute, Roorkee.

TABLE I

SOUND ABSORPTION COEFFICIENT OF ACOUSTICAL MATERIALS REVERBERATION CHAMBER DATA

Sl. No.	Material	Manufacturer	Thickness inches (cms)	Density lb/cu. ft (Kg./cu. m)	Absorption coefficients 125	250	500	1000	2000	4000	N.R.C.*	Mounting@
1.	Scrim mat fibreglass	The Bombay Co. Pvt. Ltd. Bombay	1.0(2.5)	5.00 (80.0)	0.29	0.59	0.85	0.87	0.84	0.98	0.79	With rigid backing (Mounting No. 1)
2.	,, ,, ,,	,, ,,	2.0(5.0)	,,	0.57	0.80	0.99	0.99	0.95	0.99	0.93	,, ,,
3.	,, ,, ,,	,, ,,	2.0(5.0)	,,	0.20	0.62	0.99	0.93	0.61	0.42	0.79	With rigid backing and a perforated hard board facing (10%open area)
4.	,, ,, ,,	,, ,,	1.0(2.5)	,,	0.06	0.36	0.99	0.94	0.49	0.31	0.65	,, ,,
5.	Sitatex-perforated 1600 (Standard)	Plywood Products Sitapur U. P.	0.75(1.9)	—	0.05	0.10	0.52	0.75	0.80	0.85	0.54	With rigid backing (Mounting No.1)
6.	,, ,, ,,	,, ,,	0.50(1.3)	—	0.02	0.05	0.30	0.55	0.56	0,63	0.36	,, ,,
7.	Sitatex-perforated Random (Standard)	,, ,,	0.75(1.9)	—	0.05	0.07	0.56	0.68	0.80	0.99	0.53	,, ,,
8.	,, ;, ,,	,, ,,	0.50(1.3)	—	0.05	0.06	0.34	0.56	0.67	0.70	0.40	,, ,,
9.	Uniformly perforated Jolly-Board (each Unit 2′×2′)	Anil Hardboards Bombay	0.50(1.27)	18.61 (300.00)	0.06	0.12	0.55	0.66	0.67	0.76	0.50	,, ,,
10	Randomly perforated Jolly-Board (each Unit 2′×2′)	,, ,,	0.50(1.27)	,,	0.15	0.18	0.52	0.58	0.76	0.58	0.51	,, ,,
11	Fibrosil	Indian Rockwool Co. (Pvt) Ltd. Delhi	1.00(2.5)	6.00 (98.00)	0.36	0.53	0.74	0.93	0.93	0.92	0.78	,, ,,
12	,, ,,	,, ,,	2.00(5.0)	,,	0.40	0.55	0.90	0.99	0.99	0.92	0.88	,, ,,
13	Lloydwool Board Mineral Wool. (uniform thickness of Lloydwool in bags made of jute)	Punj & Sons Pvt. Ltd. New Delhi	1.00(2.5)	6.00 (98.00)	0.41	0.26	0.99	0.99	0.85	0.93	0.77	,, ,,
14	Pulp Board (Insulation Board)	Saharanpur Straw Board Factory, Saharanpur (U.P.)	0.75(1.9)	20.00 (320.00)	0.20	0.61	0.99	0.68	0.40	0.38	0.67	,, ,,
15	,, ,, ,,	,, ,,	0.50(1.27)	13.00 (207.00)	0.08	0.42	0.71	0.49	0.38	0.26	0.50	,, ,,

*N.R C.—Average of the absorption coefficients, at four test frequencies ie. 250, 500, 1000 and 2000 c/s. @ Mounting No1. Material placed on the floor of the Reverberation Chamber.

NB : The tests were carried out on samples sent by the Manufacturer.

Tested in the Physics Laboratory
Central Building Research Institute,
Roorkee. (U. P.)

TABLE II

SOUND ABSORPTION COEFFICIENT OF ACOUSTICAL MATERIALS STANDING WAVE DATA

No.	Material	Manufacturer	Thickness inches (cms)	Density lb/cu. ft (Kg/cu. m)	Absorption Coefficients 125	250	500	1000	2000	4000	N.R.C	Mounting
1.	Lloydboard	Punj & Sons (Pvt) Ltd. New Delhi	1.00 (2.50)	15.00 (240.00)	0.06	0.25	0.40	0.79	0.82	0.80	0.57	With rigid backing
2.	Fibrosil	Indian Rockwool Co.Pvt.Ltd. Delhi	2.00 (5.00)	6.00 (96.00)	0.07	0.16	0.33	0.66	0.84	0.92	0.50	,, ,,
3.	,, ,,	,, ,, ,,	1.00 (2.50)	6.00 (96.00)	0.06	0.07	0.13	0.24	0.54	0.80	0.25	,, ,,
4.	Straw Board	Saharanpur Straw Board Factory, Saharanpur.(U.P.)	0.75 (1.90)	—	0.05	0.08	0.10	0.22	0.56	0.80	0.24	,, ,,
5.	Sitatex-perforated 1600 (standard)	Plywood Products Sitapur. U P.	0.75 (1.9)	—	0.12	0.17	0.21	0.66	0.67	0.68	0.43	,, ,,
6.	,, ,,	,, ,,	0.50 (1.3)	—	0.06	0.12	0.19	0.29	0.37	0.48	0.24	,, ,,
7.	Sitatex-perforated Random (standard)	,, ,,	0.75 (1.9)	—	0.12	0.18	0.26	0.45	0.48	0.62	0.34	,, ,,
8.	,, ,,	,, ,,	0.50 (1.3)	—	0.08	0.15	0.20	0.34	0.50	0.54	0.30	,, ,,
9.	Anil Board	Anil Hard Board, Bombay	0.50 (1.27)	—	0.08	0.13	0.15	0.22	0.33	—	0.21	,, ,,
10.	Fibrosil Slab	Indian Rockwool Co.(Pvt)Ltd. Delhi	2.00 (5.00)	4.00 (64.00)	0.07	0.10	0.18	0.36	0.63	0.65	0.32	,, ,,
11.	,, ,,	,, ,,	2.00 (5.00)	4.8 (77.00)	0.06	0.11	0.25	0.45	0.77	0.82	0.41	,, ,,
12.	,, ,,	,, ,,	2.00 (5.00)	4.9 (79.00)	0 06	0.11	0.22	0.43	0.77	0.80	0.41	,, ,,
13.	Pulp Board (Insulation Board)	Saharanpur straw Board Factory, Saharanpur (U.P.)	0.75 (1.90)	20.00 (320.00)	—	0.21	0.43	0.48	0.38	—	0.38	,, ,,
14.	,, ,,	,, ,,	0.50 (1.27)	13.00 (207.00)	—	0.11	0.18	0.21	0.34	—	0.21	,, ,,
15.	Jute Board	—	0.50 (1.27)	18.00 (297.00)	—	0.03	0.16	0.33	0.64	—	0.29	,, ,,
16.	Wood Shaving Board I	Thermolith Produc. (Pvt)Ltd. Calcutta.	0.75 (1.90)	12.00 (196.00)	—	0.08	0.10	0.50	0.76	—	0.36	,, ,,
17.	,, ,, II	,, ,,	0.50 (1.27)	24.00 (379.00)	—	0.13	0.18	0.21	0.18	—	0.18	,, ,,
18.	Foam Concrete	CBRI Manufactured, Roorkee	0.75 (1.90)	20.00 (320.00)	—	0.05	0.12	0.12	0.20	—	0.12	,, ,,
19.	Mica Brick	,,	0.75 (1.90)	43.00 (695.00)	—	0.18	0.08	0.24	0.18	—	0.17	,, ,,
20.	,, ,,	,,	0.50 (1.27)	,,	—	0.18	0.15	0.13	0.04	—	0.12	,, ,,
21.	Compressed Paper Board	,,	0.75 (1.90)	45.00 (728.00)	—	0.06	0.06	0.11	0.11	—	0.085	,, ,,

NB: The tests were carried out on samples sent by the manufacturers.

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