CENTRAL BUILDING RESEARCH INSTITUTE, ROORKEE-247667 (INDIA)

BUILDING RESEARCH NOTE

B.R.N. 82

ACOUSTICAL DESIGNING OF MULTIPURPOSE HALLS

Since the discovery of phenomenon called 'Reverberation by W.C. Sabine, there has been more and more recognition of having better acoustical characteristics of enclosures. A notable feature in the design of public buildings is the greater attention now given to their acoustics. Acoustical design is to be carried out such that the highest standard of audibility, intelligibility and clarity are established within the buildings where satisfactory listening conditions are required.

Under normal circumstances, the sound travelling directly from a source to a listener becomes unintelligible beyond a distance of 9 meters. Reinforcement of sound can generally be done by using different surfaces of the hall as redistributing elements. For useful reinforcement the sound which is reflected from different surface of a room should reach the listener within 30-35 milliseconds of the direct sound.

Sounds have many properties (like loudness and frequency) and these properties differ, to a significant degree, according to the type of sound generated at the source. The difference of levels,for example, from the loudest to the softest tones is more in music than it is in speech, although the minimum level remains the same in both the cases. Similarly, musical sound extends to a wider range of frequencies (30 Hz to 10,000 Hz) than does the sound of speach (500 Hz to 4000 Hz).

For the acoustical design of multipurpose halls where good acoustics is absolutely necessary it is important to give sufficient attention to different factors which affect the quality of sound. Attempts have, therefore, been made in this research note to throw some light upon interaction between different aspects of sound and the internal physical environment of the room.

Reverberation Time

A sound impulse takes sometime to dissipate through gradual declination. it is important to know, the time taken by this decay for high intelligibility to the listener. This decay is measured in terms of the amount of time required for any sound impulse to decay to one millionth of its initial value. This is termed as the reverberation time (R.T.) in seconds. It can be calculated from the following formula:

$$T = \frac{0.16V}{A}$$

where

V = the volume of the hall in Cu.m.
T = the reverberation time in seconds,
and
A = total absorption units in the hall in sq. meters = S a s

where a is the absorption coefficient of area S. Thus reverberation time increase with increase in volume of the room and/or with decrease in the amount of absorption.

Values of reverberation time for different activities are given in Table 1. These may be used for design purpose.

The volume per seat (person) should be close to 4.2 Cu. meters for good acoustical designing. A value of 5.7 Cu.m. should never be usuallyexceeded.

Generally, the designer makes a preliminary calculation of reverberation time when room volume and seating capacity have been established. This provides a rough estimate of the total absorption capacity that must be provided in the room for better audibility.

Table 1: Recommended Values of Reverberation Time

S.No.	Activity	Optimum Reverberation Time (500-1000 Hz) in seconds.
1.	Lecture, convocation & similar activities using sound amplification	0.6 - 1.0
2.	Cinema	0.6 - 1.2
3.	Drama Plays	0.8 - 1.4
4.	Chamber music	1.0 - 1.4
5.	Orchestra	1.2 - 1.4

Room Shape

The problem of acoustical treatment is resolved to some extent by adopting correct room shape. Rectangular shapes are good acoustically. Curved concave surface should be avoided, as these are sources of focal concentration and thus prejudicial to good acoustics. Fig. 1 shows a few such curved surfaces which concentrate sound energy in the listening area at a point at the expense of those at other points. Uniform distribution of sound energy the source to the entire listening area is one attribute of good acoustics. If under compelling situations, curved surfaces are adopted, the curvature must be very small. For a dome structure ceiling the radius of curvature must be very large. In a few instances, such as for halls and auditoria, the rear wall may have slight curvature and the radius of curvature should be large in comparison to the length of the hall. layout of the ceiling surface is often so adjusted as in Fig.2, the sound from the source is beneficially reflected to remote seats on the floor or balcony of the hall. Reflecting convex surfaces are employed in some specific cases with a view to help relieve what would otherwise result in concentration or nonuniform distribution of sound. Such surfaces, whenever installed must be carefully designed in regard to the shape and size.

Reinforcement of Sound through loudspeakers

Sound energy generally needs to be reinforced to reach the rear listeners. Rooms smaller than 1400 Cu.m., if properly designed, should not need electronic reinforcement, for most speakers and most musical performances, but beyond this size, electronic reinforcement is usually desired for speech. Column type of loudspeakers offer some advantages over other systems. In this system, a number of loudspeakers are mounted in a closed wooden cabinet one above the other. The innerside of the cabinet are lined with about 2.5 cm thick acoustical material. The speakers are connected in a way that the sound intensity is maximum at the centre of the column loudspeaker and decreases towards the ends.

The length and tilt of column loudspeakers are interdependent. In Fig. 3, l is the horizontal distance from the position on the floor above which the column is to be located to the point farthest away from the column and h is the height of the column centre from the average ear level. After h/l is known, one can determine from Fig.3, the tilt of column loudspeaker for a given nd where n is the number of loudspeakers in the column and d is distance between two consecutive speakers. As an example, let the centre of the column be chosen as 7.0 m above the ground and 6.0 m above the ear level (the ear level being taken as 1.0 m above the ground). The ratio of the height to the length is then 0.20 if l = 30 m. From Fig. 3 one can get the length of the speaker column as 1.3 m and the forward tilt as 17° from the vertical. The column loudspeaker assembly being highly directional in the vertical plane and non directional in the horizontal has two main advantages over the ordinary loudspeaker. First, it may be used to direct most of the speech towards the audience, thus decreasing the intensity of the reverberant sound which is undesirable for good ntelligibility. The second is that fall off in intensity of the direct sound with distance can be reduced by positioning the column so that more distant listeners receive more of the sound beam. The column should be placed more or less above the source, and so tilted that it transmits the beam of sound to the listeners. The low intensity of sound just below the column is highly useful for reducing acoustic feedback. Microphones, preferably with unidirectional or cardiod characteristics, a quality amplifier and one or two column loudspeakers correctly designed and located, makes suitable combination for large or small indoor or outdoor requirements. Let us take an example of acoustical design of a hall having volume 3000 m^3.

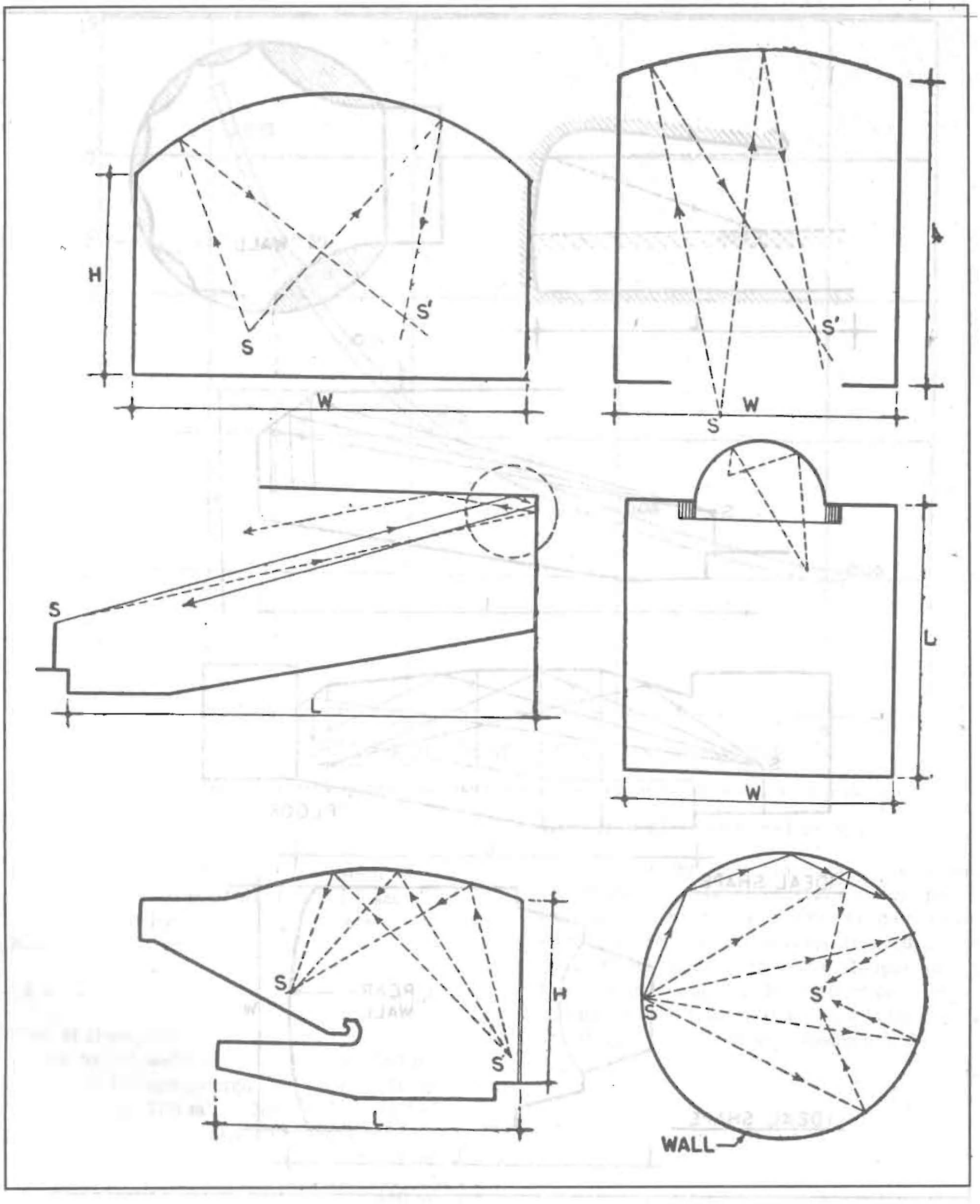

Fig. 1. Some bad shapes of halls and auditoria

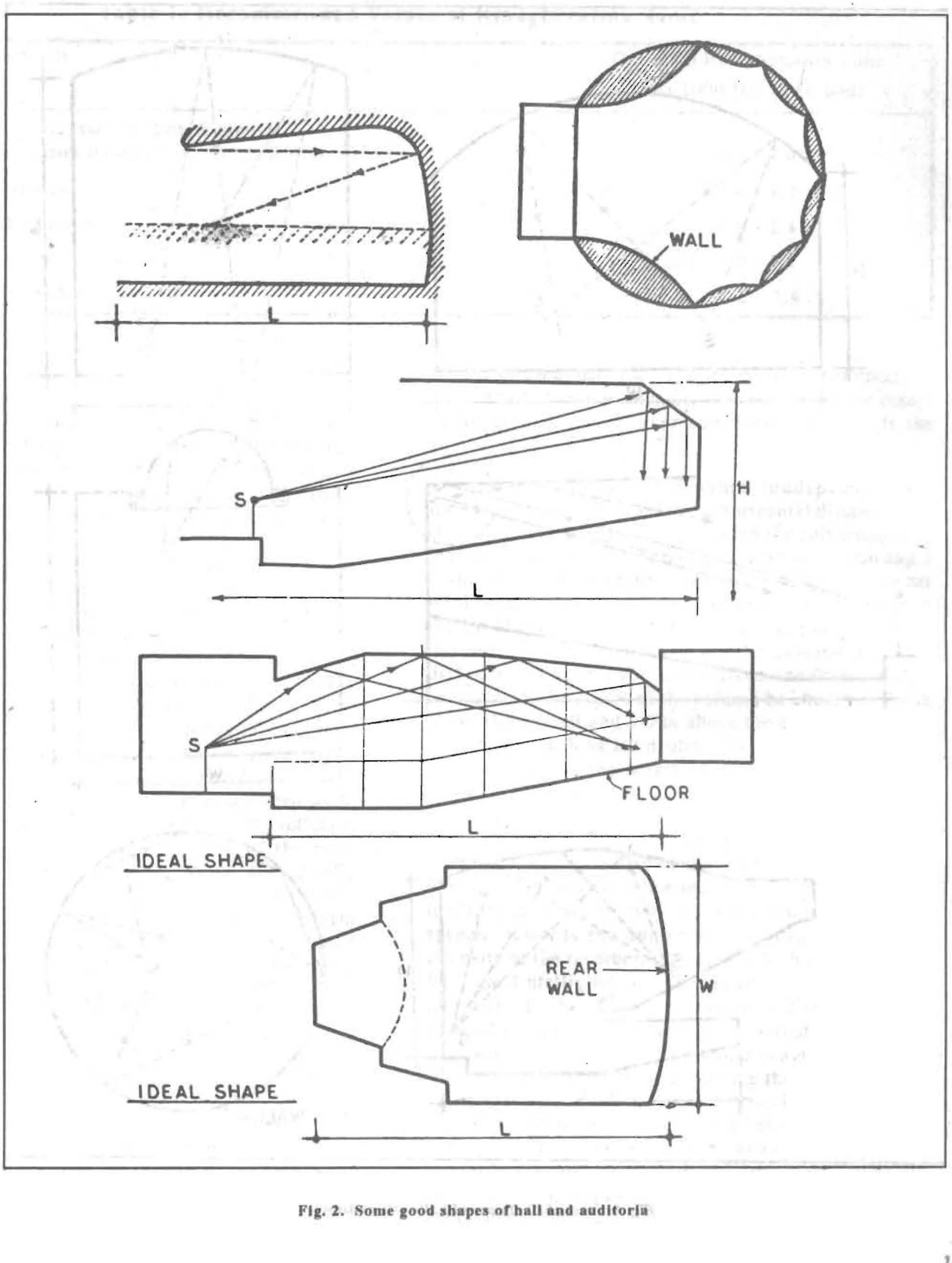

Fig. 2. Some good shapes of hall and auditoria

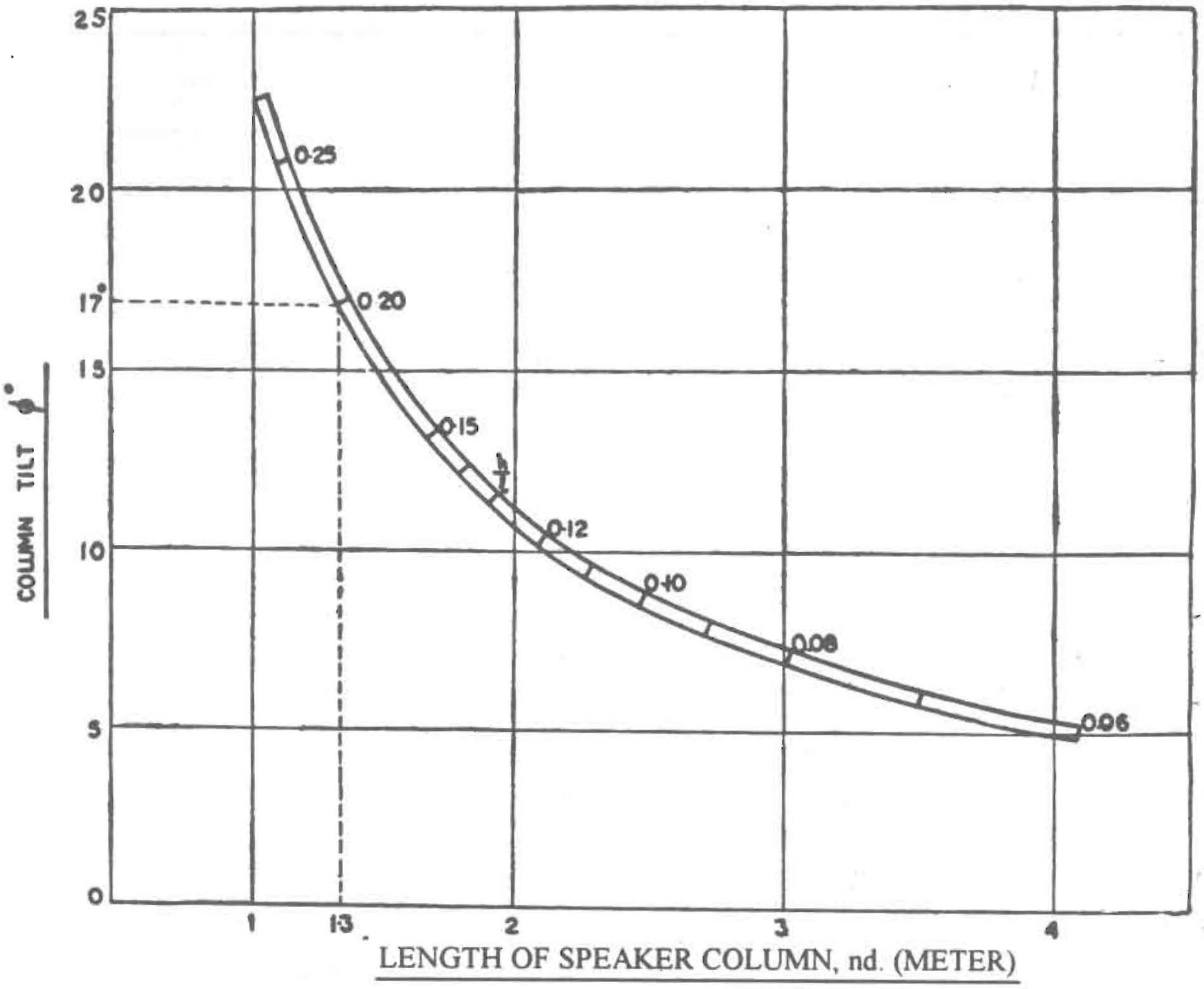

Fig. 3. Relation between the length of column loudspeaker and column tilt when h and l ar eknown

Example

Volume of the hall V	= 3000 m^3
Desirable R.T. of the hall, T	= 1.0 sec.
Seating capacity	= 600

Total absorption required

$$A = \frac{.16 \times 3000}{1} = 480\ m^2$$

Calculation of absorption

1. Absorption by 2/3 audience 400 x 0.46 = 184 m^2
2. Absorption by 1/3 upholstered 200 x 0.4 = 80 m^2
3. Perforated boards, 200 m^2 200 x 0.6 = 120 m^2
4. Other materials such as curtain,plastered surfaces floor covers = 96 m^2

Total absorption = 480 m^2

Location of acoustical materials:

In order to avoid delayed reflections, it is customary to acoustically treat the rear portion of the hall specially the rearwall. The rear parts of ceiling and sidewalls also are generally treated by absorbing materials of high absorption coefficient. In small sized lecture and assembly halls, conference rooms etc. entire ceiling area and four walls are usually treated with sound absorbing materials of high absorption.

Printed at ·
anubhav printers & packers, roorkee ph : 71237
Copies : 1000

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Published by : Central Building Research Institute Roorkee (U.P.) India
Printed : July 1996