Acoustical Design for Architects

Mike Wilson
Low Energy Architecture Research Unit
School of Architecture and Interior Design
University of North London
Spring House
6-40 Holloway Rd.
London N7 8JL
U.K.

Tel: +44 171 753 7006
Fax: +44 171 753 5780

Introduction

For good room acoustics the following conditions need to be satisfied

1) There needs to be good sound distribution in the room. This may be effected by various acoustic ‘faults’ such as concentrations and shadows, ringing and colouration, or echoes.

2) The background level needs to be an optimum for the acoustic activity in the space. Often this optimum will be the minimum sensibly obtainable but may not if masking noise is required such as in open plan offices.

3) The reverberation or rate of decay of the sound should be an optimum for the acoustic activity.

Sound Behaviour within Rooms

Sound within rooms can be analysed using different techniques. These can usefully be divided into the following categories:

1) Geometric methods. By using the basic law of angle of incidence equals angle of reflection the sound field may be described. The drawback of this method is that it takes no account of the wave nature of sound where typical wavelengths can be of the same order of magnitude as the reflecting or obstructing objects. One simple example of this is the acoustic barrier. The sound behind the barrier is not simply reduced equally over the whole noise spectrum but the tonal character is changed. The longer the wavelength or the lower the frequency the more the sound wave diffracts or bends round the barrier reducing the attenuation. With sound reflectors the lower frequencies may not ‘see’ the barrier at all, the middle frequencies may suffer diffuse reflection while only the higher frequencies undergo specular or mirror-like reflection.

2) Statistical methods. The rate of decay of sound in the room depends on the mean free path of the sound wave between reflections and the absorption of surfaces,

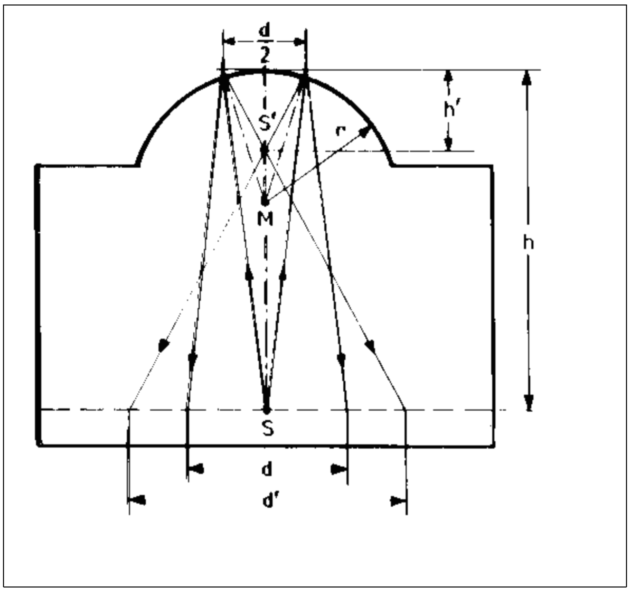
objects and air.

3) Wave Theory. A full description of the sound field in a room depends on solving the wave equations in that room. This is difficult without immense computing power and is normally limited to simple geometry. It is essential however in predicting standing waves (otherwise known as room modes or eigen functions) , and particularly important in small room (studio) acoustics.

Analysis of Room Shape

Most acousticians would try to avoid concave focusing shapes. If unavoidable they can be treated with absorber but this will often lead to loss of loudness. Concave shapes are often associated with echoes. Within approx 50 ms of the direct sound arriving at the listener the following reflections are integrated by the ear. Thus strong early reflections are very important in ensuring a sound is perceived sufficiently loudly. Where neither wall nor ceiling exist to provide these reflections the area of the floor in front of the source provides an important reflecting surface. This is important in amphitheatres where the apron provides such a facility. Rays can be drawn to ensure the audience can hear the reflected sound and this determines the raking. Note that glazing rays over the heads of an audience are heavily absorbed. A reflection arriving 80 ms after the direct sound will be perceived as part of the general reverberation of the room or if it is sufficiently strong as an echo. Concave shapes concentrate sound and therefore increase the likelihood of an echo. An important consideration is the relationship between the radius of curvature of the concave surface and the room dimensions. In the following diagram for a room with a dome or vault the radius should be less than half the source - max ceiling height to ensure the reflected sound is no more concentrated than that from a flat surface. Note that the sound reflected from a flat surface would be concentrated in distance d while the concave surface covers a distance d'.

Fig 1 (Source Ref 1)



A similar method can be applied to alert designers to the potential of an echo in an auditorium . Assuming a simple rectangular shape for an echo to occur two conditions need to be satisfied:

1) The path difference between reflected and direct sound should be at least 17m. This is the distance covered by a sound