Noise Control in Buildings

Fundamental and Applications

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Mahavir Singh
Acoustics, Ultrasonics and Vibration Section
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Mahavir Singh

Preface

Noise Control in Buildings contains a complete set of data on the properties of acoustical materials and on the sound insulation of walls and floor/ceiling constructions. This wealth of technical information provides an invaluable resource for the professional as well as the non-professional:

- The properties and selection of acoustical materials
- The design of select wall and floor/ceiling constructions
- Airborne sound insulation
- Control of noise communicated by building structures
- Acoustical characteristics of rooms

Also included are effective methods for dealing with noise problems in HVAC systems, plumbing systems, and machinery - plus innovations in techniques for the design of buildings with low noise levels.

Controlling noise in buildings is an important part of an architect's and engineer's responsibility. This book provides practical guidelines on avoiding noise problems during the design and construction of new buildings, and eliminating noise in existing structures. Noise control in buildings covers such topics as properties of sound absorptive materials, acoustical characteristics of rooms, airborne sound insulation, and structure-borne sound insulation. Included are proven methods- and technical data-for dealing with noise, HVAC systems, plumbing systems, and machinery, plus information on the design of buildings for noise control.

It provides a wealth of information, mainly without the use of mathematics that can be used to ensure that noise control measures are incorporated into buildings during the design stage. The reader will find introductory material on the general aspects of sound transmission into buildings, properties of sound waves, sound absorption coefficients, and tables of sound absorption coefficients.

It is pointed out in the preface that extensive tables of the sound absorptive properties of materials are not generally available in the literature, and that the characteristics of acoustical materials manufactured have been collected and published in Chapters 2, 3 and 4. Sound in Room, Developments in Noise Control and Sound Transmission through Building Elements respectively.

Mahavir Singh

CONTENTS

1

Basics of Noise Control

1.1 INTRODUCTION

Sound is a pervasive phenomenon and such factors as the high density of new residential construction and the use of high powered equipment in modern lightweight construction systems are leading to higher noise levels in our homes, our work spaces and generally everywhere in our cities. In fact, surveys done in the United States report that the noise level of major cities is rising at the rate of approximately one decibel per year. We can no longer ignore the trend.

While the general field of noise control is quite broad, the Insight program was limited to noise control in buildings; however, the principles of noise control are the same regardless of the environment being considered.

Inadequate noise control has often made a restaurant meal an unpleasant experience. High noise levels in the workplace are distracting and irritating, possibly resulting in higher absenteeism and loss of productivity. Inadequate acoustical privacy is common in office buildings. Conference rooms, despite the fact that their primary purpose is speech communication, are often excessively reverberant and noisy, making it difficult to understand speech from people only a short distance away. Most schools, churches, gymnasiums and swimming pools, as they now exist, could benefit from an acoustical tune-up, improving the quality of their indoor environment and their revenue-earning potential.

A recent survey in Vancouver found about 40% of the tenants in several multi-family dwelling projects dissatisfied with the degree of acoustical privacy in their homes. This was the major problem as far as the tenants were concerned, and it is a major complaint in many of our new apartment and condominium projects.

Elsewhere, in a large hotel in India, the acoustical engineers were overruled by the project designers; in order to save some ₹ 3.7 crores they provided bedrooms with single glazing and operable sashes for ventilation. When the hotel came into service, most of the rooms had so much traffic noise penetrating, that they were unusable for sleeping. To rectify the situation, the hotel had to install double glazing and air conditioning at a cost of ₹ 9.6 crores, not including the loss of revenue and general disturbance during the repair work.

Such errors are inexcusable, given that the knowledge exists to design and build quality acoustical environments.

The essence of this Insight program is a discussion of the principles of noise control in buildings. The fundamentals of sound are explained in the first paper, followed by the criteria and methods to control noise within rooms, in the second paper. The third paper examines the issue of noise reduction across walls, floors, windows and doors, and the last paper deals with acoustics of buildings, with an emphasis on machine and plumbing noises and the annoying problem of flanking noise.

1.2 PHYSICAL PROPERTIES OF SOUND

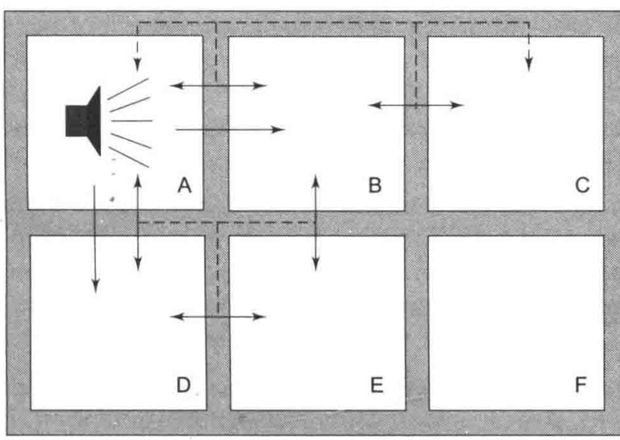
The material in this section gives a brief introduction to some of the terms used in building acoustics and the test methods used to characterize systems and materials. A very basic understanding of some fundamentals of acoustics and terms used in building acoustics, is all that is necessary to understand the material in this and the following chapters. To emphasize the simplicity of the approach, equations are kept to a minimum.

Sound is generated by creating a disturbance of the air, which sets up a series of pressure waves fluctuating above and below the air's normal atmospheric pressure, much as a stone that falls in water generates expanding ripples on the surface. Unlike the water waves, however, these pressure waves propagate in all directions from the source of the sound. Our ears sense these pressure fluctuations, convert them to electrical impulses, and send them to our brain, where they are interpreted as sound.

There are many sources of sound in buildings: voices, human activities, external noises such as traffic, entertainment devices and machinery. They all generate small rapid variations in pressure about the static atmospheric pressure; these propagate through the air as sound waves.

As well as travelling in air, sound can travel as vibrational waves in solids or liquids. The terms airborne and structure-borne sound are used depending on which medium the sound is travelling in at the time. For example, the noise from a radio set may begin as airborne sound, enter the structure of the building and travel for some distance as structure-borne sound, and then be radiated again as airborne sound in another place. The importance of structure-borne sound will become more apparent when flanking sound transmission is shown in Figure 1.1.

Air pressure is usually measured in units of Pascals (Pa). Atmospheric pressure is about 100 kPa. Sound pressure is a measure of the fluctuation of the air pressure above and below normal atmospheric pressure as the sound waves propagate past a listener.



AIRBORNE AND STRUCTURE-BORNE SOUND

Figure 1.1

The pressure variations in an individual sound wave are much less than the static atmospheric pressure, but the range of sound pressures encountered in acoustics is very large. The threshold of hearing is assumed to correspond to pressure fluctuations of 20 Micro Pascals; some individuals will have more acute hearing than this, some less. The threshold of pain in the ear corresponds to pressure fluctuations of about 200 Pa. This second value is ten million times the first. These unwieldy numbers are converted to more convenient ones using a logarithmic scale, the decibel scale. Sound pressure levels are expressed as a number followed by the symbol dB. Sound level meters convert electrical signals from a microphone to sound pressure levels in dB. Table 1.1 gives some representative sound pressure levels encountered in a range of situations.

Table 1.1: Typical Sound Levels

Jet takeoff, artillery fire, riveting	120 or more
Rock band or very loud orchestra	100 – 120
Unruffled truck, police whistle	80 – 100
Average radio or TV	70 – 90
Human voice at 1 m	55 – 60
Background in private office	35 – 40
Quiet home	25 – 35
Threshold of hearing	20

Decibels are more easily related to the response of the human ear, which also responds logarithmically to sound. The response of our ears, that is, our perception of loudness, does not increase linearly with a linear increase in sound pressure. For example, a 10 dB increase in sound pressure level would be perceived as a doubling of the loudness. In practical situations, level changes of about 3 dB are just noticeable.

It is very important to remember that decibels and similar acoustical quantities have properties different from more conventional units. Sound pressure levels, for example, cannot be added together as can kilograms. The combination of two noises with average levels of 60 dB does not give a sound pressure level of 120 dB, but 63 dB.

The addition of a noise with a level of 70 dB to a room with a level of 80 dB will result in no measureable difference in the overall level. This does not mean, however, that a large number of secondary sources can be introduced into an environment without increasing the overall level. If ten 'negligible' 70 dB noise sources are combined with one 80 dB noise source, the resulting level will be 83 dB. Fortunately in building acoustics, there is seldom a need to combine noise levels in this way or to do many complicated calculations with decibels or other logarithmic units. These examples merely emphasize the peculiarities of the decibel scale.

1.3 FILTERS AND SPECTRA

The pressure variations associated with many sounds have a repeating pattern. This is especially true of musical sounds. The frequency of a repetitive or periodic phenomenon is the number of times per second chat the pattern repeats itself. High frequency or high-pitched sounds are heard when the pressure variations in the air occur rapidly-several thousand times per second. The unit used for frequency is hertz (Hz). Thus a musical note with a frequency of 1200 Hz has a fundamental pattern of pressure variations that repeats itself 1200 times per second. In building acoustics, it is important to know the frequencies which make up a sound because different frequencies behave differently.

Typical sounds in buildings are complex without any clearly defined pattern, and are usually classified as noise. There is usually no obvious frequency or tone associated with such noises, although there may be tonal characteristics such as 'rumbling' or 'hissing'. Despite this, it is possible to analyse noises in terms of the energy contained in certain frequency intervals. This is called spectral analysis.

A narrow band spectrum shows the energy present at each frequency in great detail. Figure 1.2(a) shows the repeating time pattern of a sound source and its corresponding narrow band spectrum. This kind of information is very useful income instances but more of ten the detail is overwhelming; in building acoustics it is common to present spectra in standard one-third-octave band or even octave band plots. The term octave has the same meaning in building acoustics as it does in music; adjacent octave bands have frequencies that differ by a factor of two. Adjacent one-third-octave bands are one-third of an octave apart To produce this kind of spectrum the energy in specified regions of the narrow band spectrum is added together to give the octave or third-octave level 1. This type of presentation gives information that is easier to relate to the response of the ear. Figures 1.2(b) and (c) show the third-octave and octave band spectra obtained from the narrow-band spectrum in Figure 1.2(a).

In Figure 1.2, the horizontal axis represents the particular frequency or the frequency band of the noise. The vertical axis represents the sound pressure level or energy at the given frequency or frequency band.

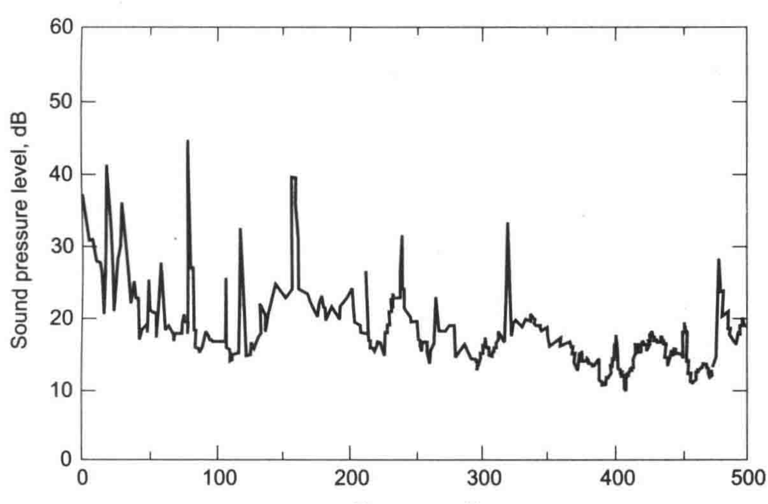


Figure 1.2(a)

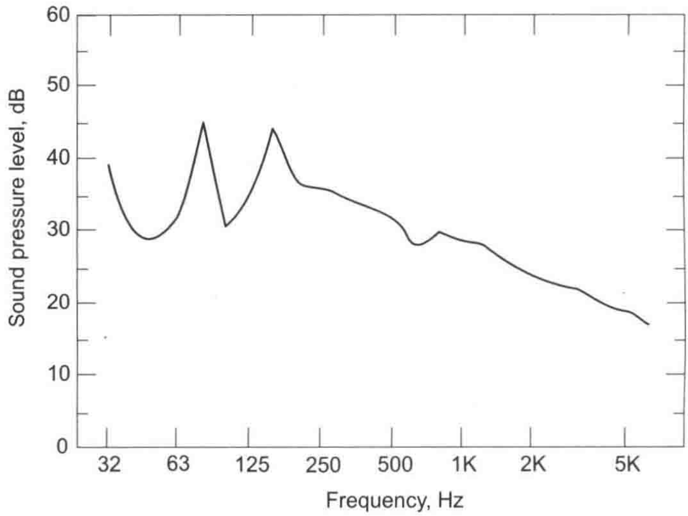


Figure 1.2(b)

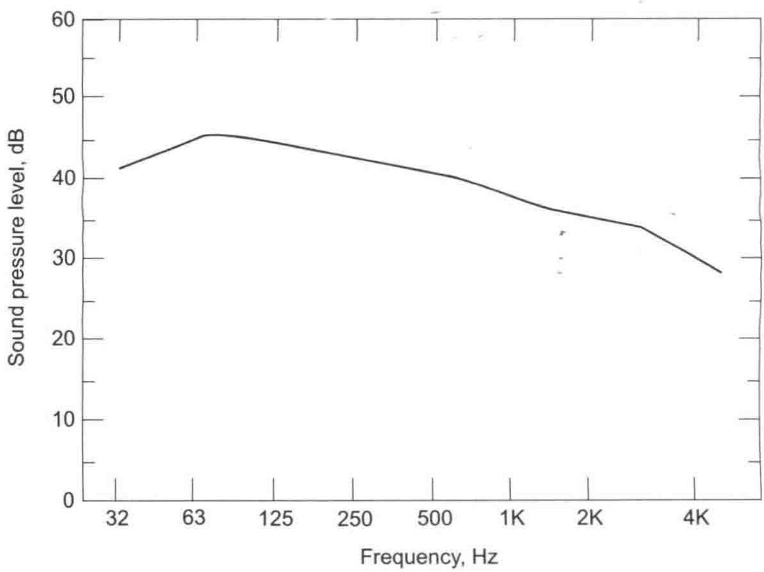


Figure 1.2(c)

The one-third-octave band spectrum for a particular noise source provides a good deal of information but a single number rating is often more convenient. One way of obtaining a single number describing a complex noise is to use A-weighted levels. The human ear is not equally sensitive at all frequencies; sounds of the same level but with different frequencies will not be considered equally loud. A sound at 3 kHz at a level of 54 dB, for example, will sound as loud as one at 50 Hz at a level of 79 dB.

The dashed curve in Figure 1.3 shows the idealised response of the human ear at intermediate sound levels. The solid curve approximates the response of the ear and is called the A-weighting curve.

The output of a microphone or sound level meter can be altered using an A-weighting electrical filter so that it more closely represents the response of the human ear. The resulting sound pressure levels are expressed as a number followed by the symbol dBA.

Noises with identical A-weighted levels can have quite different spectra and can evoke quite different responses from people. The use of such pejorative terms as whine, rasp, grate, rumble and hiss to describe sounds shows that people are well aware of the differences in spectral content. Other terms in common use such as loudness, noisiness and annoyance are not at all synonymous, nor clearly related to sound pressure levels. Despite the shortcomings of this simplistic method of rating noises, it is in common use.

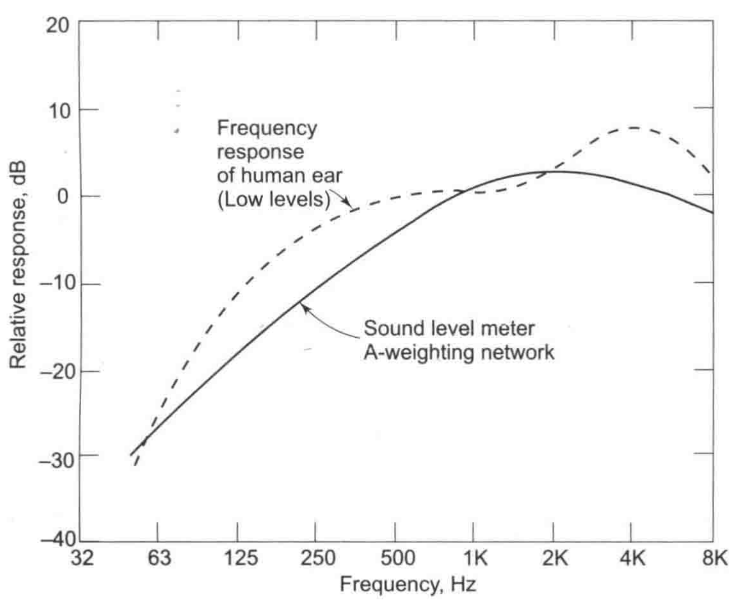


Figure 1.3

1.4 NOISE CRITERIA CONTOURS

Another method of describing the noise in buildings uses a set of octave band contours known as Noise Criteria or NC contours. In India, these are commonly used in Heating, Ventilating and Air Conditioning (HVAC) work and in other areas of building acoustics to specify maximum sound pressure levels in rooms. They provide a convenient way of rating the noise level, and to some extent, the spectrum in a room. Figure 1.4 shows two examples of