CHAPTER 3
Building Acoustics

3.1 PURPOSE

The purpose of this chapter is to provide codes, recommendations and guidelines for fulfilling acoustical requirements in buildings.

3.2 SCOPE

This chapter specifies planning and design codes, recommendations and guidelines on spatial, architectural and technical aspects of acoustics within or outside buildings to ensure acoustical performance, comfort and safety. Planning and design aspects are discussed generally and also particularly for buildings with different occupancies.

3.3 TERMINOLOGY

This Section provides meanings and definitions of terms used in and applicable to this chapter of the Code. The terms are arranged in an alphabetical order. In case of any contradiction between a meaning or a definition given in this Section and that in any other part of the Code, the meaning or definition specified in this Section shall govern for interpretation of the provisions of this Section.

Balanced Noise Criteria (NCB) Curves: L. L. Beranek developed Noise Criteria (NC) curves in 1957, which were revised in 1988 as Balanced Noise Criteria (NCB) Curves (see Appendix D).

Bel: See **Sound Pressure Level**.

Cycle: See **Frequency**.

dBA: A sound pressure level measurement, when the signal has been weighted with a frequency response of the A curve. The dBA curve approximates the human ear and is therefore used most in acoustics.

Decibel (dB): See **Sound Pressure Level**.

Direct Sound: Sound that travels directly from a source to the listener or receiver. In a room, the sequence of arrivals is the direct sound first, followed by sound reflected from room surfaces.

Echo: Echo is a reflection of a sound wave back to its source in sufficient strength and with a sufficient time lag to be separately distinguished. Usually, a time lag of at least 50 to 80 ms is required for hearing discrete echoes.

Effective Perceived Noise Level in Decibel (EPN dB): The number for rating the noise of an individual aircraft flying overhead is the Effective Perceived Noise Level in decibels (unit, *EPN dB*). This value takes into account the subjectively annoying effects of the noise including pure tones and duration. In principle, it is a kind of time-integrated loudness level.

Flutter Echo: A quick succession of echoes; it may be present as a disturbing phenomenon in small rooms or between a pair of parallel reflectors. If the time between echoes is greater than about 30 to 50 ms, the periodicity is audible as a distinct flutter.

Frequency: The frequency of sound is the number of vibrations per second of the molecules of air, generated by the vibrating body. One complete movement to and fro of the vibrating body is referred to as a 'cycle'. Frequency is expressed as the number of cycles per second (cps); it is also referred to its unit as *Hertz (Hz)*.

Impact Isolation Class (IIC): Impact Isolation Class (IIC) is a single-number impact isolation rating for floor construction. Tests are made with a standard tapping machine and noise level measured in 1/3-octave bands. These are plotted and compared to a standard contour.

Intensity: Intensity at a point is the average rate at which sound energy is transmitted through a unit area around the point and perpendicular to the direction of propagation of sound. It is also known as sound intensity. Its units is $W\,m^{-2}$

L_{10}: In environmental noise assessment, the A-weighted noise level (unit *dBA)*, with fast (F) time weighting, that is exceeded by 10 percent of sated time period is known as L_{10}.

$L_{Aeq,T}$: Symbol for Equivalent Continuous A-weighted Sound Pressure Level for airborne sounds that are non-stationary with respect to time. It is formed by applying A-Weighting to the original signal before squaring and averaging. Also known as Equivalent Continuous Sound Level.

Loudness: Loudness is the sensation produced in the human ear and depends on the intensity and frequency of sound. The unit of loudness level is *phon*.

Noise: Noise is defined as unwanted sound. Noise conditions vary from time to time and a noise which may not be objectionable during the day may be increased in annoying proportions in the silence of the night, when quiet conditions are essential.

Noise Exposure Forecast (NEF): Noise exposure forecast at any location is the summation of the noise levels in Effective Perceived Noise Level (unit *EPN dBA*) from all aircraft types, on all runways, suitably weighted for the number of operations during day time and night time.

Noise Map: A noise map is a graphic representation of the sound level distribution existing in a given region, for a defined period.

Noise Reduction (NR): Noise Reduction (NR) is a general term for specifying sound insulation between rooms. It is more general than Transmission Loss (TL). If all boundary surfaces in the receiving room are completely absorbent, the *NR* will exceed the *TL* by about 5 *dB*, i.e. $NR = TL + 5dB$.

Percentage Syllable Articulation (PSA): The percentage of meaningless syllables correctly written by listeners is called Percentage Syllable Articulation (PSA).

Reverberation: The prolongation of sound, as a result of successive reflections in an enclosed space, when the source of the sound has stopped, is called reverberation.

Reverberation Time (RT): The reverberation time of a room is defined as the time required for the sound pressure level in a room to decrease by 60 dB after the sound is stopped, and is calculated by the formula

$$RT = \frac{0.16V}{A + xV}$$

where,

RT = reverberation time, s
V = room volume, m^3

A = total room absorption, m^2 sabin
x = air absorption coefficient

Signal-to-Noise Ratio (SNR): Signal-to-Noise Ratio (SNR) defined as the power ratio between a signal (meaningful information) and the background noise (unwanted signal), which can be expressed as

$SNR = (P_{signal} / P_{noise})$
where, P is average power

SNR can be obtained by calculating the square of amplitude ratio:

$SNR = (P_{signal} / P_{noise}) = (A_{signal} / A_{noise})^2$
where, A is root mean square (RMS) amplitude

In decibel, the SNR is defined as

$SNR_{dB} = 10 \log_{10} (P_{signal} / P_{noise}) = P_{signal,dB} - P_{noise,dB}$

which might be equivalently expressed in amplitude ratio as

$SNR_{dB} = 10 \log_{10} (A_{signal} / A_{noise})^2 = 20 \log_{10} (A_{signal} / A_{noise})$

Sound Focus and Dead Spot: When a sound wave is reflected by a concave surface, large enough compared to the wavelength, it concentrates on a spot where sound pressure rises excessively. This is called a 'sound focus'. As a consequence, sounds become weak and inaudible at some other spots, called 'dead spots'.

Sound Transmission Class (STC): To avoid the misleading nature of an average transmission loss (TL) value and to provide a reliable single figure rating for comparing partitions, a different procedure for single figure rating, called Sound Transmission Class (STC) rating, of a partition is determined by comparing the 16 frequency TL curve with a standard reference contour, the sound transmission class contour. STC ratings of some common walls and floors are given in Appendix F.

Sound Pressure Level (SPL): Sound Pressure Level or Sound Intensity Level is measured in terms of the unit *bel* (B), which is defined as the logarithm of the ratio of the sound pressure to the minimum sound pressure audible to the average human ear. The unit *decibel* (dB) is one-tenth of a *bel* (B). Thus,

$$\text{Sound Pressure Level} = \log_{10} \frac{I}{I_o} \text{ bels} = 10 \log_{10} \frac{I}{I_o} \text{ decibels}$$

where, I = Sound Pressure in watt cm^2, and
I_o = Sound Pressure audible to the average human ear taken as 10^{-16} watt/cm^2.

Speech Intelligibility: The percentage of correctly received phrases is called Speech Intelligibility.

Transmission Loss: Transmission loss (TL) of a partition is a measure of its sound insulation. It is equal to the number of decibels by which sound energy is reduced in passing through the structure. Units *dB*.

Wavelength: The wavelength of sound is the distance over which a complete cycle occurs. It can be found by measuring distance between the centres of compression of the sound waves. It is dependent upon the frequency of the sound.

3.4 BUILDING ACOUSTICS: GENERAL CONSIDERATIONS AND PROVISIONS

Generalised considerations and provisions for planning and design of building are furnished in this Section.

3.4.1 **Classifications of Building Acoustics**

3.4.1.1 Considering diversity of desired objectives and salient design features, building acoustics can be broadly classified as,

a) Acoustics for Speech
b) Acoustics for Music

c) Acoustics for Multipurpose

Table 8.4.1 shows classifications of acoustics with brief description and examples of spaces involved.

Table 8.4.1
Classifications of Building Acoustics, Brief Description and Examples of Spaces Involved

Classifications	Brief Description	Examples of Spaces
a) Acoustics for Speech	Relates to speech with foremost objectives of intelligibility. A space should have relatively lower reverberation time for speech. Generally, it covers narrow range of frequency spectra in lower-mid level (about 170 to 4,000 Hz, for an average dynamic range of 42 dBA).	Classroom, lecture hall, conference hall, recital hall, assembly hall, courtroom, auditorium for speech etc.
b) Acoustics for Music	Involves music with prime objectives of liveliness or reverberance, intimacy, fullness, clarity, warmth, brilliance, texture, blend and ensemble. Music may include instrumental and vocal melody, or either of the two. A space requires relatively higher reverberation time for music. Generally, it involves broad range of frequency spectra (about 50 to 8,500 Hz, for an average dynamic range of about 75 dBA).	Music practice booth, rehearsal room, band room, listening booth, orchestra, concert hall, symphony hall, cathedral etc.
c) Acoustics for Multipurpose	Includes both speech and music acoustics to fulfil objectives of the both at a rationally compromised level. Acoustics design of a multipurpose space is quite challenging as the design objectives and measures vary remarkably for speech and music. For example, there is a significant variation in desired reverberation times of a space for speech and music.	Multipurpose hall, cinema, theatre, opera house, mosque (for speech and melodious recitation), church, temple etc.

3.4.1.2 A building or a building complex is usually a group of spaces or rooms intended for various functions. Those spaces may require involvement of different types of acoustics as stated in Table 8.4.1. For example, a school has spaces for speech (e.g., classroom), music (e.g., music room) and multipurpose (e.g., auditorium). Thus, a building or a building complex should not be generally classified as a whole for a particular type of acoustics, rather its spaces or rooms shall be classified individually and appropriate acoustical design shall be considered accordingly.

3.4.1.3 Spaces or rooms of a building or a building complex, if those even have different types of acoustical requirements, shall be designed in such a way, so that those can coexist and work as a whole.

3.4.2 **Acoustical Planning and Design Targets**

3.4.2.1 A space, involving either of the acoustical types stated in Sec 4.4.1, must achieve few design targets. Some of these important design targets are mentioned below:

a) Noise exceeding allowable limit should be controlled
b) Speech intelligibility should be satisfactory
c) Music should have liveliness, intimacy, fullness, clarity, warmth etc.
d) The desired sound level must be optimum to be heard properly
e) Diffusion of sound throughout the whole space
f) There should be no defects such as echoes, flutter echoes etc.

3.4.2.2 Necessary planning and design measures shall be taken for achieving these targets to optimum levels or standards as dictated in this Code.

3.4.3 **Factors Affecting Acoustical Planning and Design**

3.4.3.1 Among many, following are the most significant factors affecting acoustical planning and design:

a) Noise
b) Reverberation Time
c) Sound Level
d) Diffusion of Sound

3.4.3.2 For various types of building acoustics, as stated in Sec 3.4.1, the effects of these factors might be different. These factors are dependant on different conditions, like noise and sound level, room volume, building materials, surface materials, sound levels, room geometry etc.

3.4.3 **General Considerations and Provisions for Planning, Design, Assessment and Construction**

3.4.3.1 In Appendix D, a flow diagram summarises activities required for planning, design, assessments and construction related to building acoustics.

3.4.3.2 Acoustical planning and design, including all parts and details, shall be performed during design phase of any project and must comply with standards and codes as dictated in this Code.

3.4.3.3 During planning and design phase, the expected results for acoustical performance of a space or a room or building, as dictated in different Sections of this Chapter, shall be precisely analysed and assessed through standard practice, for example, precise computational methods based on computer analysis, simulation and prediction techniques.

3.4.3.4 Acoustical planning and design targets and expected results shall be clearly specified and documented as a part of the design proposal.

3.4.3.5 Acoustical planning and design measures shall be compatible with requirements of other environmental factors including natural light, ventilation and heat for working in an overall synergy.

3.4.3.6 Acoustical planning and design measures shall be congenial to other design parameters including function, structure and aesthetics for an overall harmony in design.

3.4.3.7 The proposal for acoustical design, materials, devices, supporting structures and construction methods shall be safe for health during construction and post-construction occupancy.

3.4.3.8 Acoustical materials, devices and supporting structures shall be safe in case of disasters including earthquake and fire.

3.4.3.9 The acoustical design measures and materials shall be reasonably energy efficient and compatible with Green Building practice.

3.4.3.10 The acoustical materials shall be eco-friendly, recyclable and should require minimum maintenance. Those shall be compliant to sustainable acoustics in particular and sustainable building practice in general.

3.4.3.11 It is recommended to conduct peer supervisions and periodic assessments at different phases of construction process to rectify any drawback at its initial stage.

3.4.3.12 Post-construction and post-occupancy assessments shall be conducted and findings shall be compared with expected results. Assessment shall include instrumental measurements and opinion survey of occupants. If any discrepancy is found, the space shall be modified until it reaches reasonably close to the expected result.

3.4.3.13 Preceding provisions shall be applicable for modifications of a space to eliminate acoustical faults, retrofitting a space for acoustical performance or any other acoustical design and construction activities.

3.4.3.14 *Form K, Checklist: Acoustical Planning and Design*, as shown in Appendix K, shall be filled in and signed by the acoustical consultant for each acoustical space or room or building of any project.

3.5 PLANNING AND DESIGN FOR NOISE CONTROL

3.5.1 Types of Noise

3.5.1.1 Depending on location of source, noise might be of two types:

a) Outdoor Noise.
Following are some common sources of outdoor noise:
i) Traffic noise generated from air traffic, road traffic, rail traffic etc. (see Appendix E)
ii) Noise from zones and buildings within built-up areas, machinery, appliances, construction activity, loudspeakers, people, animals etc.

b) Indoor Noise.
Following are some common source of indoor noise:
i) Household appliances, machinery, footsteps on floor, air conditioner duct etc.
ii) Activities performed by occupants, like people, pets etc.

3.5.1.2 Basing on transmission path, noise can be classified as

a) Airborne Noise
Example: Noise from appliances, car horn, telephone ring etc.

b) Structure-borne Noise
Example: Footsteps, slamming of door, furniture movement, vibrating mechanical equipments etc.

3.5.2 Design Sequence for Noise Control

3.5.2.1 In order to achieve noise control effectively, measures should be taken in the following order:

a) Suppression of noise generation at its source
b) Layout planning
c) Insulation design
d) Absorption design

3.5.3 Planning and Design for Outdoor Noise Control

3.5.3.1 Planning to control outdoor noise is an integral part of country and town planning ranging from regional to detailed zoning and three dimensional layouts of built form and traffic routes.

3.5.3.2 Noise causes more disturbances to people at rest than those at work. For this reason, outdoor noise levels in various zones or areas should be considered in planning and design with respect to critical hours of space occupancy (see Table E.1, Appendix E).

3.5.3.3 Planning and design of buildings shall consider all sources of noise mentioned in Sec 3.5.1 and keep provisions to control those from transmitting in and around buildings. For example, the orientation of buildings might be decided in way to reduce the noise disturbance from noisy neighbourhood.

3.5.3.4 A **noise survey** shall be conducted and a **Noise Map** shall be prepared to identify source, type, intensity, frequency and other parameters of noise in and around the site of any specific project. Noise levels should be measured for pick and off pick hours of both working and holidays, and also for 'Day Time' and 'Night Time' as defined in 'Noise Pollution (Control) Rules 2006' and its subsequent amendments by the Government of the People's Republic of Bangladesh (see Table E.1, Appendix E). The noise levels shall be analysed statistically for value of L_{10}, $L_{Aeg,T}$ etc.

3.5.3.5 A Noise Map shall be used to examine compliance to the permissible upper limit of noise levels set for different land use zones in the 'Noise Pollution (Control) Rules 2006' and its subsequent amendments by the Government of the People's Republic of Bangladesh (see Table E.1, Appendix E). As references, intensity levels of some common noise are shown in (see Table E.3, Appendix E).

3.5.3.6 The planning should be undertaken in such a manner that the noise can be kept at a distance. Quiet zones and residential zones should be placed with adequate setback from noise sources, like airports, highways,

railway lines and factories. It might be useful to note that doubling the distance drops the sound pressure level by about 6 dBA.

3.5.3.7 Buildings (or parts of buildings) which are considered to be especially susceptible to noise, including hospitals, research laboratories, recording studios or the like, should not be sited near sources of noise.

3.5.3.8 It might be a preferable option to place a noise tolerant buffer zone, developing green belt, public gardens etc. between a noisy zone and a quiet zone.

3.5.3.9 Noise barriers might be provided by placing buildings and occupancies less susceptible to noise between the source and the more susceptible ones. Purpose built noise barriers made of bricks, concrete, fibreglass, fibre reinforced plastic or other materials can also be used to protect buildings from noise.

3.5.3.10 If noise barriers (as stated in Sec 3.5.3.9) is neither attainable nor adequate, a building itself should have all necessary measures to protect itself against outside noise. The following might be some options:

a) In zoning of spaces, noise tolerant spaces might be placed near a noise source, while placing less-tolerant spaces at a distance.

b) External walls or partitions should have appropriate Sound Transmission Class (STC) to reduced external noise to the acceptable indoor background noise levels (see Table 8.3.4 to 8.3.7, Table I.1-I.2, Appendix I)

c) Preferably, external walls near source of noise should not have any operable window. However, to meet the demand of natural light, fixed widows allowing only light might be placed with proper noise insulation measures.

d) If need for operable windows allowing natural light and ventilation are inevitable in external walls near source of noise, special measures should be taken for restricting noise while allowing light and ventilation. Acoustic louvers, active noise cancellation devices etc. are examples of these types of special measures.

e) If natural ventilation is required but natural light is not required, ventilation ducts or chutes with lining of acoustic absorbers might be designed in a manner to absorb noise while air flows through.

3.5.3.11 Following special provisions shall be applicable for **air traffic noise**:

a) No building for human occupancy shall preferably be constructed, where NEF value due to air traffic noise exceeds 40 EPN dBA. As a reference, typical noise levels of some aircraft types are shown in Table E.2, Appendix E.

b) Educational institutions, hospitals, auditoriums etc. shall preferably be located at places where the value of NEF is less than 25 EPN dBA.

c) In areas exposed to less than 90 EPN dBA, all of the windows shall be closed and properly sealed, having double glazing, in order to provide an acceptable interior noise environment.

d) Industrial and commercial activities generating high interior noise environments might be located in areas exposed to noise levels greater than 90 EPN dBA.

e) In airport areas of highest noise levels, sparsely manned installations like sewage disposal plants, utility substations and similar other facilities might be located.

3.5.3.12 Following provisions shall be applicable for **road traffic noise**:

a) For road traffic noise level, the value of L_{10} shall be limited to a maximum of 70 dBA for zoning and planning new buildings in urban areas, while dwellings are proposed to have sealed windows.

b) The maximum permissible upper limit of L_{10} shall be reduced to 60 dBA when the dwellings are proposed to have open windows.

c) Major new residential developments shall preferably be located in areas with L_{10} levels substantially lower than those specified above.

d) Where L_{10} is greater than 70 dBA, design solutions such as barrier blocks, noise buffers or purpose built noise barriers shall be utilized in order to reduce noise levels at least to that level.

e) Through traffic roads shall preferably be excluded from quiet and residential zones to avoid excessive traffic noise.

f) In the neighbourhood of residential, educational, institutional and health care buildings, legislative control shall be exercised for road noise particularly from vehicles as dictated in 'Noise Pollution (Control) Rules 2006' and its subsequent amendments by the Government of the People's Republic of Bangladesh.

3.5.3.13 Following special provisions shall be applicable for **rail traffic noise**:

a) No residential or public building, except for the railway station and its ancillary structures, shall preferably be connected to the railway lines.

b) Mercantile or commercial buildings should not abut the railway lines or the marshalling yards. Only planned industrial zones may be located beside the railway tracks.

c) In order to reduce the high noise levels, produced at the arrival and departure of trains, platforms in railway stations shall be treated with sound absorbing materials particularly on the ceiling.

d) The main platform floor shall be separated from the station building with a minimum gap of 50 mm so that the ground or structure-borne vibrations are not transmitted to the building.

e) Windows and other openings shall preferably be placed as less as possible in the facade along the railway tracks.

f) Greenbelts, landscaping or any other form of barrier might be developed along the railway lines.

3.5.3.14 **Construction noise** shall be controlled according to the 'Noise Pollution (Control) Rules 2006' and its subsequent amendments by the Government of the People's Republic of Bangladesh.

3.5.4 Planning and Design for Indoor Noise Control

3.5.4.1 The allowable upper limits of indoor background noise levels (in dBA) are as shown in Table 8.4.2 and Fig. F.1 in Appendix F. Design shall comply with recommended range of Balanced Noise Criteria (NCB) Curve for different types of activity.

Table 8.4.2
Allowable Upper Limit of Indoor Background Noise Levels and Recommended Range of NCB Curves
(Source: Maekawa Z., Lord P. 1994. *Environmental and Architectural Acoustics*. E&FN SPON, UK)

Type of space	dBA	NCB Curve
Broadcast and recording studios (distant microphone used)	18	10
Concert halls, opera houses, and recital halls	18-23	10-15
Large theatres and auditoriums. Mosques, temples, churches and other prayer spaces	<28	<20
Television and recording studio (close microphone used)	<33	<25
Small theatres, auditoriums, music, rehearsal rooms, large meeting and conference rooms	<38	<30
Bedrooms, hospitals, hotels, residences, apartments, etc.	33-48	25-40

Classrooms, libraries, small offices and conference rooms. Living rooms, and drawing rooms in dwellings	38-48	30-40
Large offices, receptions, retail shops and stores, cafeterias, restaurants, indoor stadiums, gymnasium, large seating-capacity spaces with speech amplification	43-53	35-45
Lobbies, laboratory, drafting rooms, and general offices	48-58	40-50
Kitchens, laundries, computer and maintenance shops	53-63	45-55
Shops, garages, etc. (for just acceptable telephone conversation)	58-68	50-60
For work spaces where speech is not required	63-78	55-70

3.5.4.2 Noise generated from within a building shall not be transmitted to neighbourhood at a noise level higher than the allowable upper limit set for that zone (see Table E.1, Appendix E).

3.5.4.3 Buildings, in which there are some sources of noise, shall have buffers separating the noise producing area from the other areas. The less vulnerable areas of the building may be planned to act as noise buffers.

3.5.4.4 In the assessment of indoor noise levels, direct sound shall be separated from reverberant sound.

3.5.4.5 The reverberant sound transmitted from one room to another shall be cut down by employing suitable sound absorption materials and by structural and non-structural partitions.

3.5.5 Sound Insulation

3.5.5.1 The recommended sound insulation criteria are classified in some Grades. The STC value for airborne sound insulation is graded as stated below (see also, Fig. F.2, Appendix F):

a) Grade I STC = 55 Apply mainly to fully residential, quiet rural and suburban areas and in certain luxury apartment buildings

b) Grade II STC = 52 Apply to residential spaces in relatively noisy environments, typical of urban and suburban areas.

c) Grade III STC = 48 Express minimal requirements applicable to very noisy locations, such as commercial or business areas, like shop houses with dwelling units on the upper floors, or downtown areas.

3.5.5.2 Transmission of sound should be controlled with appropriate material, assembly of building elements. Typical STC rating for different types of building element, like stud partitions, masonry walls, doors, windows and interior partitions are shown in Table I.1, Appendix I.

3.5.5.3 Recommended STC for partitions for specific occupancies are shown in Table I.2, Appendix I.

3.5.6 Control of Structure-borne Impact Noise

3.5.5.1 Impact noise problems can be controlled in following ways:

a) Preventing or minimising the impact by cushioning the impact with resilient materials, like floor tiles of rubber and cork, carpeting on pads with desired Impact Isolation Class (IIC). Criteria for airborne and impact sound insulation of floor-ceiling assemblies between dwelling unit is shown in Table 8.3.6 and 8.3.7

b) Floating the floor for isolating the impacted floor from the structural floor by a resilient element is extremely effective. This element can be rubber or mineral wood pads, blankets or special spring metal sleepers.

c) Suspending the ceiling and using an absorber in the cavity.

d) Isolating all rigid structures, such as pipes, and caulking penetrations with resilient sealant.

3.5.6 **Control of Electro-Mechanical System Noise**

3.5.5.1 Mechanical noise is generated from mechanical devices like air-conditioning and air-handling systems, lifts, escalators, pumps, electric generators etc.

3.5.5.2 Mechanical noise problems can be controlled in following ways:

i) Reducing the vibration of electro-mechanical equipments by damping and isolation.
ii) Reducing the airborne noise by decoupling the vibration from efficient radiating sources.
iii) Decoupling the vibrating source from the structure.
iv) In air-conditioning duct system, smooth transitions at changes of duct size, large radius bends, lining with absorbing materials etc. are effective measures.
v) Active noise cancellation technique, by producing a synthesised signal exactly out-of-phase with the original noise signal to make the resultant signal effectively zero, might be applied in special cases.

3.5.7 **Occupational Noise Exposure**

3.5.7.1 Protection against the effects of noise exposure shall be provided when the sound level exceeds those shown in Table 8.4.3.

3.5.7.2 Exposure to impulsive or impact noise should not exceed 140 dBA peak sound level.

Table 8.4.3
Permissible Noise Exposure

Sound Level dBA (slow response)	Duration per Day Hour - Minute	Sound Level dBA (slow response)	Duration per Day Hour - Minute
85	16-00	98	2-50
86	13-56	99	2-15
87	12-08	100	2-00
88	10-34	101	1-44
89	9-11	102	1-31
90	8-00	103	1-19
91	6-58	104	1-09
92	6-04	105	1-00
93	5-17	106	0-52
94	4-36	107	0-46
95	4-00	108	0-40
96	3-29	109	0-34
97	3-02	110	0-30

Notes:
a) The sound level should be measured on *A* scale at slow response.
b) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1 + C_2/T_2 + ... C_n/T_n$ exceeds unity, then, the mixed exposure should be considered to exceed the limit value. C_n indicates the total time of exposure permitted at that time.

3.6 REVERBERATION TIME, SOUND PRESSURE LEVEL AND DIFFUSION OF SOUND

3.6.1 **General Considerations**

a) For an overall performing, comfortable and safe acoustical environment, along with the issues of noise, other significant aspects of acoustics should be considered. This shall include sound pressure level, reverberation time and diffusion of sound.

b) Speech intelligibility is a significant parameter to achieve satisfactory acoustical design. Percentage Syllable Articulation (PSA) is an index for assessing speech intelligibility. PSA can be expressed as

PSA = 96 $k_i k_r k_n k_s$ (%) (for English Language)
PSA = 93 $k_i k_r k_n k_s$ (%) (for Bangla Language)
Where,
k_i, k_r, k_n and k_s are the coefficient for average speech level, Reverberation Time, Noise level/ Speech level and room shape, respectively (see Fig. G.1, Appendix G).

c) For a PSA of 82%, almost a perfect Speech Intelligibility (nearly 100%) can be achieved. However, in reality, there are some background noise (>20 dBA) and reverberation time in different spaces, causing lower PSA. The minimum admissible PSA should be 75% for a satisfactory Speech Intelligibility.

3.6.2 **Reverberation Time**

Spaces for various uses should be designed for recommended optimum reverberation time to achieve a level of intelligibility and liveliness (see Fig. 8.4.1).

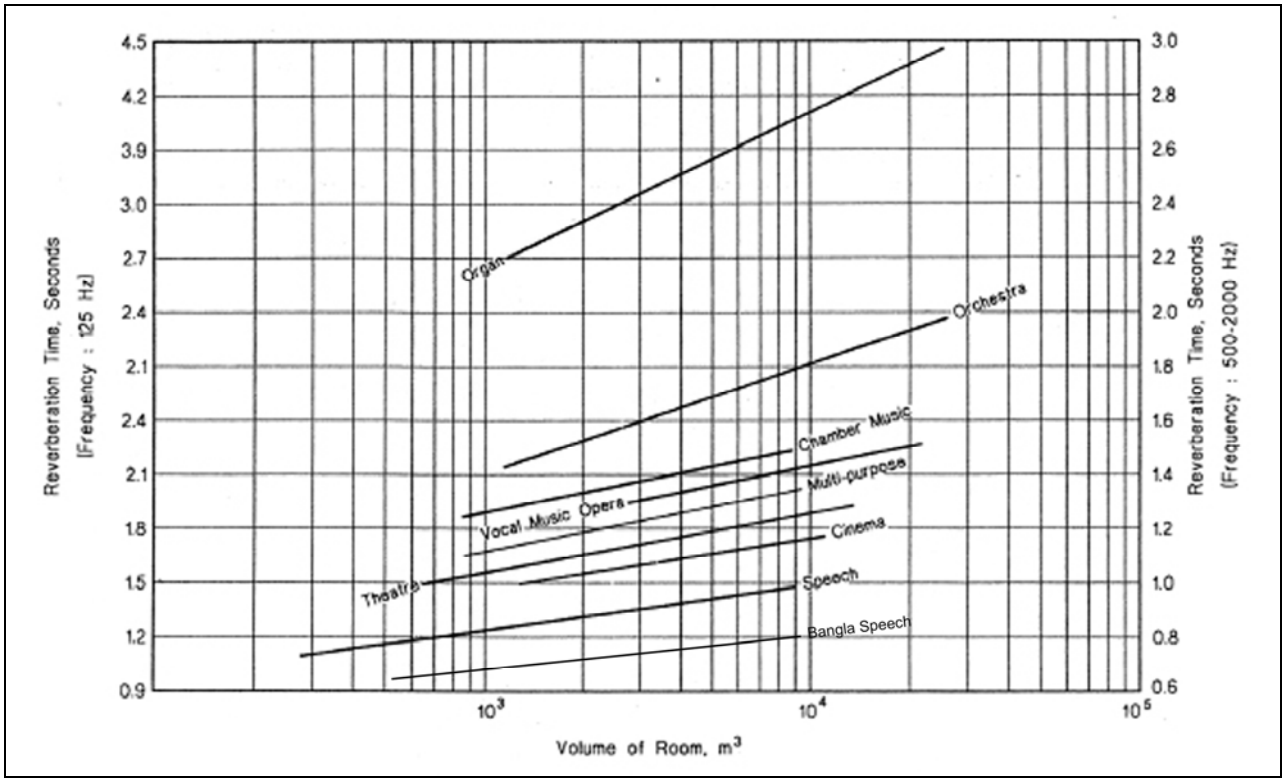

Fig. 8.4.1 Recommended optimum reverberation times for spaces of various uses

Notes:
1. The optimum RT for speech is shown here for English and Bangla language. It might be noted that the recommended optimum RT for speech in Bangla ranges from 0.5 s to 0.8 s.
2. The figure shows optimum RT for Western music and English vocals. For local music of Bangladesh, optimum RT might be assumed from its typological similarity to that of Western music.

3.6.3 **Sound Pressure Level**

a) In a space with a low background noise (<20 dBA) and a minimum Reverberation Time (close to 0.0 s), a maximum Percentage Syllable Articulation (PSA), and thus Speech Intelligibility can be achieved at sound pressure level of speech ranging from 60 dBA to 70 dBA (see Fig. G.1, Appendix G).

b) For speech halls with higher background noise (>20 dBA), the recommended Signal-to-Noise Ratio (SNR) is +15 dBA for children and at least +6 dBA for adults.

3.6.4 **Diffusion of Sound**

a) Diffusion of sound should be achieved in any space, so that certain key acoustical properties, like sound pressure level, reverberation time etc. are the same anywhere in the space.

b) There shall not be a difference greater than 6 dBA between sound pressure levels of any two points in the audience area.

b) Appropriate room geometry should be chosen to achieve diffusion of sound. Fig. I.2, Appendix I shows recommended proportion of a space to avoid standing wave, flutter echo etc., which are obstacles to achieve diffusion of sound.

3.7 SPEECH PRIVACY

3.7.1 **Principle of Speech Privacy between Enclosed Spaces**

3.7.1.1 When noise carries information, productivity and noise are related inversely. When noise does not carry information, it can be annoying, counter productive or can be useful as a masking sound, depending upon its frequency, intensity level and constancy.

3.7.1.2 The degree of speech privacy in a space is a function of following two factors:
a) The degree of sound isolation provided by the barriers between rooms
b) The ambient sound level in the receiving room

3.7.1.3 In case of an airtight barrier between two rooms, the sound intensity level of the source room (1) and the receiving room (2) are related as,

$IL_2 = IL_1 - NR$

where, NR is reduction, IL_2 and IL_1 are sound intensity levels in the receiving and source room respectively.

3.7.1.4 An transmitted noise level IL_2 is not annoying to a majority of adults, if a properly designed background sound is a maximum 2 dBA less than IL_2. For example, a transmitted noise IL_2 of 40 dBA in a room with a background sound of at least 38 dBA will not cause annoyance to most people.

3.7.1.5 The upper intensity level of usable background masking sound is usually taken as about 50 dBA; any higher intensity level itself will cause annoyance.

3.7.2 **Sound Isolation Descriptor**

3.7.2.1 For speech sound, a descriptive scale is shown in Table 8.4.4

Table 8.4.4
Relative Quality of Sound Isolation
Source: Stein, B. et al., 2006. *Mechanical and Electrical Equipments for Buildings.* John Wiley & Sons, New Jersey.

Ranking	Descriptor	Hearing Condition [a]
6	Total privacy	Shouting barely audible.
5	Excellent	Normal voice levels not audible. Raised voices barely audible but not intelligible.
4	Very good	Normal voice levels barely audible. Raised voices audible but largely unintelligible.
3	Good	Normal voice levels audible but generally unintelligible. Raised voices partially intelligible.
2	Fair	Normal voice levels audible and intelligible some of the time. Raised voices generally intelligible.

1	Poor	Normal voice levels audible and intelligible most of the time.
0	None	Normal voice levels always intelligible.

[a] Hearing condition in the presence of ambient noise, if any.

3.7.2.2 Relation between barrier STC and hearing condition on receiving side with background noise level at NC-25 is shown in Table 8.3.5

Table 8.3.5
Barrier STC and Hearing Condition on Receiving Side with Background Noise Level at NC-25
Source: Stein, B. et al., 2006. *Mechanical and Electrical Equipments for Buildings*. John Wiley & Sons, New Jersey

Barrier STC	Hearing Condition	Descriptor and Ranking [a]	Application
25	Normal speech can be understood quite easily and distinctly through the wall.	Poor/1	Space divider
30	Loud speech can be understood fairly well. Normal speech can be heard but not easily understood.	Fair/2	Room divider where concentration is not essential
35	Loud speech can be heard but not easily intelligible. Normal speech can be heard only faintly, if at all.	Very Good/4	Suitable for offices next to quiet spaces
42-45	Loud speech can be faintly heard but not understood. Normal speech is inaudible.	Excellent/5	For dividing noisy and quiet areas; party wall between apartments
46-50	Very loud sounds (such as loud singing, brass musical instruments or a radio at full volume) can be heard only faintly or not at all.	Total Privacy/6	Music room, practice room, sound studio, bedrooms adjacent to noisy areas

[a] See Table 8.4.4.

3.7.2 **Speech Privacy Design for Enclosed Space**

3.7.2.1 Fig. J, Appendix J shows a Speech Privacy Analysis Sheet, which shall be used to determine speech privacy rating number for design of enclosed space.

3.7.2.2 Following factors are involved in speech privacy rating of enclosed-space:

a) Space rating of source room (Room No. 1)

i) Speech effort - a measure of loudness of speech

ii) Source room factor - gives the approximate effect of room absorption on the speech level in the source room. The scale in Fig. J, Appendix J represents average absorption. For live rooms the factor should be raised by 2 points and for dead room the factor should be lowered by 2 points. Factors $a + b$ give the approximate source-room voice level.

iii) Privacy allowance-determines the measure of privacy required, such as *Normal Privacy* and *Confidential Privacy*.

b) Isolation rating of receiving room (Room No. 2)

iv) The STC rating of the barrier (see Table I.1 and I.2, Appendix I)

v) Noise reduction factor A_2/S indicates receiving room absorption, that is, the difference between *NR* and *TL,* where A_2 is the area of receiving room and S is the area of the barrier

between the rooms. Absorption is assumed to be average. For live rooms the factor should be lowered by 2 points and for dead room the factor should be raised by 2 points.

vi) Recommended background noise level in the receiving room. As a reference, Table 8.4.2 might be used.

3.8 SOUND AMPLIFICATION SYSTEM

3.8.1 **Objectives and Design Criteria**

3.8.1.1 A well designed sound amplification system should augment the natural transmission of sound from source to listener with adequate loudness and diffusion. It should never be used as a substitute for good building acoustics design, because it rarely overcomes or corrects any serious deficiency; rather, it may amplify and exaggerate the deficiency.

3.8.1.2 An ideal sound amplification system shall give the listener the desired loudness, directivity, intelligibility and other acoustical qualities.

3.8.1.3 Spaces seating less than 500 (approximately, 1400 m^3 volume) should not require any sound amplification system if it is properly designed; since, a normal speaking voice can maintain speech level of 55 to 60 dBA in this volume of space.

3.8.1.4 The central type amplification system is preferred, in which a loudspeaker or a cluster of loudspeakers is placed directly above the source of sound to provide desired realism and intelligibility. In case, the ceiling height is low and sound can not reach all listeners from a central type; a distributed system can be used with a number of loudspeaker each serving a small area with low-level amplification. A distributed system is particularly feasible in areas under the balcony.

3.8.1.5 A careful location of microphone should be chosen to avoid feedback of sound from loudspeaker to the microphone.

3.9 OCCUPANCY A: RESIDENTIAL BUILDINGS

3.9.1 **Controlling Noise**

Controlling measures shall have to be taken against noise coming from outdoor and indoor sources as specified in Sec 4.4 and 3.5.

3.9.2 **Space Layout**

a) Quiet and noisy quarters shall be grouped and separated horizontally and vertically from each other by rooms (or spaces) not particularly sensitive to noise such as entry, corridor, staircase, wall closets or other built-in building components.

b) If a living room in one apartment is located adjacent to a living room in another apartment, adequate sound insulation should be provided in separating wall.

c) Bedrooms shall be located in a relatively quiet part of the building.

d) Bathrooms must be separated acoustically from living rooms both horizontally and vertically.

If bathroom fixtures are installed along walls which separate living room and bathroom, adequate sound insulation should be provided in separating wall.

e) Measures should be taken to avoid transmission of footstep noise through floors.

3.9.2.2 **Sound Insulation Factors**

a) Separation for Sound Insulation: The sound insulation criteria in residential units are to be based on three grades:

i) Grade I criteria apply mainly to fully residential, quiet rural and suburban areas and in certain cases to luxury apartment buildings or to dwelling units above the eighth floor of a high-rise building.

ii) Grade II criteria apply to residential buildings built-in relatively noisy environments typical of urban or suburban areas.

iii) Grade III criteria express minimal requirements applicable to very noisy locations, such as commercial or business areas (like shop houses with dwelling units on the upper floors) or downtown areas.

iv) Among the above three categories, Grade II covers the majority of residential constructions and shall therefore be regarded as a basic guide.

v) In all grades wall constructions and floor-ceiling assemblies between dwelling units shall have STC ratings at least equal to the values given in Table 8.3.6 and 8.3.7.

v) An STC rating of not less than 45 dB is to be provided in walls and floors of residential buildings, between dwelling units of the same building and between a dwelling unit and any space common to two or more dwelling units.

vi) Table I.2, Appendix I shows STC requirements for different spaces of specific occupancies.

Table 8.3.6
Airborne Sound Insulation of Partitions Between Dwelling Units

Source: Stein, B. et al., 2006. *Mechanical and Electrical Equipments for Buildings.* John Wiley & Sons, New Jersey.

Apt. A		Apt. B	Grade II STC
Bedroom	to	Bedroom	52
Living room	to	Bedroom[a]	54
Kitchen[b]	to	Bedroom[a]	55
Bathroom	to	Bedroom[a]	56
Corridor	to	Bedroom[a,c]	52
Living room	to	Living room	52
Kitchen[b]	to	Living room[a]	52
Bathroom	to	Living room	54
Corridor	to	Living room[a,c,d]	52
Kitchen	to	Kitchen[e]	50
Bathroom	to	Kitchen	52
Corridor	to	Kitchen[a,c,d]	52
Bathroom	to	Bathroom	50
Corridor	to	Bathroom[a,c]	48

For Grade I, add 3 points; for Grade III, subtract 4 points.

[a] Whenever a partition wall may serve to separate several functional spaces, the highest criterion must prevail.

[b] Or dining or family or recreation room.

Table 8.3.7
Airborne and Impact Sound Insulation of Floor-Ceiling between Dwelling Units

Source: Stein, B. et al., 2006. *Mechanical and Electrical Equipments for Buildings.* John Wiley & Sons, New Jersey.

Apt. A		Apt. B	Grade II STC	Grade II IIC
Bedroom	above	Bedroom	52	52
Living room	above	Bedroom[a]	54	57
Kitchen[b]	above	Bedroom[a,c]	55	62
Family room	above	Bedroom[a,d]	56	62
Corridor	above	Bedroom[a]	52	62
Bedroom	above	Living room[e]	54	52
Living room	above	Living room	52	52
Kitchen	above	Living room[a,c]	52	57
Family room	above	Living room[a,d]	54	60
Corridor	above	Living room[a]	52	57
Bedroom	above	Kitchen[c,e]	55	50
Living room	above	Kitchen[c,e]	52	52
Kitchen	above	Kitchen[c]	50	52
Bathroom	above	Kitchen[a,c]	52	52
Family room	above	Kitchen[a,c,d]	52	58
Corridor	above	Kitchen[a,c]	48	52
Bedroom	above	Family room[e]	56	48
Living room	above	Family room[e]	54	50
Kitchen	above	Family room[e]	52	52
Bathroom	above	Bathroom[c]	50	50
Corridor	above	Corridor	48	48

[c] It is assumed that there is no entrance door leading from the corridor to the living unit.
[d] Criterion applies to the partition. Doors in corridor partition must have the rating of the partition, not vice versa.
[e] Double wall construction is recommended to minimise kitchen impact noise.

For Grade I, add 3 points; for Grade III, subtract 4 points.
[a] This arrangement requires greater impact sound insulation than the inverse, where a sensitive area is above less sensitive area.
[b] Or dining or family or recreation room.
[c] It is assumed that the plumbing fixtures, appliances and piping are insulated with proper vibration isolation.
[d] The airborne STC criteria in this table apply as well to vertical partitions between these two spaces.
[e] This arrangement require equivalent airborne sound insulation than the converse.

b) Reduction of Airborne Noise : In case of air borne noise (between the frequency range 100-31500 Hz), a sound insulation of 50 dB shall be provided in between the living room in one house or flat and rooms/bed rooms in another. The value shall be 35 dB in between different rooms of the same house. (See Appendix I for airborne sound insulation properties of walls, doors and windows).

c) Reduction of Airborne Noise Transmitted through the Structure: Exterior walls shall be rigid and massive and have good sound insulation characteristics with as few openings as possible. Windows with acoustic louvers might be used to protect noise intrusion, while allowing ventilation.

Ventilation ducts or air transfer openings (ventilators), where provided, shall be designed to minimize transmission of noise, if necessary, by installing some attenuating devices.

d) Construction of sound insulation doors shall be of solid core and heavy construction with all edges sealed up properly. Hollow core wooden doors and light weight construction shall be avoided because these are dimensionally unstable and can warp, destroying the seal along the perimeter of the door.

e) Rubber, foam rubber or foamed plastic strips, adjustable or self-aligning stops and gaskets shall be used for sealing the edges of the doors. They shall be so installed that they are slightly compressed between doors and stop when the door is in a closed position. In simple cases the bottom edges shall have a replaceable strip of felt or foam rubber attached to minimize the gap between door and floor.

f) Separation between the two faces of the door shall be carried through uninterruptedly from edge to edge in both directions. Damping treatments shall be inserted between individual layers of the doors. Ordinary doors with surface leather padding shall not be used.

g) Automatic damped door closers are to be used whenever applicable and economically feasible in order to avoid the annoying sound of doors slamming.

h) The difference between the TL of the wall and that of the door shall not exceed 10 dB.

i) The floor of a room immediately above the bedroom or a living room shall satisfy the Grade I impact sound insulation.

3.10 OCCUPANCY B: EDUCATIONAL BUILDINGS and OCCUPANCY C: INSTITUTIONAL BUILDINGS

3.10.1 **Sources of Noise**

3.10.1.1 **Outdoor Noise**: Measures shall be taken in planning and design to control noise from external sources mentioned in Sec 3.4 and Sec 3.5.

3.10.1.2 **Indoor Noise**:

The following sources of indoor noise shall be taken into consideration:

a) Wood and metal workshops, machine shops, technical as well as engineering testing laboratories, other machine rooms, typing areas etc. which produce continuous or intermittent noises of disturbing nature,

b) Music rooms,

c) Assembly halls, particularly those which are attached to the main building,

d) Practical work spaces, gymnasiums and swimming pools,

e) School kitchen and dining spaces,

f) Entry lobby, foyer, lounge, corridor and other circulation spaces.

3.10.2 **Planning and Design Requirements**

3.10.2.1 **Site Planning**: The school building shall be located as far away as possible from the sources of outdoor noise such as busy roads, railways, neighbouring market places or adjacent shopping areas as well as local industrial and small scale manufacturing concerns.

Where the site permits, the building shall be placed back from the street, in order to make use of the noise reducing effect of the increased distance between street line and building line.

If adequate distance between the school/institution building and the noisy traffic route cannot be provided, rooms which do not need windows or windowless walls of classrooms shall face the noisy road.

Car parking areas shall preferably be located in remote parts of the site.

3.10.2.2 **Activities and Space Layout:** The minimum requirement for sound insulation in educational buildings shall be as specified in Table 8.4.3.

3.10.2.3 **Halls and Circulation Areas:** The lobby, lounge areas etc. or other circulation spaces and linking corridors shall be separated from teaching areas, lecture galleries or laboratories. No direct window openings shall be placed along the walls of the corridors or circulation areas.

Doors, ventilators and other necessary openings shall be designed with sufficient foam or rubber seals, so that they are noise proof when closed.

3.10.2.4 **Noise Reduction within Rooms**:
Lecture halls of educational institutions (with a seating capacity of more than 100 persons) shall be designed in accordance with the relevant acoustical principles.

Lecture halls with volumes of up to about 550 m^3 or for an audience of up to about 150 to 200, shall not require a sound amplification system, if their acoustical design is based on appropriate principles and specifications.

A diagonal seating layout shall preferably be used for rectangular lecture rooms of the capacity mentioned above as it automatically eliminates undesirable parallelism between walls at the podium and effectively utilizes the diverging front walls as sound reflectors.

3.11 OCCUPANCY D: HEALTH CARE BUILDINGS

3.11.1 **Sources of Disturbing Noise**

3.11.1.1 **Outdoor Noise:** Sources of outdoor noise specified in Sec 4.4 shall be taken into consideration for planning and design. Additionally, health care service facilities like ambulance, medicine and equipment vans, store deliveries, laundry and refuse collection trolleys are also frequent sources of noise. Health care buildings shall be sited away from such sources as far as practicable.

3.11.1.2 **Indoor Noise:** Indoor noise sources include mechanical and mobile equipment like X-ray and suction machines, drilling equipment etc.

Planning and design shall take into account the following sources of noise:

a) The handling of sterilizing, as well as metal or glass equipment,

b) Wheeled trolleys used for the purpose of carrying foods and medical supplies,

c) Mechanical equipment like mechanical and electrical motors, machineries, boilers, pumps, fans, ventilators, transformers, elevators, air-conditioning equipment etc.

d) Operational facilities like refrigerators, sterilizers, autoclaves etc. ,

e) Patient service facilities including oxygen cylinders or tanks, saline stands, carrier carts and instrument cases, etc.

f) Maintenance work of engineering services like plumbing and sanitary fixtures or fittings, hot and cold water and central heating pipes, air-conditioning ducts, ventilation shafts etc., and

g) Audible calling systems, radio and television sets.

3.11.2 **Planning and Design Requirements**

3.11.2.1 **Site Planning:** Site shall be selected to keep adequate distance from traffic noise from highways, main roads, railroads, airports and noise originating from parking areas. In addition to the requirements of Sec 4.4.3, the following requirements shall be fulfilled:

a) In the selection of a site and site planning, consideration shall be given to:

i) Distance from exterior noise,
ii) Effect of high buildings adjacent to the site which can act as noise reflectors, and
iii) Traffic conditions surrounding the site.

b) Parking areas might be carefully located at the farthest possible corners of the premises. If enough space is not available to provide facilities for the desired number of vehicles, parking spaces shall be provided in more than one area. Loading platforms and service entries are to be planned in such a manner as to minimize noise in areas requiring silence.

c) Closed courts shall preferably be avoided.

3.11.2.2 **Activities and Space Layout:** The following points might be given due consideration in the planning and design of health care buildings.

a) Rooms to be used for board meetings, conference, counselling and instructional purposes shall be grouped near public zones of the building in such a way that spread of noise can be avoided.

b) Long corridors might be avoided, as it may freely spread noise.

c) The main kitchen might be housed in a separate building and connected to the wards only by service lifts or a service stair. If this is impracticable, it shall be planned beneath the wards, rather than above them.

d) Mechanical plants might preferably be placed in separate buildings.

e) Rooms housing equipment, operational facilities and patient service facilities shall be designed for adequate sound insulation.

f) Closed courts might be avoided, unless rooms facing the court are air-conditioned with completely sealed and air tight windows.

g) The units which are themselves potential sources of noise for example, children's wards and outpatient departments, shall be treated with special care regarding the protection against noise.

3.11.2.3 **Noise Reduction in the Sensitive Area**: In health care buildings, many sensitive areas such as operation theatres, doctor's consultation rooms, intensive care units and post-operative areas shall be provided with special noise control arrangements.

These rooms shall preferably be isolated in locations (or corners) surrounded by other intermediate zones which ensure protection of the core area from outdoor noise.

A sound reduction of about 45 dBA between the consulting and the waiting rooms shall be provided in order to weaken the transmission of sound.

A lobby like space in between the interconnecting and communicating doors shall be provided.

3.11.2.4 **Sound Insulation Factors:** The rooms and indoor spaces of a health care building shall be treated with sound absorptive materials.

Different STC ratings of walls specified for separate components of buildings shall have to be considered as follows:

a) For airborne noise, the average STC rating of wall and floors shall be 50 dB.

b) An STC rating of 55 dB shall be required between rooms whose occupants are susceptible to noise.

c) In general an average STC of 45 dB is to be provided for corridor walls and for walls between patient rooms.

d) All doors shall be fitted with silent closers. Doors to opposite rooms might be positioned in a staggered manner.

e) For ward doors, a corresponding STC of 35 dB shall be provided.

f) PVC mats, rubber mats or other resilient materials and rubber shod equipment shall be used in utility rooms, ward kitchens and circulation areas as floor coverings.

Other finish materials like rubber tile, cork tile, vinyl tile or linoleum which can also help reduce the impact noise substantially shall be used alternatively.

g) Mobile equipment, such as trolleys and bed, oxygen cylinder carriers and stretchers shall be made relatively silent by means of non-friction wheels with rubber tyre.

h) Special treatments such as thin nonporous coverings or films over some soft absorbent materials shall be used for good sound absorption when a washable acoustical treatment is desired.

i) Door and window curtains or screens, as well as bed sheets etc. shall be used wherever the indoor openings are located to help reduce reverberation in the hard surfaced surroundings. Curtain rails, rings and runners of silent type shall be used so that they generate as little frictional noise as possible.

j) Ventilation ducts and conduits shall be laid out in such a way that they do not open an easy by-pass for spreading out any noise from other sources. These conduits and ducts shall be completely sealed around the pipes where they pass through walls and floors.

k) Special care shall be taken to reduce noise of plumbing equipment and fixtures. Specially made silencing pipes and flushing fixtures shall be used to reduce the noise of water closet and cisterns in lavatories and toilets.

Ducts carrying waste or water pipes shall be properly lined with sound insulation material to prevent noise from the pipes passing through duct walls into the patients' wards or cabins or the spaces susceptible to noise.

l) Wherever available, cisterns shall be used to replace the pressure operated flushing system so that the disturbance becomes less irritating.

3.12 OCCUPANCY E: ASSEMBLY

3.12.1 **General**
Buildings of Occupancy E shall be designed both for transmission of noise through the walls and openings and also for internal acoustics. Public address systems installed in such buildings shall conform to the standards and specifications.

3.12.2 **Sources of Noise**

3.12.2.1 **Outdoor Noise**: The following sources of noise shall be taken into account in planning and design:

a) Traffic noise (air, road and rail) and noise from other outdoor sources entering through walls, roofs, doors, windows or ventilation openings,

b) Noise from any other gathering spaces, public meetings, outdoor activities and crowds, particularly during the time of breaking of shows and performances,

c) Noise produced from parking areas.

3.12.2.2 **Indoor Noise**: The following indoor noise sources shall be taken into account in planning and design:

a) Noise from other adjacent halls located within the same building used for similar performance, or for seminar, symposium or general meetings,

b) Noise produced from ticket counters, lobby or lounge areas, rehearsal rooms, waiting areas and corridors,

c) Noise generated from other ancillary services located within the building, like cafeteria or snack bar, tea shop, post office, bank or the like,

d) Noise generated from the mechanical or electrical equipment, air-conditioning plants, ventilation channels and ducts, plumbing and water lines etc.

3.12.3 **Planning and Design Requirements**

3.12.3.1 **Site Planning and Acoustical Requirements**: The noise control of auditoria or assembly halls shall begin with sensible site planning following the measures and precautions stated below:

a) The auditorium shall be effectively separated from all exterior and interior noise and vibration sources as far as practicable;

b) The assembly halls shall be protected from vehicular or air traffic, parking or loading areas, mechanical equipment, electrical rooms or workshops.

The following are the acoustical requirements for good hearing conditions in an auditorium which shall be ensured in planning and design:

a) Adequate loudness shall have to be ensured in every part of the auditorium;

b) The sound energy shall be uniformly distributed in the hall;
c) Optimum reverberation characteristics shall have to be provided;

d) The hall shall be free of such acoustical defects as echoes, long delayed reflections, flutter echoes, sound concentrations, distortions, sound shadow and room resonance etc.;

e) Noise and vibration shall be excluded or reasonably reduced in every part or the hall room.

3.12.3.2 **Activities and Space Layout in Divisible and Multi-purpose Auditoria**

a) A protective buffer zone of rooms between exterior noise source and auditorium proper shall be designed.

b) Rooms in the buffer zone (lobbies, vestibules, circulation areas, restaurants, ticket counters, offices etc.) shall be shut off from the auditorium proper by sound insulation doors.

c) The purposes of the subdivided spaces shall be clarified, in order to establish the predictable intensity of the various sound programmes.

3.12.3.3 **Noise Reduction within Rooms**

a) There shall not be any use of continuous, unrecognizable and loud background noise.

b) The ventilating and air-conditioning system shall be so designed that the noise level created by the system is at least 10 dB below the permissible background noise level specified in noise criteria level.

c) In order to protect the hall from external noise the minimum sound reduction value required in an auditorium is 65 dB for a concert hall and 60 dB for a theatre. This reduction shall be provided on all sides.

3.12.3.4 **Sound Insulation Factors**

a) Rooms in the buffer zone (lobbies, vestibules, circulation areas, restaurants, counter and issue desk corners, office etc.) shall have sound absorbing ceilings and carpeted floor. If the rooms are to be used for the purposes of verbal instructions only, a moderate degree of sound insulation (STC 40 to 45 dB) shall be accomplished by the movable partitions.

b) If audio equipment or loudspeakers are to be used, an acoustically more effective, efficient partition system shall be used, with sound insulation of STC 45 to 50 dB.

c) An insulation of STC 50 to 60 dB shall be provided if any section of the space is selected for the performance of live music.

d) All windows shall have to be eliminated from the main auditorium walls in order to exclude excessive outdoor noises.

e) Suspended ceilings shall accommodate the ventilating, air-conditioning and electrical services above the room.

f) In order to increase the effectiveness of the suspended ceilings the following measures shall be taken :
   i) The ceiling membrane shall weigh not less than 25 kg/m^2;

   ii) The ceiling membrane shall not be too rigid;

   iii) Noise transmission through the ceiling shall have to be avoided by the use of a solid, airtight membrane;

   iv) Gaps between ceiling and surrounding structure shall be sealed;

v) The air space between ceiling membrane and structural floor shall be increased to a reasonable maximum;

vi) An absorbent blanket is to be used in the air space above the ceiling;

vii) The number of points of suspension from the structural floor above shall be reduced to a minimum;

viii) Hangers made of resilient substance shall be preferable to the rigid ones.

g) In order to improve the airborne or impact sound insulation of a ceiling the following specifications shall be followed:

i) The ceiling membrane shall have a minimum of 25 mm solid cement plaster layer with completely closed, airtight and sealed joints all around;

ii) If further reduction of undesirable noise is desired within a sound insulated room, sound absorptive treatment shall be provided along the underside of the solid ceiling.

3.12.3.5 **Masking Noise:** The artificial noise produced by electronically created background noise for the purpose of drowning out or masking unwanted noise, shall be provided. The process shall effectively suppress minor intrusions which might interrupt the recipient's privacy.

3.12.3.5 The maximum permissible background noise levels in various occupancies are specified in terms of Balanced Noise Criteria (NCB) curves. Each of the NCB curves is expressed by the sound pressure level values in the important 1200-2400 Hz frequency band. The NCB levels shall be used to specify the desirable lowest limit under which the background noise must not fall. (See Table 8.4.1 and Fig. D, Appendix D).

Note: The general configuration of the NCB curves is quite similar to the noise rating (NR) curves established by the International Organization for Standardization, used mostly in the European practice

3.13 OCCUPANCY F: BUSINESS AND MERCANTILE BUILDINGS

3.13.1 **General**
Buildings of Occupancy F shall be planned and designed to minimize noise from external and internal sources.

3.13.2 **Sources of Disturbing Noise**

3.13.2.1 **Outdoor Noise:** The following sources of outdoor noise and those specified in Sec 4.4 shall be taken into account in the planning and design of business and mercantile buildings:
- Traffic,
- Playgrounds,
- Market places and shopping areas,
- Crowds grouped around the buildings for business purpose or other.

3.13.2.2 **Indoor Noise**: The following sources of indoor noise shall be identified for noise attenuation within buildings:

a) Mechanical noise, caused by heating, ventilating and air-conditioning systems, elevators, escalators and pneumatic tubes etc. ;

b) Noise produced by office equipment or machines such as typewriters, printers, teleprinters, reproduction, tabulating and punching machines etc.;

c) Noise produced by mechanical amplifiers, for example in seminar halls, conference rooms or staff training rooms or the like where public address system is used;

d) Machine noise generated from slide rooms, projection rooms and from electrical and mechanical machines like generators, transformers, switch rooms and electric substations etc. ;

e) Typical office noise created by speech, voices in circulation areas, opening and closing of doors etc. ;

f) Plumbing systems, ventilation plants, lift machineries, air-conditioning and cooling systems.

3.13.3 **Planning and Design Requirements**

3.13.3.1 Site Planning: Rooms susceptible to noise shall be located away from the sources of noise.

3.10.3.2 Activities and Space Layout: Spaces producing noise and those susceptible to noise shall be separated as far as practicable. The effective length of long corridors shall be minimized. Swing doors are to be provided at intervals.

3.10.3.3 Noise Reduction in the Sensitive Areas

a) Open plan Offices

i) The floor area may be carpeted in order to absorb airborne noise and footstep noise. The carpet shall preferably be thick and placed on top of resilient floors.

ii) The entire portion of the ceiling shall be treated with sound absorption materials. Such treatment shall be applied to the screens and nearby walls also.

A highly sound absorptive ceiling with a sound absorption coefficient of 0.70 shall preferably be used to absorb 70 per cent of the sound energy reflecting 30 per cent of it.

iii) Moderately noisy office equipment (like typewriters, telephones, computers etc.) shall be distributed as uniformly as possible all over the office space.

iv) Noisy office equipment shall be concentrated into specific areas of the office space. The space shall be treated with maximum amount of sound absorptive material and visually separated from the rest of the office.

b) General Offices: Sound absorbent ceiling shall be provided in corridors. Hard floor finishes and batten floors in corridors shall be avoided. Floor ducts shall be planned on one side of corridors.

3.10.3.4 Reduction of Noise at Source: The following measures shall be undertaken to reduce noise at source depending on the degree of noise reduction desired.

a) The noise from slamming of doors shall be reduced by fitting automatic quiet action type door closers. Continuous soft, resilient strip set into the door frames as well as quiet action door latches shall be used.

b) Machines like typewriters, calculators, printers etc. shall be fitted or installed with resilient pads to prevent the floors or tables (on which they stand) from acting as large radiating panels.

c) Noises from ventilating systems, from a uniform flow of traffic or from general office activities, shall be considered to generate an artificial masking noise. In open plan offices the provision of a relatively high but acceptable degree of background noise (from the ventilating or air-conditioning system) shall be provided, in order to mask undesirable office noises created by typewriters, telephones, office machines or loud conversation and to provide a reasonable amount of privacy.

The background noise masking system shall be introduced gradually without disturbing the feeling of the occupants.

The air-conditioning system may be used to generate background masking noise if the noise level from the ceiling fans, ducts etc. can be suitably reduced to generate the desired frequency spectrum.

3.10.3.5 Sound Insulation Factors: The acoustical performance of the partitions dividing rentable office spaces shall not exceed an STC rating of 25 to 30 dB, unless the background noise is so high that it masks the sound coming through the lightweight partition.

If lightweight partitions are employed for subdivision of large spaces into executive cabins and secretarial areas, the following measures shall be taken to increase the insulation factors:

a) Sound barriers shall be provided up to above the false ceiling with a noise reduction characteristic that will not be affected by ducts, conduits or other cable lines including electricity and water pipings installed in the ceiling space.

b) Where construction of light weight partitions is considered essential, a double skin panel shall be preferred.

The panels shall be installed apart from each other either by use of separate framing or by use of elastic discontinuities in the construction. Sound absorbing materials shall be provided in the air cavity between the panels so that more insulation can be assured.

c) All apertures, gaps and joints at side walls, floors and ceiling junctions shall be properly sealed.

d) A double panel hollow floor construction shall be employed with heavy sound damping materials introduced between the panels for effective reduction of the structure-borne noise transmitted from upper floors to the floors below, particularly when lightweight floors are provided in multi-use spaces.

Lightweight materials having high natural frequencies may resonate or vibrate due to an applied vibratory force, which may be caused by mechanical equipment, road or rail traffic etc. These materials, if used for specific reasons, shall be isolated from the source of noise in order to reduce the amount of vibration transmitted to the building.

e) The floor surfaces surrounding the office space may be lined with a carpet of high sound absorption.

f) For sound adsorption with floor carpeting, the following characteristics shall be maintained:

i) Fibre type carpet shall not be used, as it has practically no effect on sound absorption;

ii) Hair, hair jute and foam rubber pads shall be used for higher sound absorption than the less permeable rubber coated hair jute, sponge rubber etc.;

iii) To improve sound absorption the loop-pile fabrics with increased pile height (with the density held constant) shall be applied;

iv) The backing shall be more permeable for higher sound absorption.

3.14 OCCUPANCY G: INDUSTRIAL BUILDINGS

3.14.1 General Noise Levels

In the noise control of industrial buildings the following requirements are to be fulfilled:

a) An acceptable acoustical environment for individual workers and machine operators;

b) Speech communication among operators to the required degree;

c) Protection of other workers or office employees (either close to the noise source or at some other location within the same building);

d) Prevention of noise transmission into adjacent buildings or into the surrounding community.

3.14.1.1 **Intermittent Noises** : Intermittent noise in the form of isolated explosions, and periodic noise related to pressure relief valves, hammering, grinding and sawing operations etc. shall be identified for enforcing controlling measures.

3.14.1.2 **Sources of Noise:** The following sources of noise in industrial buildings and manufacturing plants shall be identified and investigated to find whether the machines are in smooth operation and producing minimal mechanical noise.

a) Fabrication and assembly machines;

b) Machines used for material transport and general plant services;

c) Noise caused by impact and coupled with resonant response of the structural members, connected to the impacting surfaces;

d) High frequency sounds generated from grinders;

e) Frictional noise occurring at the time of sawing, grinding or sanding, as well as during the cutting on lathe machines and in brakes or from bearings;

f) Noise generated from piping systems and valves;

g) High velocity flow of air, steam or other fluids that undergo an abrupt change in pipe diameter which give rise to turbulence and resultant noise, and noise generated by rapid variation in air pressure caused by turbulence from high velocity air, steam or gases;

h) Unpleasant noise identified with rotating or reciprocating machines, which is generated due to pressure fluctuation in the fluids inside the machines.

3.14.2 **Hearing Damage Risk Criteria**

When the sound level at a particular section in a factory or industrial building exceeds the specified level in terms of magnitude and time (as shown in Table 8.4.4 below), feasible engineering control shall be applied and implemented in order to reduce the sound to the limits shown. Personal hearing protection equipment shall be provided and used if such control fails to reduce sound levels.

3.14.3 **Interference with Communication**

In industries where the operator has to follow verbal instructions during operation of the machine the background noise shall be reduced to an acceptable level.

Precautionary measures shall be taken so that the noise generated inside may not be the cause of accidents by hindering communication or by masking warning signals.

3.14.4 **Requirements for Noise Reduction**

3.14.4.1 **Noise Reduction by Layout and Location:** Considerable noise reduction may be achieved by a sensible architectural layout in noisy industrial buildings following the steps mentioned below:

a) Noisy areas shall be separated from spaces requiring silence.

b) The office block is to be located in a separate building. If this is not possible, the office space in a factory shall be segregated from the production area as far as practicable.

c) The office building shall not have a common wall with the production areas. Where a common wall is unavoidable it should be of heavy construction (not less than 375 mm thick).

d) Electrically operated vehicles shall be used as far as practicable, since they eliminate most of the noise normally associated with combustion engines.

3.14.4.2 **Noise Reduction at Source**: In order to suppress the noise at the source relatively silent machines and equipment shall be installed. Additionally the following provisions shall be adhered to:

a) Appropriate type of manufacturing process or working method shall be selected which does not cause disturbing noise. Machine tools and equipment are to be selected carefully in order to attain lower noise levels in the machine shop.

b) Maintenance of vibrating and frictional machineries shall be ensured.

c) Impact noises in general shall be reduced; soft and resilient materials shall be applied on hard surfaces where impact noise can originate.

d) Rubber tyres or similar other materials shall be fixed on the areas or surfaces used for the handling and dropping of materials.

e) The area of the radiating surface from which a noise is radiated shall be reduced to a minimum.

f) Resilient flooring (carpeting, rubber tile, cork tile, etc.) shall be used adequately to reduce impact transmission onto the floor.

g) Flexible mountings, anti-vibration pads, floating floors etc. shall be used to prevent the transmission of vibration and shock from various machines into the building or structure.

h) Mechanically rigid connecting paths must be interrupted by resilient materials so that the transmission of vibration and noise is reduced.

3.14.4.3 **Isolator Specifications**

a) Isolators shall be made of resilient materials like steel (in the form of springs), soft rubber and corks.

b) Direct contact between the spring and the supporting structure shall be eliminated, in order to reduce transmission of high frequencies by metal springs.

c) Rubber or felt pads shall be inserted between the ends of the springs and the surfaces to which they are fixed.

d) Felt or cork shall be used under machine bases, as resilient mats or pads.

e) If the equipment is massive like drop hammers causing serious impact vibration (in larger manufacturing plants), it shall be mounted on massive blocks of concrete, on its own separate foundation.

f) The foundation shall have a weight 3 to 5 times that of the supported machines.

g) A sound reduction of 5 to 10 dBA shall have to be realized from the vibration isolation measures.

3.14.4.4 **Noise Reduction by Enclosures and Barriers**: When the plant is large in which the overall noise level results from many machines, an enclosure shall be provided.

a) When only one or two machines are the dominant source of disturbing noise, the noisy equipment shall be isolated in a small area of enclosure.

b) The enclosure shall be in the form of close fitting acoustic box around the machines. The box shall be of such character that the operator can continue with his normal work outside the box.

c) An enclosure around the offending unit shall be impermeable to air and lined with sound absorbing materials such that the noise generated by machines is reduced substantially.

d) i) When the industrial plant is a large one in which the resultant noise level is produced from a number of machines, enclosures shall be used either for supervisory personnel or operators who are engaged in monitoring the automatic machines. Such barriers may have inspection openings.

ii) Enclosures of this type shall ensure noise reduction of at least 30 dBA, and shall be made of sheet metal lined inside with an appropriate insulation material.

iii) Where curtains are used to isolate the noisy equipment in a small area, they shall be of full length i.e. from ceiling to floor and shall be made of fibreglass cloth and lead or leaded vinyl.

e) If the size of the machine is large and asks for more working spaces, thus not permitting close fitting enclosures, the machine shall be housed in a separate room or enclosure.

The inside of the enclosure shall be lined with sound absorbing materials in order to reduce the contained noise.

f) If after all these measures are taken the noise level still remains above a tolerable degree, the workers shall be provided with earplugs for protection.

3.15 ACOUSTICAL REQUIREMENTS OF SPECIAL OCCUPANCIES

3.15.1 **Susceptible Buildings**

3.15.1.1 **Recording and Radio Studios:** A recording studio shall present optimum acoustical conditions. A differentiation shall be made among the numerous various purposes of studio use.

a) Particular attention shall be given to the following requirements:
i) An optimum size and shape of the studio shall be established following the design criteria;

ii) A high degree of diffusion shall be secured;

iii) Ideal reverberation characteristics shall be provided;

iv) Noises and vibration shall be completely eliminated and acoustical defects shall be totally prevented.

b) The acoustical treatments shall be uniformly and proportionately distributed over the three pairs of opposite surfaces enclosing the studio.

c) Portable acoustic screen and a reverberation chamber shall be provided so that the desired reverberation condition can be achieved.

d) Variable absorbers such as hinged or sliding panels, rotatable cylinders, adjustable drapery etc. shall be fixed on wall surfaces and ceiling areas.

e) All surfaces shall be carefully checked for echoes, flutter echoes etc.

f) Parallel surfaces shall be eliminated or treated with highly absorptive acoustical materials (throughout the frequency range between 63 and 8000 Hz).

3.15.1.2 **Research Laboratories**

a) In the selection of site, care shall be taken to ensure that no noise generating installations exist in the vicinity.

b) Location of laboratories shall be secluded from the noisy zones within the building.

c) A sound insulation of at least 35 dB shall be achieved by means of acoustic partitions where offices are attached to the laboratory.

d) Sound absorbing screens shall be used where scientists and researchers are engaged in laboratory activities and desk work simultaneously.

e) Transmission of noise through service ducts, pipes, lifts and staircases shall be guarded.

f) Double glazed windows shall be provided in the noise sensitive areas. There shall be a minimum gap of 100 mm between the two glasses.

3.15.1.3 **Music Rooms**: The following provisions shall apply to music rooms, including rehearsal rooms, instructional space, practice booth etc.

a) Acoustical conditions in practice booths and listening booths shall have a reverberation time of 0.4 to 0.5 second.

b) Adequate floor area, room height, room shape and volume must be established to achieve proper reverberation.

c) Sound absorbing materials shall be applied sufficiently so that the excessive sound generated by bands or individual instruments can be soaked up.

d) Parallelism between opposite surfaces shall be avoided.

e) Entire surfaces of at least two adjacent walls, and all the ceiling area shall be treated with sound absorbing materials.

3.15.1.4 **Libraries:** A quite and peaceful interior shall be maintained inside libraries. The following provisions are to be adhered to in planning and design:

a) Screening and sound insulation measures shall be undertaken in and around the reception/issue desk and photocopying facility areas.

b) Stack rooms, store rooms and administrative offices shall be planned in such a way that the audiovisual areas are properly isolated from external noises.

c) Walls enclosing the library shall have a sound reduction value of not less than 50 dB.

d) Fanlights shall be double glazed and non-openable.

e) Walls facing the corridors or other noisy areas shall not have fanlights or borrowed lights unless they are double glazed.

3.15.1.5 **Law Courts and Council Chambers**

a) Entrance into court rooms and council chambers (especially from circulation areas and gathering spaces) shall be through baffle lobbies, with two sets of doors fitted with silencers.

b) Offices shall be planned around the court rooms or chambers for further protection against outdoor noise and the central rooms shall have a sound insulation value of not less than 50 dB (provided by 225 mm thick brick wall) to insulate against airborne noise in the corridors.

c) The court and chamber rooms shall have floors finished with resilient materials.

d) Ceiling and upper parts of the walls of lobbies and circulation areas shall have sound absorbing treatments.

3.15.2 **Public Address System**

3.15.2.1 Design of public address systems shall take care of equipment choice, positioning of the individual elements and other precautions to obtain optimum performance of the system.

3.15.2.2 Passenger terminals and other public places equipped with public address systems shall as far as practicable avoid the use of sound reflecting surfaces like hard walls and floors. Reverberation time shall be reduced as far as possible by using sound absorbing materials on walls and ceilings.

3.15.2.3 Reverberation built-up sound level shall not be relied upon. Direct sound shall preferably be audible in all areas to be covered by the public address system.

3.15.2.4 Sound levels of the public address system in the areas covered shall be adequately high to overcome background noise.

Related Appendices

Appendix D	Fig. D Activity Flow Diagram: Planning and Design in Building Acoustics
Appendix E	Table E.1 Allowable Upper Limit of Outdoor Noise Levels Table E.2 Typical Noise Levels Generated by Aircrafts Table E.3 Subjective Evaluation and Pressure Levels of Familiar Sounds
Appendix F	Fig. F.1 Noise Criteria (NC) and Balanced Noise Criteria (NCB) Curve Fig. F.2 Recommended Criteria for Sound Isolation between Dwelling Units
Appendix G	Fig. G.1 Coefficients for Percentage Syllable Articulation (PSA) Fig. G.2 Liveliness of a Room as a Function of its Volume and Total Absorption
Appendix H	Table H Octave Band Average Sound Absorption Coefficients
Appendix I	Table I.1 Typical STC Ratings for Building Elements Table I.2 Recommended STC for Partitions for Specific Occupancies Fig. I.1 Speech and Music in Aural Field Fig. I.2 Recommended proportion of a space
Appendix J	Fig. J Speech Privacy Analysis Sheet
Appendix K	Form K - Checklist: Acoustical Planning and Design