NOISE IN BUILDINGS

Reducing sound levels in the built environment

This Building Technology Resource explains basic building acoustics, how to prevent external noise from entering buildings, and how to control sound transmission within and between rooms.

The factors that influence noise levels in buildings are diverse and often difficult to predict. However, underestimating their importance can significantly prejudice the desired acoustic environment for a building's occupants and its neighbours. A thorough assessment at the planning stage of all potential noise sources and propagation paths, followed by appropriate construction and acoustic treatments, is the most sensible course of action. Any oversight could generate noise complaints from occupants, require expensive remedies, or even render the building unsuitable for its intended purpose.

THE PHYSICS OF SOUND

Sound propagates through air as a pressure wave with a fixed speed, which causes air particles to vibrate in the direction of propagation. The pressure fluctuations that the sound creates above and below the static value of atmospheric pressure are collectively termed the sound pressure. Due to the enormous range of sound pressures, this value is expressed as sound pressure level (SPL) in decibels (dB) using a logarithmic scale.

As sound is periodic in nature, its frequency can be expressed as the number of cycles per second in units of hertz (Hz). The audible frequency range for human hearing is about 16 Hz to 16 kHz, although sensitivity to high frequencies generally decreases with age. Most noises consist of a mixture of sounds from different parts of the frequency spectrum; exposure to single pure tones or noise at a single frequency is uncommon.

HUMAN RESPONSES TO SOUND

The human ear responds to pressure fluctuations in the audible frequency range to produce the sensation we call sound. However, the ear is not equally sensitive to all frequencies. To describe SPLs of any specific noise on an equal loudness basis, acoustic engineers weight the different frequencies making up the sound to take into account the sensitivity of the human ear (Table 1). These weighted values are added together to produce a single value referred to as the A-weighted sound level, denoted by dB(A). These weighted sound levels are widely used in noise control and noise-related occupational health assessment. Each increase of 10 dB(A) doubles the perceived volume of a noise, while each decrease of 10 dB(A) halves it. An A-weighted sound level of 0 dB(A) is approximately the lower threshold of hearing for a typical young adult.

Worksafe Australia recommends a maximum exposure of noise up to 85 dB(A), sustained for 8 hours a day. As noise levels increase, the exposure times likely to cause permanent hearing loss decrease. All Australian states and territories have workplace legislation limiting noise exposure to levels that will minimise permanent hearing damage. Such levels are well above the average sound levels of everyday human activities – including talking – and well above the annoyance threshold of most individuals (Table 2).

TABLE 1. TYPICAL SOUND LEVELS NEAR DIFFERENT NOISE SOURCES.

Situation	Sound level (dB(A))
Jet engine taking off	150
Chain saw, hammer on nail, ambulance siren, thunder	120
Shouting in ear, leafblower, car horn, baby crying	110
Electric drill	95
Street with heavy traffic, noisy restaurant	85
Blender, food processor	80–90
Noisy office	65
Normal conversation	60
Quiet residence during the day	50
Normal office	45
Quiet residence at night, library, quiet office	40
Bedroom at night, soft whisper	25–30

TABLE 2. MAXIMUM SOUND LEVELS RECOMMENDED FOR VARIOUS TYPES OF HUMAN OCCUPANCY AND ACTIVITY.
DATA FROM AS/NZS 2107:2016.

Type of occupancy/activity	Sound level (dB(A))
Houses and apartments in inner city areas or entertainment districts or near major roads	
Living areas	35–45
Sleeping areas (night time)	35–40
Houses and apartments in suburban areas or near minor roads	
Living areas	30–40
Sleeping areas (night time)	30–35
Houses in rural areas with negligible transportation	
Sleeping areas (night time)	25–30
Public buildings: Library reading area	40–45
Office buildings: General office area	40–45
Health buildings: Nurseries	35–45
Sports and clubs building: Leisure centre and gaming	40–50
Supermarkets	<55

When people perceive the volume or pitch of a noise to be annoying or disturbing, they can react negatively. Continued annoyance over an extended period can adversely affect their quality of life and potentially cause serious psychological and physiological disturbances.

ACOUSTIC PERFORMANCE OF BUILDINGS

The acoustic performance of buildings (or, more specifically, building elements such as walls, floors, windows and doors) is dependent on several basic principles:

- Mass insulates against noise. The extent to which a building element can block sound is related to its mass per unit area. In this respect, masonry (e.g. concrete and brick) is better than wood or plaster, while plant foliage is virtually ineffective.
- Openings allow sound to penetrate. Even small openings can compromise the acoustic performance of an otherwise effective sound insulator. All gaps and openings, such as those around doors and windows, should be well sealed for good sound insulation.
- Absorptive linings are effective at attenuating sound that strikes and is reflected from the surface on which they are mounted. Thus, they are useful for reducing reverberation in a room and in the cavity of a building element. However, they are not effective sound insulators by themselves.
- A solid continuous barrier that blocks the direct line of sight between a noise source and a receiver will reduce, but not totally stop, sound reaching the receiver. Such barriers attenuate mainly higher frequencies, while lower frequencies tend to bend around them.
- In the open air, sound levels decrease as the distance from a sound increases. This is not generally the case inside rooms, because sound reverberates off reflecting surfaces.
- Sound can travel from one area to another by several paths (Figure 1). The path with the least attenuation will determine the overall performance of the sound insulation.

PLANNING FOR A SUITABLE ACOUSTIC ENVIRONMENT

The most effective way of ensuring a suitable acoustic environment is to plan for it at the design stage by stipulating the desired or likely acoustic environment inside and outside the building. Rearranging areas of activity can often prevent the noise from one activity interfering with other activities or stop external noise from discouraging the use of an area. Where this is not possible, suitable acoustic treatment should be built into the design from the start. It can be both expensive and inconvenient to improve the acoustic performance of a building after it has been constructed.

LOCATION

Ideally, new buildings should be sited only in areas determined to be acceptable for their purpose. Building design may attenuate external noise – such as from front and back yards, parks and gardens, schools, traffic, public transport corridors and flight paths – but cannot eliminate it. High barriers can help to reduce some traffic and rail noise, because the sound has to bend through a significant angle to pass over the barrier, but they have little effect on aircraft noise from above (Figure 2).

BUILDING ELEMENTS

To provide good sound insulation, a building element must be airtight and have a high mass per unit area (Figure 3). One way to improve sound insulation is to increase the thickness of the building element, but unfortunately that also increases its bending stiffness, which can counteract the sound-insulating effect of the increased mass. This means that rather than replacing a single leaf of a building element with a thicker version of the same material, it is better to add extra mass per unit area by adopting a double-leaf construction.

The amount of sound that an air cavity transmits can be reduced by making the cavity wider. While the optimal width of the air cavity depends on the mass per unit area of the two leaves and on the frequency of the sound to be attenuated, 50–100 mm is a good guide for most typical building materials.

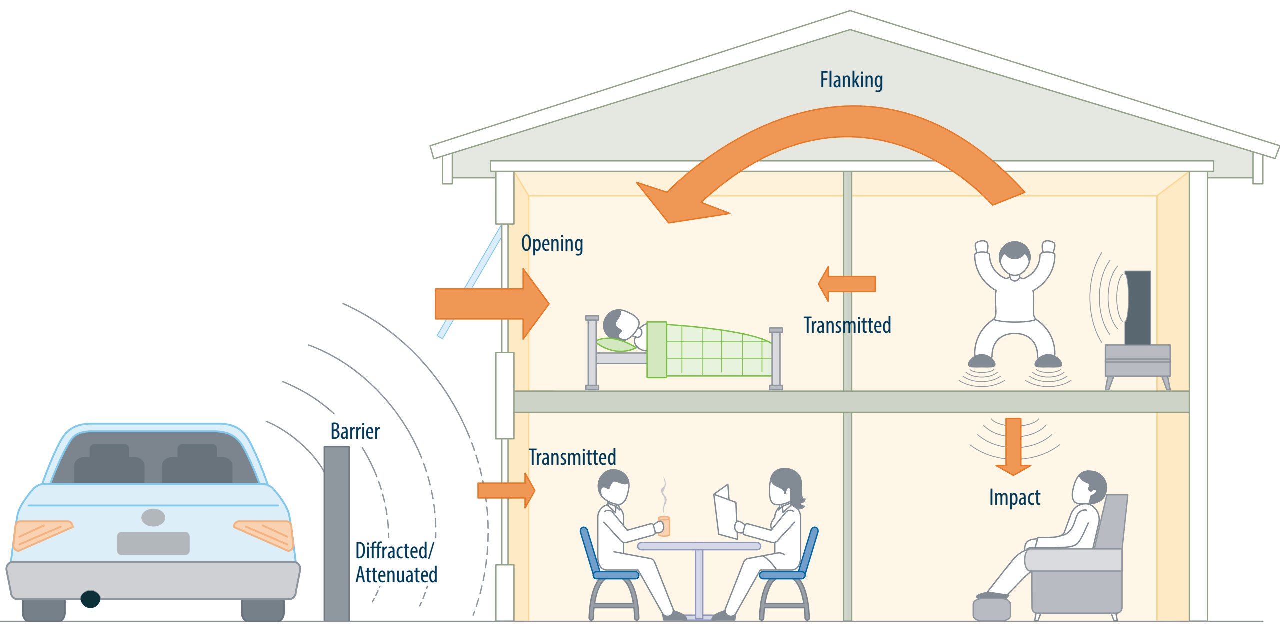

FIGURE 1 Noise is transmitted by various paths throughout a building.

FIGURE 2 Noise-absorbing barriers (also called sound walls, noise walls, noise barriers, sound barriers or acoustical barriers) are often built next to motorways to manage traffic noise. (vladdon/Shutterstock)

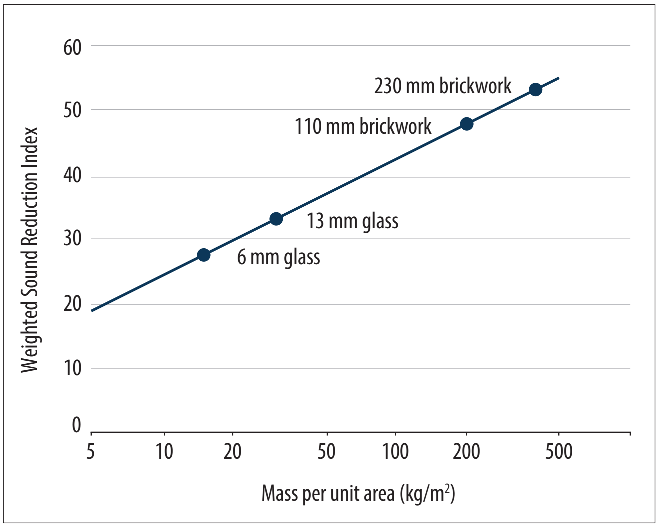

FIGURE 3 A material's ability to reduce sound transmission typically increases with its mass.

Reverberation within the cavity should be reduced, or deadened, using sound-absorbing material, such as a medium- to high-density porous material (Figure 4). Roof spaces are commonly fitted with thermal insulation such as glass fibre, mineral wool or cellulose fibre batts, which will also deaden any sound energy that intrudes into the cavity. Care must be taken to ensure that sound-absorbing batts do not bridge the cavity in multi-leaved masonry, as they may enable water to enter and cause damage.

FIGURE 4 Porous sound-absorbing material should be added to wall cavities and roof spaces to deaden sound reverberation. (BanksPhotos/iStock)

Once the air cavity has been deadened, most of the remaining sound transmission between the leaves of the building element occurs via the structural connections between them. As in the case of the air cavity, this can be reduced by decreasing the stiffness of the connections. For non-load-bearing building elements, lightweight steel studs work well. For other building elements, at least one of the leaves can be mounted on resilient channel bars and/or other resilient components. For brick cavity and brick veneer building elements, the minimum number of brick ties needed for structural reasons should be used.

WINDOWS AND DOORS

Windows and doors are often the weakest link when it comes to preventing noise from entering buildings. For better acoustical performance, it is often necessary to use double glazing with thick heavy glass and as large a cavity as is practicable. (Note that double glazing designed specifically for thermal insulation may not achieve this, as the spacing of the glass leaves is usually too narrow for good sound insulation.) Because aircraft, trains and road vehicles tend to make a lot of annoying low frequency noise, cavity construction may attenuate sound no more effectively than a single building element with the same mass per unit area, unless very wide cavities are used. In particular, thicker single glazing may be as effective as double glazing that incorporates a narrow air gap.

Similarly, as normal doors are not thick enough to take advantage of cavity construction for increasing their sound insulation, higher acoustic performance is generally achieved through a solid core design.

Whether or not they are operable, windows and doors need to be well sealed, as sound will transmit through a weak, incorrectly installed or incomplete seal. Hinged windows and doors should close onto compressible, airtight seals wherever possible. If a raised doorsill can be tolerated, a similar seal can be used on the bottom of the door. Otherwise, a seal that automatically lowers itself when the door closes should be built into the bottom of the door for optimal sound insulation.

VENTILATION

Open windows or doors will allow sound to enter and exit the building, bypassing any sound insulation in the building envelope. To prevent the need for opening windows and doors, sound-insulated buildings may require mechanical ventilation. These ventilation systems require acoustical treatment via attenuators, which usually consist of ducts lined with sound-absorbing material behind an acoustically transparent lining like perforated metal or thin plastic film.

In many parts of Australia, especially during summer, closed buildings also need to be cooled, which may add substantially to running costs. There is a complex trade-off between the acoustical performance and energy efficiency requirements of buildings.

OTHER SOUND TRANSMISSION PATHS

Any direct paths along which sound can travel from the exterior to the interior of the building envelope must be blocked. Wall and roof vents not required by the building code may be covered. If the top or bottom of the cavity in cavity brick (such as double brick) or brick veneer has any air gaps, they must be sealed. Walls with high levels of sound insulation may also need to have sound attenuators on their subfloor vents to prevent sound from bypassing them. As the high porosity of single-leaf masonry can reduce its sound insulation, this material is often rendered to reduce its porosity.

SOLVING NOISE PROBLEMS IN BUILDINGS

When trying to reduce the SPL of an environment with many sources of noise, it is important to deal with the sources of highest SPL first. If several sources are close in SPL, start with those that are simplest and cheapest to address.

In some cases, it may be more economical to treat the source of the noise itself. For example, reducing the noise generated by equipment or machinery may be best achieved by modifying, enclosing or replacing the existing equipment.

Where it is not possible to treat a noise at its source, the sound transmission may be reduced using barriers and sound-absorbing materials. For example, impacts such as footsteps on the floor of a room above – a common noise problem in buildings – may be quietened by installing thick, high-quality carpet and underlay. Alternatively, the structural coupling between the ceiling and the floor above could be reduced, or a floating floor could be installed in the room above if there is sufficient headroom. When sound propagates along ventilation ductwork, it can be attenuated by inserting a silencer in the ductwork path. A space can be shielded from noise produced in another area by increasing the sound insulation and adding sound absorption to both spaces, which will reduce the effect of the reverberant sound fields in each room. Sound transmitted from one room to another can also often be decreased by sealing cracks and openings between them, increasing the mass of the weakest links such as doors and windows, or blocking flanking paths through common ceiling spaces. Within a room, absorbent ceiling tiles and partitions can be used to minimise reflected and direct noise (Figure 5).

Regardless of the method used, noise levels should be monitored closely before and after treatment to determine whether it has been successful.

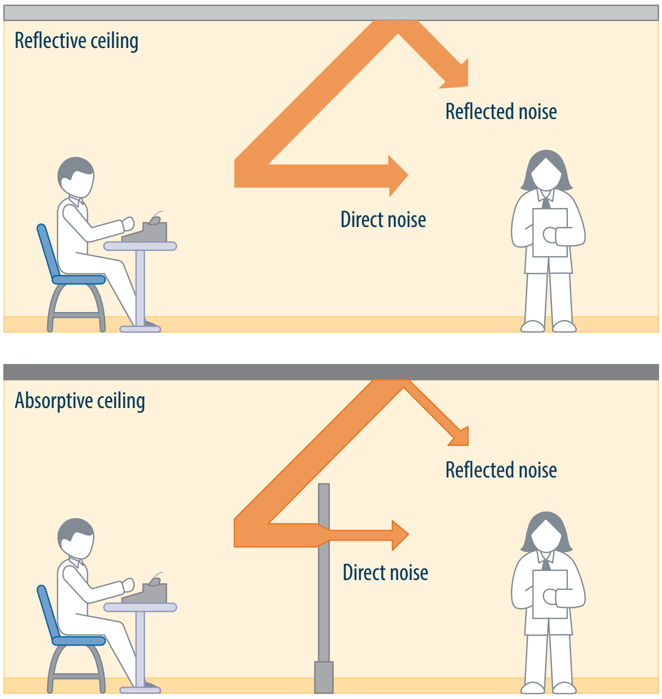

FIGURE 5 Sound transmission within a room can be attenuated using absorbent ceiling tiles and partitions.

MORE INFORMATION

Additional information can be found in the following resources. Please check your local authorities for specific legislation, codes and guidelines, as they can vary between states and territories.

Australian/New Zealand Standard AS/NZS 2107:2016 Acoustics—Recommended design sound levels and reverberation times for building interiors

Kinsler LE, Frey AR, Coppens AB, Sanders JV (2000) Fundamentals of acoustics. 4th ed. New York: Wiley

Knudsen V, Harris CM (1980) Acoustical designing in architecture. Melville, USA: Acoustical Society of America

Parkin PH, Humphries HR, Cowell JR (1979) Acoustics, noise and buildings. 4th ed. London: Faber

Vér IL, Beranek LL (2006) Noise and vibration control engineering: Principles and applications. 2nd ed. Hoboken: Wiley