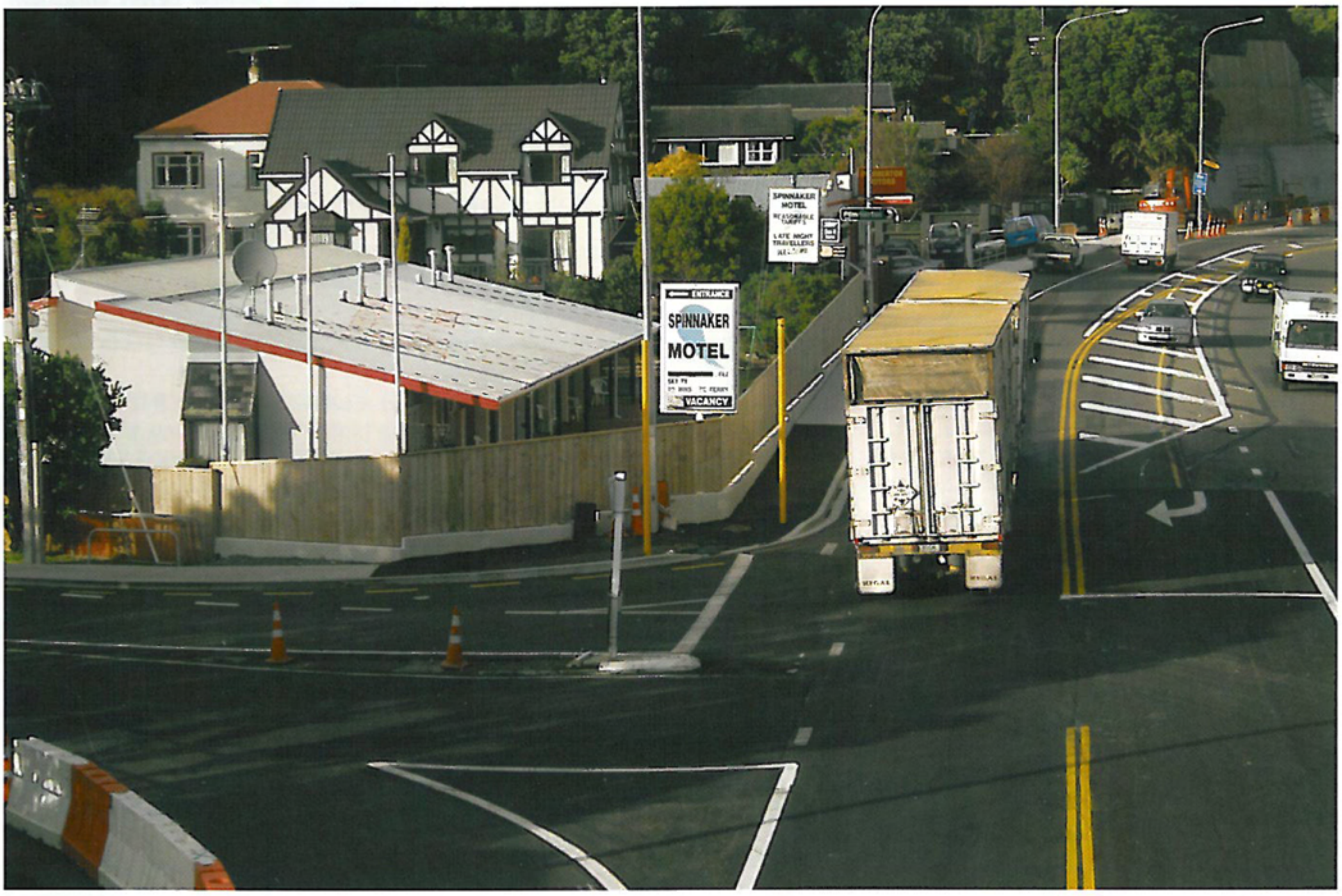
BULLETIN

BRANZ
BUILDING ON KNOWLEDGE

June 2005 NUMBER 461

PRACTICAL SOUND CONTROL



- This *Bulletin* provides a brief background to the principles of sound generation and transmission in residential buildings.
- It outlines practical methods available to help control unwanted sound, but does not attempt to provide a resource for specific acoustic design.

This *Bulletin* replaces *Bulletin 331* on the same subject published in 1995.

1.0 INTRODUCTION

1.0.1 This *Bulletin* is aimed at helping reduce noise problems for people in residential buildings. It provides background to the principles of sound generation and transmission, and outlines the methods available to reduce unwanted sound (noise) in buildings. It does not attempt to cover the specialised field of specific acoustic design which should be referred an acoustic consultant.

1.0.2 For residential situations, it may not be possible to eliminate annoying noise problems by simply placing acoustic rated barriers between the source of the noise and the recipient. It is generally necessary to also reduce structurally transmitted noise generated by direct impacts, such as foot-falls on hard surfaces, banging doors and scraping furniture. Indirect flanking paths must also be carefully addressed. For all multi-occupancy buildings, an acoustic consultant is recommended.

1.0.3 The New Zealand Building Code sets performance requirements for new construction or refurbishment of existing buildings. These include:

- inter-tenancy elements between household units are required to have a Sound Transmission Class (STC) of 55 minimum
- inter-tenancy floor/ceiling elements have a minimum Impact Insulation Class (IIC) of 55.

1.0.4 The external walls of two closely adjacent detached houses, with no windows, provide a sound reduction of approximately 60 dBA for the direct sound path. However, the indirect sound path via nearby open windows in walls perpendicular to the boundary could provide a sound path that would significantly reduce that figure.

2.0 TERMINOLOGY

The following terms are specifically related to sound and sound performance.

dB (decibel)	A measure of sound intensity or level based on a logarithmic scale. The scale extends from 0 dB (threshold of audibility) to 130 dB (threshold of pain).
dB (A)	A measure of sound intensity modified to approximate the response of the average human ear.
Frequency	The number of oscillations per second measured in Hertz (Hz), which determines the pitch of the sound. The higher the frequency, the higher the pitch. The average human response range is 20 – 20,000 Hz.
IIC	Impact Insulation Class – the single figure value for the reduction in impact sound intensity achieved by a floor/ceiling element.
Lmw	ISO equivalent of Impact Insulation Class.
ISI	Impact Sound Insulation – the degree to which a building element, such as a floor/ceiling assembly, reduces the amount of impact sound generated by footsteps. The numerical value decreases as insulation increases.
NRC	Noise Reduction Coefficient – the single figure value for the sound absorbing capacity of a material or building element averaged over the range of frequencies – 250, 500, 1000, 2000 Hz.
TR	Reverberation Time – is the time taken for the sound energy level of a sound at a certain frequency to degrade by 60 decibels. TR = 0.16V/A where V is the room volume in cubic metres and A is the total absorption in M^2 sabines.
Rw	Weighted sound reduction index – is the single figure value for the reduction in speech sounds through a building element over the frequency range 150 – 3,150 Hz.
STC	Sound Transmission Class – the single figure rating for sound energy reduction through a building element over the frequency range 125 – 4,000 Hz.
SPL	Sound Pressure Level.

Note: laboratory measured ratings quoted by manufacturers may not be achievable in the field, and additional measures may need to taken to achieve an acceptable performance.

3.0 SOUND SOURCES

3.0.1 Sound is generated when a surface vibrates to generate a pressure wave or disturbance in the surrounding air. For a sound to be audible by the human ear the vibrations must be in the approximate range of 20 to 20,000 cycles per second (Hz). The most common annoying sound sources are:

- **airborne sound from indoor sources** such as television, entertainment systems, printers, copiers, appliances, motors and voices over which we have no control. The sound from these can be transmitted to adjacent spaces through gaps or openings such as windows and through the structure
- **structural-borne sound** caused by equipment: sound caused by equipment or by objects contacting a surface (footsteps, scraping chairs and slamming doors); or by vibrating machines such as washing machines and ventilation equipment
- **airborne sounds from outdoor sources** (e.g. cars and trucks, trains, neighbour's music, lawn mowers, children, dogs and late night revellers) which enter a building through openings such as windows, gaps and weak points in the building envelope (e.g. thin single thickness glazing).

3.0.2 Sound becomes noise when it disturbs those who hear it but cannot influence the source. Overseas research indicates that even in multi-tenanted buildings, about 80% of the noise events which annoy occupants originate from outside the building. The amount of discomfort caused is influenced by the:

- time of day or night
- type of sound (i.e. repetitive, tonal content)
- level of masking by background noise
- sensitivity of the hearing of the person
- level of sound control provided by the built envelope
- frequency of the sound
- loudness of the sound.

4.0 SOUND PATHS

4.0.1 Some airborne sound paths are shown in Figure 1:

- a direct path between the source and the receiver

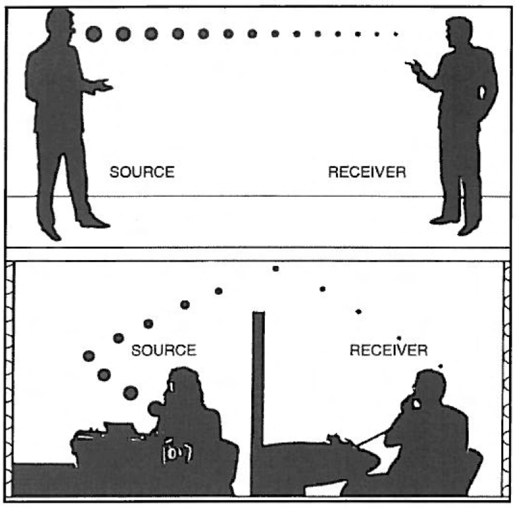


Figure 1. Direct sound travels an unobstructed path to the listener. Reflected sound strikes surfaces on its way to the listener.

- indirect path (reflected or diffracted) path where the sound goes over or around a barrier to the receiver.

4.0.2 Sound can also travel through the structural elements and solid materials surrounding the source. Airborne sound causes the solid material to vibrate, which transfers the sound through the material to become airborne sound again on the other side.

4.0.3 Flanking paths occur when sound gets around or past elements intended to control sound. Sound, for example, will pass through a porous ceiling and be reflected over a partition to the space on the other side by the floor above. Similarly, sound can pass out through one window, and either go directly through or be reflected through an adjacent window. Ventilation ducting and back-to-back electrical junction boxes can also transmit sound between spaces.

4.0.4 Sound can pass through very small cracks. A 0.2 mm wide gap along the top of a 3.6 m long wall reduces the STC rating of a 65 dB rated wall by 20 dB. Acoustic sealant must be installed at the perimeter of all acoustically rated elements to seal these gaps.

4.0.5 As sound travels readily through air, closing a door or window is often the simplest way to reduce the transmission of sound. Dealing with the sound at source by providing effective containment, such as automatic closing doors, can be a quick and cost-effective sound control solution.

Table 1. Components of sound quality.			
Sources	**Transmission paths**	**Receiving room**	**Receiver**
human voices, amplified speakers, trains, traffic, dogs, reciprocating plant and tools, footsteps, chairs scraping, doors banging	direct path diffracted over and around barriers flanking path reflected path	absorption characteristics volume geometry	in the same space in a separate space

Four main components determine the quality of the sounds we hear. Each has characteristics that will affect the sound (see Table 1).

5.0 SOUND LEVELS

5.0.1 Sound pressure levels are measured in decibels (dB) by a sound level meter. The scale is parabolic meaning that a 3 dB increase equals a doubling of the sound energy. Typical sound energy levels (in dB) are:

- threshold of pain 130
- aircraft take-off 120 plus
- loud band music 100 – 120
- heavy truck accelerating 80 – 100
- average volume of radio or TV 70 – 90
- human voice 1 m distance 55 – 60
- background noise in an office 35 – 60
- quiet house 25 – 35
- threshold of hearing 0

6.0 TREATING SOUND PROBLEMS AT SOURCE

6.0.1 There are a number of ways to attenuate (reduce) sound at its source. Within a living unit, the obvious actions of turning down the volume of sound systems, fitting soft seals on doors and pads on furniture legs can be quick and easy. However, the problem of slamming car doors or tooting horns when departing at night can only be avoided by locating communal parking areas well away from bedroom windows at the design stage.

6.0.2 For equipment which cannot be ‘turned down’ (printers, copiers and appliances) consider:

- relocating the offending item to another space which is further away or has a door
- replacing noisy equipment with quieter models
- preventing vibrations being transmitted through the structure by isolating the item with cushioning (carpet and underlay, separated construction techniques) or proprietary anti-vibration mountings
- creating a buffer zone (storeroom, lobby) between quiet and noisy activities
- isolating the source with a sound-reducing hood or enclosure using acoustic rated materials
- introducing sound-absorbing baffles around the offending noise to absorb some of the sound energy (requires specific design)
- screening car parking areas from sleeping areas.

6.0.3 Sound intensity can be attenuated to make it more acceptable for a listener by using sound-absorbing materials such as carpets, heavy drapes, upholstered furniture or specifically designed acoustic baffles. Absorption reduces reflections and reverberation time that can make sounds less intrusive, but this generally requires specific design of sound-absorbing elements which is outside the scope of this *Bulletin*. NRC is a single number rating of the sound-absorbing capacity of a material across a given range of frequencies. A material with a sound absorption coefficient of 0.85 absorbs 85% of incident sound energy. As a guide, materials are considered sound absorbing when their NRC is more than 0.40.

7.0 TREATING SOUND TRANSMISSION PATHS

7.0.1 Sound control is an integral part of all building design. Retrofitting sound control mechanisms can be expensive, disruptive and difficult to make as effective as an initial design solution.

7.0.2 Reducing sound transmission through building elements will involve one or a combination of the following mechanisms:

- decoupling parts of the structure
- resilient mountings
- adding mass in separate layers with insulating fibre-filled cavities
- reducing stiffness of potential propagating surfaces (very frequency dependant).

7.1 Decoupling

7.1.1 Decoupling the parts to reduce the transmission through the element can be achieved by using:

- wall, ceiling or floor construction where linings are not connected to the same structural or supporting member (Figure 2)
- double studs (Figure 3)
- separate floor ceiling joist systems
- resilient fixings for wall and ceiling linings (Figure 4)
- discontinuous flooring.

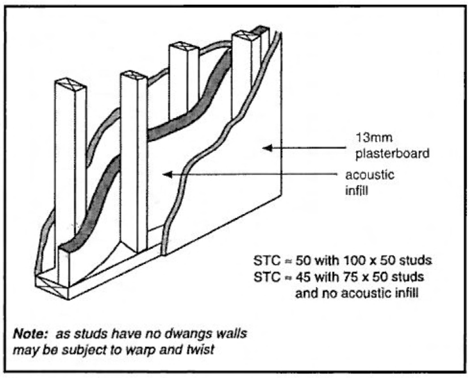


Figure 2. Staggered stud construction.

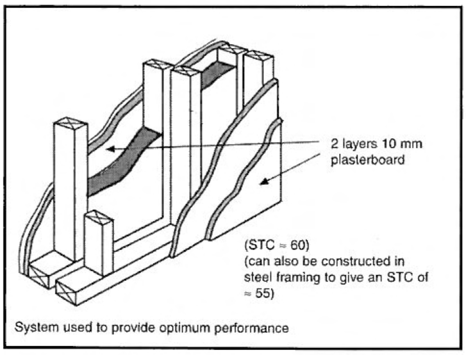


Figure 3. Double stud construction.

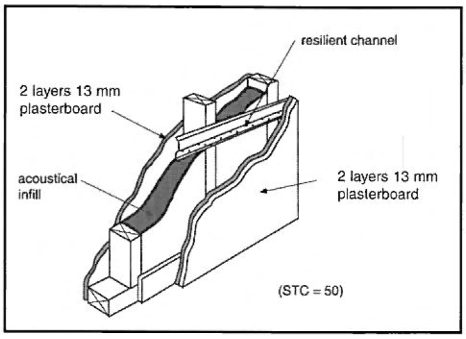


Figure 4. Use of resilient channel to support linings.

7.2 Adding mass

7.2.1 Mass can be added by:

- using proprietary acoustic rated lining or underlay materials
- adding a second layer of sound barrier material
- using solid core doors and thicker glass for windows (with appropriate edge seals).

7.3 Reducing stiffness

7.3.1 Reducing the sound transmission of wall elements by selective stiffness of elements requires specific design. A typical example is the fixing of wall linings to resiliently supported steel channels (Figure 4).

7.4 Improving acoustic performance of walls

7.4.1 Walls with sound reduction performance of:

< 30 dB – are of no sound control merit and are classified as a space divider only

> 30 dB – will allow conversations between occupants to be heard in an adjacent space

> 40 dB – will allow conversations to be heard if loud or if there is low background noise

> 50 dB – will provide reasonable acoustic security.

7.4.2 Where there is a suspended ceiling, ensure the ceiling/plenum/ceiling flanking path has the same STC rating as the walls, or that the walls extend up to the underside of the floor above.

7.4.3 Different wall construction methods and materials give different sound insulation performance ratings. To ensure the required performance levels are achieved, proprietary systems should be specified and carefully installed. It is extremely risky to use the specification relating to another brand on the grounds of generic similarity because the acoustic properties for generically similar materials can be different. It is critical that quality inspection of the installation is carried out to ensure performance. Examples of approximate laboratory measured STC's that can be achieved with typical wall construction methods are shown in Table 2.

7.5 Improving acoustic performance of floors

7.5.1 Carpet with rubber underlay or tiles with proprietary underlays can

Table 2. STC rating of walls.	
Approximate STC rating	**Typical generic wall construction methods**
25	6 mm wood fibre panels nailed to each side of 100 x 50 mm timber framing
30	10 mm gypsum plasterboard fixed to one side of 100 x 50 mm timber or steel framing
35	10 mm gypsum plasterboard fixed to each side of 100 x 50 mm timber or steel framing
40	10 mm gypsum plasterboard fixed to each side of 100 x 50 mm timber framing with the cavity filled with sound control fibreglass
45	2 layers of 10 mm gypsum plasterboard fixed to each side of 100 x 50 mm timber framing
50	75 x 50 mm studs staggered with 100 x 50 mm plates, 2 x13 mm gypsum plasterboard to each face and acoustical infill (Figure 2), or 1 layer 13 gypsum plasterboard fixed to a resilient channel on 100 x 50 timber studs with 2 layers of 13 mm gypsum plasterboard to the reverse face plus acoustical infill (Figure 4)
55	200 series concrete blocks with all cells filled plus either 12 mm of solid plaster or 13 mm plasterboard adhesive fixed to each face
60	staggered 63.5 x 35 mm steel stud with 2 layers 10 mm fire resistant gypsum plasterboard to each face and 75 mm acoustical infill, or staggered 100 x 50 mm timber studs with 2 layers 13 mm fire resistant gypsum plasterboard to each face (one face fixed to resilient channel) plus 75 mm acoustical infill
65	2 x 13 mm proprietary acoustic plasterboard each side of double staggered studs (steel or timber) plus 75 mm acoustic cavity insulation

Table 3. Typical IIC for some common acoustic rated floor/ceiling constructions.	
Approximate IIC rating	**Typical construction methods**
65	domestic weight carpet on underlay, 20 mm high density particleboard over joists which are separated from the ceiling joists by a 75 mm gap and a ceiling with an acoustical infill and 2 layers 13 mm plasterboard fixed to timber (Figure 6)
65	carpet on underlay over a concrete floor (150 mm minimum thickness and 400 kg/m^2 of face area)
70 plus	heavy duty commercial carpet on 8 mm rubber waffle underlay over 20 mm particleboard over 150 mm minimum depth timber joists with 75 mm acoustic fibreglass cavity insulation, steel furring fixed with proprietary acoustic suspension and a ceiling of one layer of 13 mm fire resistant gypsum plasterboard overlaid with 16 mm fire resistant gypsum plasterboard (this construction with foam backed vinyl in lieu of carpet and underlay has an IIC of 50)
70 plus	commercial carpet and underlay over 150 concrete with suspended ceiling with 13 mm acoustic plasterboard and insulation

improve acoustic performance of floors by reducing impact sounds like footsteps by up to 20 points as defined by Impact Insulation Class (IIC) – refer Table 3.

7.5.2 Disconnecting the ceiling below from the floor structure and adding mass such as two layers of proprietary noise control plasterboard can improve IIC by a further 25 points over a ceiling directly fixed to floor joist. However, care must be taken to ensure similar performance of the flanking paths at floor/wall junctions (see Figure 5).

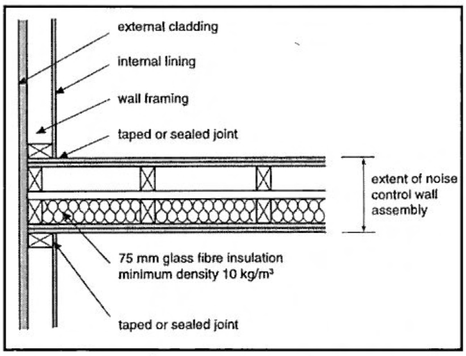


Figure 5. Internal/external wall junction for noise control between two units.

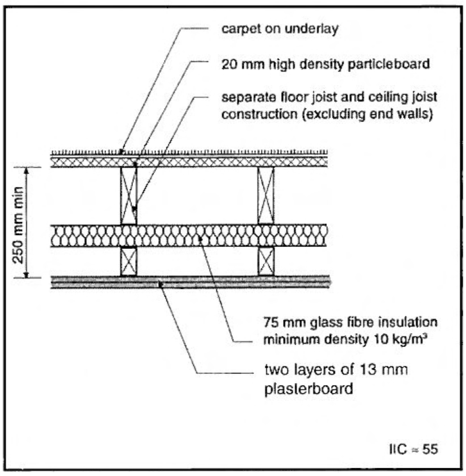


Figure 6. Floor/ceiling assemblies for noise control.

8.0 CONTROLLING EXTERNAL SOUND

8.0.1 Sound originating from outside a building is difficult to control because windows required for ventilation, light and views are weak points in the wall (especially when open). Windows with specially designed acoustic glazing will reduce noise levels, but have to be closed to be effective. The total cost of controlling external noise may have to include the cost of mechanical ventilation or air conditioning.

8.0.2 Site selection is the most significant factor for the external sound levels experienced within a new building. Factors to consider when selecting and planning a site layout are:

- potential noise sources such as motorways, arterial streets, some factories, airports, community buildings, hotels, sports clubs, facilities that operate 24 hours a day
- hill tops adjacent to traffic routes and sites in hollows and depressions can be noisier than level sites
- sites upwind from the noise source tend to be less noisy than those downwind
- existing landscape features or buildings that provide a buffer from noise, but consider the impact and likelihood of them being removed in the future.

8.0.3 Once a site has been selected, the impact of external sounds can be controlled by:

- keeping buildings on the site as far away as possible from the noise source (road etc) – noise levels reduce by 6 dB for each doubling of distance from point sources but only 3 dB from linear sources
- using the building as a barrier to shield and protect external living areas and internal spaces which require the lowest noise levels
- exploiting natural features such as slopes and using any excavated material to provide barriers (Figure 7)
- ensuring that sound barriers have no gaps
- minimising the window area facing the sound source
- dense low level multi-row planting with thick leafy growth down to ground level can reduce traffic noise, but single row planting such as a hedge has little effect.

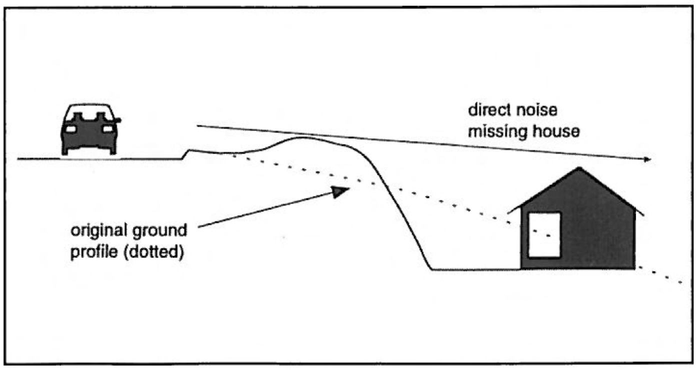


Figure 7. Use of natural slope of land and excavated material to maximise noise shielding.

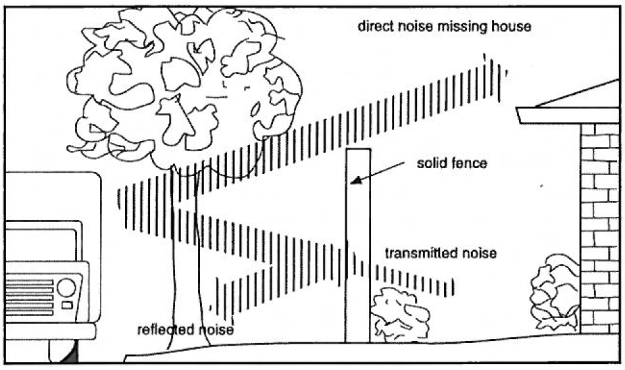


Figure 8. Noise impeded by solid wall.

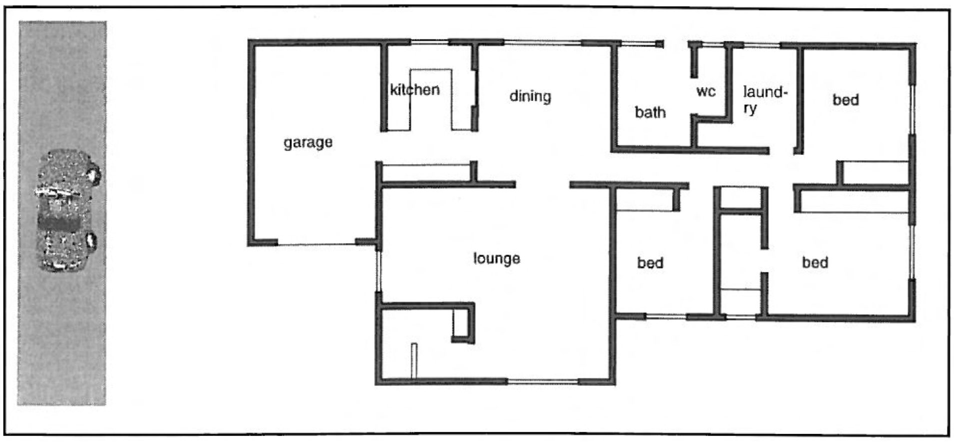


Figure 9. Locating spaces requiring quiet away from the noise source.

8.0.4 For existing buildings external sounds can be modified by:
- using high barrier fences (Figure 8) to buffer external noise. Fences must be of sufficient mass and height and have no gaps
- creating earth mounds high enough to block direct sound path
- upgrading the level of noise reduction provided by the windows by installing sealing strips around windows, reglazing with laminated acoustic glass or adding secondary glazing
- moving sleeping rooms to the quiet side of the house.

9.0 SOUND CONTROL MEASURES FOR NEW BUILDINGS

9.1.1 Sound control is easier to incorporate into the planning of new buildings than into existing buildings, although a number of the points listed can also be applied to existing buildings.

9.1.2 When planning the building layout:
- prioritise the comfort sound level for each space and use areas where a higher noise level may be acceptable to provide a buffer to those where noise may be more intrusive
- locate spaces requiring the lowest noise levels furthest away from noise sources (Figure 9)
- group noisy activities and separate from quiet activities (Figure 10)
- provide acoustic rated separations (walls) between spaces
- stagger doorways across a hallway (Figure 11)
- locate heating and cooling equipment away from quiet areas
- use layouts which are mirrored in plan (Figure 12)
- carefully consider placement of opening windows as they can transmit occupant noise between rooms
- use wardrobes and storage spaces as buffer zones between rooms (Figure 13).

9.1.3 Specific points relating to multi-unit dwellings are:
- minimise structural interconnections between units or apartments in multi-unit blocks
- locate windows as far away as possible from party walls to reduce the risk of flanking sound
- provide separation between dwelling units, i.e. locate garages between units
- stagger doorways between apartments, particularly where they open off a common area (Figure 11)
- make sides, roofs and floors to balconies of solid construction without gaps
- ensure all tiled areas have acoustic underlay.

9.1.4 Construction systems, building finishes and materials must be clearly specified for critical elements to ensure that the sound control performance is achieved. It is equally important to inspect the work and, if necessary, conduct site tests to ensure that performance requirements are met. Flanking paths require special consideration.

9.1.5 Practical means of enhancing performance are:
- constructing sound barriers from solid, and reasonably heavy, materials such as plywood, concrete,

gypsum plasterboard, fibrous plaster, sheet metal
- using isolated construction, i.e. double walls or floors
- specifying thicker or laminated glass for single glazing or double glazing with a large air gap between the panes (>100 mm)
- using solid core doors with acoustic perimeter seals
- avoiding sliding doors
- using proprietary sound seals around doors and windows
- specifying thicker or heavy materials (sound isolation provided by a solid barrier increases by 6 dB for every doubling of mass)
- for wall framing, using a sandwich construction (mass/air/mass) can often provide better sound performance than a monolithic material, particularly where a significant increase in mass is not practicable
- ensuring gaps around partitions are fully sealed with a flexible sealant. Stopping compounds which harden in place often form small cracks as the building moves; therefore it is critical to caulk the perimeter with flexible sealant before stopping (Figure 14)
- providing sound absorption within cavity spaces (adding acoustical infill insulation can improve the STC rating of some walls by 3 to 5 points)
- one larger cavity can be more effective at preventing sound transmission than two small cavities (because resonance can occur between cavities), particularly with low frequency sounds
- fixing linings on purpose-made resilient mounts can improve the STC of the wall by 5 to 10 points. Resilient mountings are designed to be attached directly to the framing and must not be entrapped between layers of lining materials.

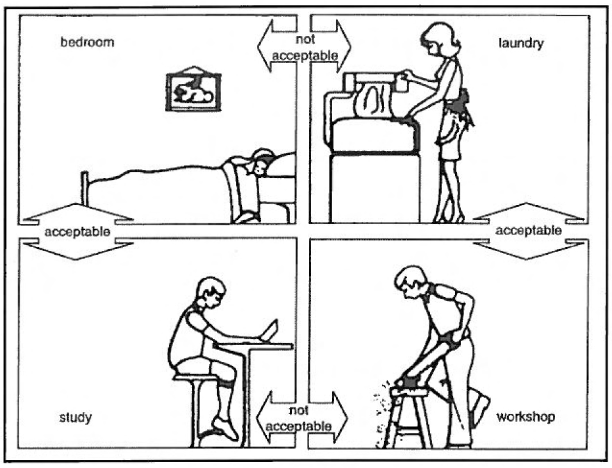


Figure 10. Associate rooms acording to their purpose.

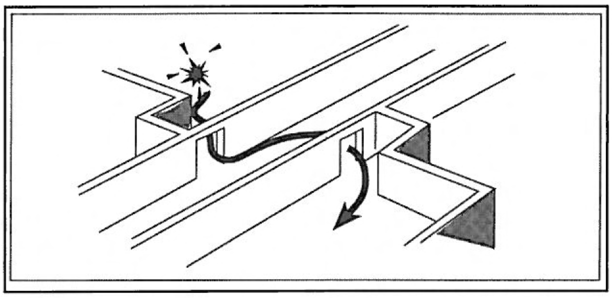


Figure 11. Offset doors in corridors.

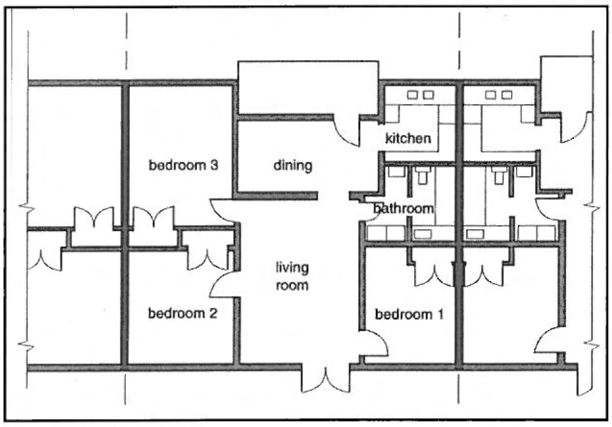


Figure 12. In compact town flats, noise can be minimised by planning which keeps sensitive and potentially noisy areas apart. For instance, the bedrooms of one flat are not adjacent to the living-room of another; the toilets are separated from dining and living-room.

9.1.6 Building services and equipment will be quieter when:
- appliances and equipment are specified to have low noise rating
- operating pressures, airflows and water flows are kept lower than maximum rating
- equipment is mounted on resilient or isolation type mounts
- resilient connectors are used for pipework and ductwork at connection points to equipment
- offsets or silencers are provided on ductwork
- internal joints in ductwork and pipework are smooth
- rotors, fans, shafts (i.e. all moving parts) are balanced to prevent vibration
- fans, impellers etc are specified with larger diameter to reduce fan tip speed. Centrifugal fans are quieter than equal capacity propeller or vane/axial fans
- ductwork is configured to ensure airflows are undisturbed by having simple layouts, smooth transitions, insertions in the flow path streamlined, long radius turns, calming chambers

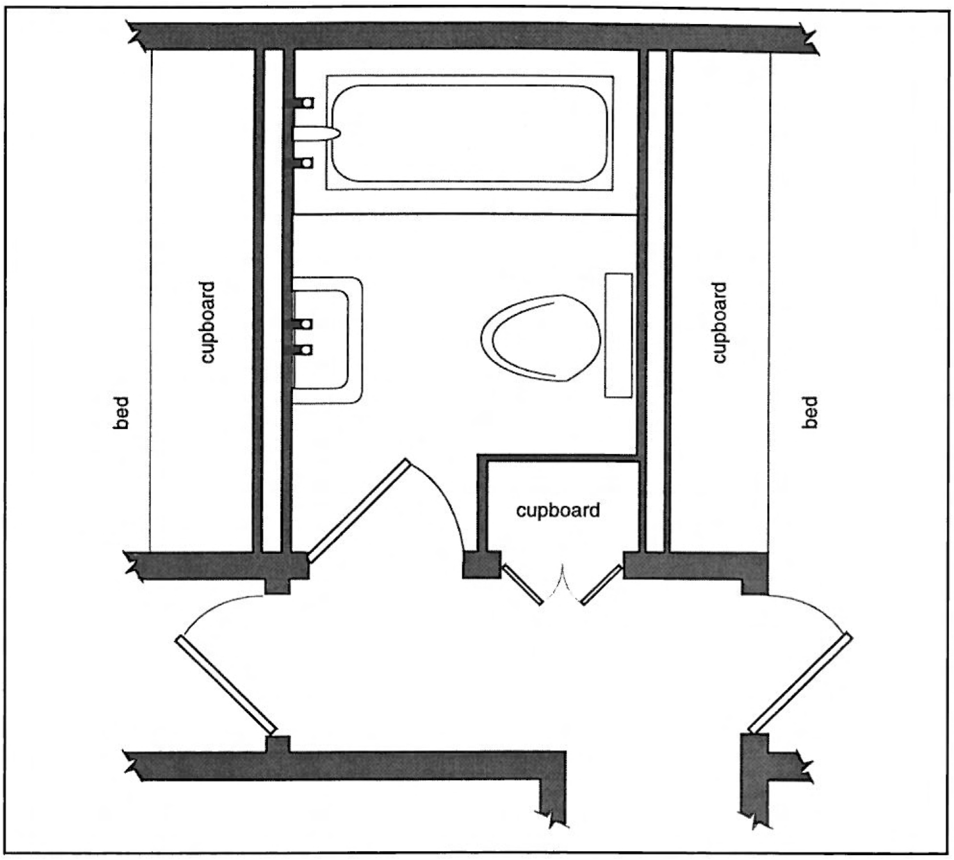


Figure 13. Well-placed cupboards control sound from bathroom.

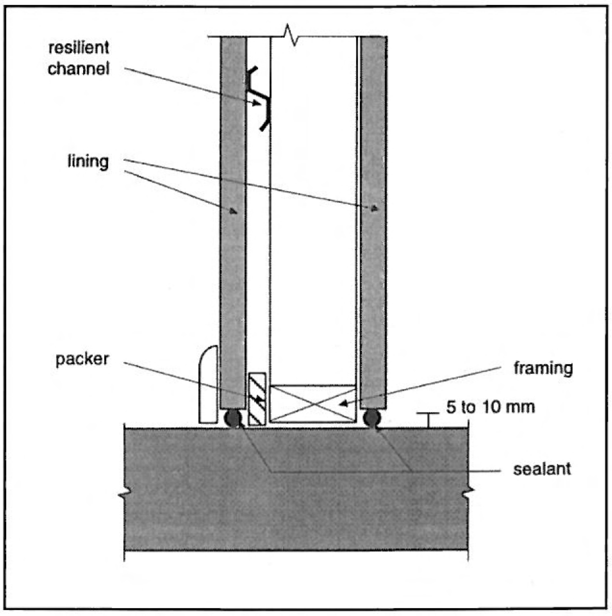


Figure 14. Sealing gaps.

- pipework is mounted on flexible mounts
- polybutylene pipework is used for domestic water supply
- copper is used for wastes instead of PVC
- pipework is laid out with the minimum possible number of formed elbows, take-off points and wing-backs as these are the primary source of turbulence and noise in piping
- swept bends are used in pipework in lieu of elbows
- vertical wastes use one long drop rather than a number of smaller drops
- fittings (power points, recessed cabinets etc) are offset
- power outlets and switches are not located on single thickness party walls
- lagging is used to improve acoustic performance of all piped services
- recessed down lights do not penetrate the acoustic ceiling.

9.1.7 Few suburban homes in New Zealand have mechanical ventilation systems that would allow the windows to remain closed to exclude external noise in hot weather. Inner city apartments are more likely to have been specifically designed to control unwanted external noise and incorporate ventilation systems that allow windows to remain closed.

9.1.8 Overseas experience suggests that greater acoustic separation is required for satisfactory performance in residential situations and STC ratings of 60–65 plus are being demanded.

10.0 REDUCING SOUND TRANSMISSION THROUGH GLAZING

10.0.1 Laminated glass absorbs sound energy with a flexible polymer interlayer which reduces sound transmitted. Double glazing systems interfere and absorb sound according to the type of glass and width of the space separating the panes. Using two different glass thicknesses, and making the second pane separated by 100 mm or more and not parallel to the first, will improve acoustic performance. To give maximum acoustic performance, double glazing systems should have:

- both panes of laminated acoustic rated glass of different thickness
- reveals, head and sill between the sashes lined with sound absorbing material such as fibreglass or heavy felt and be wider than 100 mm
- separate sashes completely sealed around all edges to prevent air leaks
- panes of glass set in flexible sealing compound
- panes not parallel.

10.0.2 The typical noise level adjacent to a busy road is 75 dB. To achieve 30–35 dB level for sleeping areas, a 40–45 dB reduction is required. A 110 mm double window of 6 and 4 mm panes would provide 44 dB reduction to 31 dB.

10.0.3 The effective design of appropriate glazing systems requires a thorough understanding of the acoustic performance of the whole wall structure and all other transmission paths (including ventilation systems).

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