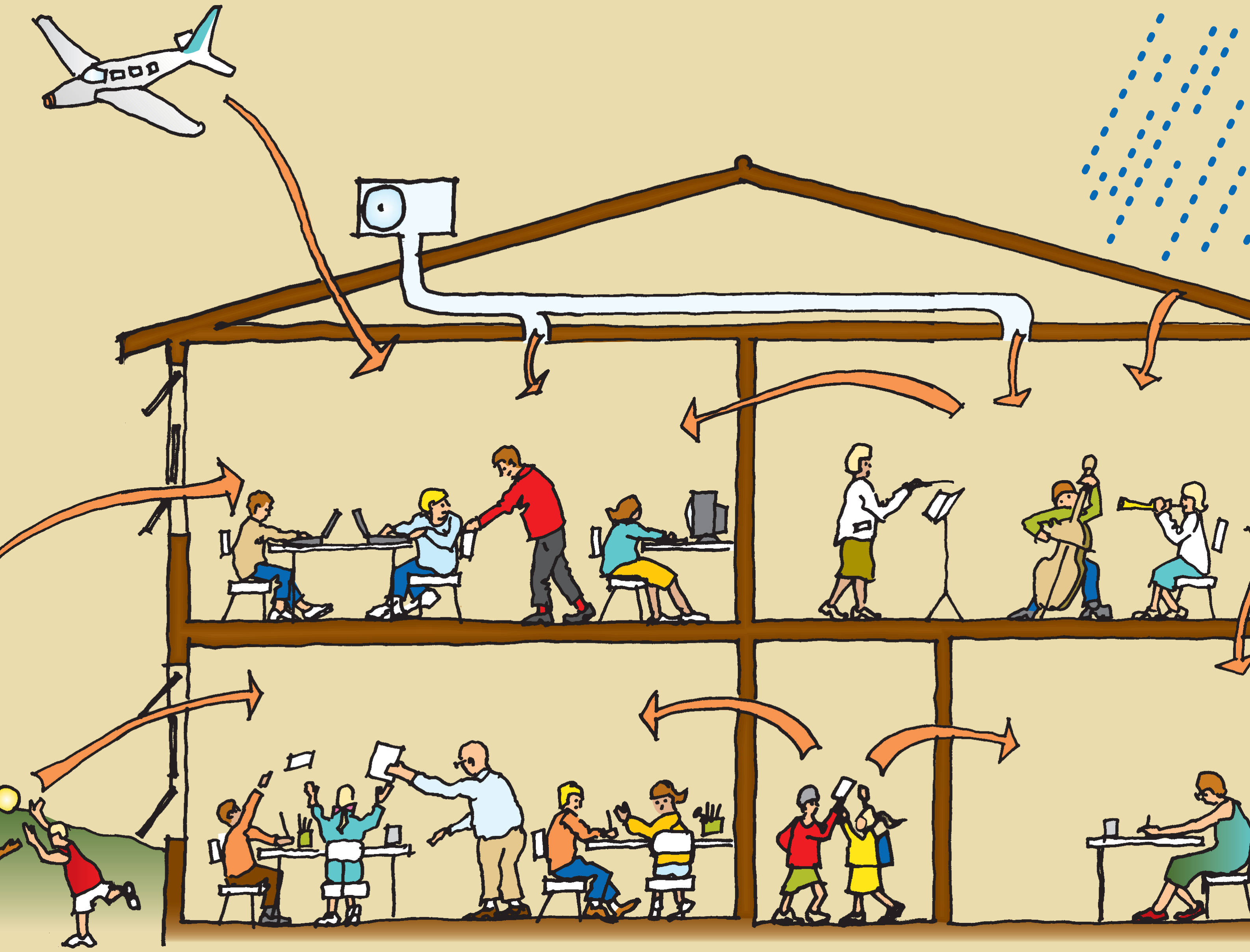
Designing Quality Learning Spaces: Acoustics

Developed by BRANZ Ltd
for the Ministry of Education



BRANZ

MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

Introduction

The Ministry of Education has prepared a series of guidelines to help boards of trustees and principals to:

- assess the performance of existing teaching spaces
- be aware of the characteristics of quality learning spaces
- achieve the highest possible quality spaces.

This information is important because of the effect the teaching environment can have on student learning.

For this series, ‘environment’ refers to the quality of the learning environment which is affected by many physical factors, including:

- acoustics
- air quality and ventilation
- heating and insulation
- lighting
- interior design, function and aesthetics.

These factors interact with one another: achieving good natural lighting must be balanced against possible uncomfortable heat gain from the sun, and the need for natural ventilation can clash with outside noise control efforts. No single factor should be altered without assessing its effect on all the others – a holistic approach is essential.

It is also important to spend the available money well (both the initial outlay and long-term running and maintenance costs).

This series gives practical advice, but it cannot provide definitive answers for all circumstances. What ***Designing Quality Learning Spaces*** can do is give advice which should improve teaching spaces for both students and teachers.

Although the main objective is to guide boards of trustees and principals, the series should also be available for teachers, to help them understand what makes a good learning environment and how they can contribute to this, such as by ensuring windows are opened for good ventilation. The guides can also be given to professional designers as part of their brief.

While the specific designs and solutions chosen will vary between schools, all quality learning spaces have certain features in common:

- there is always a fresh air supply, which helps to prevent the build up of carbon dioxide levels, clears away pollutants, odours and excessive moisture, and improves comfort in warm weather by increasing air movement and removing heat
- there is a comfortable temperature regardless of outdoor conditions
- there is good lighting, preferably natural, without glare
- students can hear and understand the teacher from all parts of the room (and vice versa), teachers don’t need to raise their voices to be heard, and noise from outside doesn’t interfere with teaching.

In their design and layout, learning spaces should:

- allow the teacher to move about easily
- allow for a variety of teaching methods
- allow enough personal space for students
- let all the students see visual aids clearly
- provide work space for specialised activities
- cater for students with special education needs
- be safe and comfortable.

A quality learning space will have furniture which:

- allows learning and tasks to be carried out efficiently without fatigue
- helps protect students from injury owing to bad posture
- reduces the risk of distraction or fidgeting owing to discomfort.

Editorial Note

This guideline on acoustics is part of a series for boards of trustees, principals and teachers to help them understand the importance the internal environment plays in the design of quality learning spaces. It will also help boards of trustees brief consultants and tradespeople on their schools' requirements when planning new buildings, alterations or maintenance. Other topics in the series include: ventilation and indoor air quality, lighting, heating and insulation, and interior design.

The series is designed to help boards assess existing teaching spaces and includes practical steps to improve the acoustic quality of those spaces. They give advice on aspects of the classroom environment that contribute to the comfort and health of students and teachers.

These acoustics guidelines will highlight the education and health benefits of providing teaching spaces with good acoustics with guidance on practical ways this can be done. Research has identified the role acoustics can play in the quality of learning environments. The Ministry of Education encourages all schools to ensure that acoustic conditions in teaching spaces provide the best possible outcome for students and teachers.

Acoustics is a subject that few of us are familiar with. These guidelines include an outline of the basic principles of how sound works and will help in understanding the practical solutions that follow.

Glossary of Terms used in Acoustics

Ambient noise level	Background noise level in an unoccupied room
Building consent	A consent for building work to be carried out in accordance with plans and specifications approved by a city or district council
Café effect	Increase in noise by people raising their voices to be heard over other noise
Decibels (dB)	Measurement unit of sound pressure level
Decibels (dBA)	Measurement unit of sound pressure level frequency-weighted to the average human hearing response
Flutter echo	Successive repetitive echoes caused by sound bouncing backwards and forwards between two parallel walls
Impact Insulation Class (IIC)	Degree to which impact sound is lessened
Impact sound	Sound caused by an impact eg, footsteps, which is heard in an adjacent space
Noise Reduction Coefficient (NRC)	Rating of the sound absorption of a material
Reverberation	Collection of time-delayed sounds resulting from reflections
Reverberation Time (RT)	Time taken for the average sound intensity to decrease by 60 decibels after the generation of the sound has stopped
Signal-to-noise ratio	Ratio of a sound (teacher's voice) to ambient noise
Sound-flanking paths	Route by which sound can pass through or around a building element eg, through a door duct or floor and around a partition or screen
Sound Transmission Class (STC)	Number rating of sound transmission loss through a building element eg, through a partition or floor

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> SECTION 1
– Acoustics and Teaching

Overview

Good acoustics complement good learning

Good acoustics in teaching spaces make for quality learning environments. It is essential to ensure good acoustics are achieved when building new facilities or upgrading older buildings.

Background noise and reverberation can create problems for students, especially younger students who haven't yet developed the skills that allow them to differentiate between what the teacher is saying and competing background noise. Students can easily miss key words, phrases and concepts.

Students with undiagnosed hearing problems have difficulty listening and concentrating in classrooms with poor acoustics. And it can be especially hard for students for whom English is their second language to understand and hear the teacher.

Adapting to different teaching methods

Many teaching spaces in older schools were not designed for current teaching methods. They do not have good acoustic qualities.

The teacher used to stand at the front of the class so they did not need to be heard from all parts of the room. Now teachers move around, working with groups or individuals, and their voices need to be heard from all parts of the room.

Figure 1 shows the percentage of time spent using each teaching style in primary schools. Figure 2 shows the trend for teachers to spend more time moving around the classroom and less time standing at the front of the room.

FIGURE 1 The proportion of time teachers spend teaching in each style (average 120 teachers)

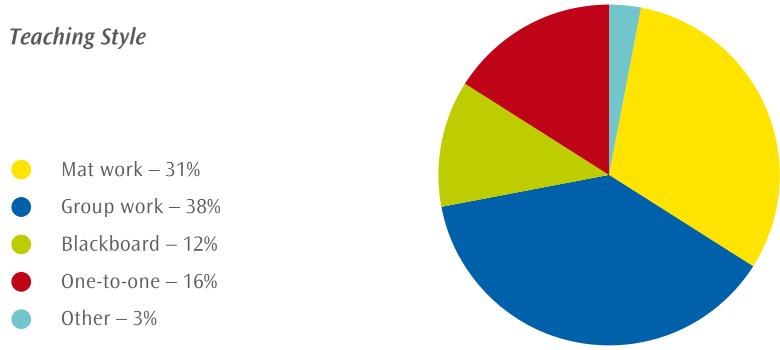
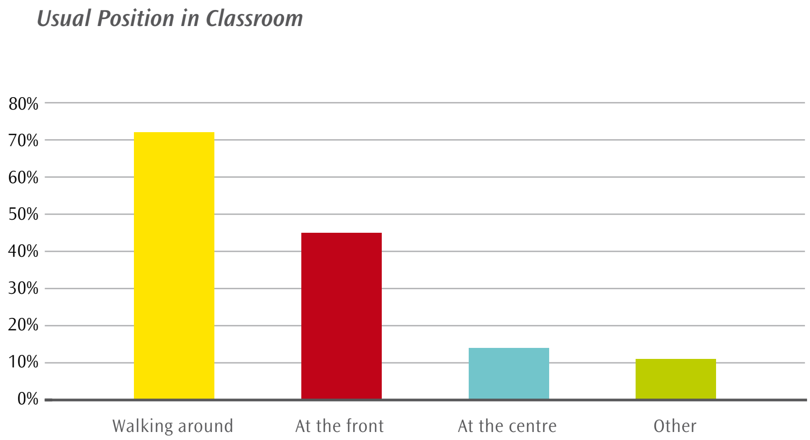


FIGURE 2 Location selected by teachers as their 'usual' position in the classroom



Why are good acoustics important to teachers?

Considerable research, both in New Zealand and overseas, confirms that good acoustics contribute to good learning environments. Poor acoustics can impact on a student's ability to learn and a teacher's ability to teach. Oticon NZ's[1] study in New Zealand primary schools noted that:

- 71% of the teachers felt that internal classroom noise was a problem
- more than one-third of the teachers indicated they had to speak at a level that strained their voices
- around half of the teachers said they had to considerably raise their voices during group work.

A survey on best practice in school design, recently carried out by AC Nielsen on behalf of the Ministry of Education, teachers and students, found that concerns about acoustics did not rate as highly as other environmental areas, such as temperature and ventilation. However, poor acoustics did receive a higher mention for the worst classrooms the teachers had taught in.[2]

Factors interfering with listening skills

Language skills are central to educational success.[3] Listening is critical to the process of language skills and, therefore, to the learning process. Listening ability may be hindered by:

- **factors relating to the student**
  - the student may have an ear infection or glue ear or students with special education needs may have hearing impairments
- **environmental acoustic factors:**
  - **background noise** – from both inside and outside the room
  - **excessive reverberation** – within the room
  - **low signal-to-noise ratio** – ratio of teacher's voice to background noise level.

How these guidelines can help you

These guidelines are designed to help schools get the maximum benefit of good acoustics. They will help you to:

- understand the basic principles of acoustics
- carry out an acoustic assessment of existing teaching spaces
- decide what remedial options are appropriate for existing teaching spaces
- prepare clear instructions to professional advisors working on new buildings, additions and alterations.

If you employ professional help, these guidelines will provide information on the standards to be achieved. Improving any aspect of acoustics should not be considered in isolation from other environmental factors. Acoustics, ventilation, temperature, air quality and daylight are all inter-related and a change to one could affect the others.

Assessments

Why make an assessment?

The critical relationship between good acoustics and a good learning outcome is explained in the Overview in this section.

Evaluating the acoustic suitability of your classrooms is the first important step to ensure that unsatisfactory acoustics do not adversely affect learning in your school. The ministry strongly recommends that you:

- make an assessment or, if in doubt, have one carried out by an acoustics specialist
- remedy any shortcomings highlighted by the assessment.

Assessment by you

Many principals and teachers may not be aware of the quality of the acoustic environment of their teaching spaces. Use the Survey Form in the Appendices to help you assess the acoustic qualities of your classrooms. It will help you to gauge the:

- extent and origin of background noise
- amount of reverberation (echo)
- level of acoustic treatment in the teaching space.

The survey seeks the opinions of teachers and students. It is important that the users of the rooms are engaged when answering the questions. Teachers should be given an understanding of the effects that acoustics have on teaching and learning.

Once you have completed the survey go to Table 1, the troubleshooting guide, below.

Assessment by professionals

You should obtain help from an acoustics specialist if you are unsure of the results of your assessment or what remedial action to take. They will use instruments to measure background noise and reverberation times and give advice on remedial measures. These services will, of course, be charged so obtain and agree a quote beforehand.

TABLE 1. TROUBLESHOOTING GUIDE

Indication	Action	See
No discernible acoustic problem	Reassess in one year	
High background noise level from internal noise	Reduce internal background noise	Section 3
High background noise level from outside sources	Insulate or screen outside noise or if outside noise cannot be reduced consider a teacher's voice amplification system	Section 3
High background noise level from adjacent rooms	Block transferred sound Improve sound insulation	Section 3
Long reverberation time	Reduce reverberation time	Section 3
Teachers find it difficult to project their voices	Reduce internal background noise *and* reduce reverberation time and consider a teacher's voice amplification system. Note that a voice amplification system will not be effective in a room with a reverberation time that is too long.	Section 3
Some students have hearing impairments	Reduce internal background noise *and* reduce reverberation time and consider a teacher's voice amplification system	Section 3

Before deciding to improve the acoustics of existing buildings consider:

- the age and general condition of the building – perhaps the work could be part of a comprehensive project that includes other essential upgrading work
- the projected lifetime of the building and projected replacement date
- how serious the acoustic problem is and what options are available to correct it
- the cost of making improvements against the expected gain. The cost of the perfect solution to all problems may be prohibitive – providing quality solutions for the major problem areas only may be more cost-effective
- re-organising the use of the spaces.

Any decisions to improve acoustics must take into account the effects on other areas. For example, if windows are treated to reduce outside noise, keeping them closed will be effective, but this may create ventilation problems (see Section 3).

Appendices

See Appendices for a flow chart on the steps of the assessment and remedies.

> SECTION 2 – Understanding Sound

How we perceive sound

Before you consider acoustics in your classrooms it is helpful to understand how sound is measured and what is normal for a classroom full of students.

Sounds are transmitted by pressure waves moving through the air. Sound pressure levels give an indication of the level of sound. The levels can be measured by a sound meter and are expressed as 'decibels' (dB).

The sound range of human hearing extends from about 16 dB, which is at the threshold of our hearing, to 140 dB, which is above the threshold of pain.

Sound pressure levels apply to the place they are measured at. In general, the pressure level decreases as the distance from the source increases. Table 2 shows typical sound levels in a school.

Background (ambient) noise

The natural level of noise in a classroom when it is occupied is called the ambient noise level. High levels of ambient noise significantly reduce a student's ability to concentrate, and speaking over it can be stressful on the teacher. Research indicates the ambient noise level in New Zealand classrooms ranges from 28–60 dB.[1]

Noise = sound we would choose not to hear if we had the choice.

TABLE 2. TYPICAL SOUND LEVELS IN A SCHOOL

dB	Source and distance (where applicable)
16	Threshold of human hearing (person with good hearing)
20	Quiet recording room
35–40	Quiet unoccupied classroom
60–70	Busy classroom – lots of students Normal voice at 1 metre
80–90	Vacuum cleaner Person shouting at 1 metre
100	Very loud disco music (maximum recommended by World Health Organisation)

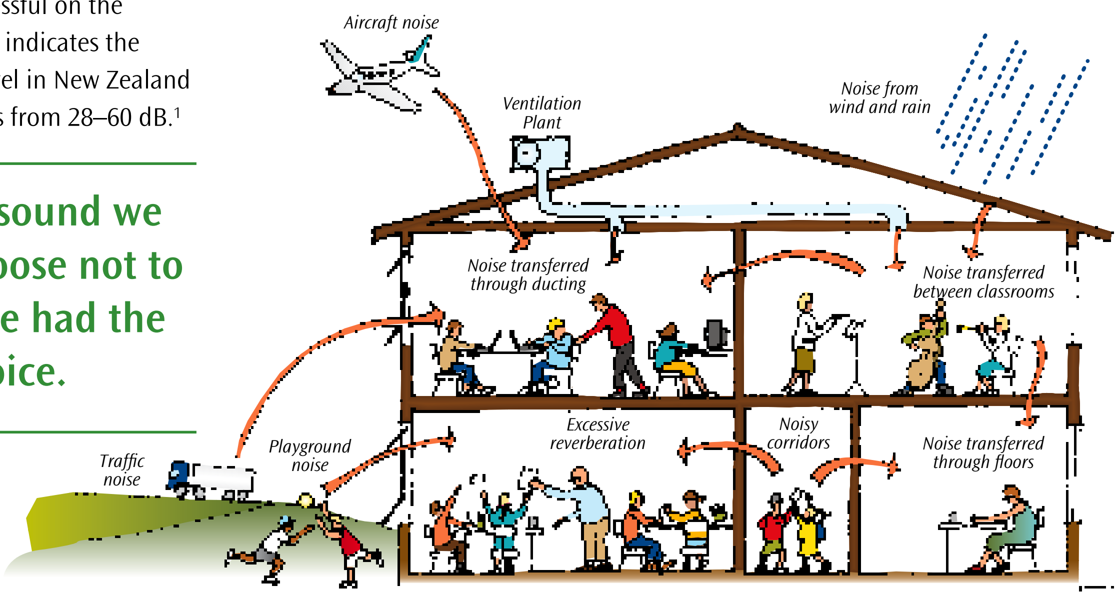
Many sources contribute to the background noise level of a classroom, including noise:

- generated outside the school property (road traffic and building construction)
- generated within the school property (grass cutting and from the playing fields)
- transferred from nearby classrooms, corridors and noisy areas (music and technology rooms)
- created within the classroom (computers and fans).

Noise from outside

Because in classrooms most windows provide ventilation, outside noise, which contributes to high classroom noise, can be difficult to control. Teachers have indicated the greatest outside noise is from lawn mowing, their sports fields and other classrooms. However, improving acoustics to help minimise outside noise cannot be seen in isolation from the impact on other important aspects such as ventilation and air quality.

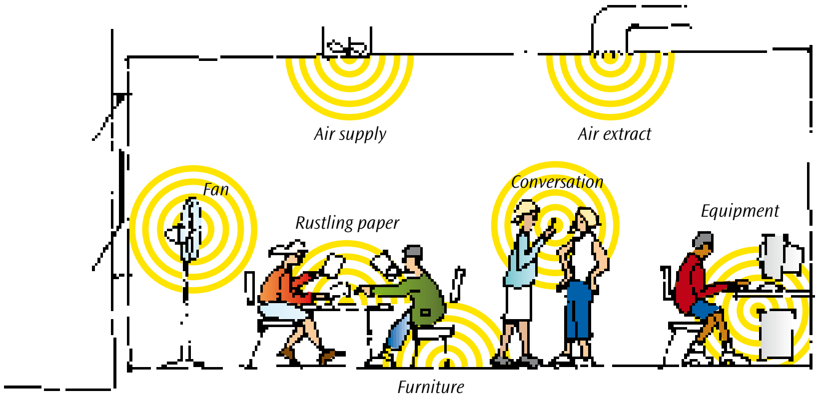
FIGURE 4 Where does intrusive noise come from?



Noise from inside

Background noise from within the classroom is often more subtle than loud external noise and can also contribute significantly to poor acoustics. Noise created by fans, computers, printers and other equipment is often not noticed by adults because of their skills in selective listening. However, such noises may be distracting for students.

FIGURE 5 Some sources of internal noise



Reverberation time

Sounds bounce off hard surfaces, such as painted walls and vinyl floors, so that listeners hear several indistinct, overlapping versions, which smear the original sound. The sound continues for a time, reflecting around after it has stopped at its source. This is called 'reverberation'. The length of time the echoes take to die away is called the 'reverberation time'.

If the reverberation time is too long the extended reflected sounds mask or blur the direct sound, which makes it hard to understand what someone is saying. Some reflected sound is good for understanding what someone is saying because it may reinforce their voice, but it's a matter of careful balance.

Reverberation times are measured in seconds, and typical ideal times range between 0.3 seconds for a recording studio to 2.0 seconds for a performing music hall.

Café effect

The combination of lots of ambient noise and a long reverberation time can lead to a situation known as the 'café effect'. This is where a speaker raises their voice to be heard above the level of background noise. This can result in everyone trying to speak 'above' the volume of everyone else. The outcome is an extremely noisy environment, which makes it hard to understand what people are saying.

Despite the name, the café effect doesn't only occur in cafés. It can also occur in classrooms, especially during 'group work', and the effect is increased even further if the room has a 'long' reverberation time.[5]

The teacher's voice

The signal-to-noise ratio is the ratio of the teacher's voice to the ambient noise. The recommended minimum necessary for students to hear efficiently in a classroom is +12 to +15 dB (+20 dB is preferred when there are students with hearing impairments).[3] This means that if the background noise level is, say, 55 dB, the teacher would need to speak at 70 dB, which is almost shouting. The louder the background noise, the louder the teacher must speak so the students can hear clearly.

Achieving the recommended ratio is more difficult where the:

- background noise is too high
- teacher has a quiet voice.

> SECTION 3 – Making Acoustic Improvements

Reducing internal background noise

Because it can lead to the café effect (see Section 2), reducing internal background noise is an important starting point for improving the students hearing the teacher and the teacher hearing the students. Internal noise can come from a variety of sources including: conversations, whispering, paper rustling, students working in groups, equipment, and furniture legs scraping on a hard floor (See Figure 5).

Reducing background noise levels within the room

Fit rubber feet to all movable furniture	• low-cost option • effective • upgrading can provide furniture which is ergonomically better for the students • depending on the age and style of the furniture it may be worthwhile upgrading it, when possible, to furniture with 'built-in' rubber feet
Fit carpet with waffle underlay where appropriate	• very effective • also reduces foot noise • helps lower reverberation time • has higher maintenance cost • high-cost option
Reduce noise from computers and other equipment such as fans and printers	• select models with low operating noise levels – check with the supplier before buying • where possible place equipment where noise is minimised (eg, in an alcove or separate room) • fit sound-absorbent panels to the walls behind and surfaces around noisy equipment

Traffic light system

With younger students you can keep rising noise levels more under control using the 'traffic light' system. You'll need three small lights (green, amber and red). The teacher switches to amber when the noise level is rising and to red when it is too loud. Green is when the noise level is okay.

Reducing reverberation time

Absorbing unwanted noise

All materials have some sound-absorbing qualities; the sound that is not absorbed is reflected. In buildings the sound-absorbing characteristic of a material is rated as the Noise Reduction Coefficient (NRC) measured at voice frequency.

If the reverberation time of a room is too long it can be reduced by adding other materials, such as pin-up boards, carpet and ceiling tiles – all with higher NRCs. For appropriate reverberation times see Table 7 (Section 6).

There are some circumstances where care should be taken not to over-reduce reverberation time, such as in rooms used for public speaking training, singing, chamber music and classical guitar (see Section 4).

The NRC of a material can vary between perfect absorption (NRC = 1.0) to total reflection (NRC = 0.0).

Some examples of the NRCs of various building materials are:

Glass: 4mm = 0.1; 6mm = 0.04

Heavy curtains = 0.22

Painted blockwork = 0.02

Plasterboard = 0.09

Fibreboard = 0.65

Timber flooring = 0.07

Ceiling tiles = 0.5 to 0.8

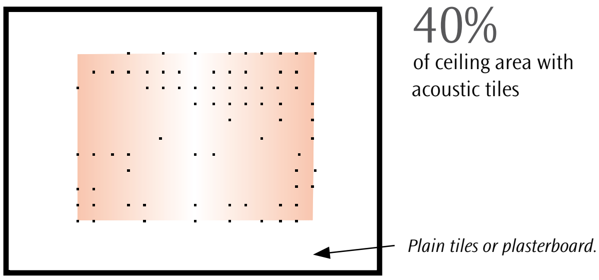
Practical options for reducing reverberation times

Ceilings

In new or existing classrooms with floor areas of 100 m² or less, install ceiling tiles with an NRC of not less than 0.70 over 40% of the ceiling

- very effective
- expensive option, particularly for existing rooms

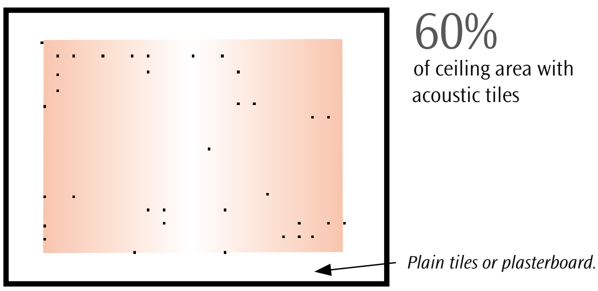
FIGURE 6 Acoustic tile ceiling.



In new or existing classrooms with floor areas over 100 m², install ceiling tiles with an NRC of not less than 0.70 over 60% of the ceiling

- very effective
- expensive option, particularly for existing rooms

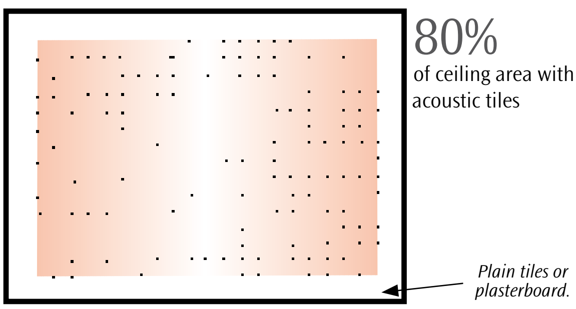
FIGURE 7 Acoustic tile ceiling.



In existing classrooms, glue and staple mineral fibre tiles with an NCR of 0.5 to 80% of the ceiling

- effective
- lower-cost option

FIGURE 8 Acoustic tile ceiling.



Floors	
Install direct-stick polypropylene carpet	• low-cost option • moderately effective
Install carpet on waffle underlay	• cost-effective • reduces impact noise as well as reverberation time • reduces heat loss on ground floors • increases general comfort level • increases maintenance and replacement cost – can be expensive
Foam-backed vinyl	• reduces impact noise • may be the only option for specialist rooms such as laboratories, art rooms and workshops • not so effective at reducing reverberation • expensive
Walls	
Install carpet dado to 900 mm high	• reduces reverberation and impact noise • protects walls from damage • expensive
Install acoustic fabric-covered pin-boards on the walls	• will reduce reverberation effectively • pin-boards save the walls from damage • pinning work on the boards reduces their acoustic effectiveness. This has less impact if the boards are higher up
Install acoustic-absorbent material on the walls at a high level and out of normal reach	• more effective in rooms with high ceilings • not so easy to use for displaying work
Windows	
Medium weight, lined cotton curtains	• cost-effective • effective at reducing reverberation, especially when drawn • makes the room more pleasant to work in • reduce heat loss when drawn • impacts on available natural light and could reduce ventilation

Sound stopping between spaces

Measuring sound transmission

The amount of noise that a wall, floor, door or sheet of glass is capable of stopping is expressed as a Sound Transmission Class (STC) rating.

The higher the STC number, the greater the expected noise reduction.

Performance figures for sound reduction in this guideline are given to compare solutions rather than to suggest definitive values. Accurate values can only be obtained from:

- manufacturers of proprietary products for which tests have been carried out
- calculations carried out by an acoustics specialist.

Technical note: STC and IIC ratings have been used in this guideline in preference to ISO 140 for simplicity.

Reducing sound transmission

Theoretically, doubling the mass of the noise-reducing barrier will increase its sound reduction index by between 5 and 6 dB. However, construction such as double-glazing or double-sided partitions are better at noise stopping than their weight indicates. This is because of the air gap between the two outer surfaces. Performance of double barriers increases as the gap widens. The addition of sound-absorbing material, such as fibreglass in the cavity, cuts down internal reverberation and further reduces sound transfer.

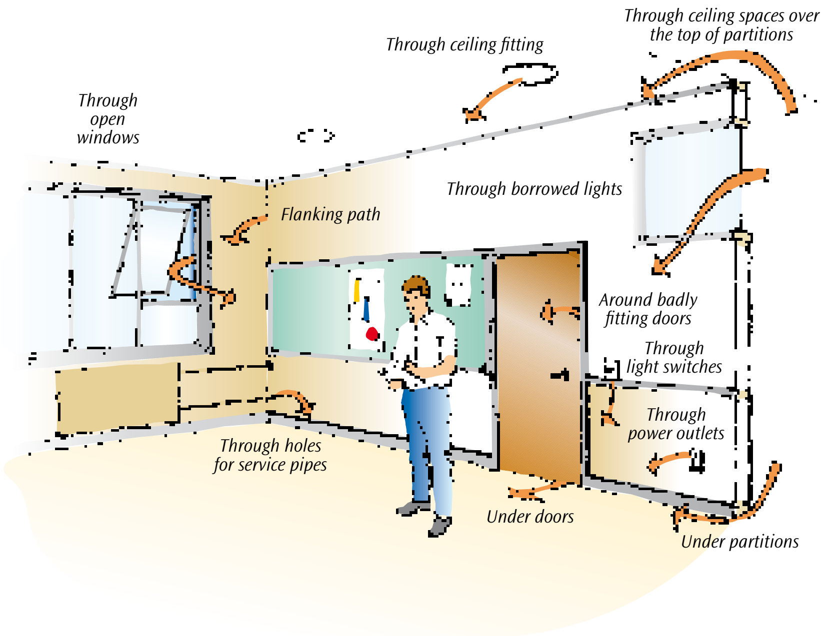
In many areas of New Zealand we are constrained in the use of heavy construction, such as brick or concrete block or by earthquake considerations. However, construction using these materials should not be ruled out where low frequency noise (eg, heavy traffic) is a serious problem. In the main, we are restricted to using lightweight materials (timber or metal framing), with heavy linings, such as plasterboard, and heavy claddings such as compressed fibre-cement.

The weakest link

When using sound barriers you need to consider all the ways that sound can get through. For example, if a wall separates two rooms, sound can still travel through if there is:

- a lightweight door
- a badly fitting door
- single-glazed borrowed light
- an open ceiling space above the wall
- small cracks between the floor and the walls
- pathways where it can travel eg, through power outlets, light switches, computer outlets and plumbing pipes.

FIGURE 10 Some of the weak points in partitions



Even minute gaps allow a significant amount of noise to pass through. Fill gaps with flexible acoustic sealant.

Dealing with external noise

Assessing the site

If your school suffers from a lot of outside noise (eg, it's located near a busy road), you should approach an acoustics consultant when planning any new building work. The consultant may sometimes carry out a noise measurement survey to enable appropriate sound control measures to be put in place (see also Section 6).

Controlling outside noise is easier when planning from scratch. The methods in this section can be used for existing sites.

Methods of controlling outside noise may include:

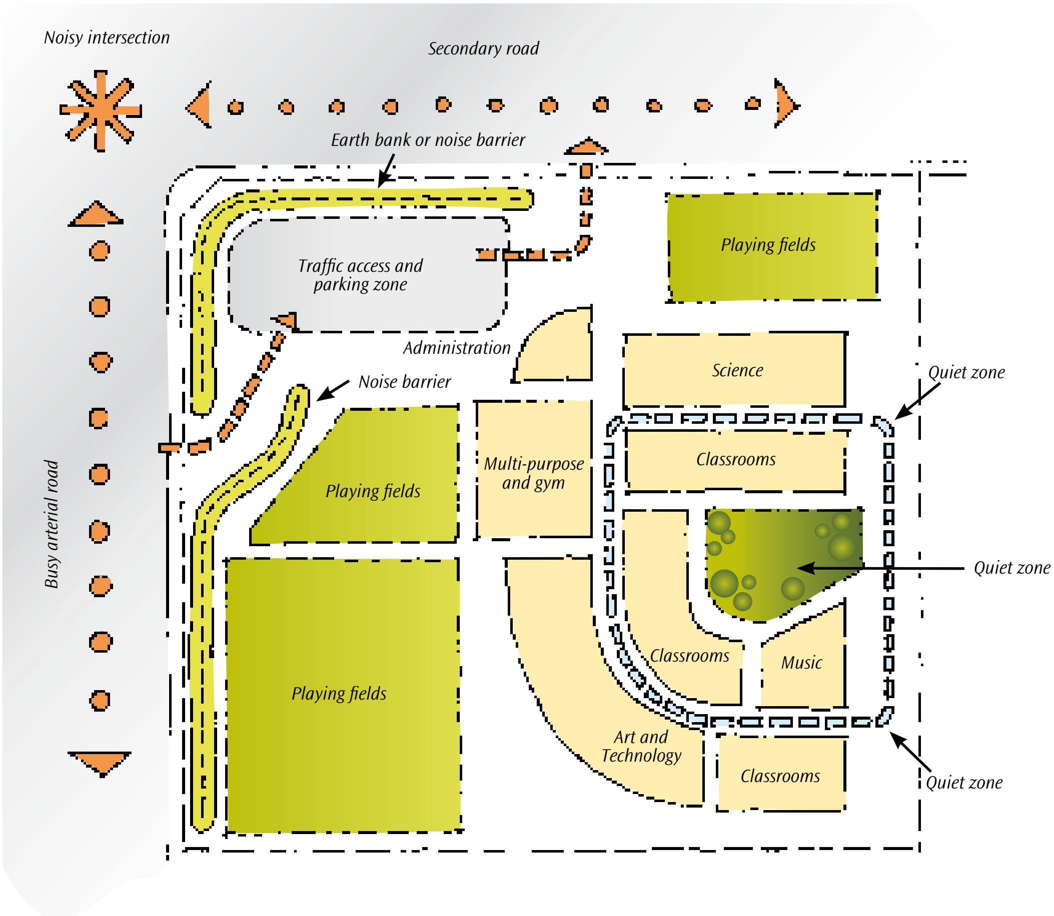
- consulting with your roading authority to help reduce traffic
- planning and zoning the site to minimise noise
- installing noise barriers
- installing a sound-insulating envelope around the buildings.

Planning and site layout

New buildings (and, where possible, extensions) should be planned so that:

- noise barriers are positioned to be most effective
- open areas, such as playing fields and car parks, are placed so buildings are as far as possible from the noise source
- the least noise sensitive activities are sited in the areas subject to most noise so that they act as a buffer
- noise sensitive activities are in the quietest areas.

FIGURE 11 Zoning plan to minimise noise in sensitive areas

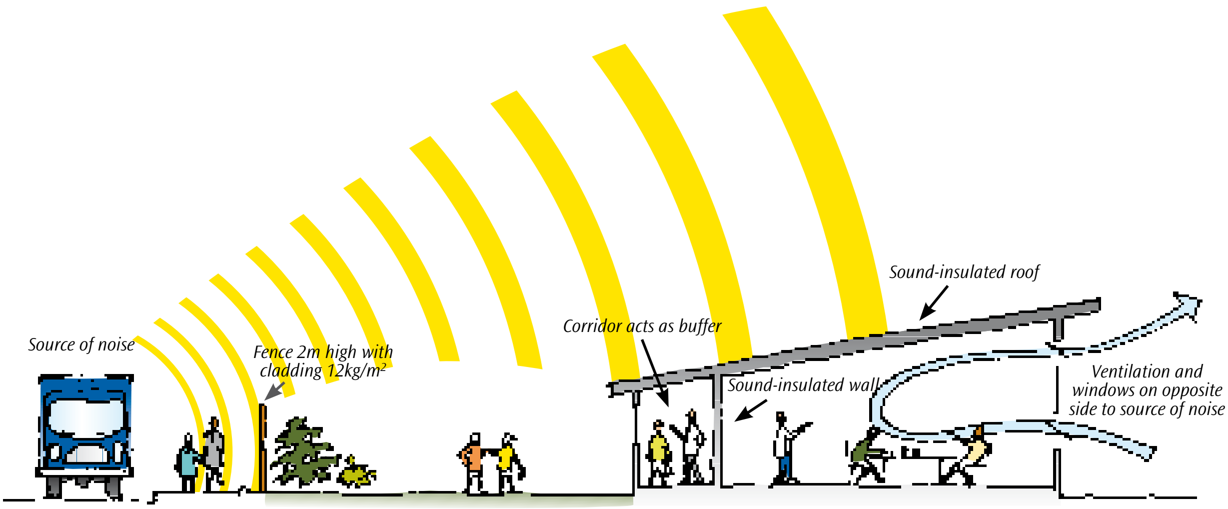


While it's easier to plan good site layout in new buildings or extensive additions, the principles can be applied when refurbishing. It may cost less and be more effective to relocate activities than to spend money on sound control.

Measures to reduce traffic noise

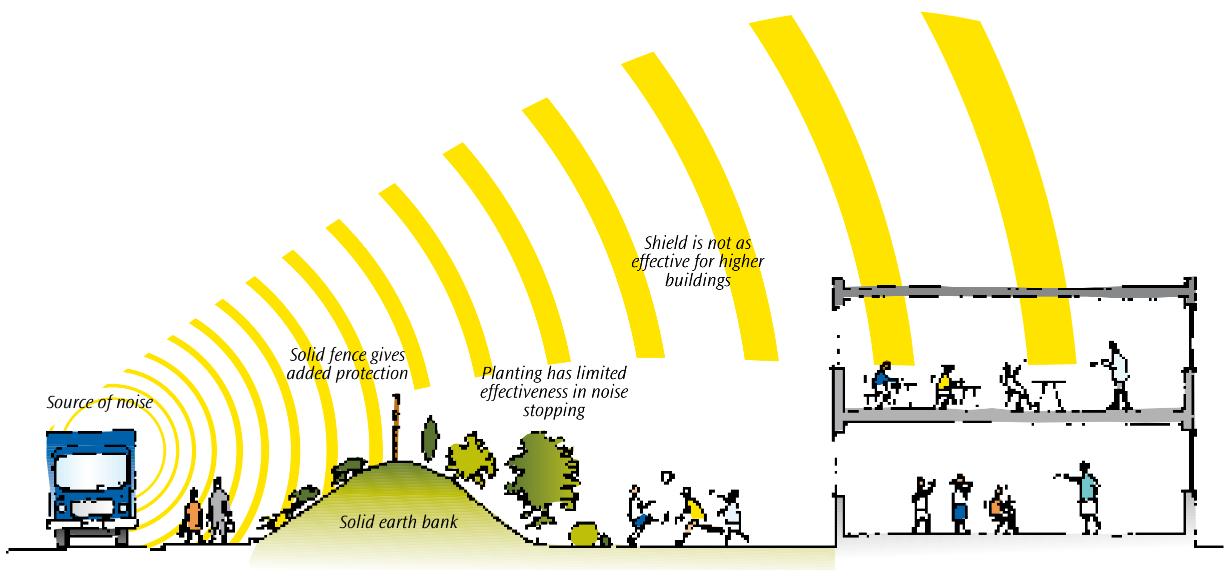
A brick or concrete block noise barrier wall	• provides additional security • very effective in stopping noise but noise passes over the barrier • expensive option
A timber fence noise barrier with solid boarding of not less than 12 kg per square metre. There must be no gaps between boards or where the boards meet the ground	• less expensive option • provides additional security • effective in stopping noise but noise passes over the barrier

FIGURE 12 Reducing External Noise



Earth bank noise barrier	• can be landscaped • effective sound barrier but noise passes over the top • more effective if the school is at a lower level than the sound source • uses up more space than a fence • cost is dependent on circumstances

FIGURE 13 Using a solid earth bank and fence



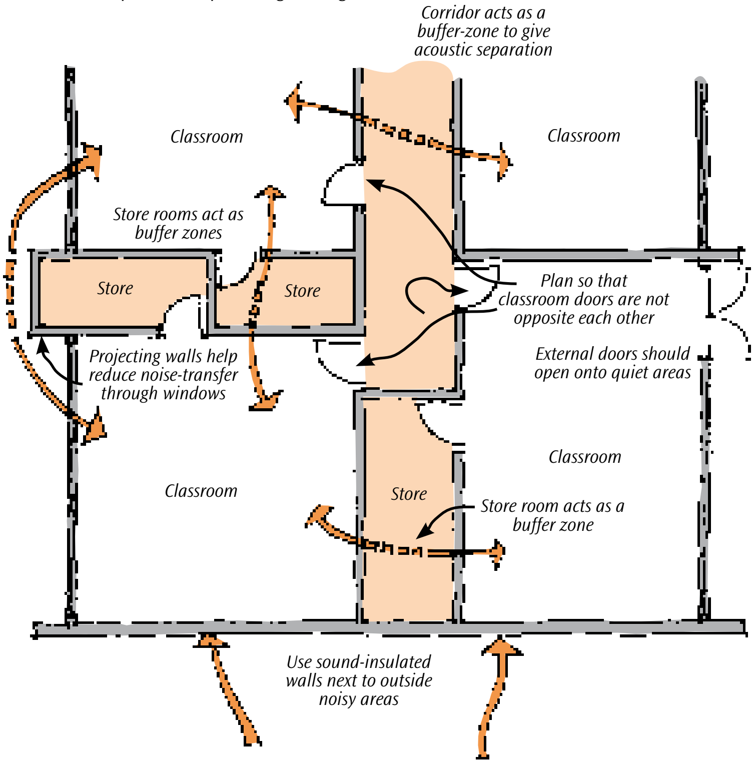
Measures to reduce traffic noise (continued)

Trees and shrubs	• ineffective as an acoustic barrier
Get the roading authority to use open-graded porous asphalt on adjacent roads	• significantly quieter than other surfaces • becomes clogged with dirt and requires cleaning
Get the roading authority to restrict trucks using their air brakes in the vicinity of the school	• trucks using air brakes are a significant source of noise

Noise barriers should be used with other sound-reducing strategies, such as:

- using a corridor or storeroom as a buffer
- having a sound-blocking wall between noise sensitive areas and the source
- ensuring that roofs and ceilings are sound insulated
- ensuring windows are away from the source of noise.

FIGURE 14 Simple sound-planning strategies



Sound-insulating envelopes

Sound-insulating your external walls and roofs will reduce sound coming into the buildings from both within the school grounds and beyond. There must be no sound-flanking paths by which the sound can bypass the insulating envelope. Here are some options for sound insulating walls and roofs:

Sound insulation of external walls

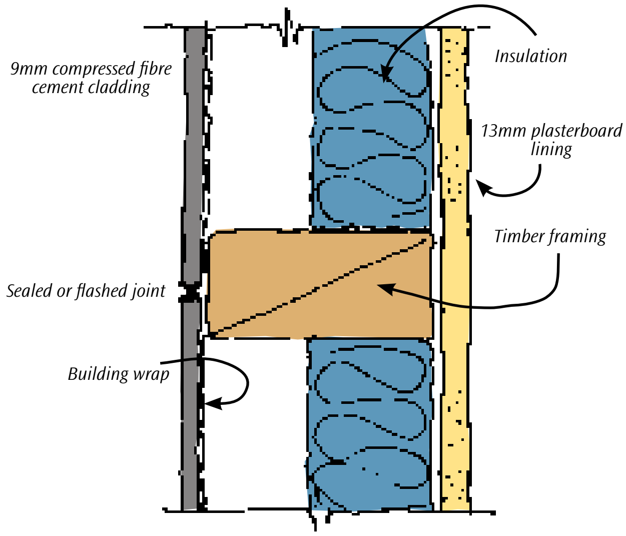
A corridor or storeroom, with few opening windows, used as an acoustic buffer	• effective • low cost
A buffer (as above) used in conjunction with a sound-insulating internal wall (see Figure 12 on page 18)	• very effective • low cost

Sound insulation of external walls (continued)

A sound-insulating timber-framed wall with high-density lightweight cladding, no windows

- effective
- moderate cost

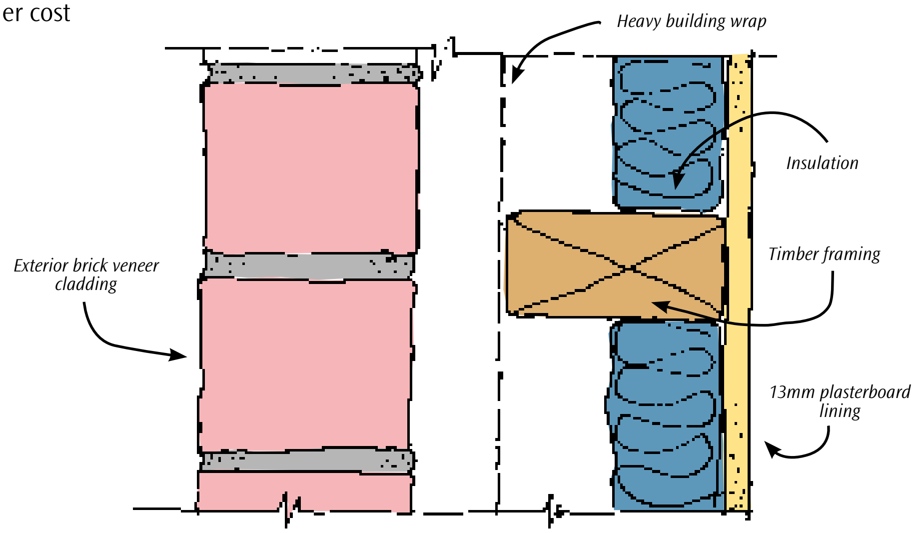
FIGURE 15 Exterior sound envelope



A sound-insulating timber-framed wall with masonry veneer cladding, no windows

- more effective
- higher cost

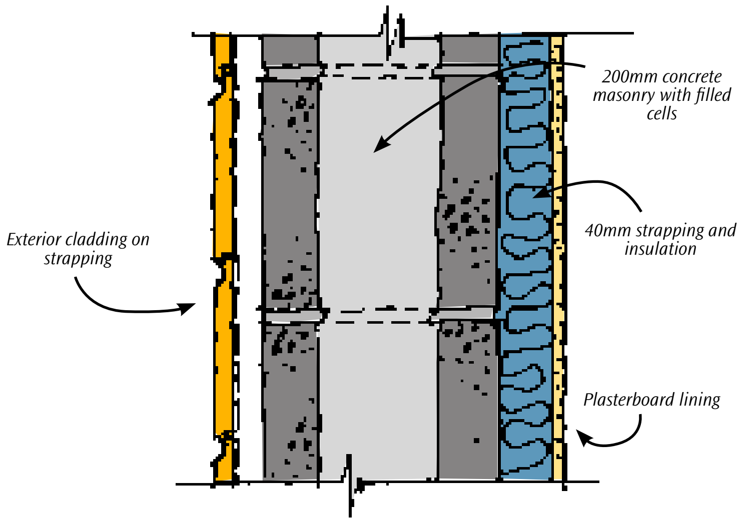
FIGURE 16 Exterior sound envelope



A sound-insulating external masonry wall, no windows

- most effective
- highest cost

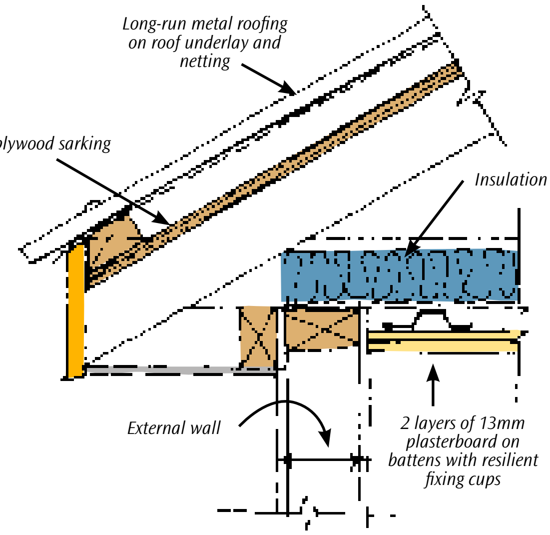
FIGURE 17 Exterior sound envelope



Sound insulation of roofs

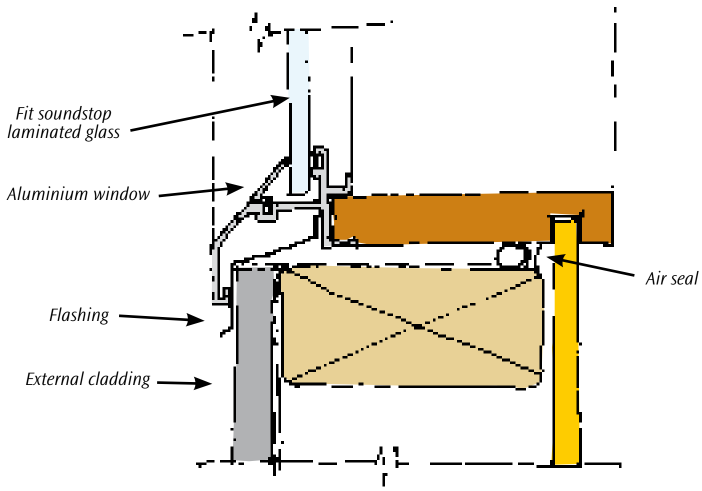
Long-run metal roofing on resilient underlay, such as bitumen-impregnated softboard	• effective • moderate cost • also effective in reducing rain noise
Skillion roof with sound-absorbing insulation of 2 x 10mm plasterboard ceiling on resilient rails, no roof lights	• effective • moderately expensive • also helps to reduce rain noise
Long-run metal roofing on plywood underlay. Ceiling space with sound-absorbing insulation 2 x 13mm plasterboard ceiling on resilient rails, no roof lights	• very effective • moderate cost • also effective in reducing rain noise

FIGURE 18 Sound-insulated roof



Sound insulation of windows

FIGURE 19 Reglaze windows to increase sound insulation



Glaze with sound-stop laminated glass	• expensive, best sound-reducing option • only effective if windows are kept shut • reduces natural ventilation
Glaze with double-glazing with a minimum of 100 mm between panes	• reduces heat loss • expensive • difficult to achieve • only effective if windows are kept shut • reduces natural ventilation

Windows and roof lights reduce the effectiveness of a sound-insulating envelope. Where possible, the windows in teaching spaces should not face the source of noise. If windows are unavoidable they can be sound-insulated, but these are only effective when they are closed. Unless there are windows on the other side of the room that can be opened, mechanical ventilation will be necessary.

School ground noise

Here are some options to help reduce noise from within the school grounds eg, from students playing sports or on their play breaks, grass cutting or rain on the roofs.

Controlling noise within school grounds

Sports, play breaks	programme activities to minimise interference with regular classes; provide a sound-insulating envelope
Grass cutting	arrange for grass cutting to take place outside teaching times
Rain or hail on roofs	sound resilient underlay, such as bitumen-impregnated softboard beneath the long-run metal; adequate sound-insulating ceiling
Expansion and contraction of long-run metal roofing; creaking and cracking noises as the roofing heats up or cools down	sliding fasteners to long-run metal; expansion joints to roofing and flashings
Wind noise through gaps around doors and windows	foam seals to badly fitting doors and windows; wind barrier or lobby to exterior doors

Internal sound insulation

Appropriate insulation levels

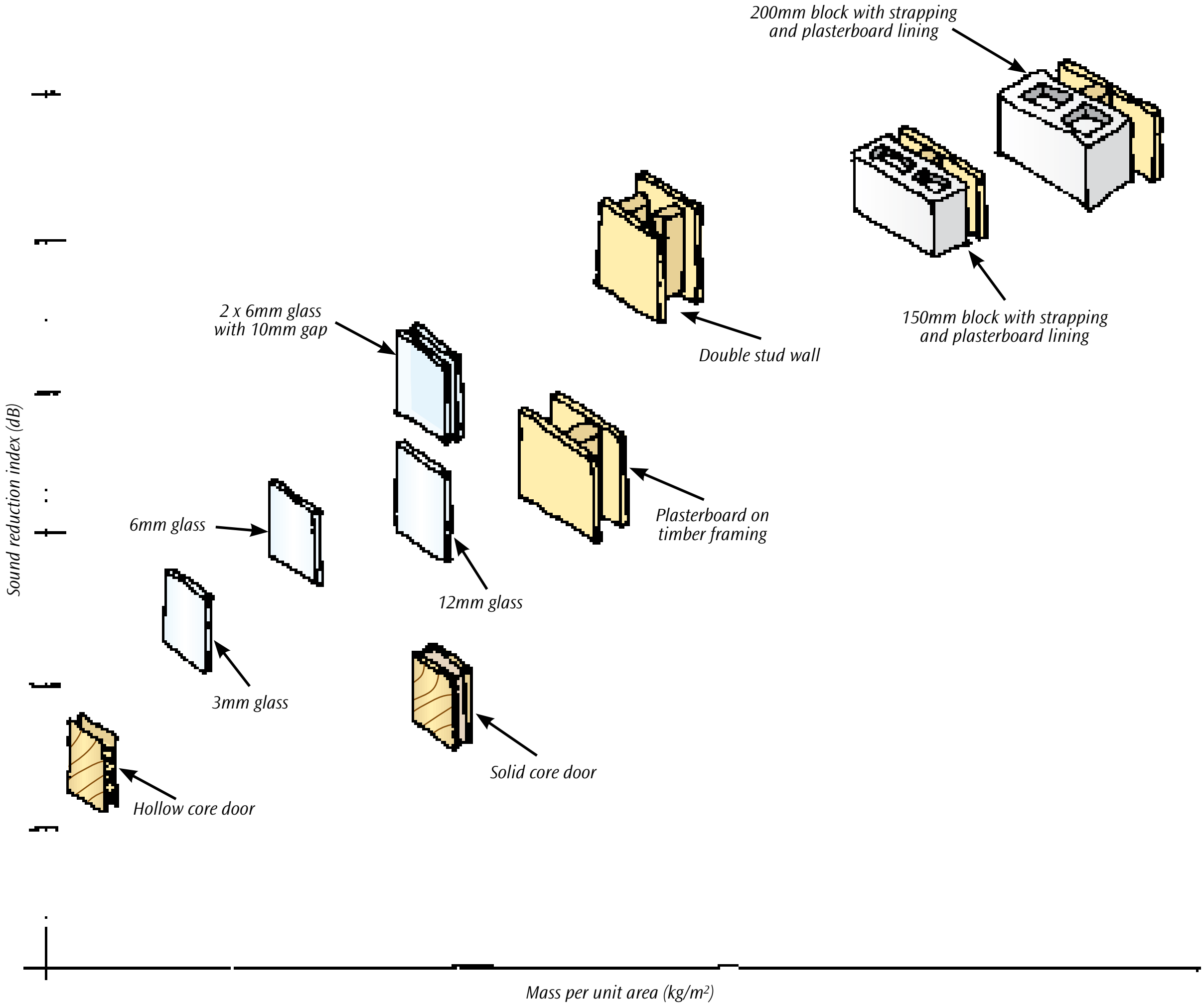
Sound transferred internally is one of the main causes of high background noise levels. Identifying a suitable STC rating is the first step in deciding how to reduce this noise. Walls between rooms with noisy and quiet activities will require a higher rating than walls between rooms with similar activities.

What type of construction reduces sound?

Effective sound insulation is dependent on the mass of the barrier. As a general rule, the heavier the barrier the more effective it will be.

Figure 20 shows the sound reduction characteristics of various constructional elements related to their mass.

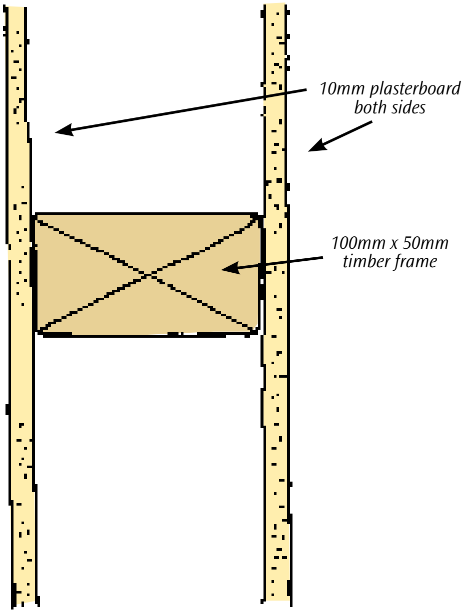
FIGURE 20 Sound reduction characteristics of various constructional elements related to their mass



Sound insulation of interior walls

Existing 100 mm timber-framed wall with 10 mm plasterboard on both sides

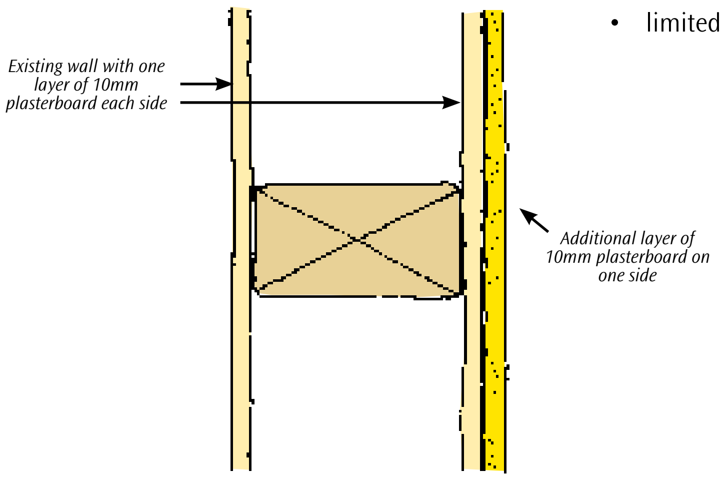
FIGURE 21 Simple partition



- STC rating 35–38 poor

Existing wall with additional layer of 10 mm plasterboard on one side

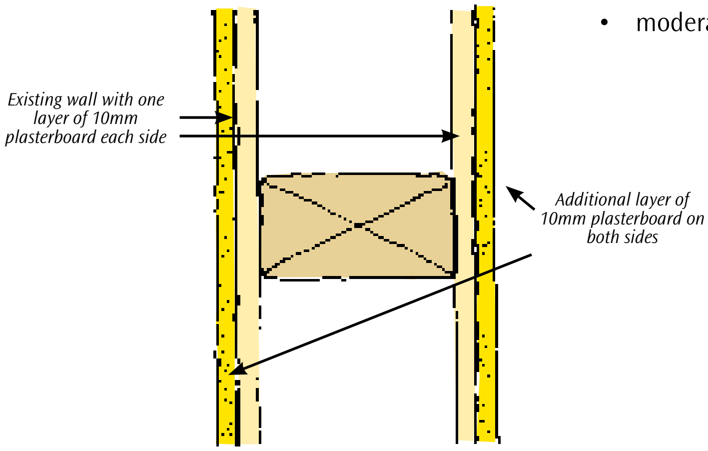
FIGURE 22 Additional layer of plasterboard on one side



- low-cost option
- STC rating 36–40 poor/average
- limited effectiveness

Existing wall with additional layer of 10 mm plasterboard on both sides

FIGURE 23 Additional layer of plasterboard both sides



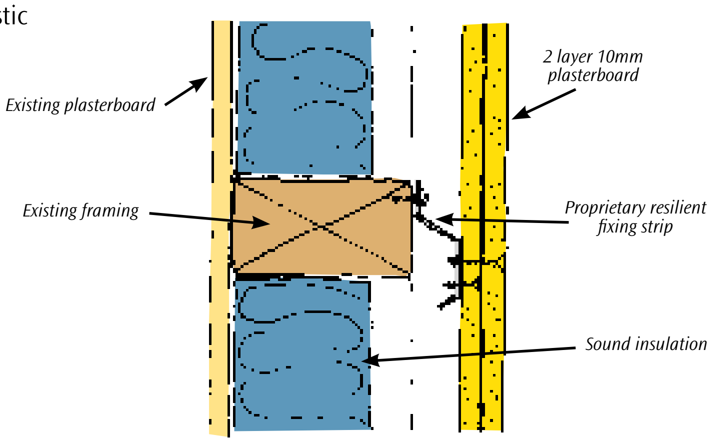
- low-cost option
- STC rating 40–42 average
- moderately effective

Sound insulation of interior walls (continued)

Existing wall – lining removed one side, R1.8 insulation, proprietary resilient rails and two layers of proprietary 10 mm acoustic plasterboard

FIGURE 24 Existing partition with new double lining on one side

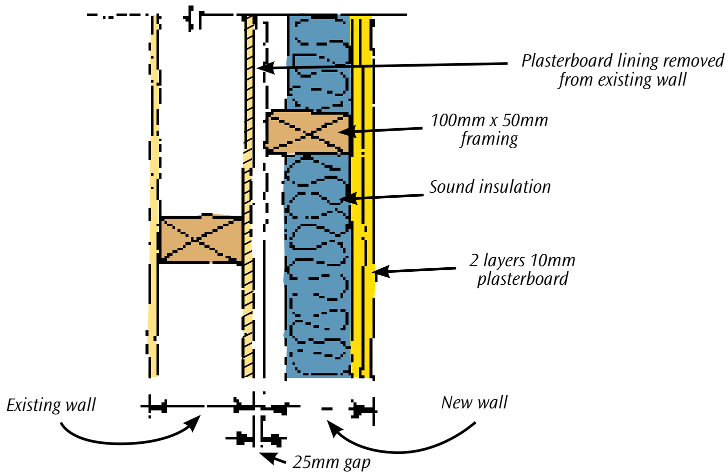
- STC rating 50+ good
- effective sound insulation
- moderately high-cost option



New additional double timber-framed wall with proprietary 10 mm – acoustic plasterboard one side, R1.8 insulation, two layers of proprietary 10 mm acoustic plasterboard other side

FIGURE 25 New partition built alongside existing

- STC rating 53
- very effective sound insulation
- high-cost option

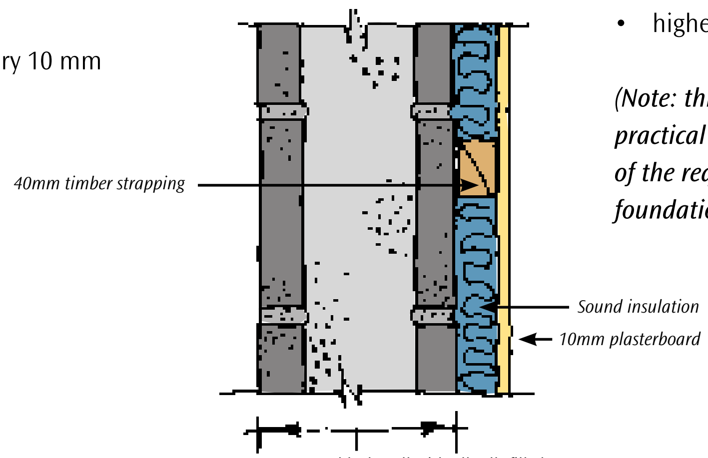


Concrete block wall with fully grouted cells 40 mm timber strapping
Sound insulation
Two layers of proprietary 10 mm acoustic plasterboard

FIGURE 26 Concrete block wall lined on one side

- best sound insulation
- 150 mm block STC rating 57
- 200 mm blocks STC rating 60
- highest cost option

(Note: this option is normally only practical in new buildings because of the requirement for heavy foundations)



Sound-flanking paths

Identifying sound paths

The most common path for sound is in the roof or floor space above walls.

An existing ceiling is most likely to be acoustically inadequate if:

- it is softboard or a single layer of plasterboard directly fixed to the rafters or joists
- the wall does not carry up into the ceiling or floor space.

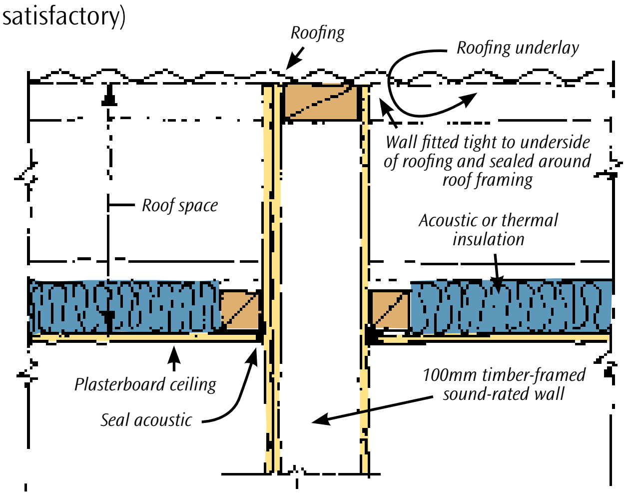
It is important to ensure that money spent on upgrading a wall is not wasted because sound is tracking through other parts of the structure once it's been upgraded. Areas to check include:

- ceiling and roof spaces
- doors
- gaps around doors
- internal windows
- service installations such as electrical outlets and ventilation ducts
- all gaps and cracks must be sealed with flexible acoustic sealant installed in accordance with the manufacturer's instructions
- the suggested construction shown in Figures 27–31 show plasterboard ceilings. Reverberation can be reduced with acoustic tiles.

Reducing sound through ceilings and floor spaces

In an existing or new open roof space, carry the sound partition framing and lining through to the underside of the roof. Fit insulation (thermal insulation is satisfactory)

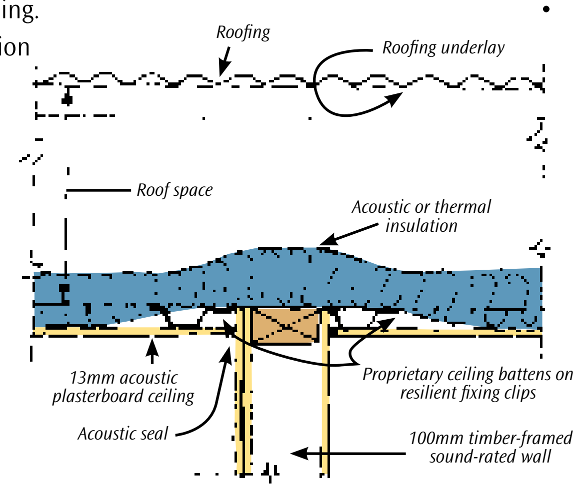
FIGURE 27 Sound partition sealed to an open roof



- acoustically effective
- low cost in new applications
- cost will vary with each depending on situation
- may not be practical in some roofs
- higher cost in alterations

In an existing open roof space, install a ceiling of 13mm plasterboard on resilient ceiling battens below the existing ceiling. Fit insulation (thermal insulation is satisfactory)

FIGURE 28 Acoustic ceiling sealed to sound-rated partition

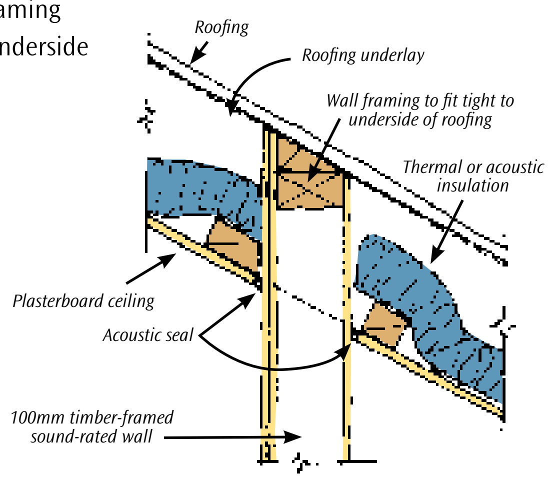


- acoustically effective
- may be the only option for practical reasons
- high cost

Reducing sound through ceilings and floor spaces (continued)

In an existing or new skillion roof (one where there is no roof space), carry the sound partition framing through and seal it to the underside of the roofing

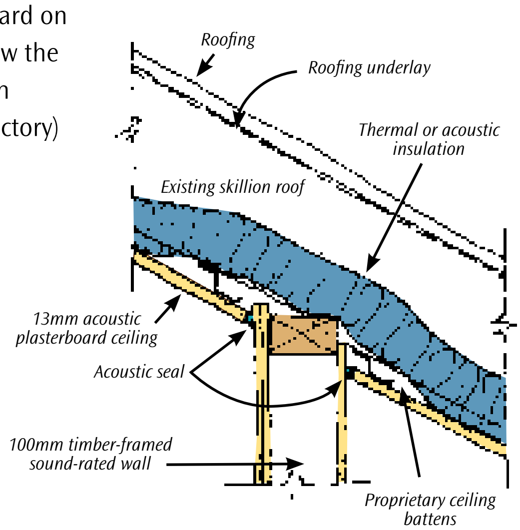
FIGURE 29 Sound partition sealed to a skillion roof



- acoustically effective
- low cost in new applications
- cost will vary with each circumstance
- may not be practical in some roofs
- higher cost in alterations

In an existing skillion roof (one where there is no roof space), install a ceiling of 13mm plasterboard on resilient ceiling battens below the existing ceiling. Fit insulation (thermal insulation is satisfactory)

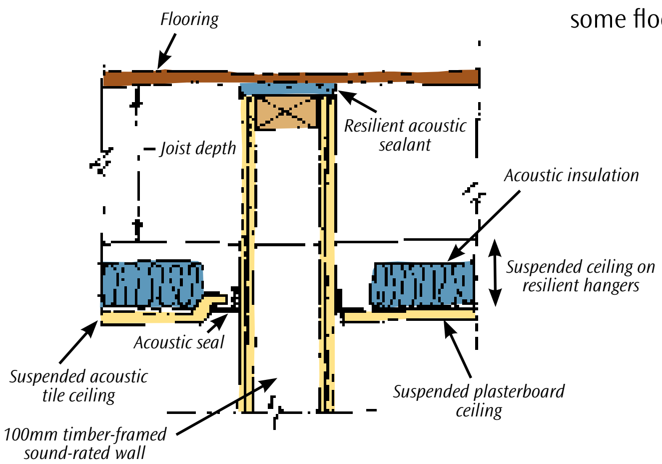
FIGURE 30 Ceiling on a skillion roof sealed to a sound-rated partition



- acoustically effective
- may be the only option for practical reasons
- high cost

On an existing or new timber floor, seal the partition to the underside of the flooring. Fit acoustic insulation

FIGURE 31 Sound-rated floor to ceiling construction

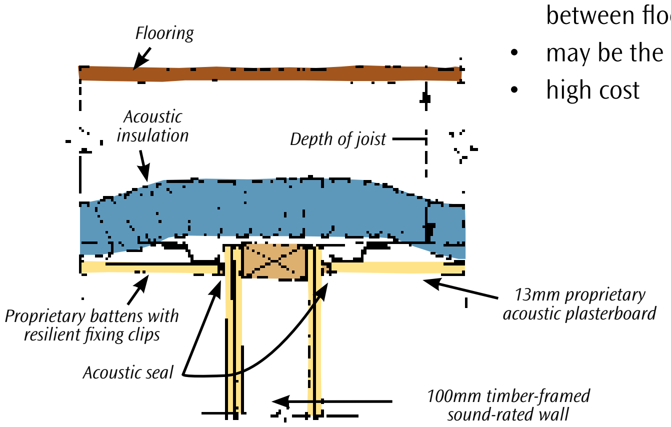


- acoustically effective
- low-cost option
- may not be practical on some floors

Reducing sound through ceilings and floor spaces (continued)

Under an existing or new timber/concrete floor, fit proprietary suspended ceiling on resilient hangers and R1.8 insulation

FIGURE 32 Acoustic ceiling under a floor, sealed to a sound-rated wall



- acoustically effective
- provides heat insulation between floors
- may be the only option
- high cost

Doors and noise control

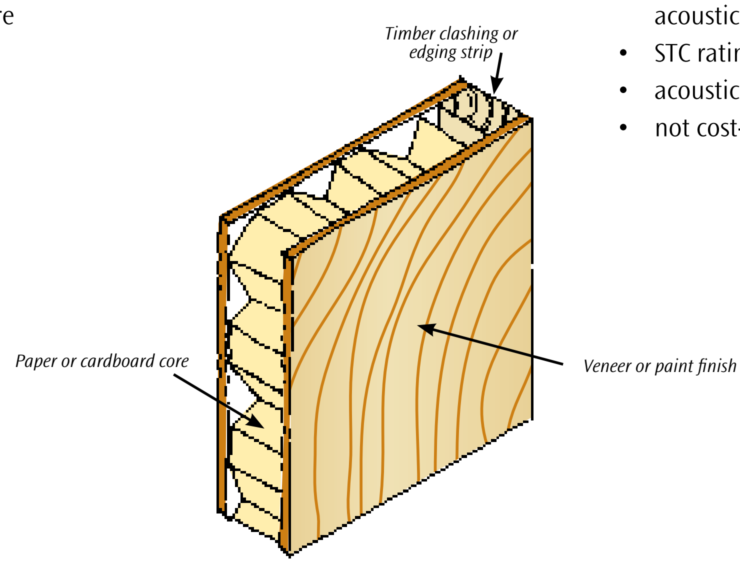
Doors are weak points in sound-insulating walls and, in many cases, may be the reason why a wall fails to meet the required standard. If possible:

- avoid putting new doors in sound-control walls
- consider removing existing doors in sound-control walls that are not absolutely necessary.

Sound insulation of doors

Existing hollow core door with cellular lightweight core

FIGURE 33 Hollow core door

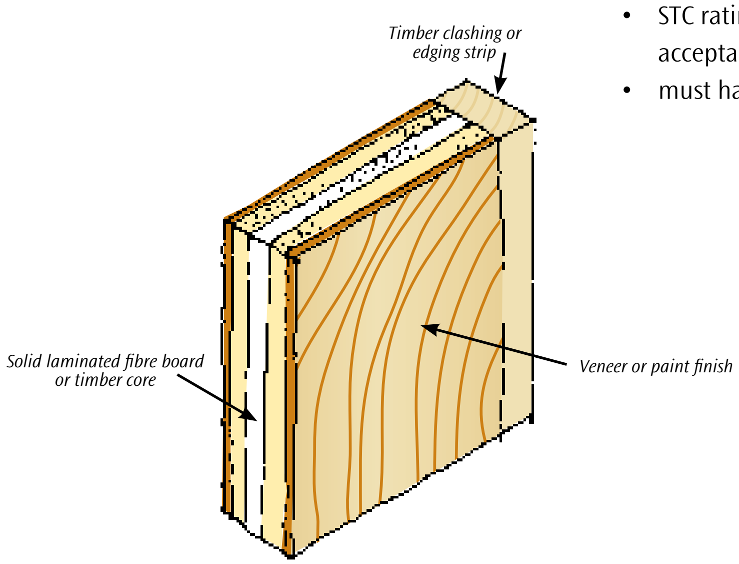


- replace with solid core door or acoustically-rated door
- STC rating 15 – poor
- acoustically ineffective
- not cost-effective to upgrade

Sound insulation of doors (continued)

Solid core – with a solid fibreboard core

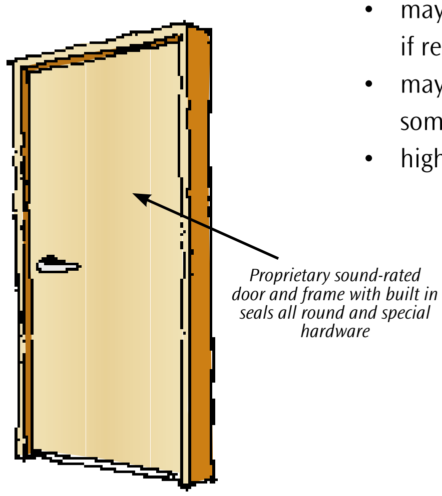
FIGURE 34 Solid core door



- low-cost option
- STC rating 20 – average/ acceptable
- must have effective seals

Proprietary acoustically-rated single door

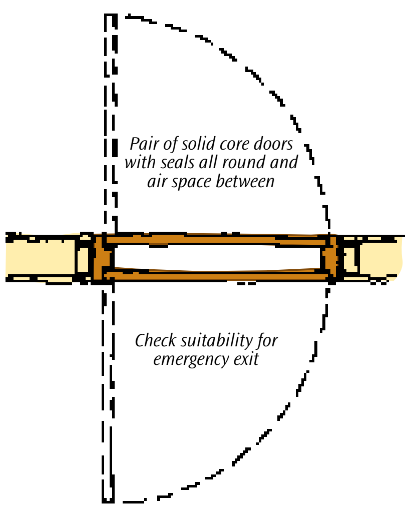
FIGURE 35 Proprietary sound-rated door



- STC rating 30–40 good
- may also serve as a fire door if required
- may be the only solution for some situations
- high-cost option

Proprietary acoustically-rated double connector door

FIGURE 36 Double doors

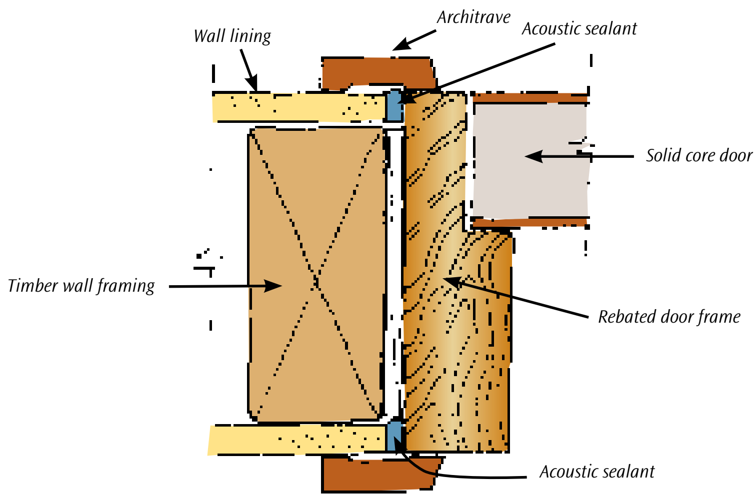


- STC rating 40–50 very good
- may be the only option for some specialist high requirement situations, eg, a recording studio door
- check compliance with emergency exit requirements
- most expensive option

Sound insulation of doors (continued)

Door frames must be sealed to linings

FIGURE 37 Sealing the door frame to the linings



Door seals

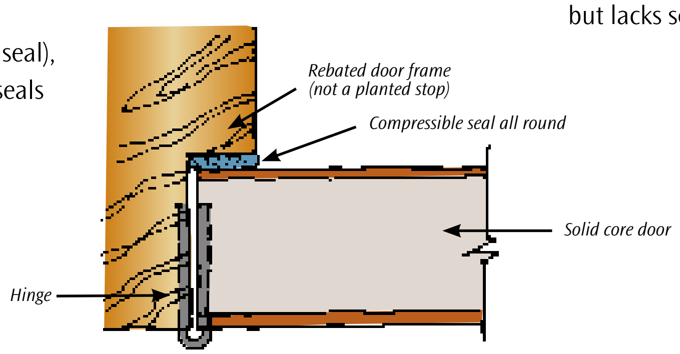
It is important to ensure that seals around doors are correctly installed to minimise gaps. Gaps in door seals are a common way for sound to pass through.

To make doors effective for stopping sound:

Door seals

Doors must fit into deep rebated stops (planted stops are not acceptable unless used in conjunction with a proprietary seal), and have resilient tight-fitting seals at the top and in the jambs

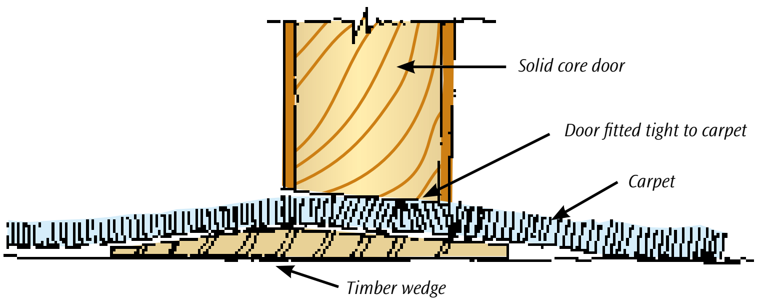
FIGURE 38 Door frame fitted with compressible seal



- low cost
- improved acoustic performance, but lacks seal at bottom of door

Bottom of door sealed using carpet

FIGURE 39 Door seals

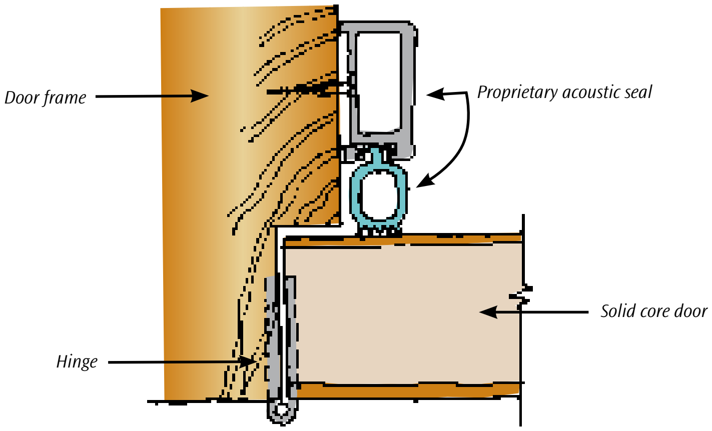


- low cost
- further improvement of acoustic performance

Door seals (continued)

Fit proprietary seals to door jambs

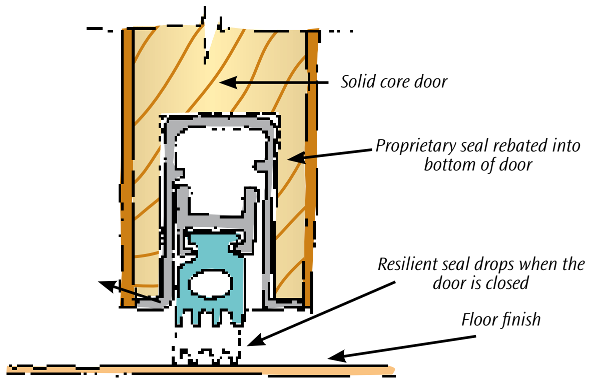
FIGURE 40 Door fitted with proprietary acoustic seal



- good acoustic performance
- more expensive option

Fit proprietary seals at the base

FIGURE 41 Door bottom fitted with proprietary rebated seal



- good acoustic performance
- more expensive option

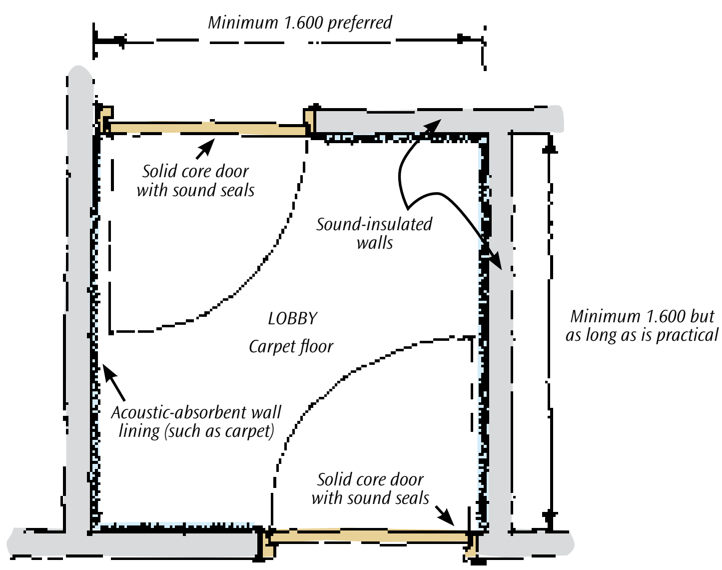
Sound-insulated double doors

Double doors are often installed as fire or smoke stoppers, fire escapes or for weather stopping, and may not be designed to stop sound. Ask a specialist for advice if you have double doors that need sound-stopping because achieving an acoustic seal on double doors is expensive and often doesn't work. Check for compliance with emergency egress requirements.

Sound-stop lobbies between doors

Lobbies are effective for sound insulation (see Figure 42) – because there are two doors between the lobby and the classroom and two doors are better than one.

FIGURE 42 A sound-insulating lobby



Folding sliding doors

Walls or doors that fold and slide are often installed to encourage flexible use of teaching spaces. However, they are expensive to build and maintain. You should work out how often they will be used before opting for this type of door.

The sound-insulating qualities of folding sliding doors depend on a system of perimeter seals combined with heavy panels. Unless correctly operated and maintained, they may not provide appropriate sound insulation.

An example of glass sliding doors at Oteha Valley Primary School.

Glazed sliding doors

Glazed sliding doors can provide flexibility, but it is difficult to achieve a good sound rating.

Use proprietary doors and ensure that they have appropriate STC ratings. Make sure that seals are well maintained.

Sliding doors at Botany Downs Secondary School.

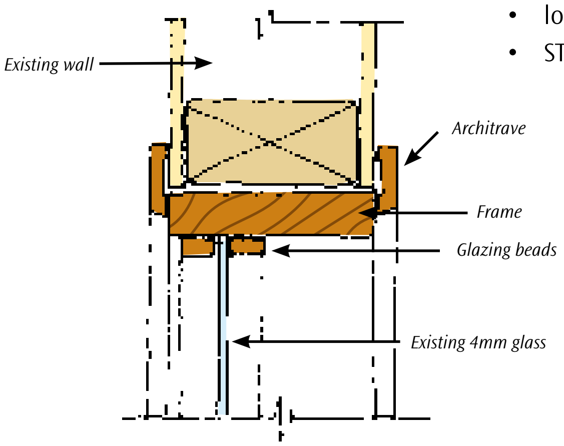
Internal windows

Fixed internal windows (or borrowed lights) are common in older schools and they provide a ready route for sound to travel. Here are some options for how to reduce the amount of sound let through these windows:

Acoustic performance of borrowed lights

Existing borrowed light with 4 mm beaded glazing

FIGURE 43 Typical existing borrowed light

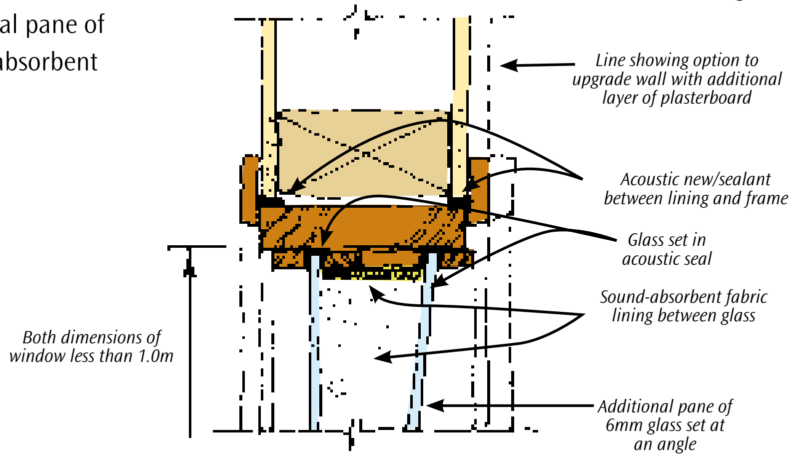


- thin glass
- loose-fitting unsealed beads
- STC rating 10 or less – poor

Acoustic performance of borrowed lights (continued)

Existing borrowed light – not more than 1 m in either dimension. Upgraded with additional pane of 6 mm glass and sound-absorbent lining

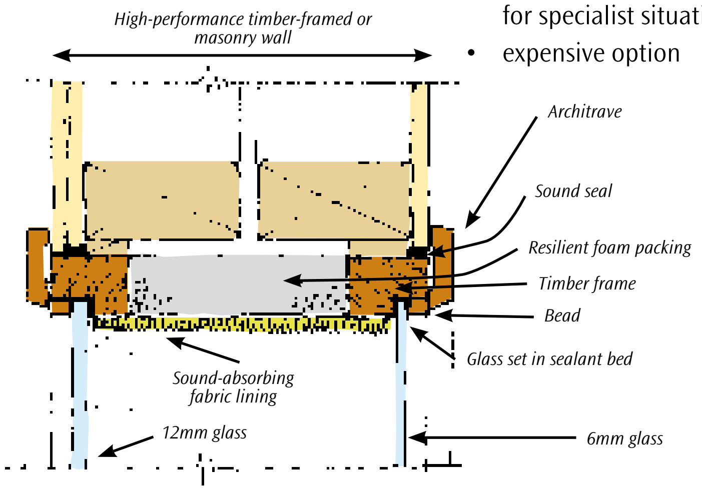
FIGURE 44 Upgrading an existing borrowed light



- low-cost option
- STC rating 25 – better

New high-performance window in sound-rated wall

FIGURE 45 Acoustic window in a double wall



- STC rating 36 – very good
- high-performance window for specialist situations
- expensive option

Re-glaze with 11 mm laminated sound-reduction glass

- cost-effective
- STC rating 39
- expensive

Services

Breaks in walls or ceilings, such as for power sockets or light switches, let sound into a room. Check:

- power outlets
- computer outlets
- telephone jackpoints
- light switches
- intercoms
- heating pipes
- water pipes
- ventilation ducts
- light fittings.

To minimise sound transfer:

- all service outlets should be sound sealed
- avoid pipes that pass through walls between teaching spaces
- fit sound mufflers to ducting.

Sealing all air gaps between the borrowed light frame and the wall framing with correctly installed acoustic sealant is critical.

Impact noise on floors

What is impact noise?

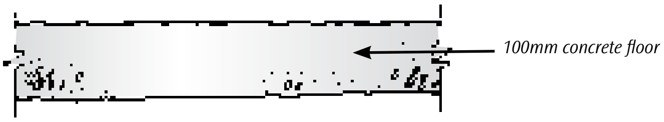
The sound performance for impact noise, such as students or teachers walking around, is called Impact Insulation Class (IIC). The higher the IIC rating, the higher the insulation against impact sounds.

Sound impact from upper floors can be particularly noticeable. A minimum IIC of 55 is recommended for floors between teaching spaces.

Impact insulation on concrete floors

Existing 100 mm concrete floor

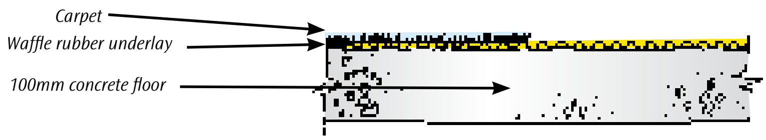
FIGURE 46 Concrete floor



- IIC 25 – poor

Existing 100 mm concrete floor with carpet and foam underlay flooring

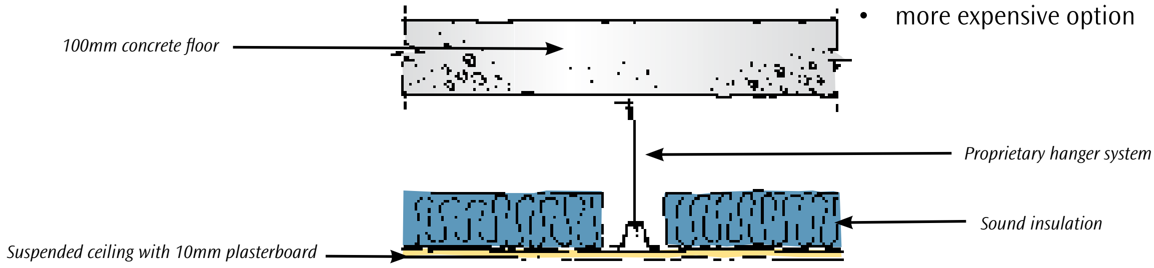
FIGURE 47 Concrete floor with carpet and underlay



- cost-effective
- carpet helps to lower reverberation time in upper floor rooms
- carpet effective at reducing impact noise in the middle-to-high frequency range, but not in the low frequency range
- IIC 38 – poor

Existing 100 mm concrete floor with proprietary suspended ceiling on resilient hangers, R1.8 insulation

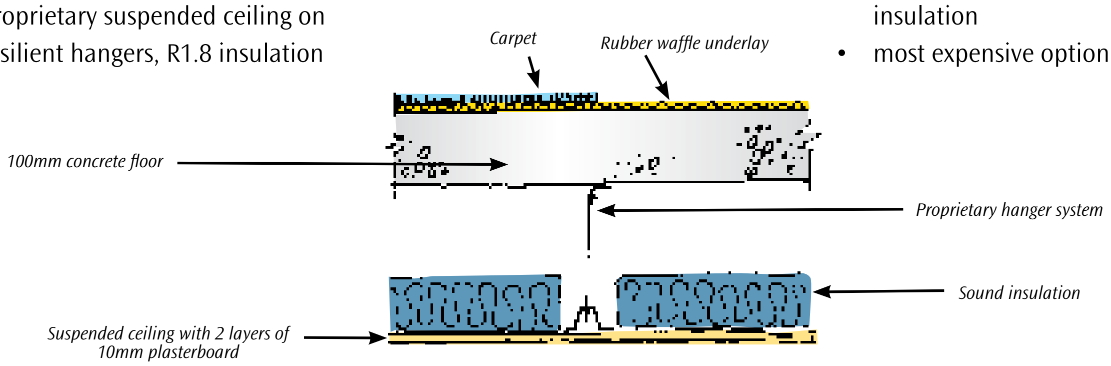
FIGURE 48 Concrete floor with suspended ceiling



- IIC 43 – average
- effective at reducing the sound of footsteps
- more expensive option

Existing 100 mm concrete floor with carpet and foam underlay flooring, proprietary suspended ceiling on resilient hangers, R1.8 insulation

FIGURE 49 Concrete floor with carpet and suspended ceiling



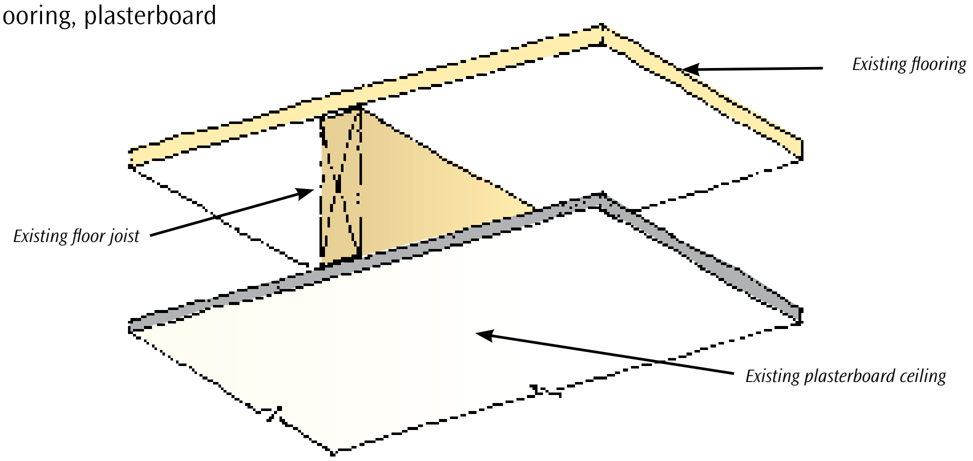
- IIC 60–63 – very good
- most effective overall sound insulation
- most expensive option

Impact insulation on timber floors

Existing timber-framed floor with particleboard flooring, plasterboard ceiling

FIGURE 50 Traditional floor and ceiling

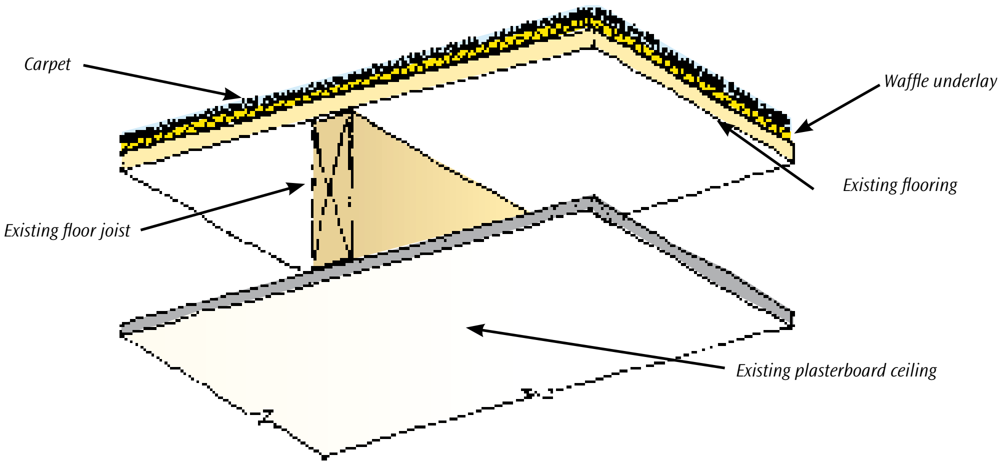
- IIC 25 – poor



Existing timber-framed floor with particleboard flooring, plasterboard ceiling with carpet and foam underlay flooring

FIGURE 51 Traditional floor and ceiling with carpet

- cost-effective
- carpet lowers reverberation time and furniture noise in upper-floor rooms
- carpet effective in the middle-to-high frequency range but not in the low frequency range

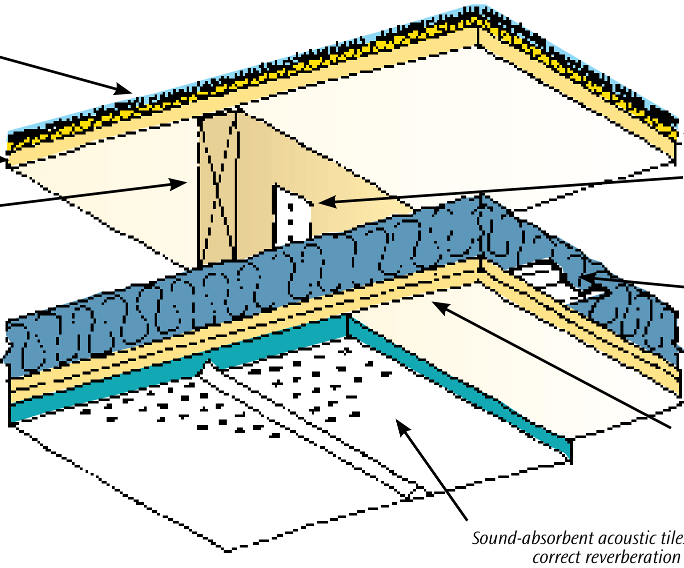


Impact insulation on timber floors (continued)

Existing timber-framed floor with particleboard flooring, plasterboard ceiling removed and proprietary suspended ceiling on resilient hangers, and R1.8 insulation installed

FIGURE 52 Timber floor with suspended acoustic ceiling

- IIC 45 – good/average
- effective at reducing the sound of footsteps
- more expensive option

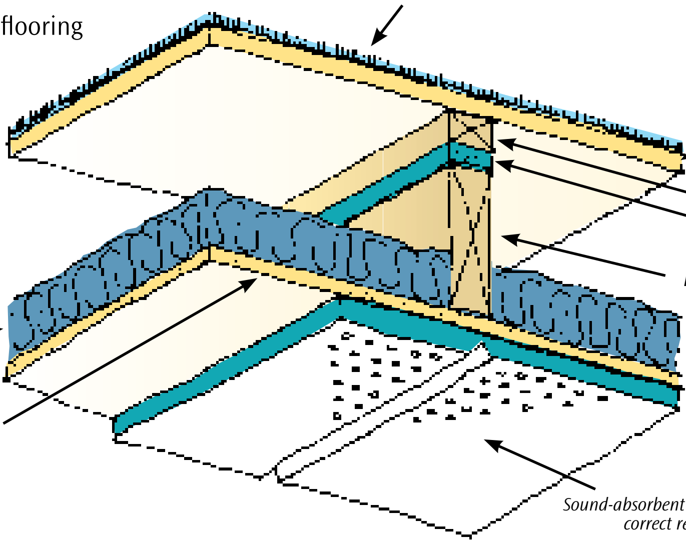


Existing as above with particleboard flooring and plasterboard ceiling removed. New proprietary suspended ceiling on resilient hangers and R1.8 insulation installed.

New timber-framed upper floor with resilient strips on top of joists, battens and particleboard. Carpet and foam underlay flooring

FIGURE 53 Floor on resilient rubber pads and suspended ceiling

- IIC 72 – very good
- effective overall sound insulation
- most expensive option



New timber-framed upper floor with two layers of particleboard with resilient sheet between

- effective impact insulation
- expensive option

Corridors

Corridors, stairs and other spaces where there are a lot of teachers and students moving about are very noisy.

If these spaces are treated to reduce noise and reverberation, this will give the whole school a quieter feel. It will also reduce the amount of noise transferred into teaching spaces.

FIGURE 54 Acoustic treatment of corridors

Noise reduction in corridors

Fit sound-absorbent acoustic tiles to all of the ceiling and to walls above two metres	• will reduce reverberation time • cost-effective
Install polypropylene direct-stick carpet on the floor	• low-cost option • hard-wearing • carpet helps to reduce reverberation time • fairly effective at reducing impact noise • additional maintenance cost
Install wool carpet on waffle underlay	• more effective impact noise control • hard-wearing • carpet helps to reduce reverberation time • higher maintenance cost • higher-cost option
Foam-backed vinyl	• reduces impact noise • not as effective as carpet at reducing reverberation • expensive
Fit direct-stick carpet dado to 1,200 mm	• effective at reducing impact noise on wall • reduces reverberation • provides hard-wearing wall finish that offsets maintenance costs • high-cost option
Make sure that doors opening onto teaching spaces have good sound-insulation properties	
Make sure that windows opening onto teaching spaces have good sound-insulation properties	

External decks

Many schools have relocatable classrooms with timber decks which are structurally joined to the classroom framing.[1]

These decks are noisy for those in the classroom. Here are some options to reduce the noise transfer to the classroom:

Sound separation of decks

In new or relocated classrooms with decks – ensure that the deck is structurally separated from the classroom floor	• a cost-effective option
In existing classrooms with structurally connected decks – overlay the deck with plywood and install direct-fixed external quality carpet	• will reduce airborne noise • may increase slip resistance of wet decks (frost and ice have also been an issue on decks) • moderate-cost option • limited effectiveness in controlling impact sound transfer
In existing classrooms with structurally connected decks – structurally separate the deck from the classroom (see Figure 55)	• effective at preventing low frequency footfall sound transfer • may be the only effective solution • expensive option (dependent on the structure)

Teacher's voice amplification systems

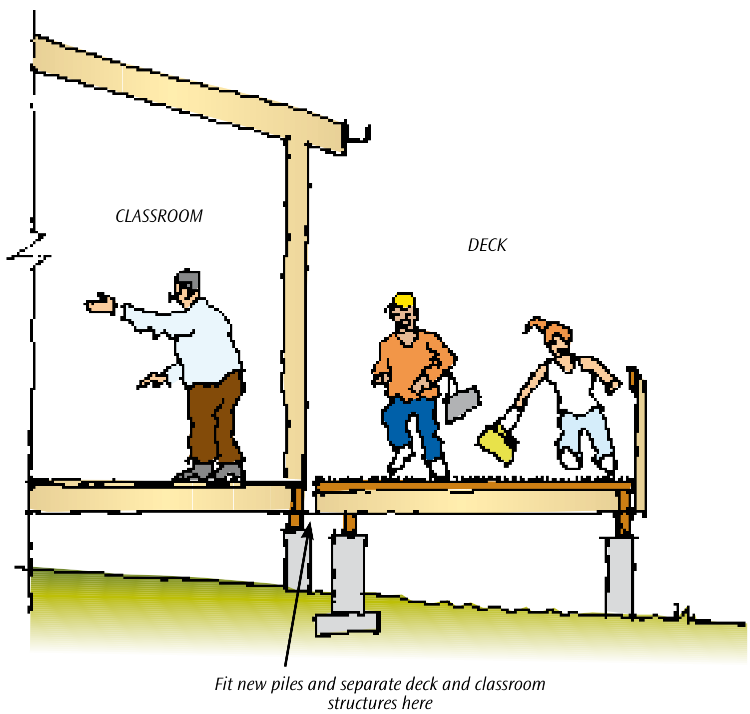
Teacher's voice amplification systems are sometimes known as sound field systems:

- the teacher wears a radio microphone which transmits their voice to a receiver
- an amplifier increases the teacher's voice level by 8–10 dB to give a satisfactory voice-to-background noise ratio
- loudspeakers (usually four) are positioned to give an even spread of sound throughout the room.

Situations may arise where it is not possible to achieve satisfactory classroom acoustic conditions for all users. There may be a variety of causes for this including:

- when outside noise is too loud to be sufficiently controlled effectively and economically

FIGURE 55 Deck/classroom/separation to reduce noise transfer



- the teacher's voice is not strong enough to achieve a satisfactory voice-to-background ratio
- the class has students:
  - with hearing impairments
  - for whom English is a second language
  - with learning difficulties.

The advantages of teacher's voice amplification systems are:[3]

- at the flick of a switch signal-to-sound ratios are improved
- the teacher can be heard from anywhere in the room
- the teacher's voice is less stressed
- students' on-task behaviour and comprehension may be improved.

The disadvantages are:

- it is expensive to install
- the need for regular maintenance
- sound levels must be set correctly to be effective
- some teachers don't like them and may not use them
- the long-term effects on the development of students' listening skills are, as yet, unknown
- they only assist a teacher/student communication and are not useful in student/teacher or student/student communication.

Teacher's voice amplification systems are assessed and installed by firms specialising in this type of work.

Teacher's voice amplification systems work best in spaces that are acoustically well designed. They are not a substitute for good acoustical design and should only be used when all other options have failed. Sound levels should not exceed 80 dB at any time and never exceed a level of 70 dB over the teaching period.

Teacher's voice amplification systems work best in spaces that are acoustically well designed.

> SECTION 4 – Specialist Teaching Spaces

Multi-purpose halls

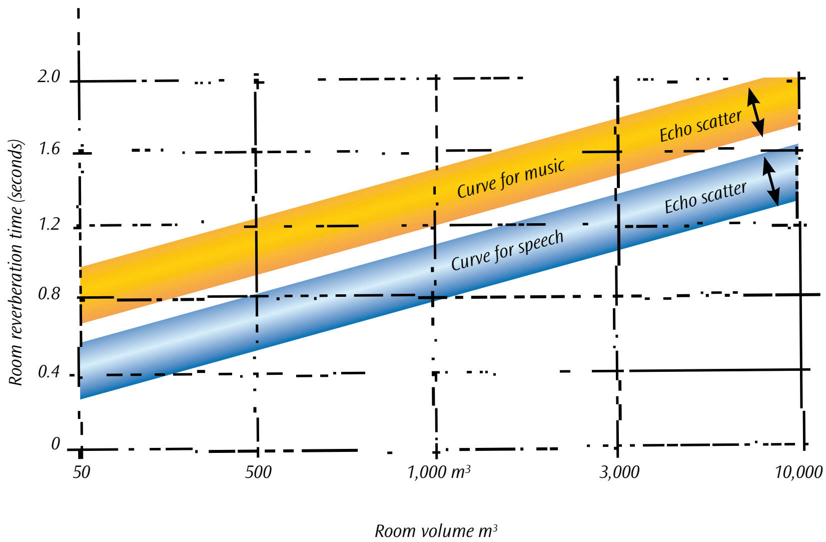
Many schools have large multi-purpose halls, which are used for a variety of activities, such as assemblies, theatrical productions, musical recitals, gymnastics and lectures.

It is unlikely one space can have acoustics characteristics that are satisfactory for all these activities.[8] The requirements for speech and live music are different to the requirements for other activities (see Figure 56). Normal speech requires a much shorter reverberation time than that ideal for live music.

The most common problems with halls are:

- a high level of background noise
- excessive reverberation, often owing to hard surfaces and lots of windows. These mean there are usually high noise levels and speech clarity is difficult.

FIGURE 56 Approximate reverberation times for speech and music in multi-purpose halls



Achieving acoustics that are acceptable for most conditions in multi-purpose halls requires flexibility to:

- change the sound characteristics of the area using curtains and screens
- vary the layout to suit the purpose.

Background noise

Table 3 shows the recommended Australian/New Zealand Standard AS/NZS 2107 background sound level and reverberation times for multi-purpose halls.

TABLE 3. AMBIENT SOUND LEVELS AND REVERBERATION TIMES FOR MULTI-PURPOSE HALLS[(1)]

Size of hall	Ambient sound level (dB)	Reverberation time (secs)
Rooms up to 250 seats	30 to 40	Note 2
Rooms over 250 seats	30 to 35	Note 2

Note 1: The terms 'multi-purpose hall' and 'assembly hall' are interchangeable.

Note 2: The reverberation time for this is given in AS/NZS 2107, which refers to a sound curve similar to that shown in Figure 56.

If background noise is a problem, consider:

Timetabling quiet events when outside noise is at a minimum	• cost-effective • may not always be possible
In noisy areas (eg, when the hall is near a busy road), it may be necessary to install mechanical ventilation or air conditioning so that windows can be closed. Consult an acoustics specialist	• may require double-glazing to gain full benefit • very expensive

If a noisy ventilation system is a source of noise, fit silencers to the system. Consult an acoustics specialist	• can be effective • moderately expensive
Make sure that all doors and windows from noisy areas are tight fitting	• cost-effective • effective
Increase the sound insulation of walls between the hall and noisy areas	• cost-effective • effective
Fit sound treatment to windows next to the source of noise (this will usually go hand-in-hand with mechanical ventilation unless natural ventilation can be arranged on a quiet side)	• effective • expensive
Fit rubber feet under all chairs and tables to reduce internal noise	• cost-effective • effective
Fit carpet to floor to reduce the sounds of footsteps and furniture noise	• very effective • will reduce reverberation time • may not be practical for all uses • expensive

Reducing reverberation time

If the room has a lot of echo, consider:

Fit carpet to floor to reduce the sound of footsteps and furniture noise	• very effective • may not be practical for all uses • expensive
Fit foam-backed vinyl flooring to reduce the sound of footsteps and furniture noise	• effective • suitable for most uses • expensive
If there are large floor-to-ceiling windows fit heavy drapes	• effective • gives flexibility • moderately expensive
Use moveable screens with sound-absorbent surfaces	• effective • may not be practical for all uses
Install areas of permanent sound-absorbent panels to appropriate walls – these can be up high if preferred	• effective • moderate cost
Fit angled panels to areas of wall to reduce ‘sound flutter’ (fast echoes between opposite walls)	• effective • moderate cost
Fit sound-absorbent ceiling tiles	• effective • moderate cost • most effective option for controlling café effect • may reduce the suitability of the room for live music

Adjusting layout to suit speech

To make it easier for speech clarity, it is important to emphasise direct sound. If listeners cannot see the speaker well they probably will not be able to hear them.

To maximise direct sound:

- arrange the seating layout so that all the audience is within an angle of 120° (see Figure 57)
- keep the majority of the audience as close as possible to the speaker. The sound level of speech falls by 6 dB when the speaker-to-listener distance is doubled
- arrange the seating so the audience's view is not blocked by the person in front. Ideally this is done by tiered seating (see Figure 58), but this is difficult to achieve and few facilities have tiered seating. A similar effect can be achieved by raising the speaker (see Figure 59).

Sound amplification

It may not always be possible for speakers to be heard clearly in multi-purpose halls because:

- the physical dimensions and shape of the hall are unsuitable
- features, such as large windows and hard floor surfaces, that create a long reverberation time, cannot be avoided – either for practical reasons or because of cost
- speakers with quiet, untrained voices may experience difficulty, even in rooms with acceptable acoustics.

FIGURE 57 Angle of audience to speaker

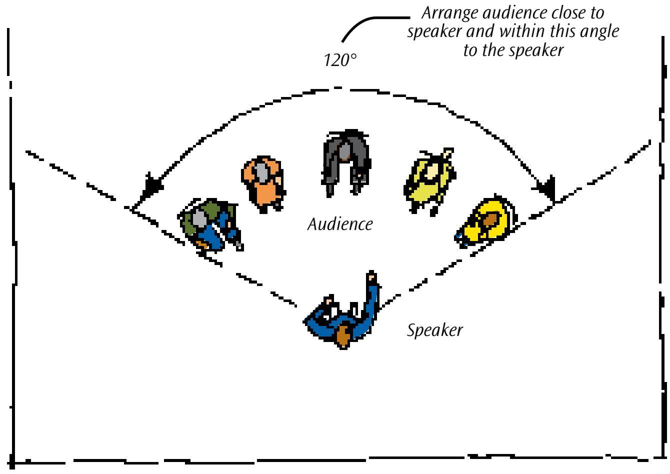


FIGURE 58 Direct line of sight by raising the audience

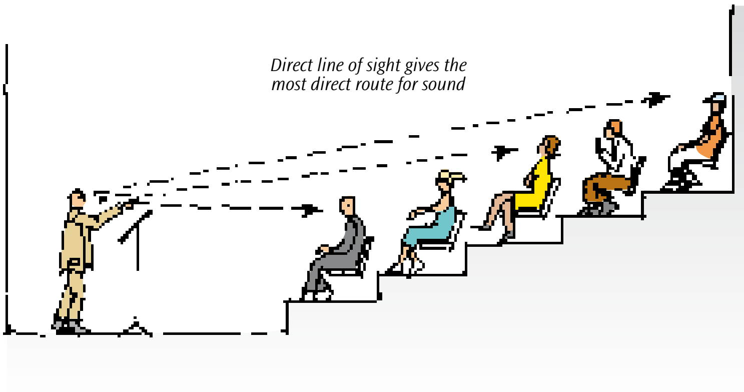
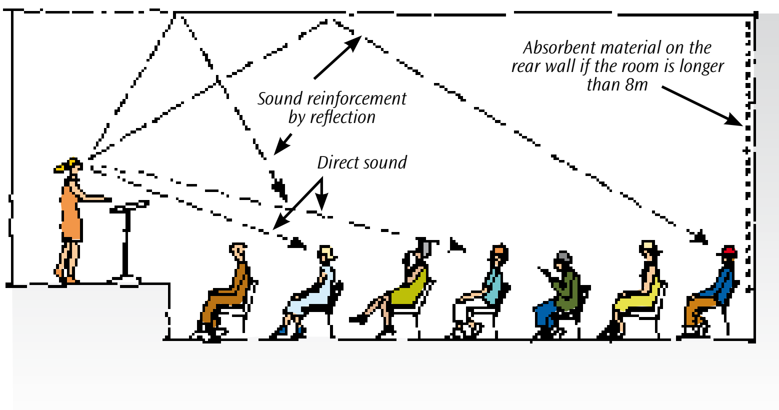


FIGURE 59 Direct line of sight by raising the speaker



These circumstances may mean you need an amplification system which should:

- increase the volume of direct sound
- keep the overall effect as natural as possible.

The correct directional characteristics, distribution and positioning is critical to the success of the system and specialist advice should be sought.

Gyms

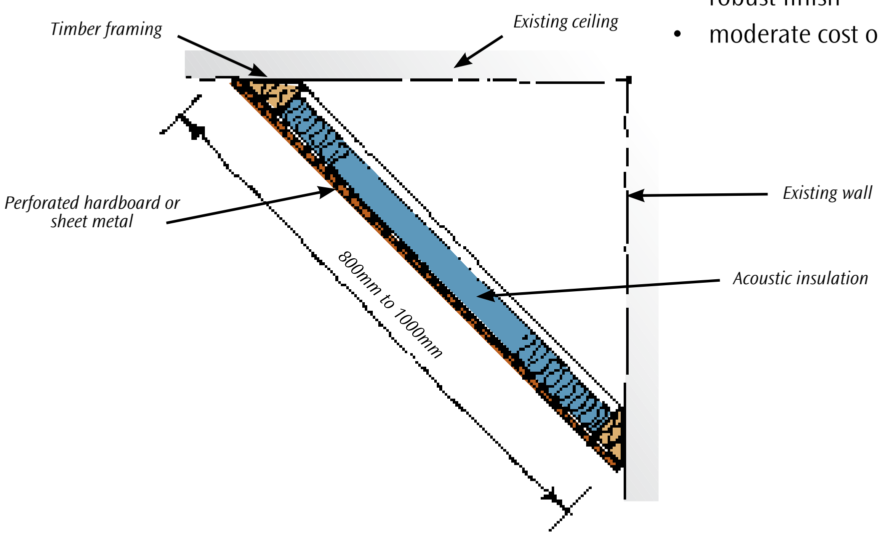
Because of the need for hard-wearing surfaces, gyms tend to be very noisy places with high reverberation times. Noise is not always a problem within the room because it is an integral part of the games and exercise. However, it is important when planning gyms to ensure they are acoustically isolated from quiet zones.

The main areas for sound-absorbent surfaces to reduce reverberation are up high on the walls and on the ceiling. However, these areas must still be robust.

Some possible solutions are:

Woodwool panel ceilings	• good sound absorption • hard-wearing • additional thermal insulation • economic solution for a new building • expensive to retrofit
Perforated metal ceilings backed by acoustic insulation	• good sound absorption • hard-wearing • additional thermal insulation • economic solution for a new building • expensive to retrofit
Fit perforated hardboard panels up high	• good sound absorption • robust finish • moderate cost option

FIGURE 60 Sound-absorbent panel for workshop areas



Fit perforated metal panels up high	• good sound absorption • more robust finish • higher-cost option
Fit foam-backed vinyl to floor	• reduces impact sounds • economic solution for a new floor • may not be suitable for all applications

Libraries

Traditionally libraries are quiet places for individual work. AS/NZS 2107 recommends a background noise level of 40 dB(A) and a reverberation time of 0.4 to 0.6.

When planning a library make sure that it:

- is in the quiet zone of the school
- is sufficiently acoustically insulated from nearby and adjacent rooms
- has a high level of sound-absorbent internal finishes.

Suitable finishes and furnishings to reduce reverberation include:

Carpet floor with waffle rubber underlay	• effective in reducing impact and reverberation noise • provides additional thermal insulation to ground floor rooms • increases comfort level • moderately expensive • higher maintenance cost
Suspended ceiling system with acoustic tiles with an NCR of 0.7	• very effective • expensive
Mineral fibre acoustic ceiling tiles with an NCR of 0.5 fixed directly to plasterboard ceiling	• effective • low cost • can be retrofitted to existing ceilings
Drapes to windows	• effective • may serve additional purpose of reducing daylight for presentations • adds to the ambience • moderately expensive
Sound-absorbent wall panels	• effective • low cost
Upholstered chairs	• fairly effective • increases comfort level • moderate additional cost

Music rooms

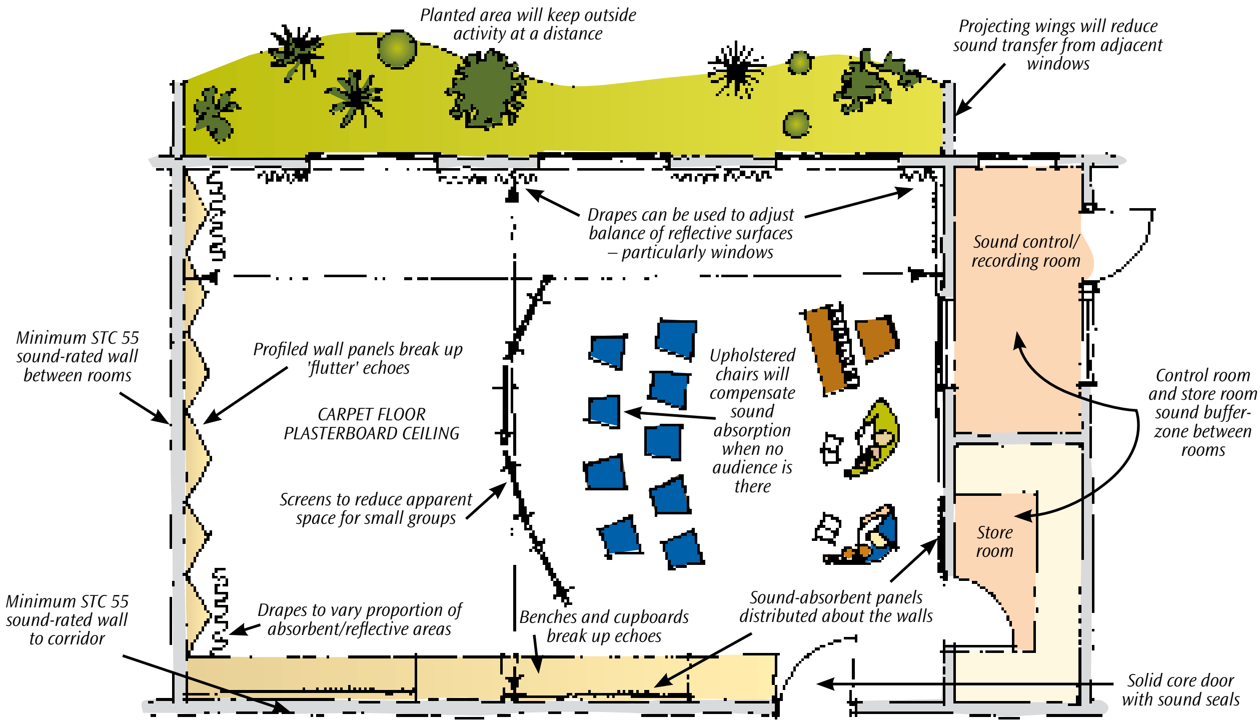
Providing acoustic flexibility is a priority for school music rooms because of the diversity of activities.[8,9] The rooms must also accommodate students playing a wide range of instruments, and singing.

For new music facilities, priority must be given to acoustics at the early planning stage by obtaining the advice of an acoustics specialist. Existing facilities can be improved, if necessary, by a careful analysis of the requirements and an understanding of the principles involved.

Specialist rooms for music may be:

- classrooms – where music theory is taught and which may only occasionally be used for live or recorded music (see Figure 61)
- small practice rooms – for small groups or individuals (see Figure 62)
- ensemble rooms – for small group performances and rehearsals
- performance rooms – for small and informal presentations
- recording studios – to accommodate musicians during recording sessions (see Figure 63).

FIGURE 61 A range of possible acoustic treatments for music rooms



These rooms have special requirements which should be considered including:

- the number of people to be accommodated
- the type of music to be played
- how much sound will be made and how this will affect other areas of the school.

There are two requirements basic to a successful music environment:

- adequate insulation of sound from outside sources
- quality sound within the room.

Sound insulation

The transmission of sound is a two-way affair:

- sound from music rooms must be prevented from disturbing other school activities
- noise from other music rooms, corridors and playgrounds must be prevented from intruding on the music being played.

FIGURE 62 Small practice rooms 8m^2 to 10m^2

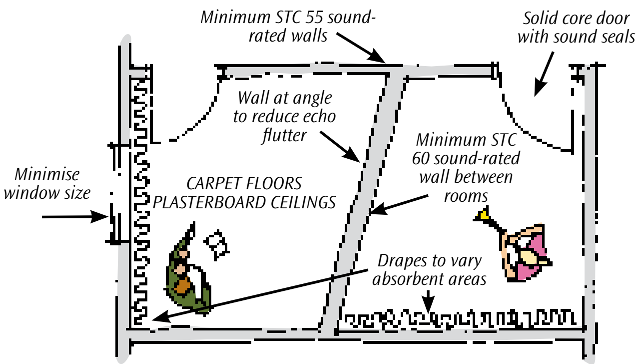
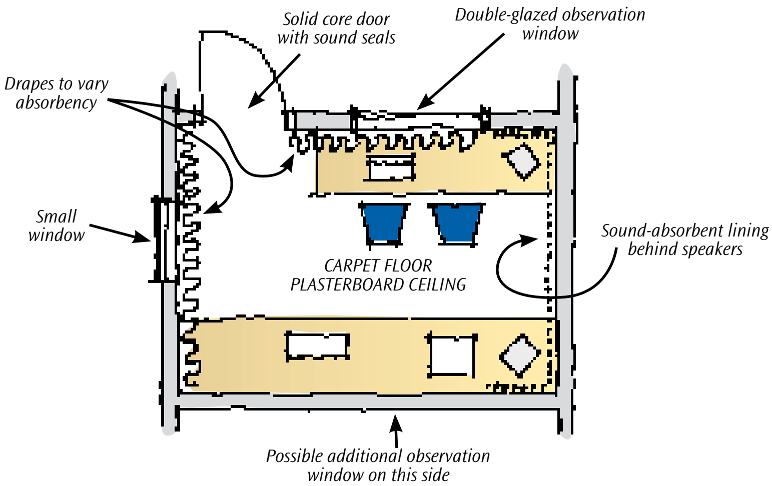


FIGURE 63 Recording/Control room



A guide to the level of insulation required between music rooms and other teaching spaces is given in Section 3. The minimum recommended level of sound insulation between a music room and a room with low tolerance to noise interference, such as a classroom, is 55 dB. However, this will not always prevent sound interference because some instruments, such as drums, produce a lot of noise.

Use the following checklist when considering sound insulation to reduce transferred noise to and from music rooms:

- minimise outside noise
- use buffer-zones – an effective way to reduce noise
- maximise sound insulation in music rooms
- reduce sound transmission by using heavy materials
- ensure there are no continuous pipes or structures between rooms, as noise will pass through these with little reduction
- take special precautions (such as installing acoustic-rated power outlets) to avoid noise which easily comes through the gaps in the sockets
- use solid core doors which are tightly fitted
- use high performance observation windows (see Figure 45)
- seal all gaps and service penetrations with acoustic sealant.

Sound quality

The sound quality in a music room is dependent on the duration and distribution of the echo or reverberation time. Reverberation time is affected by the size of the room and its total acoustic absorption capability. To achieve good sound quality, its volume and proportions must be combined to optimise the reverberation characteristics.

There are four critical factors that must be balanced to make a successful music space:

1 **Background (ambient) noise level must be low enough so that the full range of sound can be heard.**

TABLE 4. RECOMMENDED AMBIENT NOISE LEVELS FOR MUSIC ROOMS[1]

Type of room	Ambient noise level (dB)
Music classroom with listening audio	35
Music practice room or ensemble room	30
Recording and control room	25

Note 1: Ministry of Education recommendation.

2 **The room must be free from noticeable echoes, flutter echoes or any other effects which confuse or distort the sound.**

Music rooms should:

- have a higher than average ceiling height – 3 m minimum if possible for small rooms and proportionately higher for larger rooms
- avoid a plan proportion which is square or nearly square
- have a width (w) x length (l) x height (h) proportion which cannot be expressed in whole numbers (eg, 10.5 m (l) x 7 m (w) x 3.5 (h) gives a 3:2:1 ratio which is not advisable)
- avoid curved walls or ceilings because they can focus sound to small areas
- where possible, have one non-parallel wall to break up regular echo patterns (see Figure 62)
- have angled wall elements to break up flutter echo (see Figure 61).

3 The reverberation time should suit the music.

It is usually impractical to have rooms specifically set up for particular types of music – so some flexibility is necessary. This can be achieved by having heavy curtains, which can be moved to vary the reverberation time and alter the proportions of reflective and absorbent surfaces (see Figure 61).

TABLE 5. RECOMMENDED REVERBERATION TIMES FOR MUSIC PERFORMANCE[1]

Type of room	Area (m^2)	Height (m)	Reverberation time (secs)
Hall for assembly or rehearsal	250–550	3.7–7.6	1.0–1.4
Music classrooms	54–91	3.0–3.5	0.5–0.6
Ensemble rooms	16–50	2.7–4.0	0.8–1.2
Small practice rooms	6–10	2.7–3.0	0.3–0.5
Recording and control rooms	8–15	2.7–3.0	0.3–0.8

Note 1: Ministry of Education recommendation.

These reverberation times are for the mid-frequency range of sound and can be increased up to 50% for bass range frequencies.

4 Sound should be distributed evenly through the room.

This can be achieved by:

- fitting modelled surfaces to large flat walls (see Figure 61)
- using furniture, bookcases, shelving, lockers etc to break the wall surface
- distributing reflective and absorbent surfaces evenly throughout the space.

Recording/control rooms

If a small room adjacent to a classroom or recital room is used to record performances (see Figure 63) it can serve two rooms if it is positioned between them. Important considerations are:

- a good level of sound insulation with a minimum of 60 dB
- a tight fitting sound-insulating door
- a sound-insulating observation window (see Figure 45)
- sound-absorbing wall lining behind the music speakers
- heavy curtains across the window
- carpeted floor.

Design, Art and Technology rooms

Rooms used for art and technology activities fall into two acoustic categories:

- high noise levels where materials such as wood, metal and plastic are cut and shaped
- moderate noise levels used for electronics, textile skills, food production and graphics.

High noise level areas

High noise level areas must be sound insulated to prevent disturbing other quieter activities of the school. It is important to establish what equipment will be used and what the noise output will be, so that an assessment can be made of the sound-insulating requirements. Often there will be auxiliary equipment, such as dust and fume extractors, which will also be a source of noise.

Noise disturbance can be minimised by:

- siting technology areas with high noise output as far away as possible from quiet areas
- using buffer areas, such as storage rooms, to reduce sound transmission
- working out the noise output of various makes of equipment from the manufacturers and purchasing those with the lowest level
- making sure noisy equipment is correctly mounted and installed to minimise sound transfer
- correctly maintaining equipment
- reducing the reverberation time of the space as much as possible
- installing very noisy machines in purpose-made, sound-insulated enclosures
- providing appropriate levels of sound insulation around noisy areas
- programming noisy operations for least disturbance, eg, cut timber blanks outside school hours.

Reducing reverberation in high noise areas

Most areas within this section require hard-wearing surfaces, which have the effect of increasing the reverberation time. However, it is important to reduce the reverberation time as much as practically possible. Appropriate measures may include:

- having the maximum area of sound-absorbing pin-up space on the walls
- fitting sound-absorbing panels at wall/ceiling junctions (see Figure 60)
- fitting foam-backed vinyl floor finishes or firm rubber mats
- installing sound-absorbent ceiling panels
- using sound screens with sound-absorbent finishes
- in rooms with high studs, suspending sound-absorbent panels from the ceiling.

HAZARDOUS NOISE

High levels of noise can cause permanent hearing loss, depending on the level and length of exposure. Schools should ensure that staff and students are not exposed to harmful levels of noise. Preferred work practices are set out in the Approved Code of Practice for the Management of Noise in the Workplace (Department of Labour). These practices comply with the Health and Safety in Employment Act 1992. All teachers and students who are exposed to loud noise must wear appropriate hearing protection.

Moderate noise level areas

Activities, such as art and graphics classes, food production and textile technology, are generally moderately noisy. However, noise can be increased in these areas because they are likely to have:

- an informal teaching style which may lead to the café effect (see Section 2)
- larger areas of glazing and hard surfaces which increase reverberation time.

The reverberation time should be reduced as much as possible, with a recommended maximum of 0.8 seconds.

Art rooms are likely to have large areas of pin-up space. However, the acoustics of these spaces can be degraded by a large amount of artwork attached to it.

Carpets, where appropriate, should be considered to increase sound absorption and reduce impact noise. Where carpet is not practical, an alternative is foam-backed vinyl, with ordinary vinyl under heavy equipment.

> SECTION 5
– Students with Special Education Needs

Schools for all people

When considering acoustics design there is a wide range of disabilities which may need to be considered including:

- hearing impairment
- visual impairment
- physical difficulties
- emotional and behavioural difficulties
- learning difficulties.

Planning ahead

Making provision for students with special education needs must be an integral part of a school's policies and practices. This provision must be considered at all stages of planning and construction of new buildings and refurbishments. Schools should take account of both existing and future students likely to attend the school. Generally, planning and design which makes provision for students with disabilities benefits all students and teachers.

Acoustics and students with special education needs

Most students would be affected in some way by a noisy learning environment. Some studies have shown that students in noisy classrooms perform poorly when compared to those in quiet rooms. Other studies indicate that the impact of noise is greatest on students with hearing loss or hearing impairments.[11]

Some students can be startled or distressed by loud or unexpected noises, which may not even be noticed by other students or the teacher. These loud noises include:

- lawn mowers
- those from heavy traffic and sirens
- dogs barking
- the school bell and alarm
- construction noises from building work
- high reverberation noise within a teaching space.

Students startled or distressed by noise may:

- clamp their hands over their ears
- scream or groan to block out the noise
- rock or wave their hands
- attempt to leave the room.

Practical steps

Teaching spaces that are acoustically designed to be suitable for students with hearing impairments will be beneficial for all users. Factors to consider include:

- making sure the classrooms used by students with significant sensitivity to loud noises are in the quiet parts of the school away as much as possible from outside noises, such as the playground and busy roads
- taking steps to minimise outside noise as much as possible
- if there is doubt about the amount of background noise, have it tested by an acoustics specialist. Table 7 (Section 6) requires the background noise level in classrooms for students with hearing impairments to be 30 dB or below
- making sure that the reverberation time of the rooms do not exceed 0.4 seconds
- considering the classroom layout where students with hearing impairments are closest to the teacher and can see most of the other students in the class
- using a small alcove or room that is acoustically isolated from, but visually attached to, the classroom where students can go if they find the classroom too noisy
- warning students of planned fire alarm drills
- reducing the noise made by the bell to a maximum of 75 dB(A) to the student closest to it.

> SECTION 6
– Planning New Buildings and Extensions – Statutory Requirements for Acoustics

Where new buildings or substantial alterations or extensions are planned, an architect will be appointed to carry out the design. They are also responsible for the acoustics, and will be aware of the statutory requirements. To ensure the best outcome, principals and boards of trustees also need to be aware of important acoustic factors and have a basic understanding of the design and building process.

Ensuring a good acoustic outcome

To ensure that all requirements are met, that there is compliance with the New Zealand Building Code (NZBC), and that money has been well spent, boards of trustees should monitor acoustic requirements throughout the design and building process. For a good outcome it is vital that:

Boards of trustees understand:

- the importance of addressing acoustics in school design
- that acoustics need to be taken into account early in the design stage
- that poor acoustics can have an adverse effect on teachers and students.

Teachers and educators understand:

- good acoustics in teaching spaces are important for general wellbeing
- a quiet teaching environment creates a calm atmosphere
- there is no need to raise their voice to be heard in an acoustically well-designed classroom.

Architects and designers understand the:

- acoustic requirements for schools
- importance of good acoustics in teaching spaces
- requirements of students with special education needs
- potential detrimental effect that poor acoustics can have on students' education.

Monitoring the design process

Key principles

Principles that can be applied at the appropriate stages are set out in the Ministry's *Property Management Handbook*.[12]

At the initial assessment stage:

- if the volume of noise from sources outside of the site is high, obtain the advice of an acoustics consultant
- ensure that the architect is fully briefed on the:
  - statutory requirements (NZBC)[4]
  - Ministry of Education requirements (AS/NZS 2107)[2,5]
  - recommendations in this publication
  - special requirements for your school
- make sure that the architect is briefed on the acoustic requirements for each teaching space including the:
  - maximum background noise level (see Table 7, Section 6)
  - required reverberation time (see Table 7, Section 6)
  - specialist room requirements (Section 4).

At the design stage

- Ask the architect:
  - to show how outside noise will be dealt with
  - what measures will be taken to reduce internal noise
  - how compliance with the design criteria for reverberation time will be achieved
  - how transfer of noise within the building will be minimised.

Answering these questions may involve calculations and technical explanations which you are not expected to understand.

The important thing is that you are ensuring that the architect:

- has given sufficient thought to these issues
- has designed accordingly
- is providing specific information about how a good outcome will be achieved.

At practical completion

In some cases it will be appropriate to specify that acoustic testing is carried out to ensure that specific requirements of the brief have been met before the building is accepted. Such instances might be where:

- limiting the effect of external noise is required
- sound ratings between rooms are specified
- special music performance standards must be met
- background noise and reverberation times have been specified.

Noisy developments

Boards of trustees should be aware of developments which can cause noise that may be built in proximity to their schools. Some may be developed by statutory bodies, such as:

- territorial authorities
- Transit New Zealand
- regional councils
- airport authorities
- railways.

When any development or change in service is planned which will create noise (or any other nuisance) and which requires a resource consent, the approval-seeking body is required by law to consider the environmental impact, including noise, the proposed development will have on close neighbours including schools. Boards of trustees are recommended to seek their own independent advice on the impact and recommended solutions. They should discuss this first with their local Ministry of Education network facilitator as soon as they are aware of any proposed developments.

When considering noise levels in a new or renovated classroom, there are three key things to be aware of: the Building Code, the relevant Standards, and health and safety legislation.

New Zealand Building Code

If you are carrying out renovations or additions or building a new classroom you must meet all parts of the New Zealand Building Code (NZBC).[4] Clause G6 Airborne and Impact Sound covers sound.

Australian/New Zealand standards

AS/NZS 2107:2000 Acoustics – *Recommended Design Sound Levels and Reverberation Times for Building Interiors*[5] is the design standard for all new and remodelled schools specified by the Ministry of Education.[2]

This standard specifies levels of background noise and reverberation times for a range of buildings – including schools. It also specifies how background sound levels and reverberation times can be measured using a sound-level meter.

Occupational safety and health

The Department of Labour publication *Approved Code of Practice for the Management of Noise in the Workplace*[6] covers the requirements of employers for reducing the incidence and severity of hearing loss from excessive noise in the workplace. These regulations normally apply to teachers using noisy equipment, such as woodworking machinery, but they should also be referred to for other classroom teachers who may be subjected to excessive noise from other sources.[7]

Achieving higher acoustic standards

AS/NZ 2107 gives minimum performances the building must achieve. Boards of trustees should consider the benefits of providing better performance whenever and wherever possible. Although these better levels are likely to cost more, it is often cheaper to 'do it right the first time', particularly when the lifetime of the classroom and the number of students using it over time are taken into account. The Ministry of Education's suggestions for improved levels for background noise and reverberation times for various teaching situations are shown in Table 7 over. Suggestions for sound-transmissions ratings for dividing walls between rooms are shown in Table 6.

Your architect will be familiar with minimum regulatory requirements. If you decide on higher standards, you must make this clear in your brief.

TABLE 6. RECOMMENDED MINIMUM STC RATINGS OF DIVIDING WALLS

	Types of rooms by noise produced						
Types of rooms by noise tolerance	Library/ study room	Classroom	Multi-purpose Hall	Technology – moderate noise	Technology – high noise	Gym	Music room
Technology room	60	60	60	55	55	55	60
Gym	60	60	60	55	55	55	60
Classroom	50	50	60	50	60(1)	60(1)	60
Multi-purpose Hall	60	60	60	55	60(1)	60	60
Library/ study room	45	50	60	50	60(1)	60	60
Music room	60	60	60	60	60(1)	60(1)	60

(1) Ideally these rooms should not be located directly adjacent to each other.

TABLE 7. MINISTRY OF EDUCATION SUGGESTIONS FOR IMPROVED LEVELS OF BACKGROUND NOISE AND REVERBERATION TIMES

Type of space	Upper limit of ambient noise level (dB)	Reverberation time (secs)	See
Art rooms	40	0.5-0.7	Section 4
Classroom – primary school	35	0.4	
Classroom – intermediate or college	35	0.5	
Classrooms for students with hearing impairments	30	0.4	Section 5
Computer teaching rooms	40	0.5	
Laboratories – teaching	35-40	0.5-0.6	
Libraries and resource areas	35-40	0.5-0.8	Section 4
Multi-purpose rooms			Section 4
Music rooms	35		Section 4
Open plan teaching area	40	0.4	
Materials technology	40	See Note 1	Section 4

NOTE 1: Reverberation time in technology rooms should be reduced as far as practical, but should not exceed 0.8 secs.

New and existing buildings

Boards of trustees must know what standard to achieve when building new, remodelling or extending.
The documents referred to in this section provide an overview of minimum mandatory standards. Where possible, boards should aim for higher levels to achieve the best acoustics (see Table 6).

Alterations and refurbishment

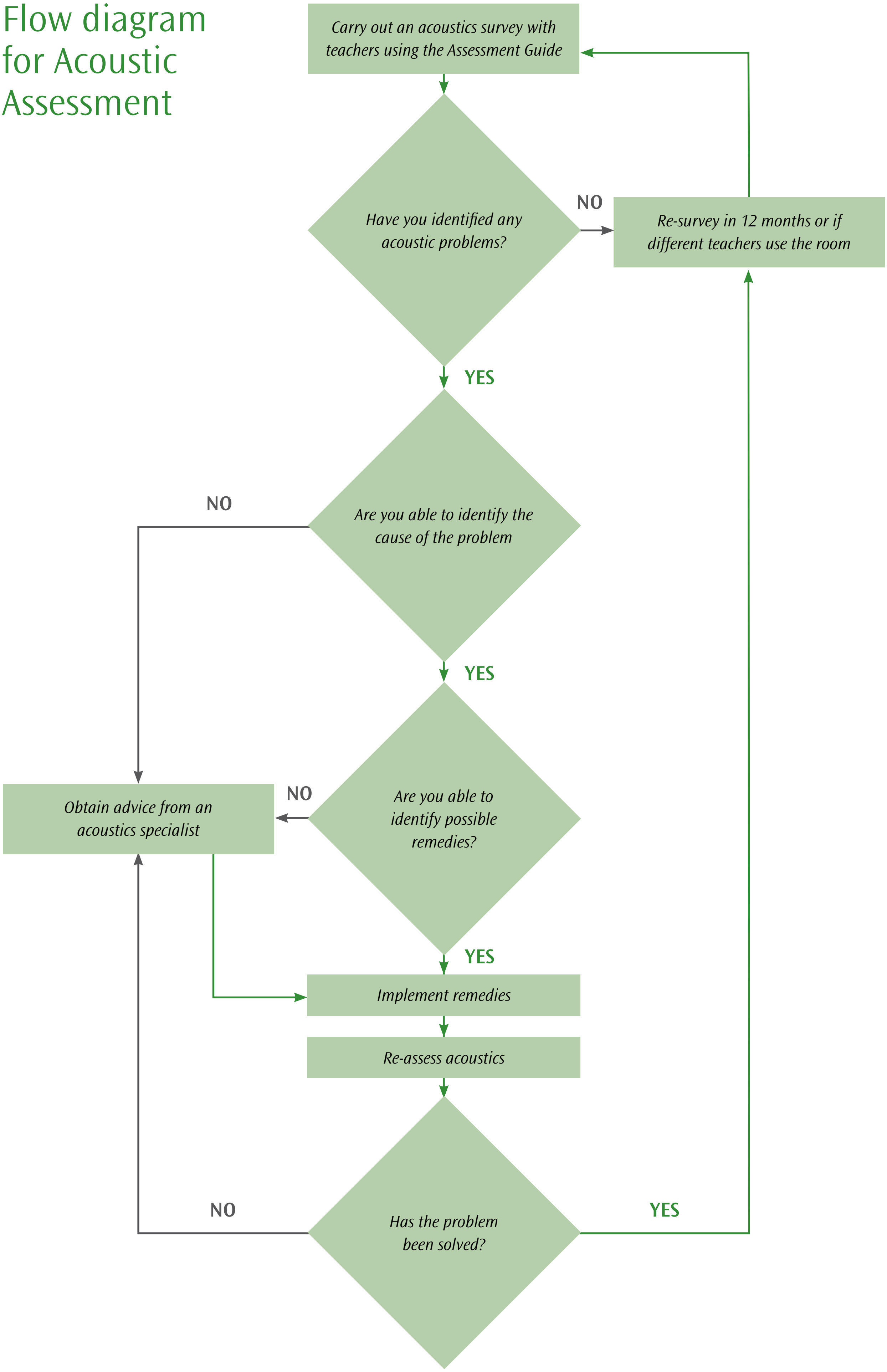
The documents referred to in this section, with the exception of occupational safety and health, are not mandatory for existing buildings. However, the ministry encourages schools to bring the acoustics of their teaching spaces up to an acceptable level as soon as practicable.

Basic work, such as repairs and maintenance or fitting cupboards, does not require a building consent. If you are considering building work other than the most basic, you should consult your building consent authority to be sure. Many of the proposals in these guidelines will require a consent. All work must comply with the NZBC.

> APPENDICES

– Flow diagram for Acoustic Assessment
– Acoustics Survey Form
– End Notes
– References

Flow diagram for Acoustic Assessment



Acoustics Survey Form

Use this Survey Form to help you assess the suitability of the acoustics in your classrooms.

1. **Are you aware of the effect that good and poor acoustics can have on a child's learning ability?**

Yes ☐ **No** ☐

Comment: There is evidence that poor acoustics can have a detrimental effect on a child's ability to learn.

2. **Are students able to hear and understand the teacher from all parts of the room?**

Yes ☐ **No** ☐

Comment: Asking them will give another early indication of the room's acoustic qualities.

3. **Does the teacher have to raise their voice to be heard?**

Yes ☐ **No** ☐ **Sometimes** ☐

Comment: If the answer is yes this may indicate:

- too much background noise
- too much reverberation in the room
- the teacher has a soft voice.

Speaking with a constantly raised voice can cause vocal strain and be tiring.

4. **Can the teacher hear and understand the students?**

Yes ☐ **No** ☐

Comment: If the teacher can't hear the students it may mean there is too much background noise.

5. **Can the teacher hear some students better, depending on where they speak from?**

Yes ☐ **No** ☐

Comment: There may be areas in the room where the acoustics are very poor.

6. **Does outside noise interfere with teaching or are students distracted by outside noise?**

Yes ☐ **No** ☐ **Sometimes** ☐

Comment: Outside noise can be extremely distracting for students and teachers and can come from many sources. It is difficult to determine the background noise level of a classroom just from observation. If the users are aware of background noise, steps should be taken to reduce it.

7. **When working in groups, does the noise of one group interfere with the work of another?**

Yes ☐ **No** ☐

or

Does the noise level in the classroom steadily rise as groups or individuals try to talk above the noise of others?

Yes ☐ **No** ☐

Comment: Rising noise levels may be owing to the café effect (where people raise their voices to be heard above others). This effect can be caused by high background noise, long reverberation times, or both.

8. **Do you know of any students with hearing impairments who use the room?**

Yes ☐ **No** ☐

Comment: A large proportion of primary students have some type of hearing impairment – possibly up to 30% of students, according to separate studies by K Coddington and J Allcock. While your classroom may have good acoustics, students with hearing impairments may still have difficulty hearing.

- Students with hearing impairments should be seated closer to the teacher.
- If you are concerned a student has a problem with hearing, ask that the family have their hearing checked through the vision hearing technician who is employed under the Ministry of Health contract for National Vision Hearing Screening Programme and who visits schools and early childhood education centres, or the child's medical practitioner.
- If the child has a diagnosed hearing impairment and the teacher is concerned about the child's learning, contact your local Ministry of Education, Special Education Office – details are in the blue pages of your local phone directory or on the ministry's website: ***www.minedu.govt.nz***.

End Notes

1 ***Classroom Acoustics – A New Zealand Perspective***

The Oticon Foundation of NZ
Wellington

2 ***Best Practice in Classroom Design***

Report prepared for the Ministry of Education by
AC Nielsen
Wellington, NZ

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6 ***Management of Noise in the Workplace – Approved Code of Practice***

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7 ***Noise in Early Childhood Centres and its Effects on Staff and Children***

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8 ***Music Accommodation in Secondary Schools - Building Bulletin 86***

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9 ***Music Education Suites***

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www.edfacilities.org

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New York, USA

Classroom Acoustics and their Relationship to Children with Hearing Losses in New Zealand Schools

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(formerly Department for Education and Employment)

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Ministry of Education

Wellington, NZ

Design for Access and Mobility - Buildings and Associated Facilities

New Zealand Standard NZS 4121:2001

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British Columbia

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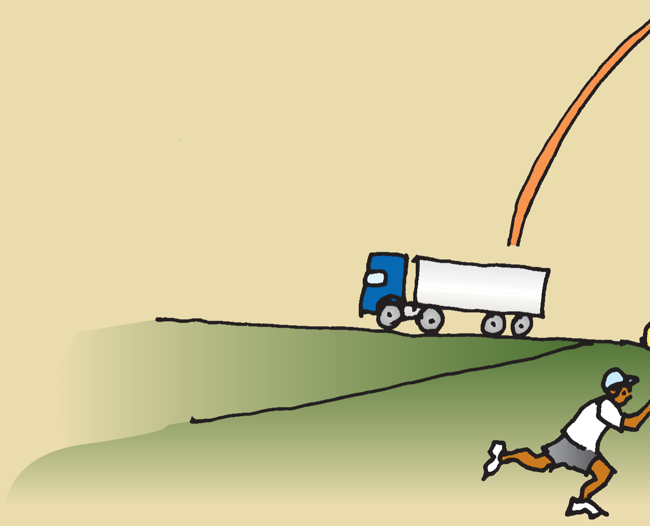

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