MINISTRY OF EDUCATION
TE TĀHUHU O TE MĀTAURANGA

Designing Schools in New Zealand (DSNZ)

Designing Quality Learning Spaces (DQLS)

Acoustics

Version 3.0, December 2020

Document history

This is a **'living document'**, and the table below is a record of the changes that have been made to this document.

Revision date	Version	Summary of changes
2007	1.0	First version for general release:
September 2016	2.0	• Substantial changes to content to reflect current teaching practice and flexible learning spaces • Document rewritten for a target audience of architects, designers and engineers involved in the design and specification of schools • Document restructured to bring mandatory requirements to the first section of the document • Ministry requirements are now clearly marked as 'mandatory' or 'recommendation' to make them easy to find throughout the document
December 2020	3.0	• Document updated to align with the Ministry's Te Rautaki Rawa Kura - School Property Strategy 2030 • Document rewritten to separate the mandatory requirements from the design guide to enhance navigation and readability • Removal of rain noise criteria in favour of a reference design-based requirement • Mandatory requirements are now clear for new builds and refurbishments • Clear requirements for seals around openings (doors and windows), and lower STC requirements for walls with openings of certain size • More specific guidance for types of large spaces e.g., assembly hall, auditorium, gym • Inclusion of verification methodologies i.e., site testing for mandatory requirements • Clarification on STC requirement for doors in section 1.2.2 (June 2021)

Foreword

The Designing Quality Learning Spaces (DQLS) series of documents has been prepared by the Ministry of Education (the Ministry) and a panel of expert advisors. Compliance with the mandatory requirements is required for all projects starting the preliminary design phase after 1 January 2021.

This document was first released by the Ministry in partnership with the Building Research Association of New Zealand (BRANZ) in 2007. The second version was released in September 2016 and its mandatory requirements were applied after 1 January 2017.

Changes in this third version have been made to align with industry best practice, the latest research, feedback received from design reviews and responses to a wide range of technical queries.

The mandatory requirements have also been strengthened to improve acoustic performance and to align with the Ministry's Te Rautaki Rawa Kura - School Property Strategy 2030. The primary objectives are to provide quality learning environments to support teaching and learning, and the wellbeing of everyone who use or occupy school buildings.

This document is not intended to address every conceivable condition experienced in learning spaces. It provides solutions where experience has indicated that problems commonly arise and has been structured for continual improvement to incorporate new research, technologies, developments, concepts and feedback.

This document is freely available for download from the Ministry's Property pages.

Background

The Ministry owns one of the largest property portfolios in New Zealand, with more than 18,000 buildings and over 35,000 teaching spaces in more than 2,100 schools. Learning space design and upgrades are commissioned in various ways – nationally via Ministry-led programmes, regionally through the Ministry's Capital Works and Infrastructure Advisory Service divisions, and locally through schools' Boards of Trustees.

The objective of this DQLS Acoustics document is to ensure that school buildings provide quality physical environments that support effective teaching and learning. The requirements are not intended to be prescriptive to the degree of restricting thinking, but the information provided will help facilitate school design that represents the best value for money, while supporting a variety of teaching and learning styles.

Acknowledgements

The Ministry gratefully acknowledges the following DQLS - Acoustics Panel members for drafting this document:

- James Whitlock — Associate, Marshall Day Acoustics
- Dr Michael Kingan — Senior Lecturer, University of Auckland
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- Renelle Gronert — Senior Manager, School Design, Ministry of Education
- Craig Cliff — Senior Policy Manager, Ministry of Education
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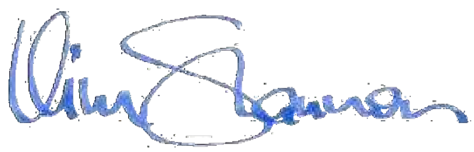
The Ministry would like to thank Design Review Panel (DRP) members for reviewing this document and Prendos New Zealand Limited for preparing the illustrations.

Feedback, Review Date

Where architects, engineers, designers, building scientists or users have feedback, they are encouraged to contact the Ministry through the School.Design@education.govt.nz mailbox to facilitate continual improvement and usability of this document. Your feedback will be reviewed and, where accepted, incorporated into future amendments.



Kim Shannon

Head of Education Infrastructure Service

Contents

Colours and Hyperlinks in this document

Important acoustic concepts are grouped by colour

This means that they can be easily identified and separated by readers. The colours are established on the Important concepts page.

Every underlined word in green font is a hyperlink

It may be a defined term that links to the glossary, a reference or a link to a webpage that explains a concept in more detail or gives background information. Hovering over a hyperlink will give information about that link and clicking will activate it.

References to figures, tables and other sections of this document are also in green font but are not hyperlinks.

Introduction

Purpose and scope

This document is part of the Ministry's Designing Quality Learning Spaces (DQLS) suite of design requirements for building quality learning environments for schools. The DQLS series covers requirements for four main internal environmental quality factors: lighting and visual comfort, acoustics, indoor air quality and thermal comfort.

These requirements form part of a set of documents for Designing Schools in New Zealand - Requirements and Guidelines (DSNZ), which is the overarching guidance for school design.

This DQLS – Acoustics document has been developed to provide technical requirements to assist architects, designers and engineers. It sets the requirements for creating quality physical learning environments that are fit for purpose, and technical guidance for property managers undertaking school projects.

The acoustic requirements set out in this document apply to all 'new-build' structures including extensions, pre-fabricated and any new contracts for modular buildings. The requirements also apply to refurbishments of existing school buildings, including significant alterations and temporary learning spaces that are used at a school for more than 28 days.

Overall purpose of the DQLS – Acoustics document
• Set mandatory minimum requirements for acoustic design that are appropriate to and consistent across school facilities
• Create spaces and environments that are comfortable and support the educational delivery process across different teaching styles and practices
• Set a basis for evaluating the acoustic design of school buildings
• Set methods for evaluating acoustic performance when undertaking Post Occupancy Evaluation (POE)
• Facilitate school design that represents best value for expenditure while supporting educational outcomes

In order to demonstrate compliance with the mandatory requirements, design teams must submit a completed IEQ Design Report with their design. Accuracy is critical as POE will be based on this report.

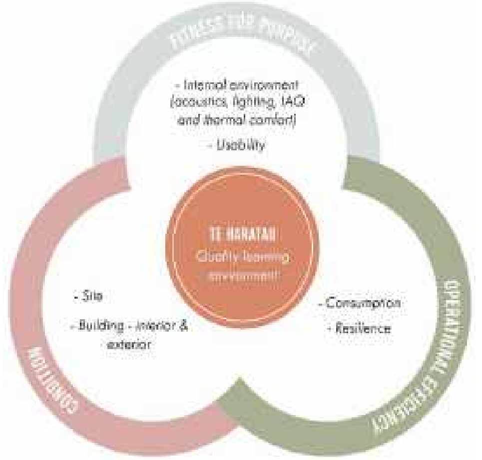
This document is divided into three key sections:

- Section 1 specifies the Mandatory Requirements for Acoustics
- Section 2 explains concepts and provides design guidance for the main areas of acoustic performance
- Section 3 outlines the verification methodology to be used when signing off completed spaces and undertaking POE

Te Haratau: Lifting the quality of New Zealand learning environments

The Ministry’s programme Te Haratau: lifting the quality of NZ’s physical learning environments, is aimed at delivering the strategic objective of quality learning environments, as set out in Te Rautaki Rawa Kura – The School Property Strategy 2030. Te Haratau involves the collection and analysis of performance data on the “quality” of all school assets for property planning and making evidence based decisions. The Te Haratau model consists of three interrelated objectives for the delivery of quality learning environments which are set out in Table 1.

Table 1: The three main interrelated aspects of Te Haratau

<table>
<tr><th colspan="3">TE HARATAU MODEL</th></tr>
<tr><td>1</td><td>Fitness for Purpose – internal environment (acoustics, lighting, thermal comfort and air quality) and usability. Data sourced through internal environment monitoring and user feedback through the School Evaluation of the Physical Environment (SEPE) tool.</td><td rowspan="3">
</td></tr>
<tr><td>2</td><td>Asset condition assessment – data relating to condition grade and remaining useful life for building and site elements is sourced through detailed condition assessments.</td></tr>
<tr><td>3</td><td>Operational Efficiency – energy and water consumption, resilience and maintenance costs. Data is sourced through a range of approaches.</td></tr>
</table>

The Te Haratau model will capture data across these key aspects to provide information about a school’s buildings and site, and how each of these three aspects moves from the design phase into operation. The DQLS requirements provide the framework for assessing the internal environment’s fitness for purpose. For example, when reviewing data about sound levels within a learning space, the DQLS – Acoustics provides the acceptable threshold and context (refer to **Sections 1.3.1 and 2.4.1**).

Understanding internal environmental quality

Internal environmental quality refers to the entire quality of a building’s environment in relation to the health and wellbeing of its occupants. Internal environmental quality is determined by many factors, including the four Te Haratau fitness for purpose aspects:

Internal Environment Quality Factors	
1	**Lighting and Visual Comfort** – illuminance, luminance ratios, view, reflection, etc.
2	**Acoustic Quality** – ambient noise, reverberation time, noise from other spaces, etc.
3	**Indoor Air Quality (IAQ)** – fresh air supply, odour, indoor air pollution, etc.
4	**Thermal Comfort** – temperature, air velocity, relative humidity, moisture, etc.

There is strong evidence that quality learning environments support educational outcomes (Barrett et al., 2015; Wall, 2016; Ackley et al., 2017). For example, a United Kingdom study of 3766 students in 153 classrooms in 27 schools identified seven key design parameters that together explain 16% of the variation in students’ academic progress. (Barrett et al., 2015).

Better internal environmental quality in learning spaces supports teachers/kaiako and learners/ākonga to succeed. For example, poor lighting conditions cause visual discomfort, which can lead to eyestrain and headaches. Poor acoustics can make communication difficult and increase activity noise levels. Poorly ventilated rooms can increase temperature and humidity, and lead to high levels of carbon dioxide which can cause drowsiness. Poor air quality can introduce air pollutants that can be odorous and irritate the trigeminal nerve endings in the nose and eyes, causing itching and other negative reactions, impeding learning.

The built internal environment is considered a system with sub-systems that do matter, but the system will only function if all sub-systems (components) are optimized along with the total system. Internal environmental quality factors are one of the key sub-systems that are interrelated in a building (**Figure 1**).

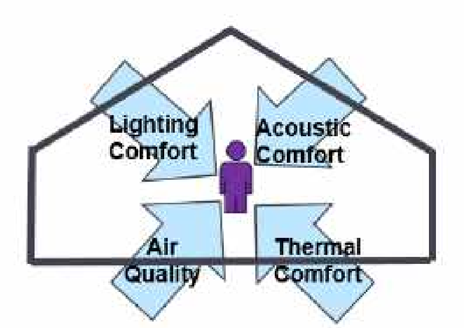


Figure 1: What is internal environment quality? Source: Bluyssen, (2009)

These factors must be considered during the design phase so that comfort is achieved. A holistic approach is essential, and no single internal environmental quality factor should be altered without assessing its effect on all the others. This is because they interact with one another e.g. achieving good daylighting must be balanced against possible uncomfortable heat gain from the sun, and the need for ventilation can increase noise levels inside.

Given the complex nature of the internal environment, design teams must ensure that the acoustic requirements set out in this document are applied, together with the requirements set out in the other DQLS series of documents (lighting, indoor air quality and thermal comfort).

This document sets out requirements and guidance that will produce acceptable acoustic conditions to the majority of occupants in a learning space. Special consideration for inclusive design is given in Section 2.8.

To ensure that all new buildings and refurbishments provide comfortable environments, design teams must consider the effective control strategies in **Table 2**.

Table 2: Internal environment quality factors, parameters and effective control strategies. Adapted from Bluyssen, (2009)

Description	Lighting Quality	Acoustic Quality	Air Quality	Thermal Quality
Parameters	• Illuminance and luminance • Reflectance(s) • Colour temperature and colour index • View and daylight	• Sound level (s) • Reverberation time • Frequency spectra • Speech intelligibility • Sound insulation	• Pollution sources • Carbon dioxide concentrations • Types of pollutants • Ventilation rate and efficiency	• Temperature (air and radiant) • Relative Humidity • Air velocity • Activity and clothing
Control	• Daylight harvesting • Luminance distribution • Artificial lighting	• Acoustic design • Sound absorption • Sound insulation	• Source control • Operable windows • Ventilation systems • Maintenance • Air cleaning • Activity control	• Building design (e.g. insulation, façade, etc.) • Heating and cooling systems

The importance of good acoustics

There is strong evidence that good acoustic design contributes to good learning outcomes and that poor acoustics can impact on students' ability to learn and teachers' ability to teach (Shield & Dockrell 2003; Cheryan et al., 2014; Ackley et al., 2017).

For all learning spaces – from traditional cellular configurations to large open plan spaces – incorporating good acoustics is essential to support a broad range of learning activities.

Learning is about communication, and most people communicate using speech. If a classroom isn't well designed for sound, speech can be hard to understand. Too much noise or reverberation may cause students to miss keywords, phrases and concepts. This is especially important for students still developing their language skills (whether first or second language), and those with hearing impairment and other learning challenges.

Good acoustic design supports all students and creates a better place in which to learn and teach in. In the last 20 years, changes in curriculum and teaching philosophy have resulted in some large learning spaces (over 300 m^3). Many schools are choosing to create large learning spaces because they support a range of teaching methods and allow team teaching of many students in one space. Students can also make use of a variety of learning areas inside the space and find the ones that work best for them.

Just as in traditional learning spaces, these large open spaces can support learning with appropriate acoustic engineering to address potential background noise issues. These issues can be addressed by using materials to control the build-up and spread of activity noise, and breakout spaces that provide acoustic separation for small group work or self-directed learning that requires intense concentration. All large learning space users need to be aware of how their noise can affect others, by realising how noise affects them.

A learning space's design and the way it is used have significant influence on its acoustic performance. The guidance in this document helps to manage noise levels in learning spaces, but acoustic design cannot, by itself, ensure good outcomes. Coordinating learning activities to manage activity noise extremes is also important.

Important concepts

Figure 2 shows the key acoustic concepts. Each concept's colour is applied throughout this document to provide a clear distinction between different acoustic concept. For example, pink text is about sound absorption.

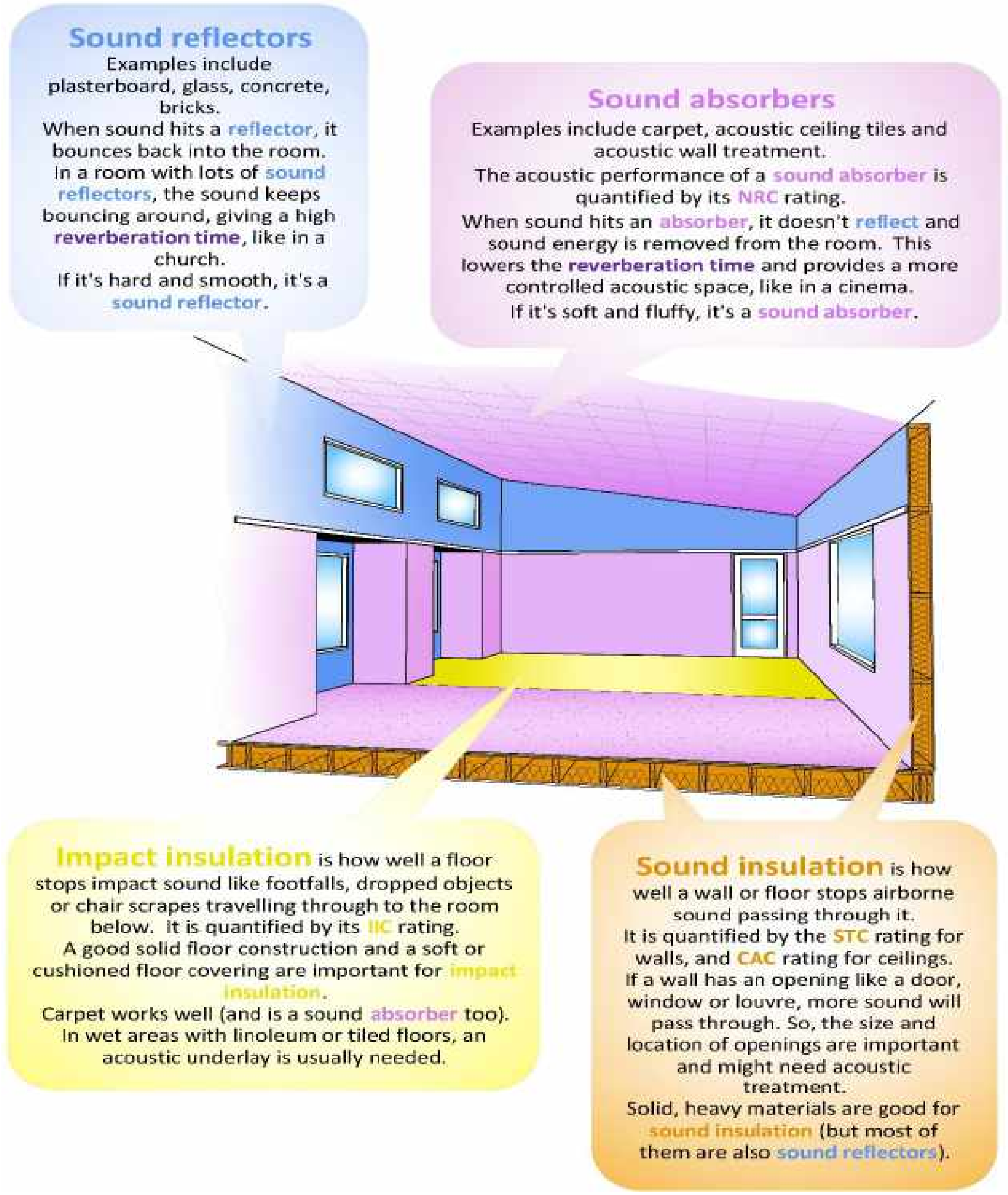


Figure 2: Important acoustic concepts and their colour codes used throughout this document

Reverberation time (RT) is how long it takes for sound in a room to die away. It depends on the room volume, the total area of sound absorbers and the acoustic performance of those absorbers.

1. Mandatory Requirements for Acoustics

This section sets out the mandatory requirements for acoustic performance for common learning space types in schools. New buildings, refurbishments, pre-fabricated and modular classrooms must be designed to achieve these mandatory requirements, which will be checked for compliance using the verification methods in **Section 3**.

Tables 3 to 6 shows mandatory requirements for reverberation time (RT), sound absorption, sound insulation, **impact insulation** and indoor ambient noise levels. If a particular space is not listed, designers are to apply the limits for the space that is most relevant in terms of size and function.

1.1. Reverberation time (RT)

Reverberation times of small learning spaces (with volumes less than 300 m^3) must comply with the requirements set out in **Table 3**.

The RTs of larger learning spaces (with volumes greater than 300 m^3) depends on their volume and must comply with the relevant RT range shown in **Figure 4**.

Table 3: Mandatory Reverberation Times

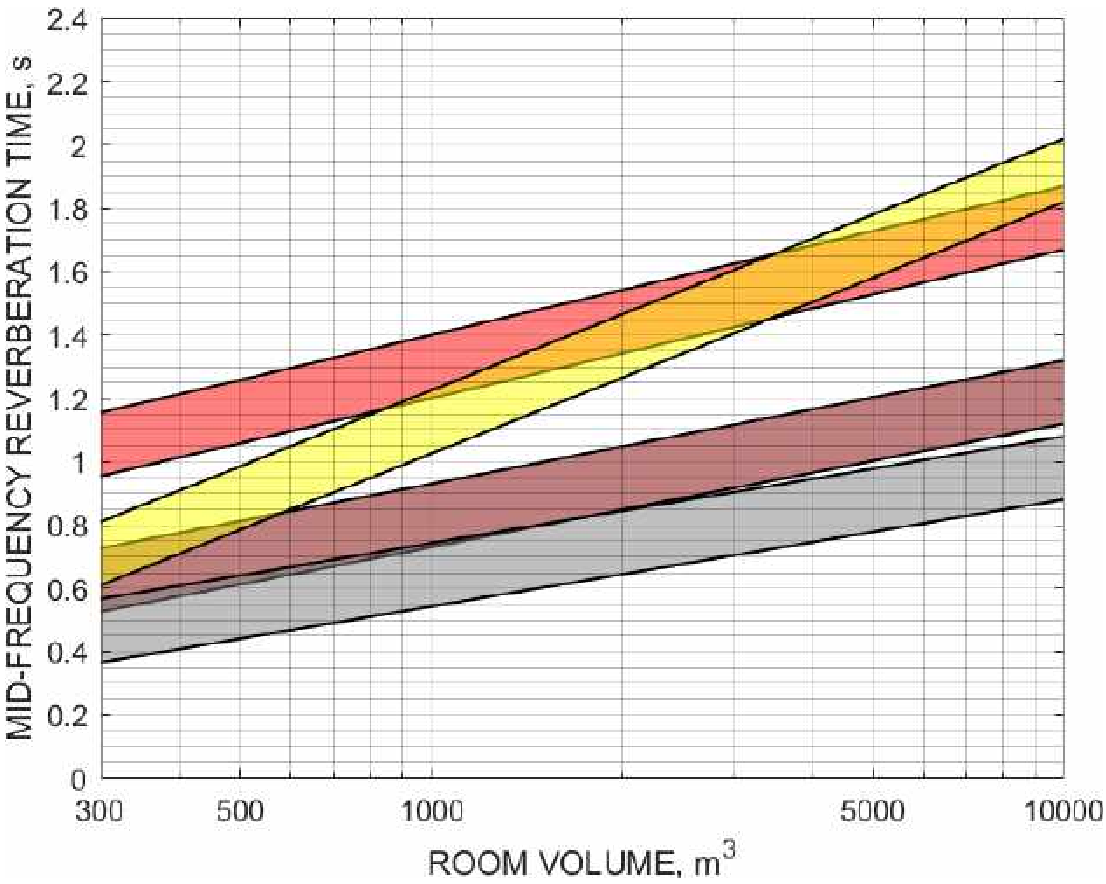
Space	Reverberation Time (seconds)
	New Build & Refurbishments
Learning Spaces > 300 m^3 Assembly halls Auditoria Gyms	See Figure 3
Learning Spaces < 300 m^3 – Primary Schools Breakout spaces Offices Meeting rooms Teacher workspaces	0.4 – 0.5
Learning Spaces < 300 m^3 – Secondary Schools Staff rooms Libraries Whare	0.5 – 0.6
Music teaching rooms Music practice rooms Technology spaces and laboratories Circulation spaces	0.5 – 0.8
Multimedia rooms Recording rooms	0.2 – 0.4

The RT values in Table 3 and Figure 4 are for unoccupied rooms and are mid-frequency RTs (the average of the 500Hz and 1 kHz octave bands). They generally follow guidance in the AS/NZS 2107:2016 Standard. For rooms with more than one purpose, the lowest RT value applies.

Rooms must have a balanced reverberation spectrum with similar RTs at low, medium and high frequencies. For the 125Hz, 250Hz and 2kHz octave bands, RT shall be ± 30% or ± 0.2 seconds of the mid-frequency RT, whichever is the greater.

In rooms where live music is played (i.e. assembly halls, music rooms and performance spaces) a bass rise is allowed - refer **Section 2.2**.

Sound absorption must be well distributed throughout spaces to avoid unwanted acoustic flaws – refer **Section 2.2.**



Key			
Auditoria	***Gymnasia***	***Assembly Halls***	***Large learning spaces***

Figure 3: Mandatory reverberation time ranges for large spaces

1.2. Sound transmission and impact insulation

There are a number of variables to consider with sound insulation between spaces. They include whether the spaces are connected, whether there are any openings, visual connectivity, and the expected noise generation / sensitivity of both spaces.

In order to determine the mandatory sound insulation requirement of a partition, follow this process:

Select the default STC rating in Table 4 → **Check if an exception applies (fourth column)** → **If there is a door, window or opening, check Table 5 and apply the relevant correction**

1.2.1. Sound and Impact insulation

Mandatory sound insulation and impact insulation requirements for internal walls and floors are shown in Table 4. These should be applied along with the recommendations on doors, windows and openings in **Section 1.2.2**.

It is important to identify whether two spaces are connected or not, because the STC ratings for connected spaces are different. Connected spaces are rooms that are:

- physically connected to each other by a door, corridor or opening (i.e. one can walk between them without going outside), and
- are part of the same general space in which learning activities are coordinated.

Connected learning spaces should be clearly grouped and labelled in design drawings.

Sound travels more easily between connected spaces, but this is okay if the activities throughout the large learning space are coordinated to be acoustically compatible e.g. all quiet or all noisy at the same time.

Walls between connected spaces are permitted to have lower STC ratings (see the 2nd row of **Table 4**).

The STC ratings do not apply to floors on grade, or façade walls (see **Section 1.3**).

Table 4: Mandatory sound insulation ratings for walls and floors

Space	Default rating (walls and floors)		Exceptions
	New Build	Refurbishment	
Learning Spaces Breakout spaces Low noise tech spaces Offices Toilet blocks Whare	STC 50	STC 50	STC 60 to high-noise tech, gyms, halls and music spaces STC 55 to moderate-noise tech and plantrooms Refer **Section 1.2.2** for openings
Connected Learning spaces Breakout spaces Low-noise tech spaces Offices	STC 45	STC 45	Refer **Section 1.2.2** for openings
Teacher workspaces Libraries Meeting rooms Staff rooms	STC 45	STC 45	STC 60 to high-noise tech, gyms, halls and music rooms STC 55 to moderate-noise tech and plantrooms Refer **Section 1.2.2** for openings
Moderate-noise tech Laboratories Plantrooms	STC 55	STC 55	STC 45 between adjacent moderate-noise tech spaces Refer **Section 1.2.2** for openings

Gyms Assembly halls Auditoria High-noise tech spaces Music teaching rooms Music practice rooms	STC 60	STC 60	STC 45 between adjacent high-noise tech spaces STC 55 to corridors Refer **Section 1.2.2** for openings
All spaces with suspended floor slabs	IIC 55 (floors only)	IIC 50 (floors only)	If a hard floor area is less than 10% of the ceiling area of the space below, IIC 50 is acceptable

Refer to **Section 3** for the verification requirements for on-site acoustic performance.

1.2.2. Doors, windows and openings

Doors, windows and openings in acoustic walls and floors must comply with the relevant **Table 5** requirement.

Doors in STC-rated walls must not have door grilles or be undercut for ventilation.

Table 5: Requirements for doors, glazing and openings in acoustic walls and floors

Opening type	Requirement
Fixed windows between separate spaces	Windows must have an STC rating within 5 points of the wall
Fixed windows between connected spaces	Windows must have an STC rating within 10 points of the wall
Hinged door/openable windows	Door/windows must have STC rating within 15 points of the wall If the combined door/openable window area > 15% of the entire partition area (to ceiling height), the wall STC may then be reduced by 5 points. The door/window STC remains within 15 points of the *original* wall STC
Sliding door	Sliding doors must not be used in > STC 45 walls. This means that they can only be used between connected spaces All sliding doors between learning spaces must be minimum STC 25 (refer to **Section 2.3** for more guidance) If the combined door/window area > 15% of the entire partition area (to ceiling height), the wall STC may be reduced by 5 points. The door/window STC remains within 15 points of the original wall STC

1.3. Indoor noise levels

1.3.1. Indoor ambient noise

Indoor ambient noise must not exceed the levels in **Table 6**. These levels apply when the room is unoccupied, but ready for occupancy. This means that if the room is naturally ventilated, compliance must be achieved with ventilating windows open.

Section 1.3.3 sets out requirements for rooms with mechanical ventilation.

Rain noise does not need to comply with these levels – it is managed separately. Refer to **Section 1.3.2.**

Table 6: Maximum indoor ambient noise levels

Space	Maximum Indoor Ambient Level (L_{Aeq})	
	New Build	Refurbishment
Gyms Circulation spaces	50 dB	50 dB
Learning spaces > 300m^3 Technology Spaces Laboratories Libraries	45 dB	45 dB
Learning spaces < 300m^3 Breakout spaces Music teaching rooms Music practice rooms Teacher workspaces Staff rooms Meeting rooms Offices Whare	40 dB	45 dB
Auditoria Assembly Halls	35 dB	35 dB
Multimedia rooms Recording rooms	30 dB	30 dB

1.3.2. Rain noise

Three approved design solutions for roofs have been developed to cater for areas of high, medium and low rainfall intensity. The approved solutions are warm roofs, where the thermal mass is in a rigid panel directly below the cladding. This is the Ministry's preferred roof type for learning spaces, but others may be accepted if they are of a robust design.

To comply with the mandatory requirements, a roof-ceiling system must adopt the approved solution relevant to the school's region – or a design that is acoustically equivalent (as confirmed by an **acoustic engineer**).

Further information is provided in **Section 2.5**.

Approved solution for high rainfall rate areas
(Northland, Auckland, Bay of Plenty, Taranaki, and West Coast)

- A profiled steel warm roof system including a mass layer
- 150 mm ceiling cavity with insulation batts and CAC 35+ ceiling

or 150mm ceiling cavity with (no insulation) and CAC 40+ ceiling

Approved solution for medium rainfall rate areas
(Waikato, Gisborne, Hawke's Bay, Manawatū-Whanganui, Wellington, Nelson, Tasman, Otago and Southland)

- A profiled steel warm roof system including a mass layer
- 150 mm ceiling cavity with insulation batts and CAC 25+ ceiling

or 150mm ceiling cavity with (no insulation) and CAC 30+ ceiling

Approved solution for low rainfall rate areas
(Marlborough, Canterbury)

- A profiled steel warm roof system including a mass layer

(No acoustic requirement for ceiling or cavity)

All the approved solutions require the warm roof to have a mass layer (defined in **Section 2.5**). The differences are in the ceiling's CAC specification. Note that each solution has two options – with and without insulation batts. This is to provide options for controlling roof space moisture, particularly in colder regions.

Skylights and other roof glazing must have an STC performance within 5 points of the roof system (as calculated by an acoustic engineer).

1.3.3. Mechanical plant noise

Mechanical plant noise (including duct breakout and outdoor plant) must comply with the relevant **Table 6** values minus 5 dB. The values apply when the system is operating as it would for normal occupancy.

The requirement for split-system heat pumps (high wall and cassette units) depends on whether each unit is user-controlled, or automated by a Building Management System (BMS):

- Heat pumps must not be specified in spaces with ambient noise limits of 35 dB or less, refer **Table 6**
- User-controlled heat pump indoor units must comply with the relevant **Table 6** values when operating at their design speed
- BMS-controlled heat pump indoor units must comply with the relevant **Table 6** values minus 5 dB when operating at their design speed

The design speed is the speed setting (low, medium, high etc.) the unit must be on to maintain the required room temperature. Refer DQLS Indoor Air Quality & Thermal Comfort.

2. Acoustic Design Guidance

Learning spaces should be designed with the assistance of a qualified acoustic engineer. Acoustic engineers are professionals with the knowledge and experience required to design learning spaces. The Ministry of Education requires all acoustic engineers for school projects to be Members of the Acoustical Society of New Zealand (MASNZ).

2.1. Room shape can help to manage acoustic issues

During the design process, room shape is the first important acoustic aspect to consider

First and foremost, the shape and size of a learning space needs to support the school's intended use of that space. But some shapes and sizes work better than others for acoustics and getting this right early in the design can avoid problems later on.

Sound bounces back and forth between parallel sound reflectors like plasterboard, glass and timber. It is important to recognize where this could occur and either add sound absorption to one side or change the shape (e.g. angle one wall so it is not parallel).

Figure 4 shows some common learning space shapes. They are provided to show basic differences in spatial arrangement, not as templates for design. In practice, a variety of designs would align with each basic shape. The most important thing is to choose a shape that ensures the learning space supports the type of teaching used, so it is fit for purpose.

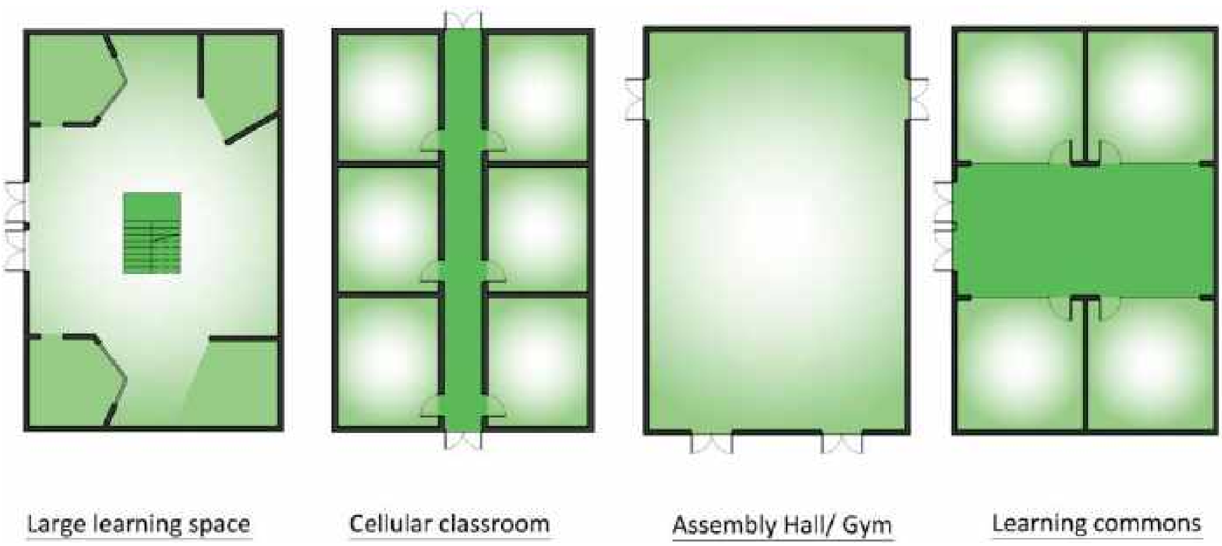


Figure 4: Example of a breakout space within a large learning space: adapted from Cleveland et al, (2016), and defined by Dovey and Fisher (2014)

Refer to **Section 2.7** for guidance on specialist spaces.

2.1.1. Large learning spaces (with volumes higher than 300 m^3)

Large learning spaces work best when they have odd shapes, with corners, nooks and alcoves for small groups of students to make use of.

Large rectangular spaces do not make for successful learning spaces because everyone can see and hear everyone else in the room. Clever positioning of breakout spaces and partitions are the best way to manage this. Although, it is still useful to retain one vantage point where the room's entire length can be seen – for assembly-style activities involving all class units.

2.1.2. Breakout spaces

Breakout spaces are essential in large learning spaces because they allow groups to withdraw from the hustle and bustle of the larger space. A large learning space and its attached breakout spaces are always connected spaces.

Breakout spaces need to be large and/or numerous enough to allow at least one class unit to withdraw at a time. They should be positioned to make a rectangular large learning space more irregular (**Figure 6**). Furniture and sliding doors can also be used to break up large rectangular learning spaces (refer to **Section 2.2.4**), but should not be prioritized over room design.

Figure 5: Example of a breakout space within a large learning space

2.1.3. Small learning spaces (with volumes less than 300 m^3)

Learning spaces less than 300 m^3 (e.g. cellular classrooms) can have a more simple shape because they are small and cater for only one class unit and teacher. They still need enough sound absorption to manage activity noise build-up – particularly on the ceiling and walls.

Furniture can provide some learning flexibility by creating zones for standing, sitting, stretching out, reading and huddling (refer to **Section 2.2.4**).

2.1.4. Learning commons

Learning commons are connected spaces that are a blend of large learning spaces and small learning spaces. Each class unit has its own small learning space, but the rooms can open up (fully or partially) to a shared large learning space.

Whereas a large learning space has breakout spaces to allow students to withdraw from the large learning space, learning commons have break-**in** spaces to allow students to come together.

All spaces in learning commons are considered to be connected spaces.

2.1.5. Assembly halls and gyms

Assembly halls and gyms are typically large and rectangular because they are designed for sports, large audiences and good sightlines (**Figure 7**).

Sound absorption and diffusion are the only ways to manage the acoustics (particularly the RT) in these spaces (refer to **Section 2.2**). The school needs to be clear about what types of activity the space will cater for, so that the acoustics can be designed to be fit for purpose.

Figure 6: Example of assembly hall / gym – note absorption on ceiling and walls

2.2. Sound absorption controls reverberation time

This section explains some important aspects of designing good room acoustics.

The Mandatory Requirements for RT outlined in **Section 1.1** will inform how much sound absorption is needed in a space. The right RT will help to control the build-up of activity noise that happens because of the café effect.

The café effect occurs when students are working in groups and talking amongst each other, producing activity noise. Students in other groups then naturally increase their own voice levels, so their group members can hear them over the noise from other groups. This sets up a chain reaction resulting in high activity noise levels. High RTs exacerbate this effect and so sound absorption is an essential tool for controlling the café effect (Whitlock & Dodd, 2007).

The values in the mandatory requirements (**Section 1.1**) are for unoccupied rooms. Depending on the space, the RT will reduce to some degree when it is occupied, because people (particularly their clothes) absorb sound.

2.2.1. Sound absorption must be well distributed

Sound absorption must be well distributed throughout a space.

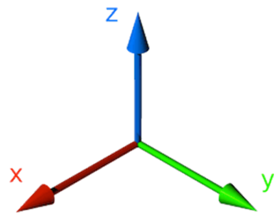
If sound absorption were placed on one surface only (say the ceiling), sound would reflect off all the other hard surfaces (the walls) and prolong the RT. Even if the room complies with the mandatory RT with only one surface treated, it could still have unwanted acoustic flaws like flutter echoes, room modes, focussing and image shift.

The larger the space, the more critical this issue becomes. For example, in a gymnasium with a fully absorptive ceiling, sound in the vertical axis will be well managed, but in the horizontal axes it will still bounce back and forth between the sound reflecting walls. This makes for a nasty acoustic environment with poor speech intelligibility and high activity noise, despite the treated ceiling.

Spread sound absorption evenly around the room, with the following order of preference:

- First – treat one surface in each x-y-z axis with as much sound absorption as possible. Acoustic ceiling tiles are common in learning spaces, so sound reflections in the vertical z-axis are usually well controlled

  For walls, it's better to put sound absorption on two perpendicular walls rather than two parallel walls. That way, reflections will be absorbed in both the x and y directions, rather than just one of them



- Second – make sure that the lower parts of walls have sound absorption i.e. from the floor up to 1.8 metres. This deals with reflections at occupant ear heights, whether they are adults standing up or students working on the floor

- Third – put sound absorption on walls opposite large glass panes to deal with reflections off the glass

2.2.2. The RT spectrum must be balanced

The performance of a porous sound absorber depends on the size and shape of the product's pores and its total thickness.

Sound exists at a range of frequencies. Low frequency sound (like beats from a bass drum or notes from a bass guitar) needs thicker materials to absorb it. Thin materials (like carpet) only absorb higher frequencies, so a room with only thin materials will sound 'boomy' because the low frequencies aren't being absorbed.

Sound absorbers are available from multiple suppliers and manufacturers, with thickness ranging from about 10 mm to 100 mm. The most common products for learning spaces are:

- 15 – 50 mm thick acoustic tiles in a ceiling grid. Note that the deeper the ceiling cavity, the better its low frequency absorption will be

- 10 – 15 mm thick acoustic pinboards

- 25 – 50 mm thick wall absorbers (which can also be used on the ceiling or suspended as clouds/baffles).

One of the essential tasks for an acoustic engineer is to specify the right amount of each product to achieve the required RT, and make sure it is balanced across the frequency range.

Bass rise

A balanced RT is important for speech intelligibility in learning spaces, but in larger rooms where music is played, a bass rise is permitted.

For music rooms and auditoria – where playing music is part of its primary purpose – it's better for the room to support low-frequency sound so that the full spectrum of music can be enjoyed. This means that a longer low-frequency RT is desirable in assembly halls and music performance rooms (up to 40% higher at 125Hz compared with the mid-frequency RT – see Barron, 2009).

2.2.3. Glass can cause unwanted reflections

Glass is a desirable material to use in a large learning space because it allows visual connectivity and natural light to permeate through the space. Also, teachers want to be able to see what is happening in breakout spaces, and other parts of a complex learning environment.

But glass is a sound reflector, so it increases the room's RT and can cause unwanted acoustic flaws. When designing a space, think about where glass reflections will occur and whether they will interrupt learning (**Figure 7**).

Careful placement of sound absorbers and diffusors, changes to the room shape and angling the glass elements will help to manage reflections. Another solution is to use smaller panes of glass as visual portals in walls that are treated with sound absorption, instead of large glass walls.

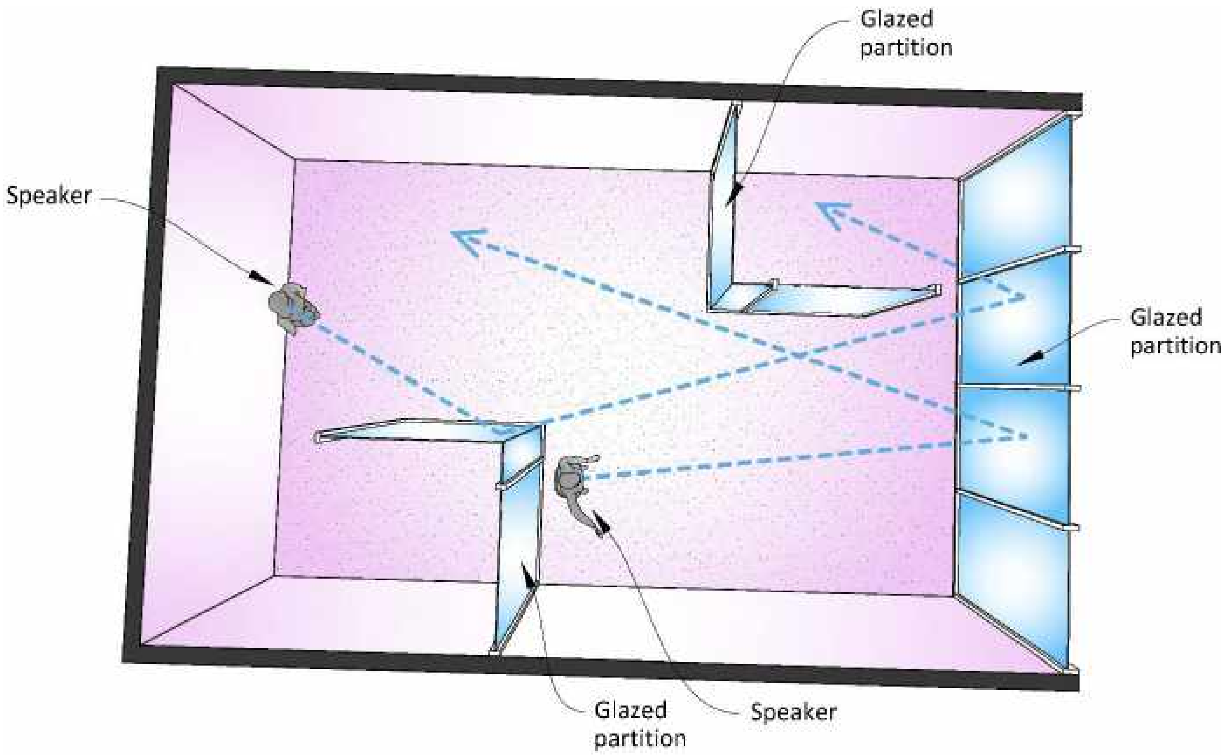


Figure 7: Image showing reflections of glass partitions

2.2.4. Furniture can help to manage acoustic issues

Furniture has many acoustical uses in a learning space. It can help to absorb or reflect or block sound and can be positioned where it's needed most. For example:

- Large soft furniture – like couches with an open-weave fabric – will add absorption to a space and help to control the RT. It's the padding inside the furniture that absorbs sound, so closed fabrics like vinyl or leather won't work
- Freestanding screens and storage units can be positioned to block line-of-sight between activities, or perpendicular to walls, creating nooks and alcoves. They can also be positioned to disrupt reflection paths, as shown in **Figure 9**. They can be covered with sound absorption or left hard to reflect sound as needed
- Bookshelves, cupboards and other wall fixtures with some depth will diffuse sound, and can be positioned to manage reflections

Figure 8: Example of furniture being used to create separation in a large learning space

2.2.5. Helpful tips and rules of thumb – sound absorption

Here are some helpful tips and rules of thumb to keep in mind regarding sound absorption and RT:

- Treat the whole ceiling with a highly absorptive product (NRC 0.85 or higher). The ceiling has a large uninterrupted area (other than maybe lights, heating panels and ducts) and treating it first can go a long way to achieving the required RT

- In large learning spaces, most – if not all – available wall area should be treated with absorption. This is because doors, glass, whiteboards, interactive teaching surfaces, cupboards and other hard surfaces are all sound reflectors, so all the remaining wall area needs to be soft to control RT and horizontal reflections

- In gyms, a good rule of thumb is to put absorption on a wall with an area at least 20% the ceiling area e.g. if the ceiling is 800 m^2, distribute 160 m^2 of absorptive treatment on the walls

- Position some thick (25 – 50 mm) wall absorbers down low (below 1.8 metres), to control reflections in the horizontal axes over a wide frequency range

- Absorbers can be covered with a hard impact-resistant material, as long as at least 20% of its area is 'open' i.e. at least 20% of the covering comprises holes or gaps. Slotted timber, wooden slats and perforated steel are common in gyms, although there are some hardwearing absorptive products that don't require facings. Facings will change the frequency response of an absorber, so seek advice from an acoustic engineer

- Just because a wall material feels soft, that doesn't mean it is a good absorber. Thin (2 – 3 mm) felt-like materials purchased by the roll only absorb very high frequency sound. Products need to be at least 10mm thick and have a porous structure to provide useful sound absorption. Closed cell foams are not good sound absorbers

- Having a reflective surface behind areas where presentations occur (like didactic teaching or student speeches), helps to project the speaker's voice. Although be careful that it does not project their voice into other parts of the room, where separate activities may be happening

- If an absorptive wall is covered by something like a shelving unit, cupboard, whiteboard etc, then it will no longer absorb sound. Find another place to put that piece of absorption

2.3. Sound transmission and impact insulation

This section explains some important aspects of managing sound transmission between spaces.

The louder the sound is in one room, the more likely it is to be audible in an adjacent room. So, controlling activity noise with a suitable RT and good placement of absorption (refer to **Section 2.2**) are good first steps in managing sound transmission to adjacent spaces.

When it comes to the acoustic performance of the walls and floors, the most important thing is to ensure they are made of solid, heavy materials. For timber framed structures, this may mean multiple wall linings and structurally isolating one side of the partition from the other using rubber clips or similar.

2.3.1. Control sound flanking around walls

In general, all STC-rated walls should be full height i.e. to the underside of the floor slab or roof above. This is essential for walls rated higher than STC 45 to avoid sound flanking up and over the wall via the ceiling.

For walls rated STC 45 and below, there is an acceptable design – with CAC 35+ ceiling tiles and a baffle wall – to stop the wall just above ceiling level. A baffle wall is a stack of sound absorbing batts that is compressed and inserted into the ceiling over the top of the wall. This, combined with the good sound insulation of CAC 35+ ceiling tiles, controls the up-and-over flanking path.

An STC-rated wall can also be compromised if its connections to the floor and other walls are not designed carefully. For instance, at a T-junction, sound can travel along the continuous wall section (the top of the T), bypassing the wall that separates two rooms (the bottom of the T).

Junction flanking is common:

- At T-junctions, when the continuous wall section has a much lower STC rating than the separating wall
- At T-junctions that have too many framing elements in them
- Where full height walls are not well sealed to the soffit
- In glass mullions, where a wall meets façade glazing and is not well sealed to it
- In STC 60+ walls where the floor slab runs continuously either side

Door and window frames can leak sound. Wall linings must be cut to fit, and well sealed to avoid gaps.

An acoustic engineer should review all junctions at a project's detailed design stage.

2.3.2. Doors and windows compromise a wall's acoustic performance

Putting a door or window in an STC-rated wall reduces its ability to provide sound insulation. Unless the door or window has an STC rating that matches or exceeds the wall's rating, the combined STC value will drop. This is why some of the requirements in **Table 4** allow the wall to be down rated.

Choosing the right element to put in an opening is a balance of acoustic performance and cost. In order to comply with the mandatory requirements, a design will need:

- Doors that are solid core with weight of at least 24 kg/m^2
- Windows that are at least 10.38 mm laminated glass
- Doors and openable windows that have compressible rubber seals around the entire element. The seals must engage properly when closed – particularly the threshold seal, which has a drop-down mechanism that needs to be adjusted correctly (**Figure 9**)
- To avoid issues with seals, a competent installer with experience and an eye for detail is recommended

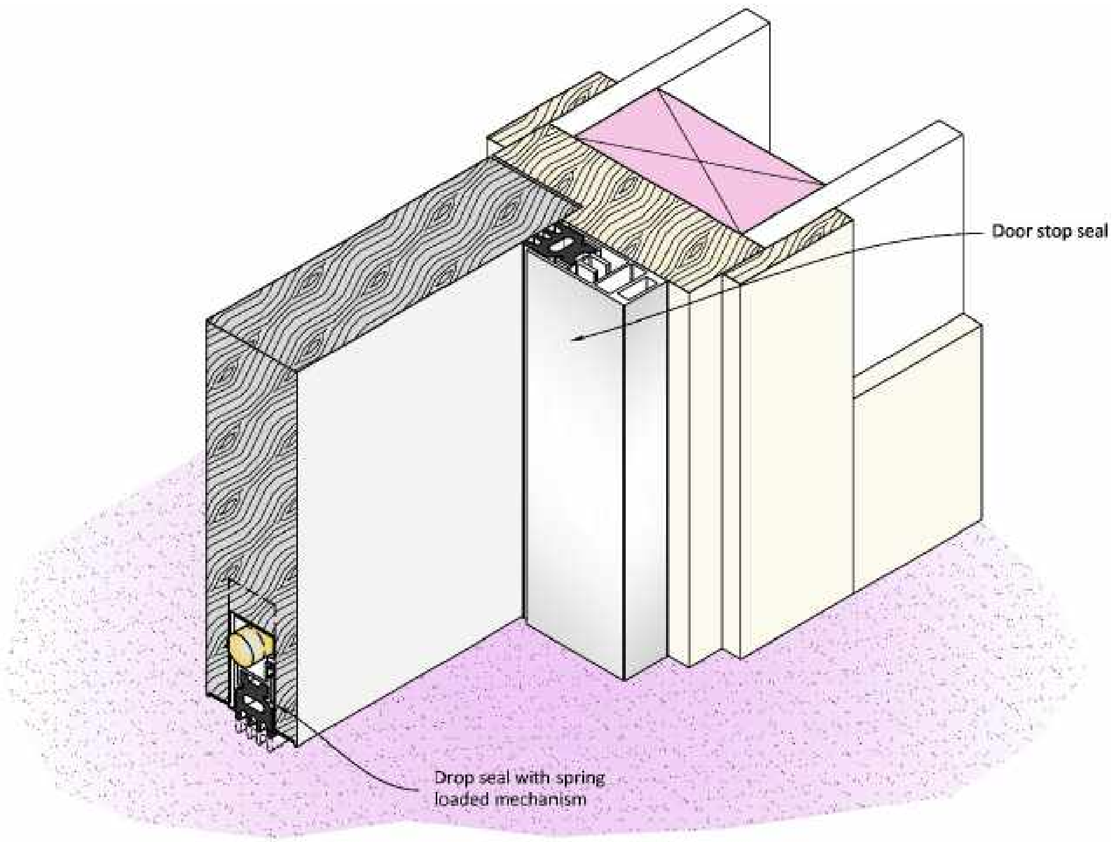


Figure 9: Acoustic seals for a hinged door. Note the perimeter seals and the threshold seal under the door

Some of the STC ratings for doors/windows in **Table 4** are difficult to achieve. This is intended to maintain acoustic integrity and should prompt the designer to:

- Change the layout to avoid putting the opening in such a highly rated wall, or
- Design a better separation solution – for example, two doors with a lobby or corridor in between, instead of a direct connection

Sliding doors are desirable in large learning spaces, because the occupants can choose whether to open up their learning space or close it off for more traditional learning. However, sliding doors don't perform as well as hinged doors because it is difficult to seal the gaps. This is why **Table 4** only requires

STC 25 for sliding doors – it's simply too expensive to achieve higher values but the other benefits of sliding doors, in terms of usability, mean they are not prohibited.

The same issue applies to operable walls. Some manufacturers claim performance of STC 45+, but it is rare for them to achieve these values in practice. Only specify an operable wall if the supplier and installer guarantee its acoustic performance.

The following guidelines will help to optimise sliding door performance:

- All doors – including glass sliders – must be fully framed with perimeter seals (including underneath the door)
- Frameless sliding doors must not be used
- Seal arrangements must include 2 lines of fin seals, or 2 lines of brush seals with silicone/rubber fins – refer **Figure 10**
- Glass doors are preferred because visual connection fosters considerate behaviour

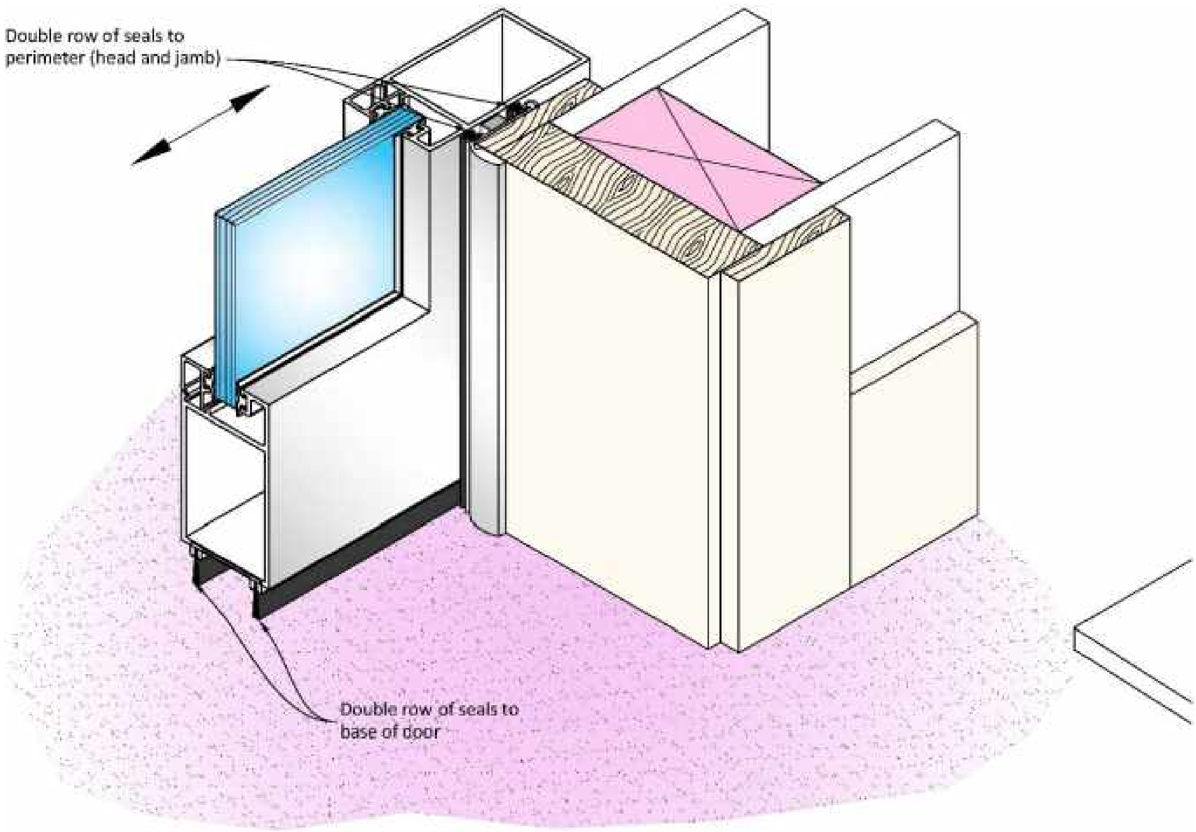


Figure 10: Acoustic seals for a sliding door. Note the double lines of seals

2.3.3. Be clear about which spaces are connected

Large learning spaces can be adjacent to each other (vertically or horizontally), and share wall and/or floor elements, so it is important for a design to be clear about which spaces are connected. This means that the school understands which activities need to be undertaken in a coordinated manner, and which do not.

Figure 11 shows a situation where the line between two separate large learning spaces runs through a pair of breakout spaces. The wall colours indicate the mandatory STC performance according to

Table 2. Note where the STC has been downrated because of the door, and its size relative to the wall (refer to **Section 1.2.2**).

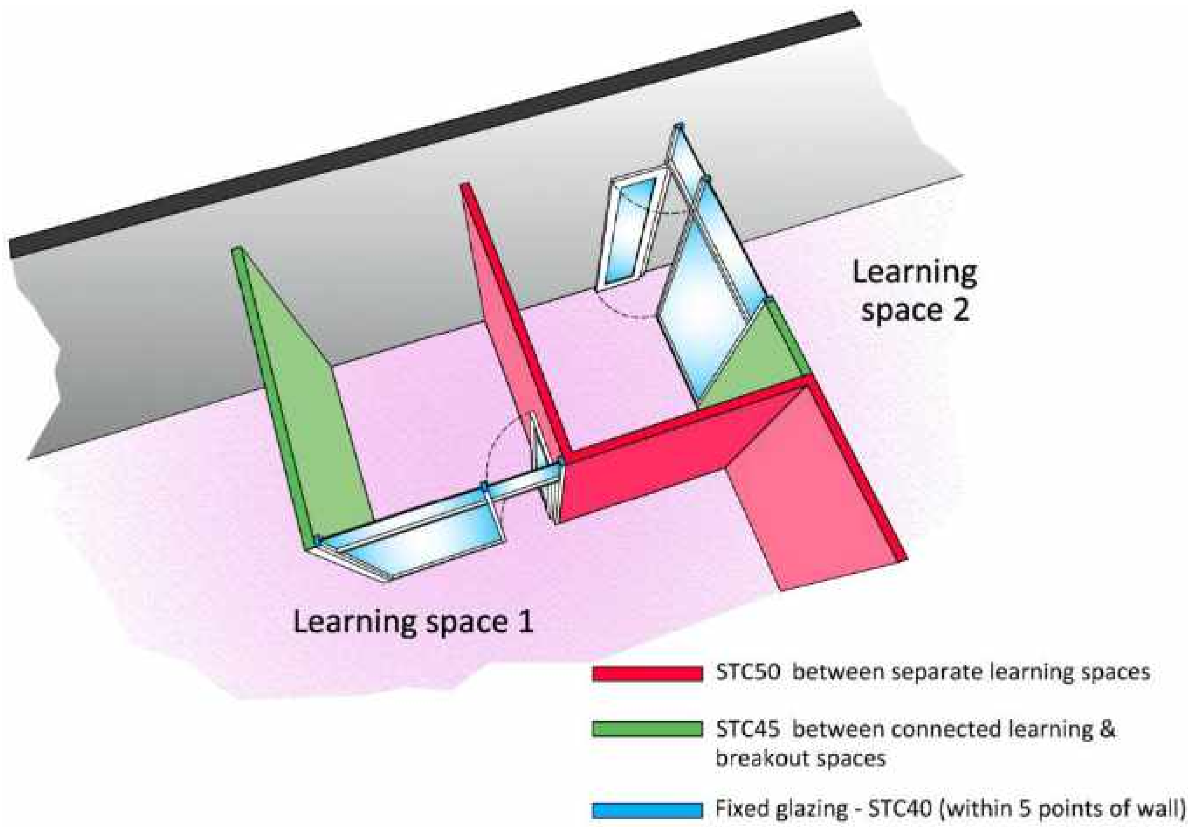


Figure 11: Example of connected spaces and non-connected spaces

Using glass to provide a visual link between learning spaces reminds users that they are acoustically connected to the room next door and need to be more mindful of their activity noise. This is particularly important for glass sliding doors which have relatively poor sound insulation performance.

Stairs and atria

If learning spaces are connected by a stairwell or atrium, sound from student activities will transfer freely between them. Schools and designers need to consider this risk, and how it may impact on learning.

Much will depend on the design and an acoustic engineer can advise on ways to limit the sound transfer, which may include:

- Enclosing the stairwell/atrium with glass walls and doors
- Positioning breakout spaces, shelving units, glass balustrades etc. near the openings to act as barriers
- Adding sound absorption to the stairwell/atrium to control sound reflections
- Advising that the spaces close to the stairwell/atrium must be connected spaces, so they operate in a coordinated way

2.3.4. Potential noise from toilet blocks should be considered

Toilet blocks can be noisy places because their floors and walls are hard and smooth for easy cleaning, which means that most surfaces are sound reflectors. This means that the RT in toilets is high and activity noise will be higher than similar sized rooms with more sound absorption.

Some schools like to have passive surveillance into toilet lobby areas by removing doors or having a fairly open design. This increases the acoustic connection to learning spaces. In these cases, the toilet lobby may need to be treated with sound absorption to manage activity noise build-up and cubicle doors may need to be fully framed with no gaps underneath, to retain privacy. This type of design for toilet blocks is not particularly common though, and STC-rated walls with appropriate doors between the lobby and learning spaces is usually sufficient.

Hand dryers can be very noisy, so careful selection of the right unit is needed. They should be fixed only to double-framed walls, the same as plumbing (refer to **Section 2.6.5**).

2.3.5. Impact insulation manages footfall noise

Ceilings are important for **impact insulation** performance. Designers sometimes opt for exposed soffits – where the underside of the floor slab is visible from below. This is common in office design but is discouraged in schools because of the difficulty it poses for **IIC**.

For hard flooring finishes, even with the 10% rule applied (refer to Table 3), very few acoustic underlays can reliably achieve compliance with no ceiling system below.

An acoustic floor covering can have up to five layers:

- A levelling compound (usually for tiled floors)
- An acoustic underlay (it could be made of foam, rubber, cork or other material(s))
- An adhesive or grout
- A waterproofing layer (for wet areas)
- The floor covering itself (e.g. carpet, carpet tiles, vinyl, tiles, parquet)

Some products may be incompatible with others – for example an adhesive or waterproofing compound could soak into the acoustic underlay and harden it, compromising its acoustic properties. Therefore, it is preferable to select a flooring system that has been acoustically tested as a system, rather than selecting each product separately.

The key parameter that an acoustic engineer looks for, when specifying a flooring system, is ΔL_w. This is measured by laboratory testing.

Trafficable spaces

When they are suspended (i.e. not built on grade), trafficable spaces like corridors, walkways and stairwells can transmit footfall noise into learning spaces. Teachers have noted this as a major source of annoyance, particularly in prefabricated classrooms that are connected by timber walkways and decks (Wilson et al., 2002).

For indoor stairwells and corridors, soft floor coverings like carpet are a good option.

For outdoor stairwells or walkways with no floor covering, it is best to support them on their own structure so there is no connection to the building. If a connection is needed, soft weatherproof floor coverings can be used, or resilient connections (with rubber or neoprene elements) can be used to minimise **impact transmission**.

2.3.6. Helpful tips and rules of thumb – sound and impact insulation

Here are some helpful tips and rules of thumb to keep in mind:

- Make walls full height to avoid flanking over the top
- Junction details are important to reduce flanking around STC-rated walls
- Good seals are critical for doors and windows in STC-rated walls
- Carpet is the best way to control **impact transmission** (including weatherproof carpet outside)
- For hard floors, specify floor systems not individual products, to avoid failures due to incompatibility
- Build decks, outdoor stairs and walkways on their own structure with no connections to the building

2.4. Indoor ambient noise

2.4.1. Occupants and equipment generate ambient noise

Although they are not usually part of a building's design, indoor equipment like computers, servers, cooling fans, electric heaters, projectors, fish tanks etc. create noise. Each item may not be too noisy by itself, but the sound energies from multiple items will combine and could result in noticeable ambient noise levels.

The Ministry of Education doesn't prescribe the equipment a school can put in their learning spaces, but it is important to highlight the risks around equipment noise in terms of complying with the mandatory guidelines.

When purchasing new equipment, its noise level output should be considered. Choosing quieter options will help to manage the accumulated noise levels and make the requirements easier to achieve.

Learning space occupants also generate noise through conversations, teacher instructions and other typical school activities. Typical activity noise level in learning spaces is 45 – 55 dB L_{Aeq} for quiet activities like reading and during tests, and 65 – 70 dB L_{Aeq} for group work and other more interactive activities. These high noise levels can impact on learning performance (Shield, Greenland, & Dockrell, 2010).

To avoid effects on learning, average activity noise levels should be controlled to around 60 dB L_{Aeq} (Canning et al., 2015; Cutiva & Burdorf, 2015; Fidêncio, Moret, & Jacob, 2014; Hygge, 1993; Kristiansen et al., 2015; Mikulski & Radosz, 2011; Rashid & Zimring, 2008).

As part of Te Haratau, the Ministry will investigate learning spaces where noise levels are measured to exceed 70 dB $L_{Aeq(30\ min)}$.

Some noisy activities may be perfectly acceptable and part of learning, for example, kapa haka or music practice. But other activity noise may be unacceptable – particularly where speech intelligibility is important – and should be addressed by changing the way the space is used or by adding sound absorption.

2.4.2. Outdoor activities will influence the noise levels inside teaching spaces

Noise from outdoor activities like transportation (roads, rail and aircraft) can affect students' cognitive performance and attainments (Evans & Maxwell, 1997; Haines et al., 2002; Vilatarsana, 2004).

Just like for interior walls and floors, the acoustic performance of façade walls and roofs are compromised by openings. Doors and windows are, of course, essential and can be designed to have good STC-ratings and seal arrangements, but they only perform when they are closed.

A school building with open doors and windows provides a sound reduction (from outside to inside) of 10 to 15 dB, depending on the size of the openings. So, if the outdoor noise level exceeds the relevant **Table 6** requirement plus 10 dB, naturally ventilating the building may not be an option.

This means that if the school is near a busy road or noisy industrial site, an HVAC ventilation system may be required.

Many schools report that significant noise is generated on school grounds by activities under their own control, such as lawn mowing, sports fields and other outdoor learning spaces (Wilson *et al.*, 2002). Schools can choose to manage these activities themselves with appropriate timetabling and by locating them in suitable areas.

Dealing with ambient noise from sources outside the school grounds is more difficult. For a new build, it is best managed during the master planning stage by positioning non-noise sensitive buildings and areas – like gyms, carparks, courts and sports fields – closer to the main source of outdoor noise. They will provide useful shielding, or a distance buffer to learning and performance spaces.

The same options might be available during extensive school refurbishments, where the uses of existing buildings can be shuffled around according to noise sensitivity.

Noise from schools to its neighbours can also be a problem. Noise to nearby dwellings and other noise-sensitive receivers should be considered, particularly from mechanical plant, carparking, sport fields, music rooms and halls (which may be used for events outside normal school hours). The local council will normally consider this during the resource consenting phase.

2.4.3. Noise barriers can help reduce traffic and industry noise on school grounds

The key difference between a normal fence and a noise barrier is that a noise barrier has no gaps. They can be made from standard materials like timber, plywood and concrete (with minimum mass of 10 kg/m^2 – refer to NZ Transport Agency State Highway Noise Barrier Design Guide, 2010) but special care is needed to avoid gaps between palings and under the fence.

Barriers need to be high enough to block the line-of-sight between the source and receiver – refer **Figure 12**. For traffic, a 2 metre boundary fence is usually sufficient (depending on the relative heights of the school and road).

Trees and bushes do not block sound (this is a common myth). About 70 metres of dense forest is needed to provide the same attenuation as a barrier (Watts et al. 2011). Even then, diffusion and sound absorption are the primary reasons for the reduction, the sound is not blocked.

Trees and bushes can provide other benefits though. Leafy trees create their own noise when the wind blows through them, and this nice natural sound can mask other unwanted sounds like traffic. They also provide a visual screen, and an unseen noise source is less likely to cause annoyance.

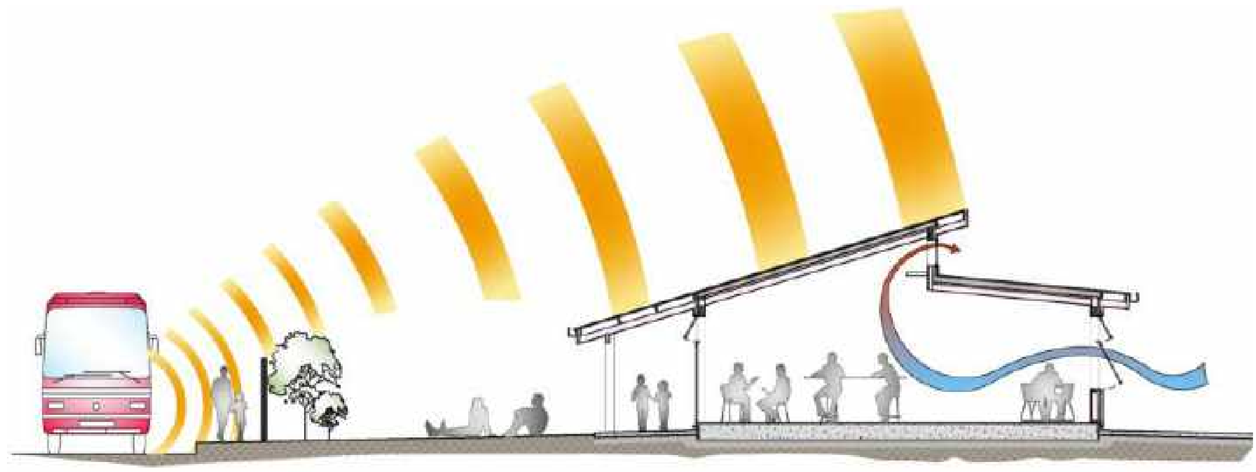


Figure 12: Example of reducing external noise with a solid fence and building configuration

2.4.3. Helpful tips and rules of thumb – ambient noise

Here are some helpful tips and rules of thumb:

- Select quiet indoor equipment
- A high outdoor noise level (from traffic, industry etc.) may mean HVAC systems are needed
- Locate learning spaces and other noise sensitive rooms away from busy roads, shield them with other buildings or noise barriers, or orient buildings so the noise-sensitive rooms face away
- Consult the local road authority to consider quiet road surfaces or divert traffic to reduce vehicle numbers
- Schools need to manage their own outdoor activities
- The key to a good noise barrier is having no gaps
- Trees are not effective noise barriers

2.5. Rain noise

This version of DQLS – Acoustics doesn't set a rain noise criterion because it is difficult to test and predict rain noise according to international standards. Also, in terms of verification, it isn't practical to test rain noise performance in the real world, because consistent rain falling at a specified rate during tests is difficult to arrange.

Rain noise must be controlled in all learning spaces by designing the roof-ceiling structure to cope with periods high intensity rainfall – because this is when rain noise can interfere with learning. The likelihood of high rain intensity varies throughout NZ, so a school's roof design should be appropriate for its regional rainfall intensity.

2.5.1. An approved solution provides confidence in acoustic performance

The Ministry prefers warm roof systems because their polystyrene or rigid foam layer provides an effective thermal envelope. But these materials have poor sound insulation because they are light and stiff, so the system must be improved to control rain noise.

Most warm roof systems have a mass layer option (usually plasterboard or fibre cement) so all warm roof systems in schools must include this option. In high and medium rainfall intensity areas a second mass layer is to be provided by the ceiling.

A mass layer is a solid board or high-density material (with a weight of 10 kg/m^2 or more) such as:

- Plasterboard
- Other solid sheeting materials like fibre cement, particle board etc.
- Ceiling tiles with a CAC rating (usually plaster-backed or high density)

Acoustic engineers prefer ceiling cavities to have absorption to control cavity resonance, but if this causes moisture issues, a ceiling layer with a higher CAC rating can compensate.

Section 1.3.2 divides NZ up into three rainfall intensity areas and a different approved solution is given for each area. **Figure 13** shows the general design of an approved warm roof system, which must comply with all relevant DQLS documents, including DQLS Indoor Air Quality & Thermal Comfort, and Weathertightness and Durability Requirements.

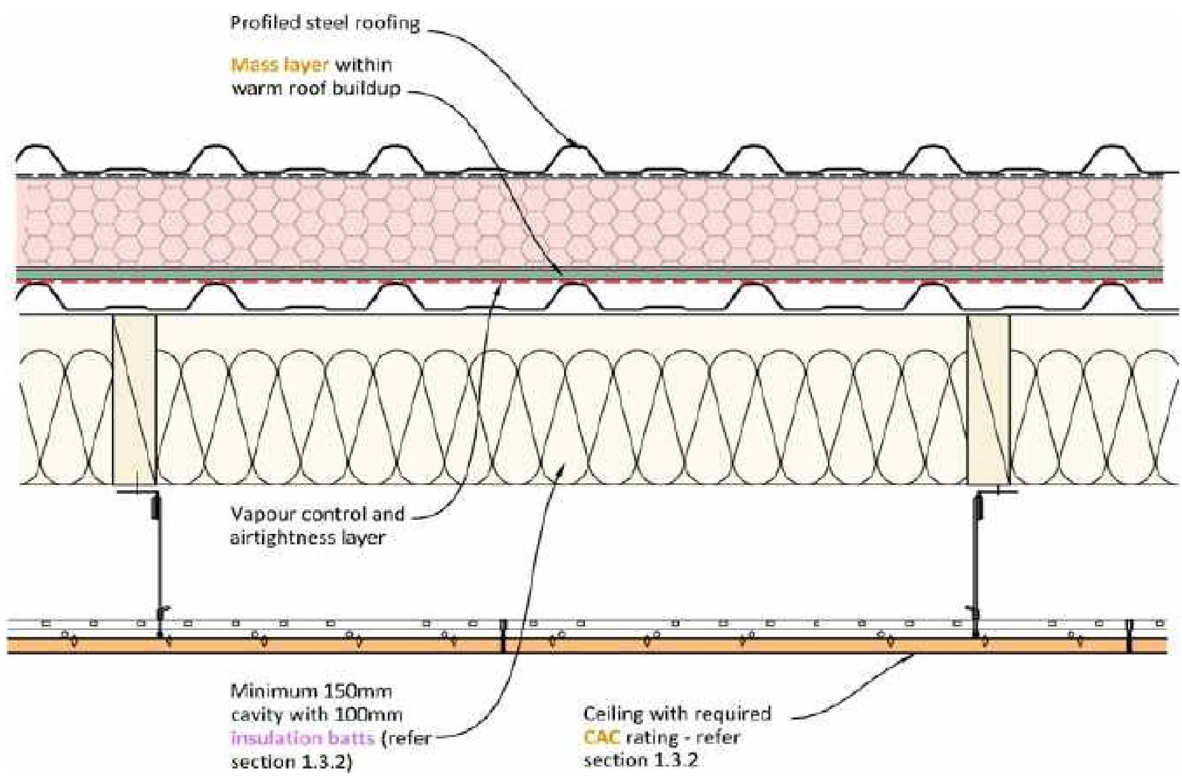


Figure 13: General design of approved warm roof solution

Different roof-ceiling designs may be accepted by the Ministry, but they must be confirmed by an acoustic engineer as being acoustically equivalent.

2.5.2. Other roofing materials have acoustic advantages over steel

The approved solutions assume the roofing material (i.e. the surface the rain falls on) is made of profiled steel. Steel is by far the most common roofing material, but others are available such as:

- Torch-on bitumen or polymer membranes (this is an option for most warm roofs)
- Pressed metal tiles
- Concrete or other ceramic tiles
- Asphalt

These roofing materials all have better damping properties than steel, which means that raindrops falling on them don't generate as much structure-borne noise i.e. they behave less like a drum. Selecting a non-steel roofing material may mean that acoustic equivalence can be achieved with fewer mass layers, or a down-rated ceiling.

2.5.3. Skylights can be an acoustic weak point

Just like for walls, openings in a roof-ceiling system will compromise its sound insulation performance. Skylights and other transparent elements like light tubes or glass panels must have an STC rating within 5 points of the roof system in which they are built – refer to Section 1.3.2.

Many skylights in the market may not have been laboratory tested by their manufacturer. So, when selecting an element, give preference to those that have been independently tested or ask an acoustic engineer to predict its performance.

2.5.4. Helpful tips and rules of thumb – rain noise

Some helpful tips and rules of thumb to keep in mind include the following:

- Approved solutions have been provided for steel-clad warm roof systems, based on regional rainfall intensity
- Other roof-ceiling systems can be used but need to be acoustically equivalent to the approved solution
- Skylights and other roof openings need to have good sound insulation

2.6. Building services noise

2.6.1. Ducted HVAC systems can be designed to be quiet

Mechanical ventilation systems must be designed, supplied and installed to comply with the mandatory requirements in **Section 1.3.3**.

Noise is generated by the following parts of an HVAC system:

- The fan (motor noise).
- The ductwork (noise radiating from the duct walls – known as breakout noise)
- Bends and transitions in ductwork (turbulence causes regenerated noise)
- Dampers and actuators (turbulence causes regenerated noise, and actuator mechanisms may be audible)

- Supply diffusers and return grilles (turbulence causes regenerated noise)
- When a room is pressurised by a ventilation system, air escaping around the edges of closed doors and windows can cause a whistling noise
- Outdoor HVAC plant, including the outdoor units of a split-system heat pump. The noise can transfer from outside to inside through the walls, roof and windows

When designing a school HVAC system, the most important thing is to comply with the DQLS – Indoor Air Quality and Thermal Comfort document. It acknowledges that an HVAC system should be designed to provide low acoustic impact.

An acoustic engineer should calculate the noise levels from each fan and duct run (including breakout and regenerated noise) and work with the mechanical services engineer to achieve compliance. Specifying attenuators in duct runs is a key part of this collaboration.

A common acoustic error in HVAC design is duct velocities that are too high, because this generates higher levels of regenerated noise. The best ways to address this are to increase duct dimensions and/or use low-noise diffusers and grilles.

HVAC systems should be programmed to heat or cool the room as needed, well before the school day starts. This means that learning spaces will be at the correct temperature when the teacher and students arrive and may reduce the need for HVAC use throughout the day.

2.6.2 Noise from heat pumps cannot be mitigated

Split-system heat pumps (like the ones in dwellings) are popular in schools. But they have the potential to generate high noise levels when running at high speeds.

In high wall and cassette units (the indoor parts of a split-system) the fan is inside the unit so its noise can’t be mitigated the same way a ducted HVAC system can. Noise from high wall and cassette units can only be managed by specifying a quiet unit, reducing its fan speed or turning it off altogether.

Therefore, the mandatory requirements for heat pumps depend on whether the system is user-controlled or not. If a teacher is finding that the noise is interfering with learning activities, they can choose to turn it down or off for a while. If they have no direct control, the system itself needs to be designed to be quieter.

When specifying a split-system indoor unit, its design speed should be low or medium speed – not high speed. This will ensure that the unit is suitable for the space under normal conditions and doesn’t have to generate too much fan noise in order to maintain the right temperature.

2.6.3. Extraction systems are noisy, but used infrequently

Dust and fume extraction systems in technology and science rooms, and kitchen rangehoods are always noisy (and difficult to mitigate) but are only used for brief periods at a time. So, learning activities can be managed around them.

If the school or designer has concerns about this, specify quiet systems, with the fan outside the room, or make use of sound insulation and sound absorption techniques to reduce noise transfer to learning spaces.

2.6.4. Plantrooms can transmit noise and vibration into learning spaces

Noise inside plantrooms can be high and can include lots of low frequency sound. So, it is important to separate them from learning spaces either acoustically – using high STC walls or enclosures (as per the mandatory requirements in Table 4) and vibration isolation – or physically, by positioning them away from sensitive spaces.

Plantrooms and plant decks can be roof mounted. This means there will be a structural connection, so an acoustic engineer should be engaged to design a solution.

2.6.5. Plumbing can be a source of ambient noise

Water supply, wastewater and toilet flushes run through pipes in the walls. Noise and vibration from the pipes can transfer into the wall structure and radiate into learning spaces.

Options for reducing plumbing noise include:

- Installing pipes in a double-framed wall, with the pipes in (or attached to) the frame furthest from the learning space
- Lagging the pipes with a sound insulator e.g. mass-loaded vinyl or use acoustically-rated pipes
- Using resilient pipe isolators for all connections

2.6.6. Helpful tips and rules of thumb – building services

Here are some helpful tips and rules of thumb to keep in mind:

- A high outdoor noise level (from traffic, industry etc) may dictate the need for an HVAC system. This should be established early in the design process (concept design)
- The mandatory requirements for HVAC systems are 5 dB less than the ambient noise requirements, to ensure they have a minimal contribution to the overall indoor noise level
- The mechanical services engineer and acoustic engineer should work together to design quiet HVAC systems
- Select low noise fans, diffusers and grilles, and size ducts to keep air velocities down
- Split-system heat pumps are very common. Select quiet units because, once installed, their noise levels can only be controlled by turning them down, or off. This is why having user control permits a higher noise level in the mandatory requirements
- Put outdoor plantrooms and outdoor HVAC units on separate foundations to minimise structural noise transfer into buildings
- Walls with plumbing in them should be double-framed

2.7. Specialist spaces

Specialist spaces are used for activities that may generate more noise and/or be more noise sensitive than other learning spaces. It is best to cluster these spaces together by type, in their own block. This means that they will be acoustically separate from other learning spaces and incompatible activities.

2.7.1. Technology rooms generate a range of noise levels

Technology rooms cater for a range of subjects and are generally divided into three categories:

High-noise tech

High-noise tech includes automotive, hard materials technology, building and construction and other trades involving metalwork and woodwork. Activities and machinery in these rooms can be very noisy, which is why the mandatory sound insulation requirement for walls and floors is STC 60.

These rooms tend to have hard floor coverings too, so sufficient sound absorption is needed on ceilings and walls to meet the mandatory RT requirements.

Schools need to carefully consider the health and safety of teachers and students while high noise machinery is being operated. This means raising awareness and taking precautions to avoid hearing loss, such as hearing protection and workroom enclosures.

Moderate-noise tech

Teaching spaces for food technology, textiles and the like generate moderate noise levels. These learning spaces include equipment that produces moderate noise levels, such as kitchen extract systems, cutting equipment, and sewing machines.

These rooms tend to have hard floor coverings too, so sufficient sound absorption is needed on ceilings and walls to meet the mandatory RT requirements.

Low-noise tech

In low-noise tech spaces such as art rooms and maker spaces, student activity is the primary noise source.

These rooms tend to have hard floor coverings too, so sufficient sound absorption is needed on ceilings and walls to meet the mandatory RT requirements.

2.7.2. Music teaching rooms are noise sensitive and high-noise generating

Music teaching rooms are primarily for learning, but when loud music is played – especially by percussion, brass and amplified instruments – sound will transfer to adjacent rooms.

At other times, music rooms are noise sensitive, because of the clarity needed for tone differentiation and when listening to quieter, more subtle works.

This is why the mandatory requirements are stringent – STC 60 for sound insulation and 40 dB for ambient noise. It is a good idea to cluster music teaching and practice rooms together in their own block, to provide separation from other learning spaces.

Music practice rooms are small, and room modes are a common problem. Avoiding parallel walls is a simple and effective way to address this. It works well when a number of practice rooms are clustered together because angling one wall serves two practice rooms, as shown in **Figure 14**.

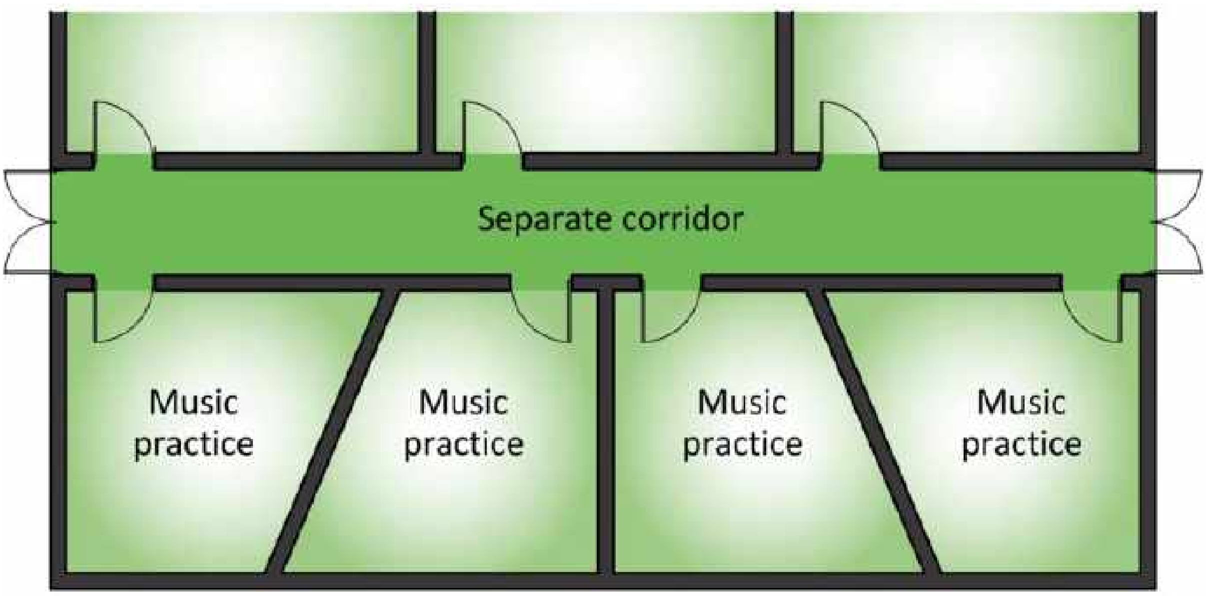


Figure 14: Example of music practice rooms – note the angled walls

Schools should provide hearing protection (e.g. earplugs) to teachers and students for when loud music like rock bands, brass and percussion ensembles are played in music rooms.

2.7.3. Auditoria and music performance spaces need specialist design

Acoustic quality is critical for these rooms, so advice from an acoustic engineer is essential. They should be engaged early in the design process, so they can advise on the location and shape of the rooms.

An acoustic engineer can also provide an early indication of STC and RT requirements, to help prepare an accurate budget. Getting the acoustic design right early is more cost effective than fixing problems down the track.

For some schools, assembly halls and gyms fulfil the role of a performance space, but are not specifically designed to be one. For these spaces, follow the mandatory requirements and where possible, apply the most stringent values based on its range of uses.

2.7.4. Multimedia and recording rooms have stringent acoustic needs

The activities in these rooms involve audio recording. This means they need to have:

- A low RT so that the room doesn't alter the sound being recorded
- Walls and floors with high sound insulation
- Low ambient and HVAC noise levels, so unwanted noises aren't picked up in the recording

Achieving the mandatory requirements will result in good outcomes. But if the school wants a true recording studio with a control room, live rooms, vocal booths etc., an acoustic engineer should be engaged to advise on:

- Room layout and orientation
- Room modes
- Loudspeaker placement

- Sound insulation between recording and control rooms (including window design, patch panels and cable trunking)

2.7.5. Libraries are becoming ICT hubs

The form and function of libraries has changed over time, and may continue to do so in future. The size of book collections is tending to reduce, and the rise of information and communication technology (ICT) means computers are now commonplace.

Library areas are often incorporated into large learning spaces and can be positioned to provide some separation between connected learning spaces. Books absorb sound, and bookshelves can be positioned as screens – refer **Section 2.2.4**.

If a library is part of a large learning space, the mandatory requirements for large learning spaces apply. If the library is in its own building and not connected to any learning spaces, the mandatory requirements for libraries apply.

2.8. Inclusive design

Schools are required to be inclusive under the Education and Training Act 2020 and the Ministry of Education supports national and international obligations in their curriculum and design practices.

Students with hearing impairment and other learning difficulties are often very sensitive to specific types of noise including those with strong tonal, impulsive or intermittent character. There are a range of services and aids available for teachers and schools as part of learning support. Assistive technology can also help to improve learning outcomes.

It is important for school design to provide learning spaces that accommodate all learners, including those with hearing or vision impairments and learning, emotional or behavioural challenges. Many students in New Zealand with learning support needs are mainstreamed or have dedicated units within a school.

The mandatory requirements are set at a level that ensures acoustically balanced and well controlled learning spaces. Special units designed for a specific learning need may require additional consideration and bespoke acoustic design.

The following sections offer some guidance for designing learning spaces for students with specific learning support needs. It is not a comprehensive account of what should be considered. Te Haratau requires learning spaces to be fit for purpose and these suggestions may help schools, designers and acoustic engineers to provide this.

2.8.1. Hearing impaired students

Hearing impaired students need activity noise to be well controlled and clear communication channels with their teacher and other students. FM Systems – where the teacher wears a microphone connected to a hearing impaired student's hearing aid – are common and can be funded by government. They are an excellent way of making sure the teacher-student communication channel is clear, but the room acoustics still need to support student-teacher exchanges and interaction with classmates. Breakout spaces, quiet areas and nooks also offer some acoustic separation when needed.

Note that FM systems are not the same as soundfield systems, which amplify the teacher's voice through loudspeakers. Soundfield systems are not recommended for schools.

The Ministry of Education provides support for HI students. Organisations such as National Foundation for the Deaf and Hard of Hearing (NFDHH) and Deaf Aotearoa can also provide guidance on how schools and acoustic design can help.

2.8.2. Blind and low vision students

Blind and low vision students will benefit from the acoustic control provided by the mandatory requirements. Although, it is important not to suppress sound reflections too much because they give "the visually impaired individual key data about his or her area and the idea of the surroundings" (Southworth, 1969 and Salapura, 2019).

Blind and Low Vision Education Network NZ have units in many schools. They don't publish acoustic criteria but have experience with creating supportive learning environments and recommending assistive technologies for the students they support.

2.8.3. Students with emotional, behavioural and learning difficulties

Students with emotional, behavioural and learning difficulties need to feel safe, and high noise levels can cause distress (McLaren & Page, 2015). The mandatory requirements will provide a good foundation to manage noise levels and provide areas where one-on-one teaching can occur, but the following solutions can also be considered:

- Ensure a breakout space or quiet area is always available and easily accessible
- Limit the noise level of the bell or announcement system to 75 dB L_{Aeq} inside learning areas
- Warn learners about planned fire alarm drills

Support groups such as Learning Disabilities Association of NZ (LDANZ) and Autism NZ can provide advice.

3. Acoustic verification

A number of methods can be used to verify if the acoustic performance of a learning space meets the mandatory requirements listed in **Section 1**. The preferred method is for an acoustic engineer to carry out commissioning tests.

Commissioning tests are not mandatory on every project but may be required by the Ministry – particularly if concerns about acoustic performance are expressed through user surveys, post-occupancy evaluations or via noise monitoring devices.

The Ministry may not require commissioning tests if they are satisfied that the acoustic report submitted with the design documentation provides a sufficient level of confidence that the mandatory requirements will be met. The design documentation should include the completed IEQ Design Report.

Where commissioning tests are deemed necessary, they should be carried out according to the following sections.

The advice provided does not supersede the requirements of the referenced standards, but is meant to assist in their interpretation and application specifically to learning spaces.

3.1. Schedule of testing and requirements for testing equipment

3.1.1. Reverberation time and ambient noise

A representative sample of spaces should be tested. The sample should comprise at least 25% of all rooms with mandatory requirements and should include at least one of each type of learning space.

All rooms with special acoustic requirements should be tested e.g. music teaching rooms, music practice rooms, auditoria, music performance and recording spaces.

3.1.2. Sound transmission and impact insulation

Testing of STC and **IIC** should only be carried out on STC-rated walls and floors without doors, windows or openings. These partitions should be tested for compliance with the mandatory requirements in Table 4 minus 5 points i.e. a 5 point leeway is given for on-site results.

A representative sample should be tested, including one of each partition type of partition (if possible, given the restriction on walls with openings).

Doors and windows in STC-rated walls should be visually checked to ensure seals are installed and engaging properly.

3.1.3. Testing equipment

Acoustic testing should be conducted using a measuring system that complies with the requirements in AS/NZS 2107:2016. It normally includes a sound level meter, microphone and preamplifier. loudspeaker, signal generator and tapping machine.

The sensitivity of the measuring system also needs to be checked on site using a microphone calibrator. Sensitivity checks should be made before and after each set of measurements and the results stored with the measurement data. If the checks show a discrepancy greater than ±1 dB, any measurements made in the interval between the two checks shall be disregarded.

All component parts of the measuring system, including the calibrator, shall have current and valid calibration certificates for their full frequency and dynamic ranges, in accordance with the requirements given in AS/NZS 2107:2016.

3.2. Measurement procedures and reporting requirements

3.2.1. Reverberation times

The mid-frequency RT, T_{mf}, is defined (in section 5.4 of AS/NZS 2107:2016) as the arithmetic average of the RT values in the 500 Hz and 1000 Hz octave bands.

The room should be finished, unoccupied but furnished and ready for occupation. The windows and doors should be closed.

During commissioning, RT shall be measured according to the procedures described in AS/NZS 2460:2002.

Measurements should be made using at least two different source positions and at least three different microphone positions – a minimum of 6 different source-microphone combinations. In rooms with a large volume and/or complicated geometry, more source and/or microphone positions should be used. These positions should be distributed throughout the room and should represent where speakers and listeners will typically be.

A test report should be prepared in accordance with AS/NZS 2460:2002.

If the type of room being tested isn't specifically listed in **Table 3**, the report should state the most relevant space in Table 3 and the criteria that have been applied.

3.2.2. Indoor ambient noise levels

Indoor ambient noise levels should be measured using the procedures described in AS/NZS 2107:2016. These measurements should be used to determine the equivalent continuous A-weighted sound pressure level, L_{Aeq}. The measurement time interval needs to be sufficient to obtain a representative level.

The room being tested should be finished, unoccupied but furnished and ready for occupation. The windows and doors should be closed unless the room is naturally ventilated, in which case these should be opened to an appropriate degree.

When assessing compliance with the mandatory requirements for ambient noise in **Table 6**, HVAC systems (including heat pumps) should be turned off. Any other mechanical systems should be in use and running in their usual manner.

In order to assess compliance of mechanical plant, the indoor ambient noise level should be measured together with the HVAC system operating as it would for normal occupancy. The measured level (of the ambient noise and mechanical plant *combined*) must not exceed the relevant value in **Table 6** by more than 2 dB.

Measurements should be made at a sufficient number of locations to provide an estimate of the volume-average ambient noise level. In most rooms this would be in at least three positions unless the room is small such that a one-point measurement is suitable.

The measurements should be made at a time that represents the ambient noise during teaching. If there are significant variations in noise level throughout the day, for example due to intermittent noise events such as from aircraft or traffic, the measurement should include a representative sample of these events.

Measurement reporting should include the information listed in section 7 of AS/NZS 2107:2016. The description of the state of the room should include details of the furnishings, whether the windows and doors were open or shut, significant noise sources within the room and any significant external noise events which occurred during the measurement.

3.2.3. Sound transmission of walls and floors

Sound insulation testing should only be conducted on walls and floors without openings. If possible, a sample of every different acoustic rated wall and floor should be selected for testing.

STC performance should be verified using the procedures detailed in ASTM E 336, and the field sound transmission class may be verified using the method described in ASTM E 413.

Field test results shall be within 5 points of the relevant mandatory requirement in **Table 4** i.e. a 5 point leeway is given. This is consistent with the New Zealand Building Code, Clause G6.

Key measurement procedures include the following:

- Two speaker positions should be used within each source room. The loudspeaker should be placed facing away from the partition to ensure a reasonably even sound field on the tested partition.

- Measurements are required within both the source and receiver rooms. These can be taken using either moving or fixed microphone positions:

  – Moving microphone locations should be selected so they are reasonably distributed throughout the space. Measurements should be taken over a minimum period of 30 seconds. Longer measurements may be required for larger spaces

  – Six fixed microphone positions should be selected. These should be evenly distributed within the space at least 1 metre apart, however, less is acceptable in small spaces. These measurements should be made over a minimum period of 10 seconds in each location

- Reverberation time and background noise measurements are required in each receiving space

For walls that include openings, a visual inspection should be made at the time of commissioning to ensure that that all door and window seals are engaged and well-sealed when closed.

3.2.4. Impact sound insulation of floors

IIC performance should be verified using the procedures detailed in AS/NZS ISO 140.7 and the field **impact insulation** class may be verified using the method described in ASTM E 989. Field test results shall be within 5 points of the relevant mandatory requirement in **Table 4** i.e. a 5 point leeway is given. This is consistent with the New Zealand Building Code, Clause G6.

Key measurement procedures include the following:

- At least four tapping machine positions should be used within the source room. These should be randomly distributed and oriented on the floor, at least 0.5 metres from the edges of the floor

- Measurements are required within the receiving room. These can either be taken using fixed or moving microphone positions:

  - Moving microphone locations should be selected so they are reasonably distributed throughout the space. Measurements should be taken over a minimum period of 30 seconds. Longer measurements may be required for larger spaces

  - Four fixed microphone positions should be selected. These should be evenly distributed within the space at least 1 metre apart; however less is acceptable in small spaces. These measurements should be made over a minimum period of six seconds in each location

- Reverberation time and background noise measurements are required in each receiving space

Glossary

Description	Definition
Acoustic engineers	These are consultants with professional expertise in acoustics. The professional body for acoustic engineers in NZ is the Acoustical Society of New Zealand (ASNZ).
Acoustical Society of New Zealand (ASNZ)	An incorporated society for people with a professional or other involvement in acoustics. People with the society grade 'Member' have had their qualifications and experience reviewed by an independent panel, and must maintain a minimum standard of continued professional development to retain their Membership status. They are entitled to use the post-nominal letters MASNZ.
Ambient internal noise level	Sound level in an unoccupied space. Sources may include ventilation systems, computer fans etc, or outdoor sources such as traffic, aircraft or playground activity.
Bass rise	In rooms designed for music, a longer reverberation time at low-frequencies is desirable to support bass notes from unamplified instruments. An RT of up to 40% higher at 125Hz compared with the mid-frequency RT is permitted (Barron, 2009).
Café effect	Increase in activity noise due to people raising their voices to be heard over other activity noise. It is related to the Lombard Effect – which is a person's natural reflex to increase their speech level in the presence of noise.
Ceiling attenuation class (CAC)	Rating of a ceiling system's sound insulation properties. A higher number is better and CAC 35+ achieves good performance.
Connected spaces	Adjacent learning spaces that are: • physically connected to each other by a door, corridor or opening (i.e. one can walk between them without going outside), and • are part of the same general space in which learning activities are coordinated Sound travels more easily between connected spaces, but this is okay provided activities are acoustically compatible e.g. all quiet or all noisy at the same time. Walls between connected spaces are permitted to have lower STC ratings.
Decibels (dB)	The measurement unit of sound. Typically, A-weighted to match the frequency response of average human hearing. Measurements of sound are usually time averaged, so are expressed as L_{Aeq} levels in dB.
Diffusion	Surfaces with diffusion scatter sound reflections in different directions. Rooms with diffusion are less likely to suffer from unwanted acoustic flaws such as flutter echoes, focusing and room modes. Typical diffusing objects in a learning space include chairs, tables, cupboards and bookshelves.
Flutter echo	Successive repetitive echoes caused by sound reflecting backwards and forwards between two parallel surfaces. It has a peculiar sound that can be distracting and affect speech intelligibility.

Focussing	Focussing occurs when sound reflects off multiple surfaces – especially curved ones – towards the same location in a room, resulting in a strange sense of amplification and envelopment. It is an unwanted acoustic artifact.
HVAC noise	Noise from heating, ventilation and air-conditioning (HVAC) systems. They have their own set of criteria – separate from ambient noise. HVAC systems are typically ducted systems with units in the ceiling or in a separate plant room, or split-system heat pumps (which are treated slightly differently). Heaters and cooling fans that plug into a wall socket are not an HVAC system, and are dealt with as ambient internal noise.
Image shift	Image shift occurs when a particular sequence of sound reflections makes it sound as though the source is in a different location to where it actually is. It is an unwanted acoustic flaw that can cause distraction, influence speech intelligibility, and affect enjoyment in performing arts spaces (Barron, 2009).
Impact insulation class (IIC)	Acoustic rating of a building element (usually a floor / ceiling system) in terms of its ability to prevent **impact sound transmission** from footfalls etc. A higher number is better and **IIC** 50+ achieves reasonable performance.
Impact sound	Sound caused by an **impact**, such as footsteps, closing doors, dropping objects etc. It travels through the building structure and is heard in adjacent spaces.
Mid-frequency RT	The mid-frequency RT, T_{mf}, is defined (in section 5.4 of AS/NZS 2107:2016) as the average of the RT values in the 500 Hz and 1000 Hz octave bands.
Noise reduction coefficient (NRC)	Rating of a material's sound absorption properties, averaged across a range of frequency bands. A material with NRC 0.7 absorbs (on average) 70% of the incident sound. An NRC of 1.0 means 100% is absorbed.
Reverberation time (RT)	A room's RT is how long (in seconds) it takes for sound to die away (decrease by 60 dB). It depends on the room volume, and the combined area of sound absorbers. See also mid-frequency RT
Room modes	Resonances which can occur within a room when sound reflects off its surfaces. Each mode has a particular 'natural frequency' and is characterised by a strong variation in sound level throughout the room. They are common in rooms that have a small volume and are rectangular in shape and can be mitigated by introducing diffusing surfaces or sound absorption.
Sound Absorption	Sound absorption is provided by materials that convert sound energy into heat and suppress reflections. Sound absorbing materials are the primary tool for controlling reverberation time and activity noise build up.
Sound Transmission Class (STC)	Acoustic rating of a building element in terms of its ability to prevent airborne sound transmission. A higher number is better and STC 50+ achieves reasonable performance.

Tables

Figures

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Published by the New Zealand Ministry of Education, Education Infrastructure Service, November 2020

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