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ACOUSTICS

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NZ Wood Design Guides is a Wood Processors and Manufacturers (WPMA) initiative designed to provide independent, non-proprietary information about timber and wood products to professionals and companies involved in building design and construction.

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Aim and Scope of this Design Guide

This design guide is an introductory design guide produced with the aim to help designers produce cost-effective multi-residential timber buildings for the New Zealand context. It is intended for residential buildings and does not cover commercial buildings. In practice, this means that relatively small, apartment-sized rooms are assumed, rather than large halls.

In this design guide fundamentals of acoustics are presented first along with the New Zealand building code and local authority requirements. The reader is then introduced to some principals for improving acoustic insulation in timber building elements. Finally, some example details are presented for timber frame construction and for massive timber (CLT) construction.

Contents

Fundamentals

It is helpful to understand some basics of acoustics and noise control before we cover the acoustic design of timber buildings in New Zealand. This section provides a quick overview of key concepts.

Sound

Sound is defined as vibrations that travel through the air or another medium and are then heard when they reach a person's ear. Sounds have a range of frequencies (measured in Hertz – Hz) and strengths or levels (measured in decibels – dB).

Measurement and perception of sound

We measure sound in air using a microphone which usually measures sound pressure. This sound pressure measurement is presented as a sound level in decibels (dB). The decibel scale is logarithmic; each time the sound energy doubles, the level is increased by 3 dB. For sound in air 0 dB is defined to be the average threshold of human hearing at 1 kHz.

People are normally able to detect sound frequencies from about 16Hz to about 20 kHz, with reduced sensitivities at the low and high frequency ends. The A-weighting curve was introduced to try to take this frequency dependent sensitivity into account. We thus get A-weighted sound levels, which are denoted by dB(A). Figure 1 illustrates the A-weighted sound levels of some typical sounds.

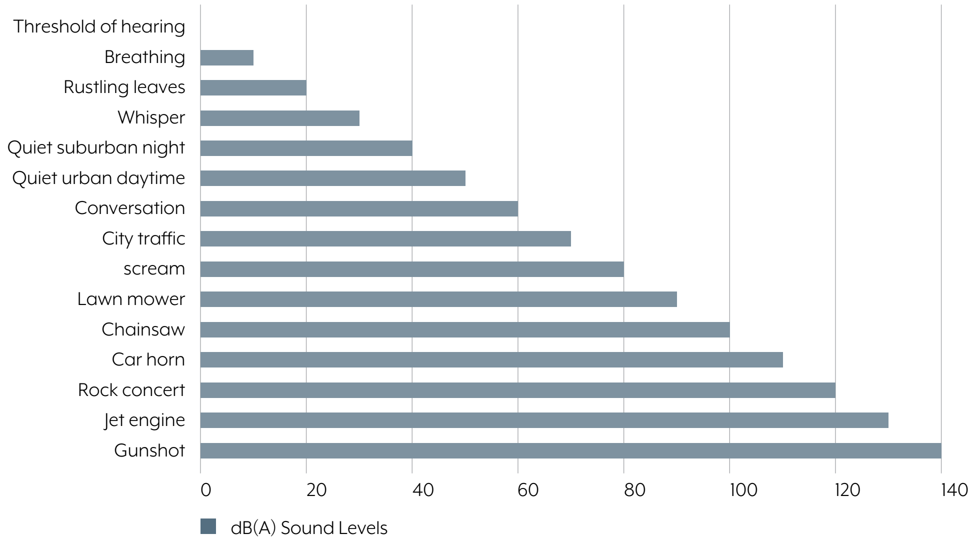


Figure 1. A comparison of sound levels in dB(A).

Perception of sound loudness does not follow the same change as the measured sound level in dB. For example, 10 dB decrease in sound level is generally perceived by a person as a halving of the sound loudness, and a change in sound level of 3 dB is barely perceptible.

Table 1. Human perception of sound level changes

Change in Sound Level (dBA)	Subjective Perception	End-user Impact
1 – 2	Imperceptible change	Negligible
3 – 4	Just perceptible change	Slight
5 – 8	Appreciable change	Noticeable
9 – 11	Doubling of loudness	Significant

If we wish to undertake an acoustic design it is necessary to evaluate sound in terms of third-octave frequency bands; 50 Hz to 5 kHz being the normal range of interest. A frequency analysis is necessary because the acoustic properties of materials vary with frequency. As a general rule, the lower the frequency the less sound reduction a material achieves.

Sound transmission and insulation

Sound striking the surface of a building element will be partly reflected and partly transmitted into the building element. Depending on the construction of the building element, some of the sound will be absorbed and some will be transmitted to the other side to emerge as transmitted sound.

The ability of building elements or structures to reduce sound transmission is called 'Sound Insulation'.

Airborne and impact sound

We divide sound transmission into two types of sources: airborne sound sources and impact sound sources. Airborne sound sources are those sound sources which transmit sound energy to a partition through the air, whereas impact sound sources transmit sound energy through direct contact with a structure. In both cases the sound energy is radiated into the air to be heard. Sources of airborne sound include, for example, speech and music, and sources of impact sound include footsteps and door slams.

The insulation of sound generated by airborne sound sources is known as airborne sound insulation, and the insulation of sound generated by impact sound sources is known as impact sound insulation.

Direct and flanking transmission

We tend to think of sound as being transmitted directly through a separating building element, but sound can also be transmitted along other paths in the building structure. Any sound transmitted to the receiver not directly through the separating element is referred to as flanking transmission. These in-direct or 'flanking' paths between source and receiver, are harder to predict and can often significantly affect performance. An example is sound carried via a common floor slab: even if the wall directly between the rooms transmits an insignificant amount of sound, some noise will still be heard in the receiving room via the floor. Airborne and impact sound transmission are usually made up of sound travelling via direct and flanking paths.

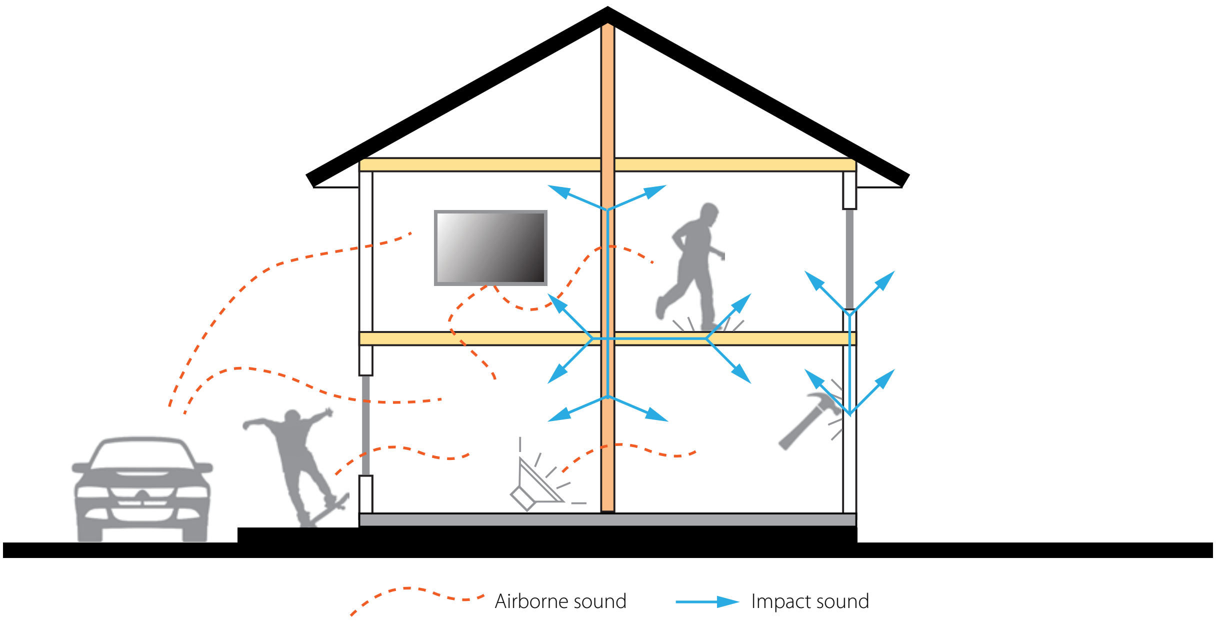


Figure 2: Examples of impact and airborne sound

Acoustics of wooden materials

Wood has a much more complex cellular microstructure than other common building materials. This gives wood a high stiffness to density ratio. This high stiffness to density ratio means wooden building materials and wood-based structures can be much lighter than some other building materials. While this is good for structural design considerations, a high stiffness to density ratio is generally not so good for sound insulation performance of monolithic, single-layer structures. For example, airborne sound at 500Hz is reduced by 48dB for 140mm of concrete but is only reduced by 32 dB for 140mm of CLT. However, by using multiple layers to create a cavity structure the sound insulation can be greatly increased. Two layers of 140mm thick CLT separated by a 75mm cavity gives a sound reduction at 500Hz of more than 80 dB, even though such a structure has less than half the mass of a single concrete slab.

This CLT versus concrete slab example shows that excellent acoustic performance can be obtained using wood, whilst keeping the mass of the structure down. The trade-off using wood is that the overall building structure may be more complex and buildings elements may need to be thicker.

The structure of wood also gives wood-based materials a greater acoustic damping characteristic than many other materials. Greater acoustic damping stops sound waves travelling very far in a building structure. This means that we are generally only concerned about sound transmission paths from one room to adjacent rooms, and do not generally need to consider sound transmission across the whole building structure.

Determining Sound Insulation

The sound insulation of a building element is its ability to reduce sound transmission. Sound insulation can be predicted, measured and given a numerical rating.

Predicting sound insulation

Sound transmission is a complicated process which is dependent on numerous factors, some of which can be difficult to determine. As a result, it can be difficult to model and predict the sound insulation of building elements, particularly for more complicated structures such as timber framing. However, there are tools available to experts which enable prediction of sound insulation properties in certain cases, particularly airborne transmission of direct sound.

Sound insulation measurement

The measurement of sound insulation consists of:

- generating a reference test sound (pink noise for airborne sound or a tapping machine for impact sound on floors) in one room (the source room).
- measuring the sound in the neighbouring room (the receiving room).
- correcting the measurements by deducting any disturbing background noise, and any room effects (e.g. the size of the partition, the volume of the room and the presence of soft furnishings).

The sound insulation performance of a building element is then determined for a range of frequencies.

Tests can be performed in controlled conditions in laboratories or in a building. The non-destructive nature of the tests makes them suitable for final verification of sound insulation performance. In a typical building the sound transmission will include sound transmitted through flanking paths. In a laboratory these paths are suppressed to enable a more accurate measurement of partition performance.

The measurements are performed in accordance with standards specified by standards authorities such as International Standards Organisation (ISO) and ASTM International (formerly the American Society for Testing and Materials). The New Zealand Building Code specifies standards ASTM E90 (laboratory) and ASTM E336 (building) to measure airborne sound insulation, and ASTM E492 (laboratory) and ISO 140: Part VII (building) to measure impact sound insulation.

Sound insulation descriptors

Sound insulation descriptors are also specified by standards authorities and are a key component of sound insulation regulations. These values give a quick tool to assess and compare sound insulation but must be used with care since they combine information across the full frequency range into one or two numbers.

New Zealand, US and Canada use the ASTM E413 descriptors "Sound Transmission Class" (STC) rating for airborne sound insulation and ASTM E989 "Impact Insulation Class" (IIC) rating for impact sound insulation, whereas Australia, European and most other counties use various different ISO 717 descriptors such as R_w, $D_{n,Tw}$, L_w along with supplementary numbers (spectrum adaptation terms C and Ctr) which describe low-frequency performance.

Descriptor values are either measured using standardised acoustic tests, or estimated through prediction modelling either using experience, calculations or software tools.

Airborne sound insulation

The Sound Transmission Class (STC) is determined by measuring the sound insulation of the contiguous sixteen third-octave frequency bands between 125 Hz and 4000 Hz and comparing them to a reference curve. In this way, the STC value may be thought of as a kind of average value of the sound insulation in decibels.

As an example, Figure 2 shows the individual third-octave sound insulation (sound reduction index) values of an STC 62 double-stud timber-frame wall. The STC reference curve is also shown, from which the STC value is determined.

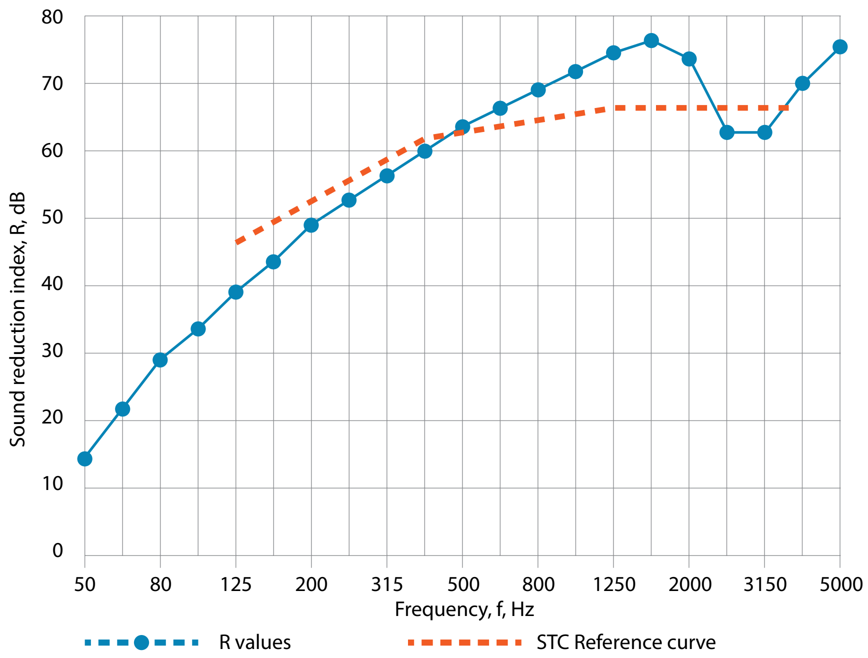


Figure 3. The third-octave sound insulation values of a double-stud wall with STC 62.

The ISO equivalent of STC is R_w. They are almost identical, but one difference is that a slightly lower frequency range is considered: the third octave bands from 100Hz to 3150Hz are compared to the reference curve. Because of this R_w and STC ratings are often (but not always) identical for a given building element.

STC and R_w descriptors were developed some time ago with speech transmission in mind – they may be good indicators of performance if this is the kind of sound you wish to control. If you are trying to control other types of sound, they may not be so relevant. For example, noise generated by sound systems may contain a lot of low-frequency sound which may not be very well controlled by a wall with a high STC.

Impact sound insulation

The Impact Insulation Class (IIC) is determined by measuring the sound insulation of the contiguous sixteen 1/3 octave frequency bands between 125 Hz and 4000 Hz when using a standardised impact source, and comparing them to a reference curve. In this way, the IIC value may be thought of as a kind of average value of the impact sound insulation.

The Impact Insulation Class (IIC) of a floor construction increases with increasing impact sound insulation performance, i.e. a greater IIC means greater insulation. Conversely, the ISO standard single number descriptor for impact insulation, $L_{n,w}$, is a measure of the impact sound level experienced in the adjoining room, and so a greater value means worse impact insulation.

IIC (and $L_{n,w}$) were developed to focus on higher frequency impact sounds such as those made by hard shoes on floors. Insulation of these hard, sharp impacts are effectively addressed by increasing IIC (or reducing $L_{n,w}$). Unfortunately, IIC and $L_{n,w}$ do not adequately rate such low-frequency impact sounds, which can be an important end-user issue for lightweight floor systems. In some countries special measurements are employed to measure and rate the low-frequency impact insulation of floors but these have not been adopted in New Zealand.

STC ratings are often expressed as STC followed by the numerical rating. For example, an STC rating of 55 (dB) is written as STC 55. Similarly, for IIC; an IIC rating of 60 (dB) would be written as IIC 60.

Code Requirements

Building code requirements

The core regulation relating to sound insulation for attached dwellings is Clause G6 "airborne and impact sound" of the NZ Building Code (found as Schedule 1 of the Building Act 1992 [Ref 16]). Clause G6 is repeated in Figure 3. This sets the relevant performance standards for new building work under the Building Act 2004.

Clause G6—Airborne and impact sound

Provisions

Objective

G6.1

The objective of this provision is to safeguard people from illness or loss of *amenity* as a result of undue noise being transmitted between abutting occupancies.

Functional requirement

G6.2

Building elements which are common between occupancies, shall be constructed to prevent undue noise transmission from other occupancies or common spaces, to the *habitable spaces* of *household units.*

Performance

G6.3.1

The *Sound Transmission Class* of walls, floors and ceilings, shall be no less than 55.

G6.3.2

The *Impact Insulation Class* of floors shall be no less than 55.

Figure 4. NZ Building Code Clause G6

The Clause is also supported by the associated compliance document "Compliance Document for New Zealand Building Code Clause G6 Airborne and Impact Sound" also available through MBIE's Building Performance website and last minorly amended in 1995. This document clarifies the following terms:

Amenity An attribute of a *building* which contributes to the health, physical independence, and wellbeing of the building's users but which is not associated with disease or a specific illness.

Building element is defined as "Any structural and non-structural component or assembly incorporated into or associated with a building. Included are fixtures, services, drains, permanent mechanical installations for access [e.g. lifts], glazing, partitions, ceilings and temporary supports"

Habitable space is defined as "A space used for activities normally associated with domestic living, but excludes any bathroom, laundry, water-closet, pantry, walk-in wardrobe, corridor, hallway, lobby, clothes-drying room, or other space of a specialised nature occupied neither frequently nor for extended periods."

Household unit is defined as "any building or group of buildings or part of any building or group of buildings, used or intended to be used solely or principally for residential purposes and occupied or intended to be occupied exclusively as the home or residence of not more than one household; but does not include a hostel or boarding-house or other specialised accommodation."

The Clause G6 Compliance Document includes verification methods for clauses G6.3.1 and G6.3.2 (Figure 4).

Verification Method G6/VM1

1.0 Airborne Sound Insulation Field Tests

1.0.1 The performance for airborne sound insulation may 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 5dB of the performance requirement.

2.0 Impact Sound Insulation Field Tests
2.0.1 The performance for impact sound insulation may be verified using the procedures detailed in ISO 140: Part VII, and the field impact insulation class may be verified using the method described in ASTM E 989. Field test results shall be within 5dB of the performance requirement.

Figure 5. Clause G6 Verification Method

G6 utilises the ASTM sound insulation descriptors. Specifically, the ASTM E413 "Sound Transmission Class" (STC) rating for airborne sound insulation and the ASTM E989 "Impact Insulation Class" (IIC) rating for impact sound insulation. When tests are performed on a building element in the field, that is in a completed building, STC and IIC are referred to as Field STC and Field IIC, or simply FSTC and FIIC.

The specific versions of the standards referenced in G6 are ASTM E:336:1990, ASTM E 413:1987, ASTM E492:1990, ASTM E989:1989, ISO 140/VII: 1978 . All these standards have had updates since the 1992 G6 Clause and 1995 compliance document were written.

Current building code interpretation

Since the release of G6 and its compliance document various 'determinations' from the Ministry of Business, Innovation and Employment have confirmed interpretation of some aspects of the code, in terms of what areas are included or excluded. In addition, different local authorities may have their own accepted interpretations of G6.

In basic terms, G6 and its subsequent interpretations by national and local authorities require that:

* Common walls and common floor/ceiling assemblies between any room of an occupancy and habitable spaces of a separate household unit must achieve a laboratory or predicted airborne sound insulation STC of at least 55, and must have an in-situ measured, apparent (formerly 'field') airborne sound insulation FSTC of at least 50. The apparent airborne sound insulation includes all flanking paths.
* Common floor/ceiling assemblies between any room of an occupancy and a habitable space of a vertically separate household unit must achieve a laboratory or predicted impact sound insulation IIC of at least 55, and must have an in-situ measured, apparent impact sound insulation FIIC of at least 50. The apparent impact sound insulation includes all flanking paths.
* Multi-unit dwellings which have no shared habitable spaces, regardless of unit title arrangement, are required to comply with the Building Code Clause G6 (e.g. self-contained apartments in retirement complexes, but not hostels with shared habitable spaces) [MBIE Determination 2012/070, 2015/04]
* Apartment entrance doors are not required to comply with the Building Code Clause G6 [MBIE Determination 2015/04]
* Horizontally transmitted impact sound insulation and diagonally vertical transmitted impact sound insulation across an inter-tenancy wall are not required to be measured to comply with the Building Code Clause G6 [MBIE Determination 2015/07]
* Diagonally vertical airborne and impact sound insulation measurements (FSTC and FIIC) from one apartment directly to another from a bathroom to a living room or a deck to a bedroom are required to comply with the Building Code Clause G6.

There may be some differing interpretations by some local authorities (e.g. some may not require a field measurement), but the above requirements represent the most likely interpretations a designer will find in New Zealand. A designer should check with the appropriate local authority to confirm their exact G6 interpretation and requirements.

Exterior noise control requirements

Controlling the intrusion of noise into dwellings fulfils two key roles: firstly the control of external noise provides a minimum standard of acoustic quality for the occupants; secondly, controlling external noise intrusion reduces the risk that new occupants will be adversely affected, thus reducing the potential for such occupants to attempt to control existing noise generating activities in the area. It is often the second function known as "reverse sensitivity" that is the primary driver for the current external noise control requirements in New Zealand.

The Resource Management Act 1991(RMA) is used today as the basis for current environmental noise controls in NZ. These controls are primarily enacted through district plans and resource consents. These set appropriate zoning and noise limits, and requirements to avoid, remedy or mitigate the adverse effects of noise based on local conditions. These may therefore set requirements for building siting, exterior acoustic screening, building services locations, and building façade performance, primarily in noisier residential locations.

The degree of external sound insulation required is determined primarily by the location of the dwelling and its proximity to noise generating activities, rather than any specific features of the dwelling itself. Because the requirements are location specific, they have been developed and enforced through District Plans and Resource Consent conditions rather than in the Building Code.

Enforcement of sound insulation performance through the standard building inspection process can be problematic as the consent process is designed to achieve compliance with the limited provisions of the Building Code and not additional requirements contained, for example, in the relevant district plan.

District plan noise control examples

New Zealand district plans do not consistently deal with exterior noise intrusion into a building. They either specify an acceptable sound level within a building and the expected exterior sound levels, or they specify the sound insulating performance of the building envelope.

Specifying the acceptable internal sound level is achieved using a variety of different environmental noise descriptors (i.e. L_{Aeq}, L_{A10} , L_{dn}, NCB and L_{max}).

The performance of the façade is also specified as either a simple level difference in decibels (dB) or as a more specific and internationally standard performance requirement such as $D_{tr,2m,nTw}$.

As an example of a level based control scheme, the **Auckland Unitary Plan** rule E25.6.10 requires that "noise sensitive spaces" in business zones must be designed and/or insulated so that the internal noise levels at night do not exceed" 35dB L_{Aeq}, 45dB at 63 Hz L_{eq} and 40dB at 125 Hz L_{eq} "based on the maximum level of noise permitted by the zone or precinct standards or any adjacent zone or precinct standards".

Determining the sound insulation performance of the exterior envelope of a building for a level-based control scheme therefore requires that the difference between maximum level of noise permitted in a zone and the required internal noise levels be calculated.

The Auckland Unitary Plan does not include consideration of traffic, or other unregulated noise sources.

The **Wellington and Christchurch District Plans** rules for dwellings in the central city, both use a façade performance specification rather than specified internal and external levels. For example, for dwellings within the Courtney Place Area of the Wellington District Plan Central Area, rule 13.6.1.2.1 states: "*any habitable room in a building used by a noise sensitive activity ... shall be protected from noise arising from outside the building by ensuring the external sound insulation level achieves...* $D_{nT,w} + C_{tr} > 35$ *dB*". This approach is potentially less tailored to specific situations but effectively covers all potential sources.

In addition to noise from general industry, sound insulation requirements are provided by key noise generators including road and rail, ports and airports. Area-specific requirements are incorporated into District Plans.

Designing for Sound Insulation

Sound insulation is not just about adding more 'batts' or using 'sound-rated linings', but is a property of all the individual parts of the building element, how the parts of the building element are connected to each other, and how the whole building element is connected to other building elements.

Recommended design procedure

The sound insulation performance achievable depends on the layout and structure of the building with suitable details for building elements and junctions. It is therefore imperative that acoustic considerations, along with structural, seismic and fire safety requirements, are included from the earliest stages of building projects. For instance, if it is determined later in a project that an inter-tenancy wall or floor needs a greater depth to meet sound insulation requirements, the knock-on effect is significant to the whole project.

The following steps are recommended for good acoustic design:

1. Determine legal minimum requirements (NZ Building Code, Resource Management Act and District Plans)
2. Decide the levels of acoustic comfort required by the customer (These may exceed the legal minimum);
3. Identify noise sources, loudness and direction, including external, plant rooms, services, etc.
4. Work with other design disciplines through the project's design phase to ensure designs will meet the acoustic criteria as closely as possible, while also meeting other building constraints such as structural, fire protection, ventilation (including for air quality and thermal comfort), energy efficiency, water tightness, economic and aesthetic.
5. Implement quality assurance and compliance plans. This includes expert inspection of construction and certification that the final design and build meets intended design requirements. Post-construction, pre-occupancy acoustic testing is also likely to be needed to ensure compliance.

Predicting insulation performance for a building design is not always straight forward, and sourcing professional acoustic advice is advisable to confirm that all aspects have been considered and to check design details.

Construction errors can also have a large effect on the final building performance, so it is generally prudent to design to a slightly higher level than required to provide some tolerance.

When multi-unit construction is being planned it is prudent to recommend a staged test programme to ensure that a completed construction will comply with requirements. This can be achieved by selecting a few units to be finished early with the required acoustic treatments and finishing surfaces (e.g. full sealing and final floor surfaces). Such a testing scheme is particularly important if there are any doubts about products or designs used.

When acoustic testing indicates an assembly has not met the minimum field requirements, mitigation is needed prior to sign-off from the acoustical engineer. While it is often simple to identify the root cause of the acoustical deficiency, it can be challenging to develop a mitigation solution that is cost-effective, simple to implement, and provides the required level of acoustical performance. Mitigation is almost always costlier than the cost of obtaining good design advice in the first place and undertaking relevant monitoring of the construction.

Building and Room Layout

It is important to check that the room layout is beneficial to sound insulation. Bathrooms, laundries and kitchens create extra sound compared to living rooms and bedrooms. For example, water movement through pipes and the vibration from washing machines and dishwashers can create sound problems. It is therefore a good idea for the rooms in one dwelling to back onto the same type of rooms in an adjoining dwelling. Try to make sure that bathrooms, laundries and kitchens do not back onto bedrooms or living rooms in a different dwelling. Also, try to ensure service ducts are away from bedrooms and entrances to dwellings are an appropriate distance from adjacent units (Figure 5).

It is also advisable that the apartment layouts are replicated vertically. This ensures the same room types sit above each other. For example, ensure that bedrooms are directly above bedrooms, and bathrooms are above bathrooms. This also ensures two tenancies don't share the same suspended floor joist span between walls or beams, possibly leading to expensive acoustic detailing.

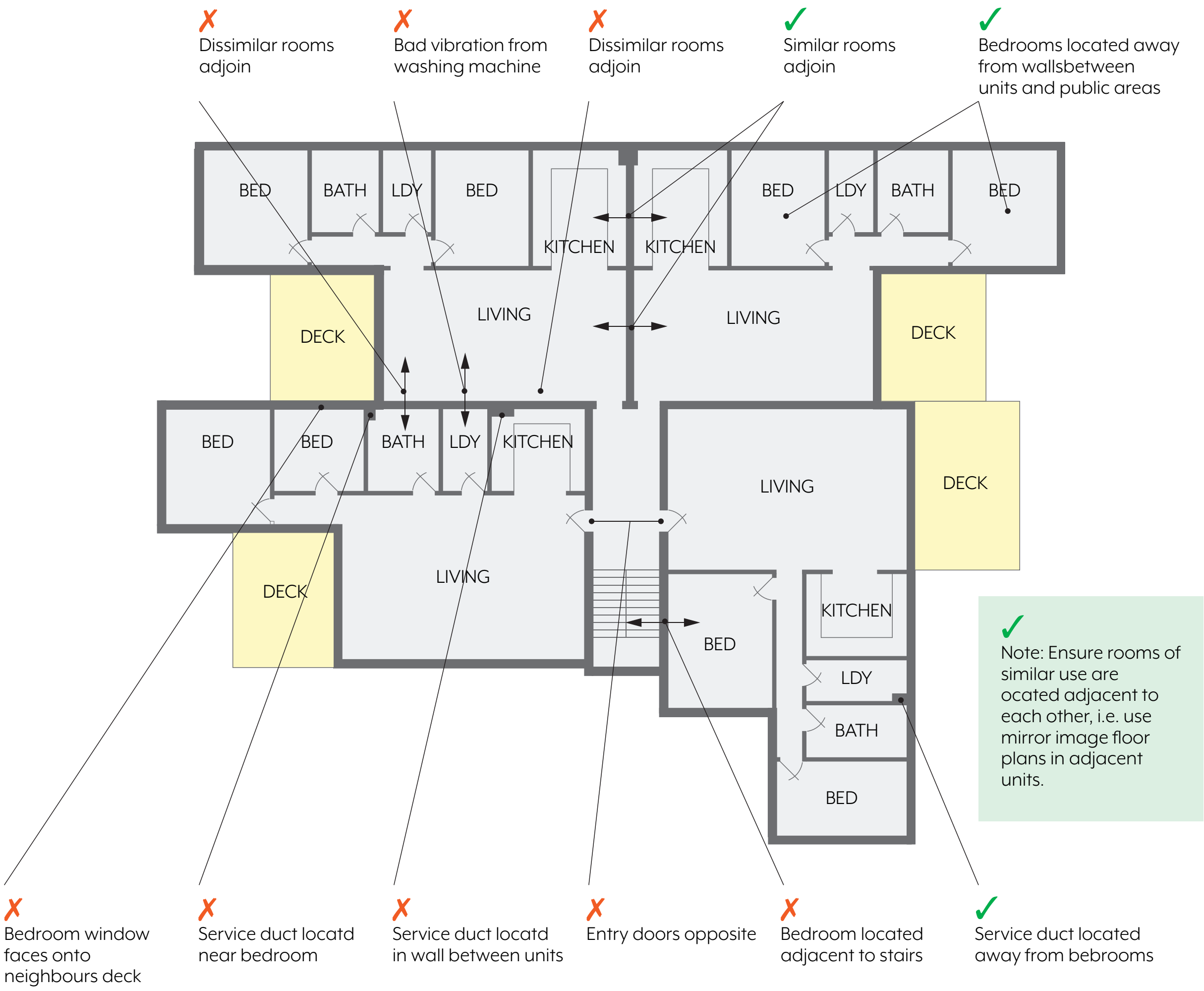


Figure 6. An apartment design illustrating good and bad layout choices.

Wall airborne sound insulation

The sound insulation achieved in a wall can depend on the dimensions and physical properties of the framing or slab, facing types, cavity, insulation and sound absorbing material, fixings, penetrations, air gaps, sealants, as well as the distances between components and connection to other elements (floors, ceilings). Resonance effects can also occur, both within air cavities and in solid components, significantly increasing vibration transmission at certain frequencies.

The main methods for increasing sound insulation include:

- Sealing air gaps: to remove direct air paths through or around a building element. For example, using flexible sealants where wallboards and floor/ceiling meet and sealing around penetrations for things like pipes and power outlets.
- Increasing mass: it takes more energy to vibrate more mass. For example, two layers of plasterboard have a higher sound insulation performance than one layer.
- Adding absorption: adding fibrous material, such as fiberglass or polyester blankets, in cavities reduces sound build-up and dampens low frequency resonances.

- Incorporating isolation and de-coupling: physically separating solid components from one another, to minimize the conduction of vibrations e.g. double stud walls and floating floor systems.
- Reducing resonance effects: different components of a system have natural resonances (e.g. a stiff wall board will have certain frequencies where its resonates and transfers sound well). Combining different components with mismatched properties, for example plasterboards of different thicknesses can help improve performance.

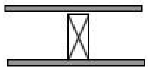
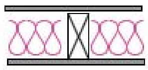
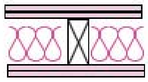
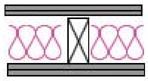
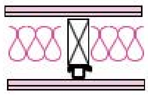
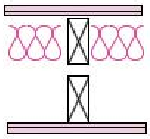
Description	**Diagram**	**Estimated STC lab rating**	**Comment**
– 10mm standard plasterboard – 90mm stud – 10mm standard plasterboard		STC 33	Comon internal wall
– 10mm standard plasterboard – 90mm stud with 75mm fiberglass insulation – 10mm standard plasterboard		STC 36	Insulated internal wall
– 2x13mm fire-rated plasterboard – 90mm stud with 75mm fiberglass insulation – 2x13mm fire-rated plasterboard		STC 49	Superior internal wall
– 2x13mm acoustic plasterboard – 90mm stud with 75mm fiberglass insulation – 2x13mm acoustic plasterboard		STC 50	Acoustic plasterboard is denser then standard and fire-rated plasterboard
– 2x13mm fire-rated plasterboard – 90mm stud with 75mm fiberglass insulation – Furring channels with resilient acoustic connectors – 2x13mm fire-rated plasterboard		STC 61	The addition of resilient clips makes the wall suitable for intertenancy use
– 2x13mm fire-rated plasterboard – 90mm double stud with 20mm gap – 75mm fiberglass insulation – 2x13mm fire-rated plasterboard		STC 64	Isolating each side of the wall by using separate frames improves performance if edges are also separated

Table 2. Estimated airborne sound insulation performance progression of timber frame walls isolated from surrounding structures (no flanking sound).

Floor impact sound insulation

The principals of airborne sound insulation for walls also apply to floors. However, often the main challenge in floor design is to achieve effective impact sound insulation.

One of the most practical methods to increase the impact sound insulation of a floor is to reduce the amount of impact sound energy that can get into the floor structure. This is achieved by reducing the effects of impact near the point of contact. In the case of a floor, the point of contact is on the upper surface, so isolating or softening that area is beneficial. For example, it is possible to isolate the walking surface of a floor from the main structure by inserting a resilient layer between the two. This is known as a floating floor and acts to reduce the sound transmission from the walking surface into the main floor structure.

Beyond reducing the amount of impact sound energy getting into the floor structure, one can apply the same principals as outlined for airborne sound insulation of floors. For example, a common way to increase both airborne and impact insulation performance of a floor is to isolate the ceiling from the main floor structure above by using resilient mounts.

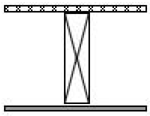
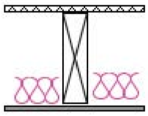
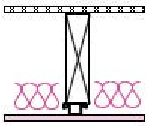
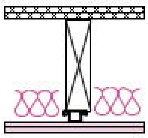
Description	Diagram	Estimated lab IIC rating	Comment
– 20mm particle board flooring – 250mm floor joist – 10mm standard particle board		IIC 28	Low quality lightweight flooring system often used in typical housing construction. Poor performance
– 20mm particle board flooring – 250mm floor joist – 90mm fiberglass insulation – 10mm standard particle board		IIC 40	Better performance for internal floors
– 20mm particle board flooring – 250mm floor joist with 90mm fiberglass insulation – furring channels with acoustic resilient clips – 13mm fire-rated plasterboard		IIC 50	Furring channel fixing through resilience connections offer significant improvement
– 2x20mm particle board flooring – 250mm floor joist with 150mm fiberglass insulation – furring channels with acoustic resilient clips – 2x13mm fire-rated plasterboard		IIC 58	Increased mass on both flooring surfaces and ceiling offers useful benifit

Table 3. Estimated impact sound insulation performance progression of bare surface timber frame floors isolated from wall structures (no flanking sound).

Low-frequency sound insulation

In an age of sound systems and more traffic noise, low-frequency sound insulation is becoming more of a concern. Unfortunately, it is more difficult to measure and describe low-frequency sound insulation performance. The STC and IIC sound insulation descriptors only measure sound down to 100Hz,whereas people can hear down to about 20Hz.

The lightweight nature of timber systems makes it more difficult to insulate low-frequency sounds. This is particularly true for the impact sound insulation of timber-based floors, where low-frequency booming or thumping noises produced by walking can be quite loud and annoying (even though the IIC performance of the floor meets the building code). Although good quality carpet and underlay significantly improve IIC performance, simply adding thick carpet does not improve the situation where low-frequency impact sounds are concerned. One way to deal with these low-frequency sounds is to increase the mass on the floor upper surface by adding concrete or some other heavy material. In many countries a concrete (gypsum or cement-based) screed (19 to 50mm thick) is added to the floor to reduce this low-frequency impact insulation problem. The screed is often poured over a resilient layer to create a floating floor to provide additional high-frequency impact sound insulation. In New Zealand seismic loading concerns may limit how much mass can be floated on a floor. In such cases a solution is to structurally connect the concrete slab to the subfloor to improve low-frequency sound insulation, and to float a less heavy raft on top to improve mid to high frequency sound insulation. Sometimes sheet materials are used to add mass on top of the floor to avoid a wet trade, for example flooring grade plasterboard is used in some countries. It is also possible to top the floor with a battened cavity filled with a sand or other granular mixture to increase the mass and absorb sound. Such sand/granular layers have been used successfully in Europe.

Flanking sound insulation

Consideration of total room sound insulation includes the effect of flanking sound transmission. Flanking sound is sound that propagates around the direct partitioning building element by some other path. An example of flanking sound is sound that is carried along an exterior wall which is common to two adjoining tenancies. Other examples of flanking are shown in Figure 6, Figure 7 and Figure 8. The effectiveness of any sound insulating building element is also dependent on addressing the flanking sound insulation.

Many local authorities require that STC and IIC (for floors) be measured on site, after construction (such 'field' measurements are given the designation FSTC and FIIC). Therefore, there is an expectation in the NZ Building Code that designers and builders will address flanking sound insulation in order to ensure that wall and floor elements perform well in the field.

The main approaches used for addressing flanking noise in timber-framed building are:

- Platform flooring breaks over double stud walls,
- Cavities within sound rated building elements blocked or sound travel paths damped,
- Isolating elements and layers, e.g. resilient mats or brackets.

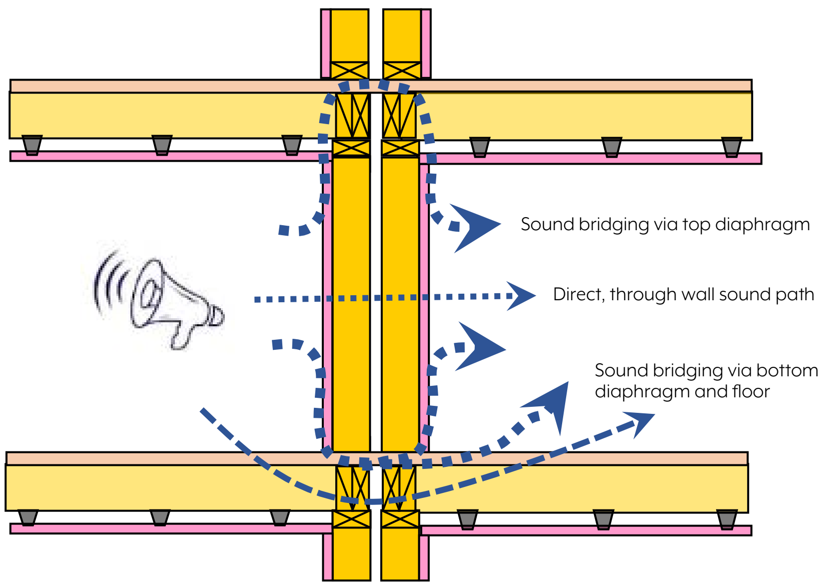


Figure 6. Horizontal flanking paths for airborne sound in double stud walls via continuous floor diaphragms.

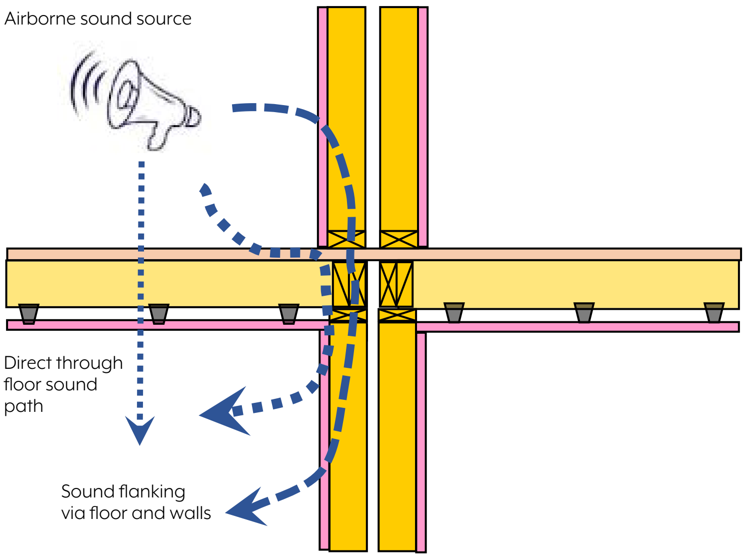


Figure 7. Vertical flanking paths for airborne sound.

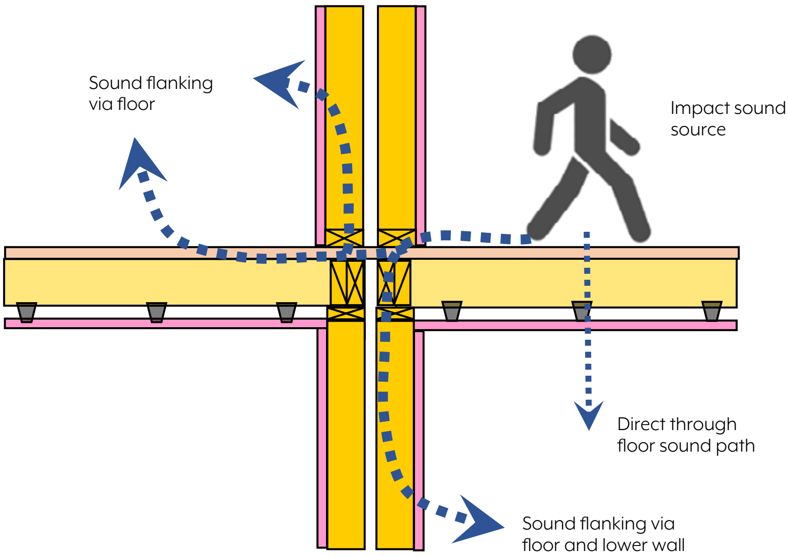
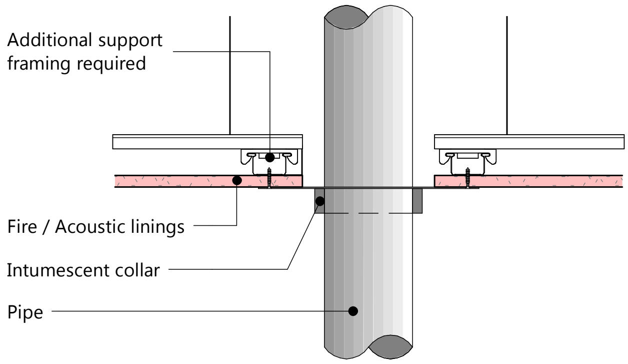


Figure 8. Flanking paths for impact sound in double stud walls via continuous floor diaphragms.

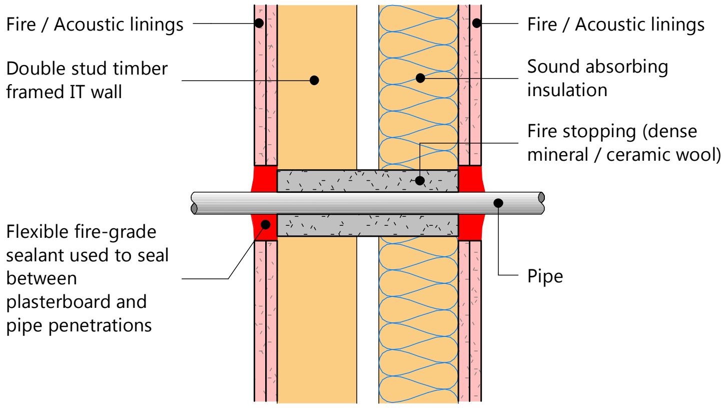
Services sound insulation

Internal building services have the potential to generate noise within an apartment. These include building services such as ventilation systems, lifts, hydraulics wastes and water supply systems, garbage chutes. Devices within apartments such as spa baths and appliances will also affect adjacent apartments. The location and detailing of services are some of the most important considerations in controlling sound transmission in residential buildings. Obtaining specialist advice is recommended for controlling the noise from services.

Generally, however, services and service penetrations should not be located on sound-insulated walls between separate dwellings but rather on internal walls or dedicated sound resistant service shafts. In all instances, service pipes should be located away from noise sensitive parts of the dwelling such as bedrooms.
If it is necessary for pipes to penetrate through intertenancy building element linings, then they need to be sealed off with fire and sound-rated sealant and mineral wool (Figure 9).



A. Generic example of pipe penetrating a ceiling



B. Generic example of pipe penetrating a wall

Figure 9. Examples of pipe penetrations through intertenancy walls and linings (from Australian Wood Solutions).

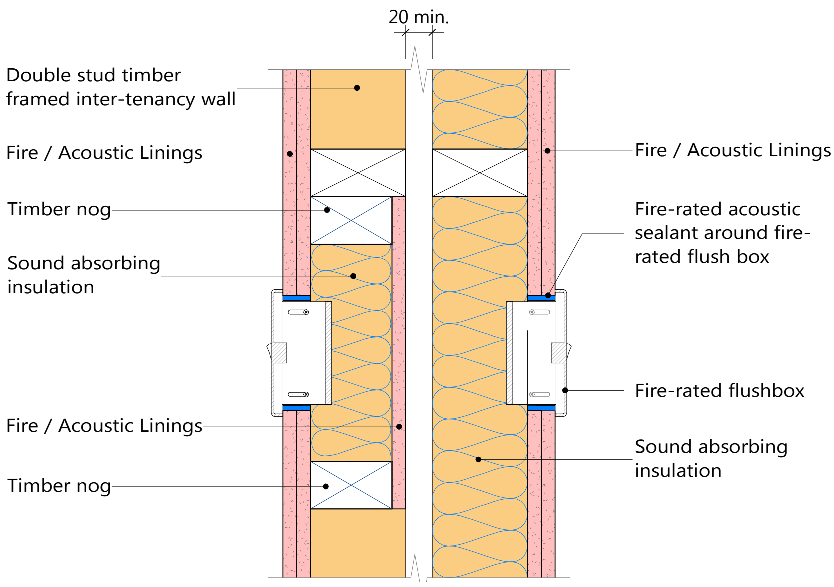


Figure 10. Examples of flush box penetrations through intertenancy walls and linings.

Exterior envelope sound insulation

New Zealand district plans either specify an acceptable sound level within a building or specify the sound insulating performance of the building envelope. If the expected maximum external noise levels and the acceptable internal noise levels are given (from district plans), then the required acoustics insulation performance of the building envelope will have to be calculated from these two values.

When determining the performance of a building façade to control the ingress of exterior noise, the contribution of the walls, roof, windows and other openings must all be considered. This is because exterior noise can come through all these elements to contribute to the sound level within a building.

As a result of this, the sound insulation performance of all the elements in a building envelope must be factored when considering suitable sound insulation performance. Nevertheless, walls, roofs, and windows can be designed and constructed to minimise the intrusion of unwanted external noise.

The designer should also be aware that the penetrations for building services in a system can compromise its acoustic performance and will require extra consideration.

Structural and seismic considerations

Design and detailing to achieve structural performance requirements will have an impact on acoustic detailing. This is particularly true in New Zealand which has specific requirements for seismic performance. As a result, designs will need to be considered in discussion with structural engineers. The designer will need to be acutely aware of this when transferring acoustic design solutions from other countries, or regions of New Zealand, which have lesser seismic performance requirements.

Acoustic requirements often require discontinuities and resilient connections to achieve excellent results. However, in New Zealand it is challenging and expensive to detail the structural bracing requirements for such acoustic discontinuity.

In multi-storey timber buildings, it is likely a continuous structural diaphragm will be required on the floor slab level in the form of either continuous plywood sheets or concrete slabs that are structurally connected to loadbearing bracing walls. It can be challenging to design effective acoustic insulation on a continuous structural diaphragm. Nevertheless, some example design details are presented in this guideline. Some of these issues can be avoided by designing for a vertically continuous layout, and by judicious use of load bearing walls at inter-tenancy boundary such that timber slabs and beams do not span over tenancies.

Another challenge is to consider the acoustic detailing with respect to the deformation of the timber structure over time via shrinkage and expansion and intermittent wind/seismic inter-storey movement. Non-loadbearing walls for example need to have deflection head detailing to accommodate vertical movement and inter-storey drift. The deflection head detailing and how the partitions are seismically braced will require additional consideration if acoustic separation through them is required. Similarly, the seismic restraint and movement allowance of the ceiling-partition interface will need to be detailed if an acoustic separation is required through the junction.

Expert advice

It is common for acoustic consultants to be engaged to provide expert advice during a largescale residential development project, but it is not compulsory. The involvement of an acoustic expert on the project provides greater certainty that the acoustic objectives would be achieved. For large projects the cost of an expert acoustic review is relatively small (often 0.1 % of construction costs) and this cost is soon regained by efficacies in the building design and by reduced risk of substandard construction.

It is expected that the acoustic aspects of the design and design advice will be supplemented with co-ordinated input from all relevant design aspects and the appropriate consultants. As such, the acoustic consultant will be part of an expert advisory team, which will include structural engineers, fire engineers, and the project architect. Failure to adopt a holistic approach often results in frequent design and on-site issues.

The services that could be provided by an acoustic consultant on a typical apartment project can include:

Design stage

- Determine acoustic design criteria in line with Building Code requirements and client expectations. Criteria would cover airborne and impact sound insulation for the apartments, as well as other considerations such as mechanical services. An initial site visit and ambient noise survey would be undertaken.
- Attend design concept meetings to ensure critical acoustic considerations are incorporated from the earliest stage in the project.
- Review developed architectural drawings and proposed surface finishes
- Identify areas of acoustic concern and address issues through Design Advice Notes to the architect
- Review detailed architectural drawings to ensure that acoustic requirements are incorporated
- Prepare acoustic design report summarising the acoustic requirements and assessing the construction design against the Part G6 of the Building Code. This report would be suitable for submittal as part of a Building Consent
- If required a Producer Statement PS1 (Design) would accompany the acoustic design report. Producer Statements are part of the compliance options for the NZ Building Code.

Construction stage

- During construction, the consultant is generally available to carry out site inspections to check progress and offer advice on detailing as required.
- Upon completion of construction, they would also be available to measure the performance of inter-tenancy walls and floors, and external noise reduction to ensure compliance with agreed standards and consent requirements and issue a Producer Statement PS4 (Construction review) if required.

Examples of Timber Designs

In this part of the design guide we present design details for commonly used systems to achieve acoustic insulation results which meet the building code requirements. We do not explicitly consider exterior envelope noise control solutions. The focus of this section is on residential applications. Commercial applications may require different details due to the larger spaces and spans required.

For the most part conceptual design descriptions and illustrations will be presented. These descriptions and illustrations are purposefully devoid of any reference to any proprietary systems or products. The reader is referred to the reference section at the end of the design guide for links to products and systems.

The timber design examples are split into two types of timber construction: timber frame and CLT (massive timber). For each type of timber construction, examples of the acoustic design of building elements and junctions commonly found in apartments (Figure 11) and terraced houses (Figure 12) are presented. It is assumed that all intertenancy building elements are load bearing.

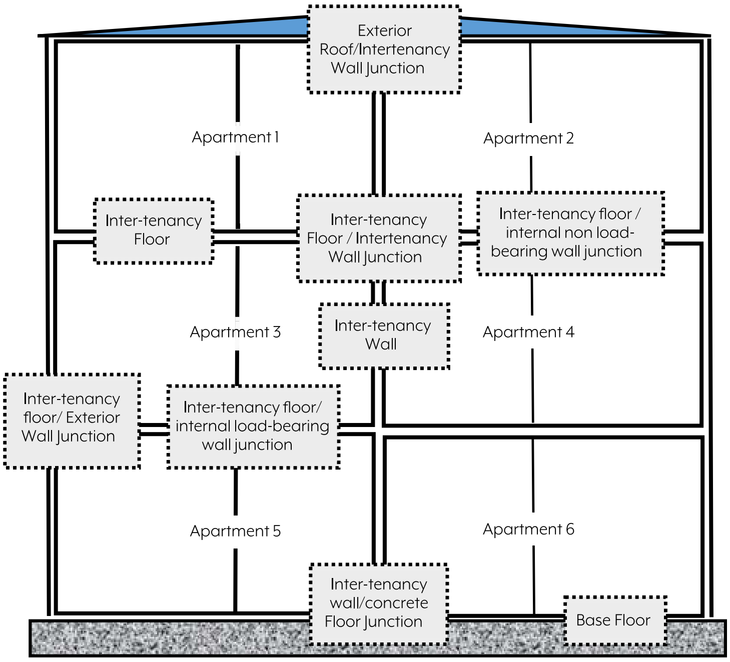


Figure 11. Conceptual drawing of multistorey apartments showing elements and junctions requiring acoustic consideration to achieve building code compliance.

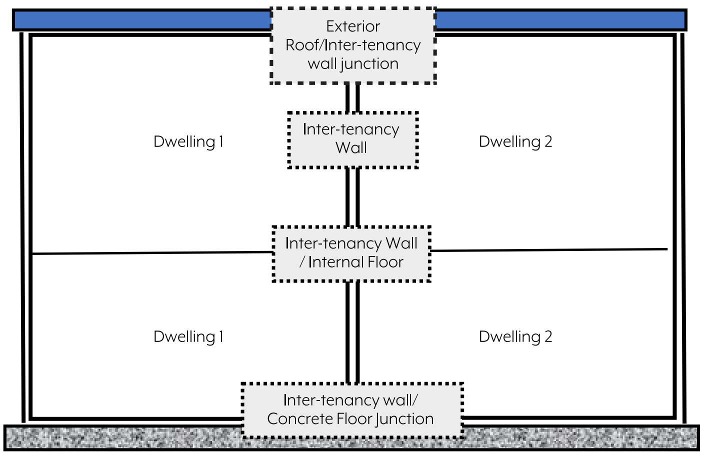


Figure 12. Conceptual drawing of terraced housing showing elements and junctions requiring acoustic consideration to achieve G6 compliance.

Timber frame construction

Timber frame construction is the most commonly used timber construction system in New Zealand and can be used to create multi-residential buildings up to 4 or more stories high. This lightweight construction method can be fabricated on site or prefabricated off site.

Intertenancy wall designs

The cavity structure of timber frame systems can give good acoustic results provided the linings on each side of the wall are not rigidly connected to each other. Fixing the linings on each side of the wall to a separate frame using a double-stud construction is one way to achieve this separation if the perimeter of the wall is also disconnected. Another method is to use a single-stud framing system and to mount the lining of one side of the wall to the frame using a resilient connection system. In both cases sound absorbing infill is required. Greater cavity depths and more massive linings will improve performance. Wall perimeter and junction details are important, since incorrect detailing will degrade acoustic insulation performance of the wall and will result in flanking sound paths.

Double-stud walls (> STC 58)

Sound insulation performance of fire-rated double stud walls generally range from STC 58 to STC 67, depending on linings, cavity depth and infill. Structural bridging at the perimeter (e.g. top and bottom plates) will degrade performance.

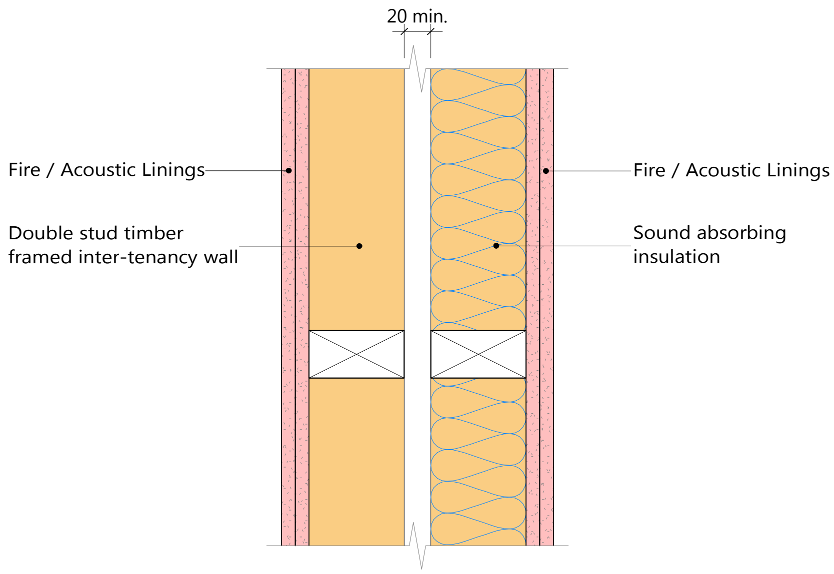


Figure 13. Double stud timber frame wall.

Single-stud walls with acoustic resilient mounts (> STC 55)

In some cases, a double stud will not be feasible, or the performance may be compromised due to perimeter detailing. In such situations a single-stud wall can be used with high-performance resilient connections and furring channels on one side of the wall. Reliable buildability is often more of an issue with such systems, and care must be taken to select sound isolation clips that are effective and easy to install.

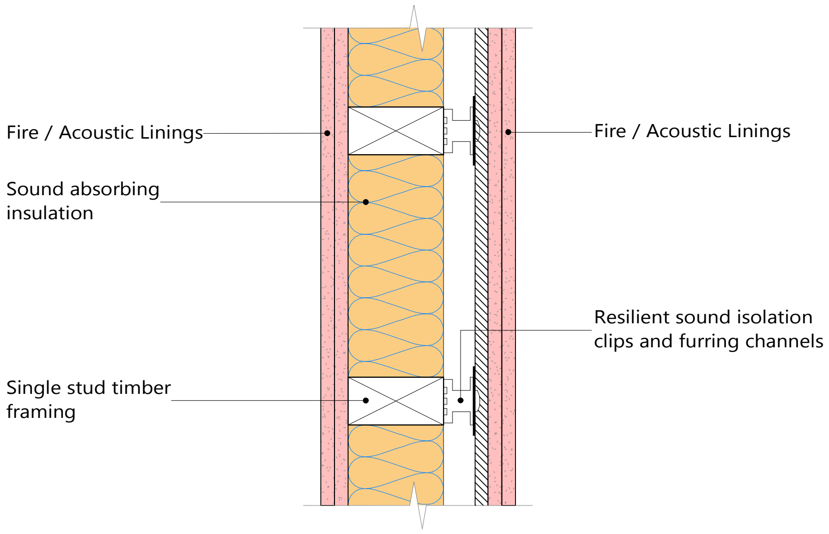


Figure 14. Single stud wall with resilient acoustic clips and furring channel.

Intertenancy barrier wall systems (> STC 60)

Barrier systems consist of a double stud timber frames with a central barrier between the frames (Figure 15). The primary fire resistance is provided by the central barrier, with some fire resistance provided by the wall linings. The wall linings are primarily used for structural bracing and acoustic insulation. The double cavity system and mass of the central barrier gives good acoustic performance. Insulation is inserted in both cavities allowing certain services to penetrate the wall linings.

Barrier systems are most often employed in terraced housing in the place of traditional double stud timber frame systems. There are several proprietary central barrier systems on the market in New Zealand ranging from thick reinforced plasterboard to lightweight concrete. The acoustic insulation performance of central barrier systems ranges from STC 60 to STC 69.

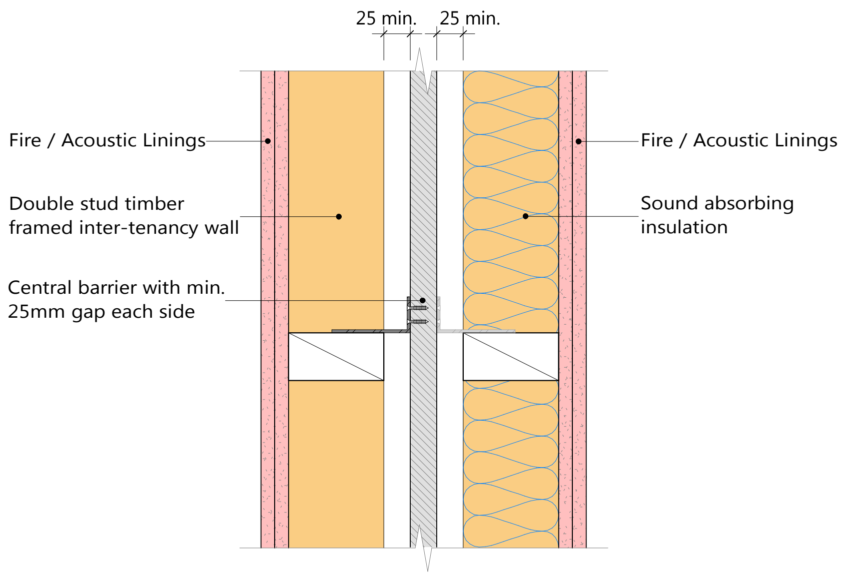


Figure 15. Conceptual central barrier wall system.

Intertenancy floor designs

Timber-framed intertenancy floors usually have good airborne sound insulation performance, even with the most basic floor system, using a resiliently attached fire-rated ceiling (Figure 16). This is a cavity system just like the walls. Therefore, increasing the cavity depth (joist depth), increasing the mass of the ceiling linings and flooring, and adding more infill will improve performance. The basic floor system shown has an airborne sound insulation performance of approximately STC 57 (for 2x13mm fire-rated plasterboard, 17mm plywood flooring, 190mm deep joists, and 75mm thick 10 kg/m3 glass wool infill, and rubber sound insulating clips).

The main challenge with timber frame floors is to ensure acceptable impact sound insulation performance, especially for low-frequency impact sounds (such as footsteps). The basic floor system shown has an impact sound insulation rating of about IIC 45 for the bare surface. The only sure way to achieve an IIC 55 or greater is use a soft floor covering such as carpet on a foam underlay. Soft floor coverings may not be acceptable for some areas of an apartment (e.g. kitchen floors), and will require the addition of a floor topping (or floating floor) system on top of the basic timber-framed floor to obtain a suitable impact sound insulation rating. Relying on soft floor coverings to achieve a required IIC may not be a robust solution since future occupiers will be prevented from replacing carpets with hard surface finishes.

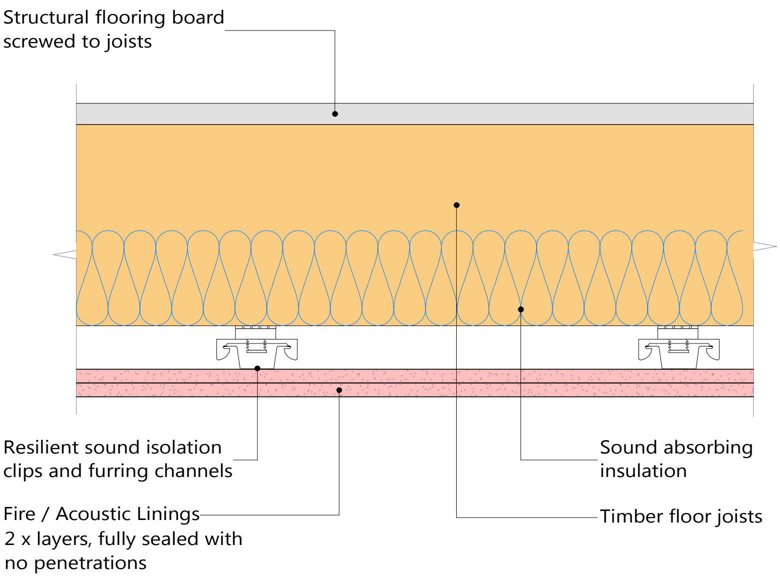


Figure 16. Basic timber-frame intertenancy floor.

Direct fix panel toppings

One of the simplest forms of topping systems available is to directly fix more panels to the existing structural board. The aim of these layers is to increase the mass and stiffness of the upper floor panel. These extra layers increase acoustic performance both for direct vertical sound transfer and for flanking sound of horizontal sound insulation.

For example, adding a layer of 20mm flooring grade particleboard (Figure 17) will likely result in laboratory impact insulation performance of IIC 50 or more. In-situ performance of this system could result in performance less than FIIC 50 since flanking sound effects will likely reduce the FIIC value.

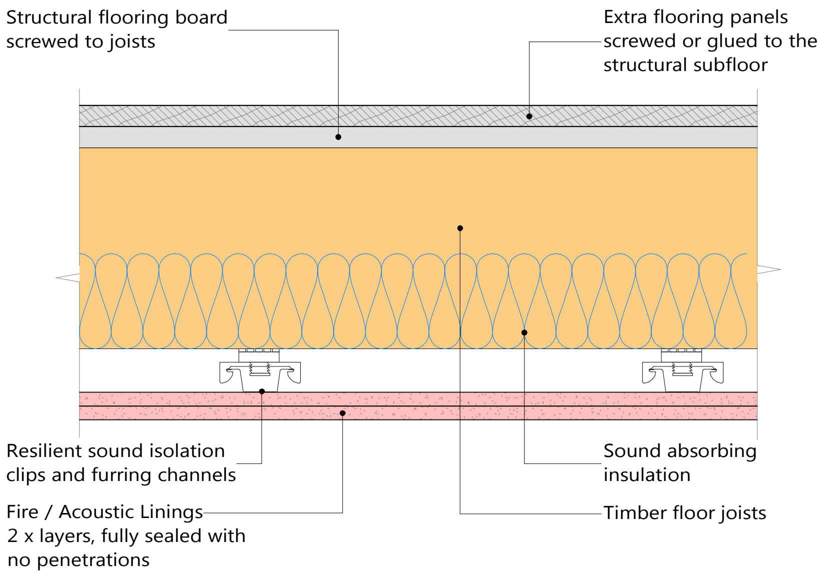


Figure 17. Topping of additional flooring panels fixed to subfloor. Heavier and more layers will improve performance.

Floating floor topping systems

Floating floor systems are a type of floor topping system which consist of a rigid, heavy flooring layer lying on top of soft, resilient layers or connectors. They are used to create floor systems that achieve good impact sound insulation performance, regardless of the surface finish of the floor. They also reduce flanking sound problems for horizontal airborne sound transfer, enabling the use of continuous floor diaphragms. Increasing the mass of the flooring surface upper layers and increasing the resilience of the connections to the floor underneath will result in better performance. The perimeter of the floating floor must be surrounded with a foam layer to prevent the floating floor upper surface from directly contacting the perimeter walls.

Lightweight floating floor systems often consist of battens sitting on resilient holders with a flooring surface fixed to the battens and sound absorbing fibre within the cavities (Figure 18). There are proprietary systems readily available in New Zealand and their performance is approximately IIC 56 or more for hard flooring finishes, depending on the system.

Lightweight floating floors can also be fabricated by fixing one or more layers of particleboard or fibre cement board together and laying them on a resilient foam or fibreglass board layer. Two layers of 20mm flooring particleboard on 13mm fibreglass board or 10mm closed-cell polyethylene foam sheet can achieve above IIC 55 for hard flooring finishes.

Thick concrete flags or screeds at least 35mm thick laid on resilient mats can be used to create a heavy-weight floating floor. This will improve the STC and IIC rating and reduce low-frequency impact and airborne sound transfer. Whilst popular in many countries, concrete screeds are not often used in New Zealand due the complications caused by introducing a wet trade. The use of a heavy screed floating on a lightweight subfloor can also cause structural and seismic issues as it may needed to be braced against seismic movement.

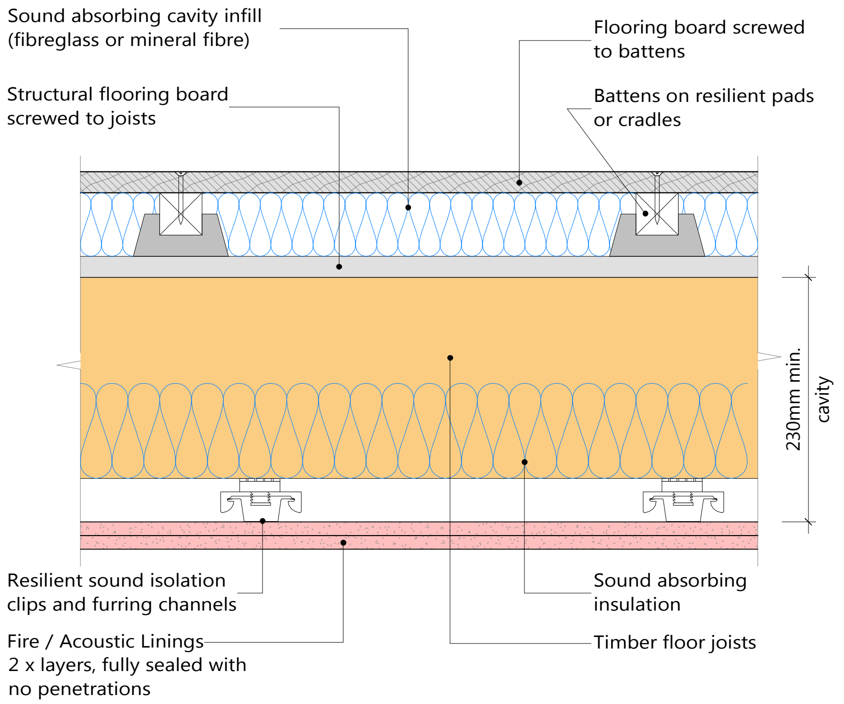


Figure 18. A generic lightweight floating floor system.

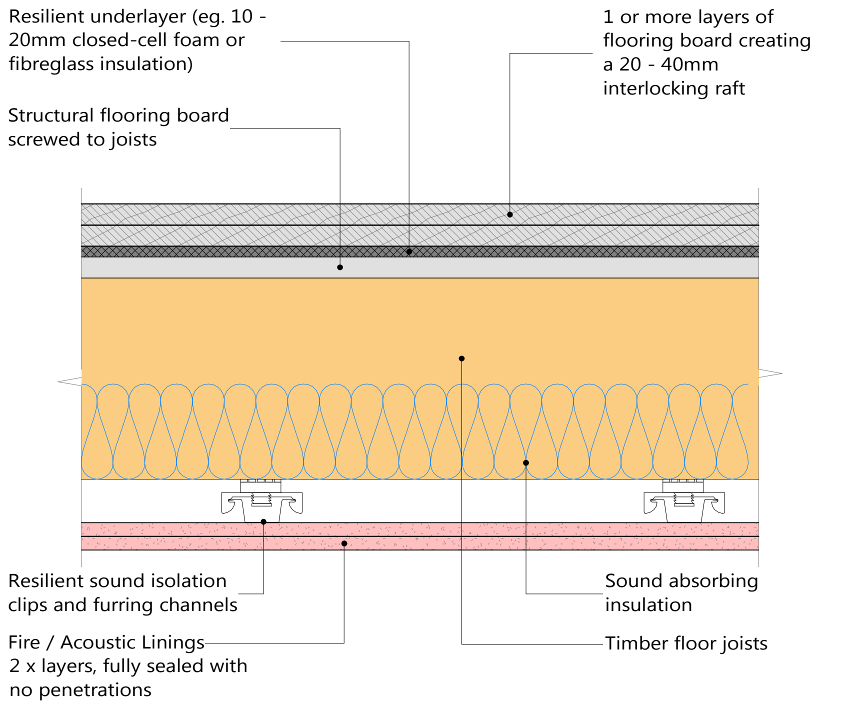


Figure 19. Floating floor made from flooring panels on thick resilient underlayment.

Vibration damping topping systems

Instead of using concrete screeds or resilient layers, the sound and vibration damping qualities of sand or other heavy granular materials can be employed in the floor upper surface layers. A system (Figure 20) using 45mm deep battens with the cavities filled with a 60% sand / 40% sawdust mix achieved sound insulation ratings of STC 66 and IIC 63 for a bare floor.

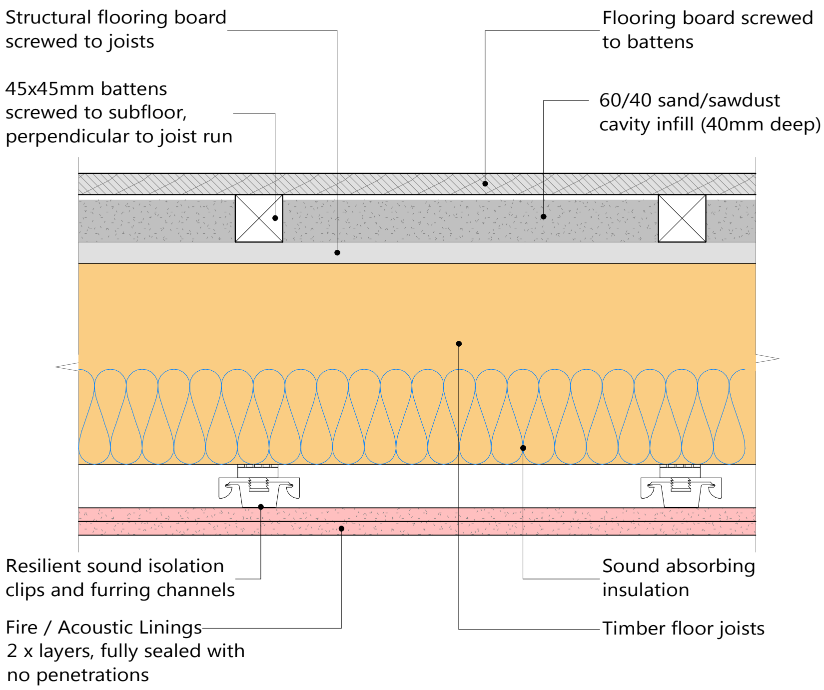


Figure 20. Vibration damping floor topping using sand and sawdust in a cavity.

Exterior wall designs

When a building is sited in a noisy environment the acoustic insulation of the exterior envelope becomes an important consideration and a minimum sound insulation rating may be a requirement to comply with local authority requirements. The same sound insulation principles found for intertenancy walls apply to exterior walls. Exterior walls will normally be single stud walls and so won't achieve as much sound insulation as intertenancy double stud walls. Performance will generally range from STC 38, for 6mm fibre cement board or sealed weather board claddings on battens, to STC 55 for brick veneer claddings. Increasing the thickness of linings and resiliently attached linings to the frame will improve performance.

Flanking sound can also be transmitted between apartments through exterior walls. Thicker and double layered linings may need to be used to reduce this flanking sound transmission.

Roofs, windows, doors and unenclosed floors will also contribute to the sound insulation of interior spaces from external noise sources. Their design will also need to be part of any building envelope external noise control solution.

Junction details

Designing and specifying good design for building elements to enable effective sound insulation performance is only half the challenge when designing effective room to room sound insulation. Suitable junction detailing is important to reduce flanking sound transmission through the junctions. Flanking sound transmission can reduce the effectiveness of a wall or floor resulting in poor overall sound insulation performance.

The junction details in this section are based on designs which use double-stud walls, as these high performing wall systems can be easily compromised with inappropriate junction detailing.

Intertenancy wall / intertenancy floor junction

Acoustically, it is most desirable to have a structural break in the floor diaphragm (Figure 21 and Figure 22). This minimises horizontal sound transmission by reducing flanking transmission and enables a double-stud wall to perform to its maximum capacity.

However, in many seismic zones in New Zealand it is difficult and expensive to structurally brace each apartment sufficiently to enable breaks in the floor diaphragm. In such cases a continuous floor diaphragm is desirable. Horizontal sound insulation will be compromised due to flanking sound traveling along the floors, and it will be necessary to add a floor topping to the intertenancy floors in order to achieve the required G6 field sound insulation. Even with a floating floor installed the airborne sound insulation performance of the double stud will still be compromised due to sound vibrations travelling through the floor diaphragm at the bottom and top of the double-stud wall. Thicker or denser (or more) plasterboard layers (i.e. at least two layers of at least 13mm thick fire-rated plasterboard) will be required to achieve the required performance.

When the floor joists run perpendicular to the wall, they may be spliced across the gap between the wall frames (with blocking between joists on both sides of the wall). This may increase flanking sound transmission via the floor and a better performing floor topping system may be required.

Some extra acoustic isolation for horizontal sound transfer (up to 3 STC points – depending on floor topping system and wall) can be obtained by cutting the diaphragm below the bottom plates on both sides of the wall (diaphragm will need to be fixed on each side of cut to joist blocking for structural connection).

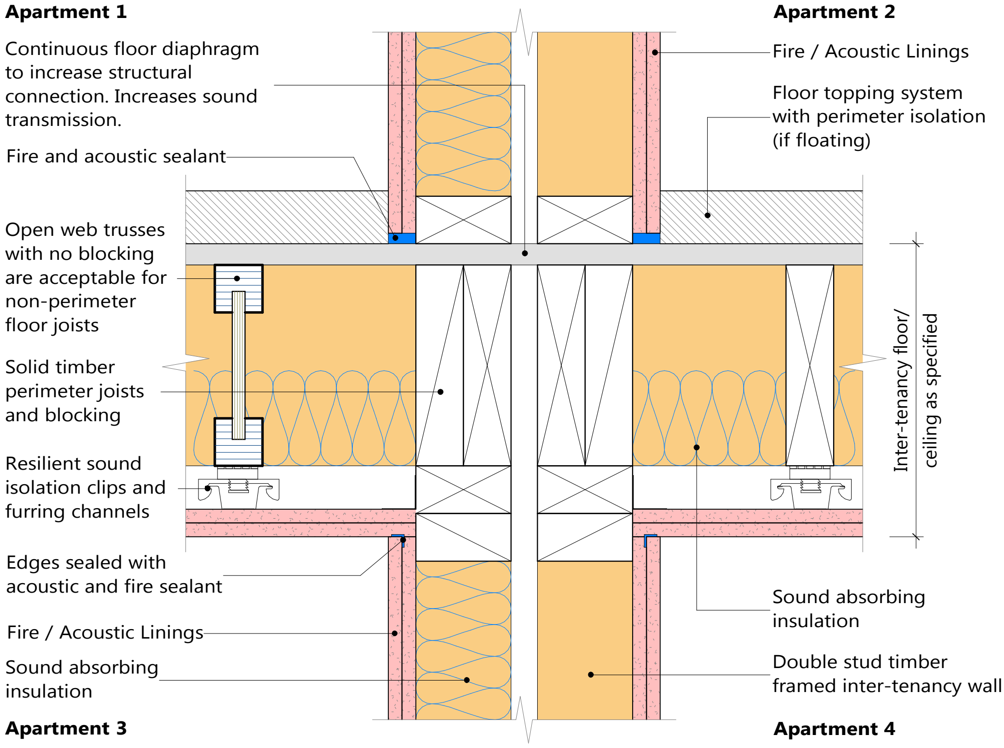


Figure 21. Floor junction detail with continuous diaphragm- joists parallel to inter-tenancy wall

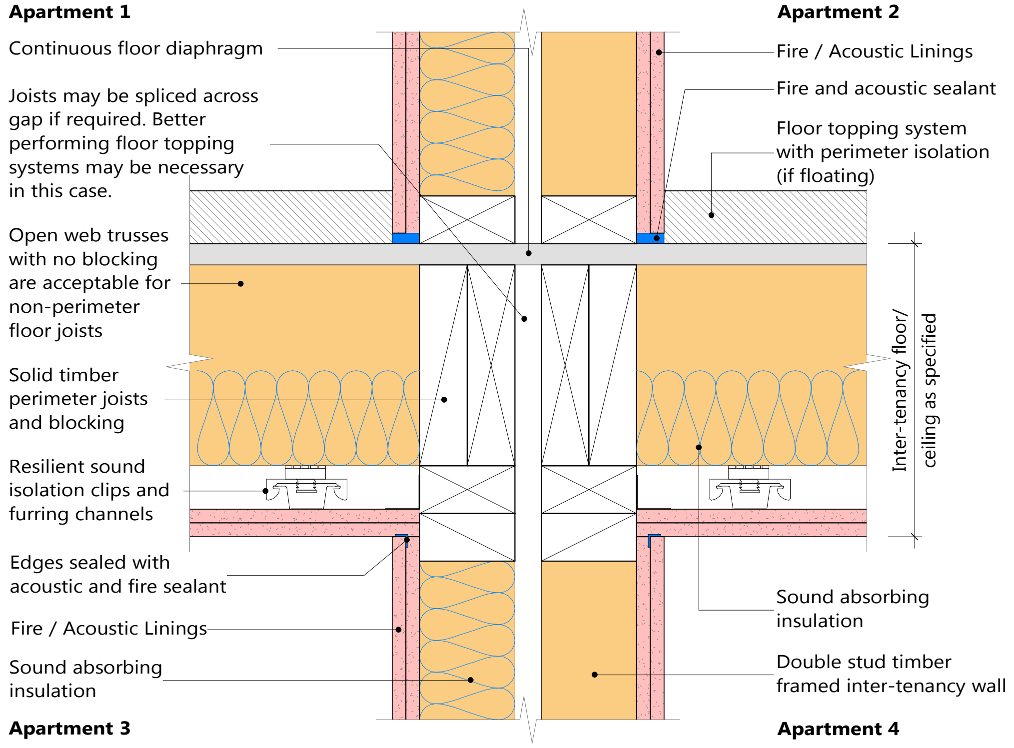


Figure 22. Floor junction detail with continuous diaphragm- joists perpendicular to inter-tenancy wall.

Table 4 shows results of some floor topping systems tested on an intertenancy horizontal cruciform with double stud walls, ceiling lining of 2x13mm fire rated plasterboard and bare floors [BRANZ report SR208]. A floor topping system is necessary to achieve the required horizontal sound insulation performance, and more substantial floor topping systems will achieve better impact insulation performance.

Table 4. Approximate in-situ performance of some example floor topping options.

Floor Topping (No covering)	Vertical FSTC	Vertical FIIC	Horizontal FSTC
No topping	52	43	45
20mm particleboard	57	48	54
2x20mm particleboard on 10mm foam	61	53	56
20mm particleboard on 45mm sand-filled cavity	62	58	57

Notes: Wall linings are 2x13mm fire-rated plasterboard. Results are from BRANZ report SR208.

Intertenancy wall / intertenancy wall (vertical T-junction)

Intertenancy wall junctions for double stud walls must have isolated studs at the junction to ensure there is minimal acoustic bridging across separate tenancies. Fire resistant components must also be flexible to ensure little acoustic transmission. Figure 23 shows an example of an intertenancy T-junction. Structural connection for structural and seismic purposes is achieved through continuous floor diaphragms and continuous bottom and top plates. Note that such structural connections will increase flanking transmission and a floor topping system will be required.

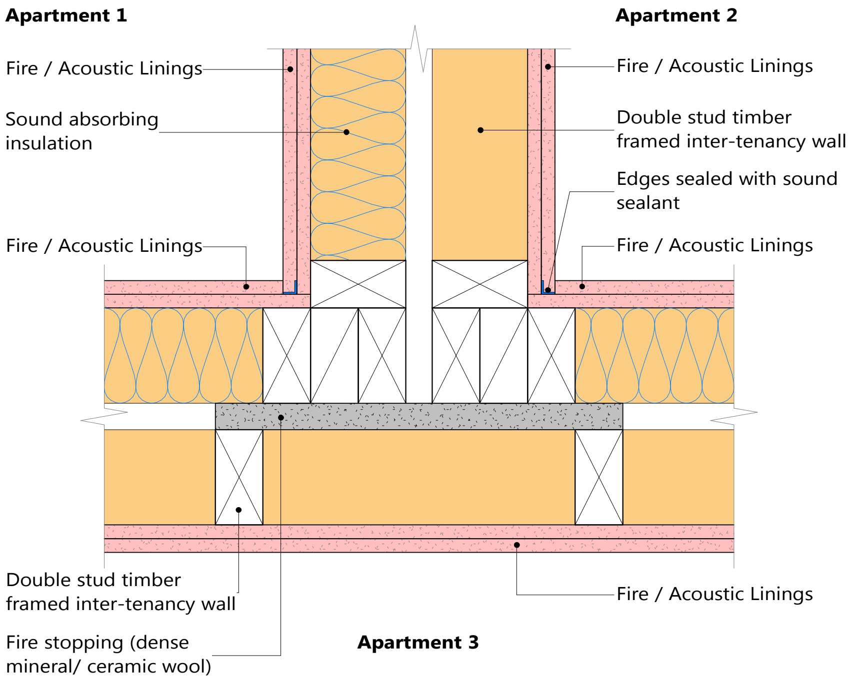


Figure 23. Apartment inter-tenancy T-junction to minimise acoustic flanking transmission (plan view).

Intertenancy wall / base floor (horizontal T junction)

An intertenancy double stud wall can be fixed to a concrete base floor (Figure 24). The flanking path through the floor may limit the sound insulation performance of the wall. A concrete thickness of at least 150mm is recommended to reduce the airborne flanking sound to acceptable levels. Although not necessarily required for current interpretations of G6 of the building code, resilient underlays are recommended for hard surfaces to reduce horizontal travel of impact sound.

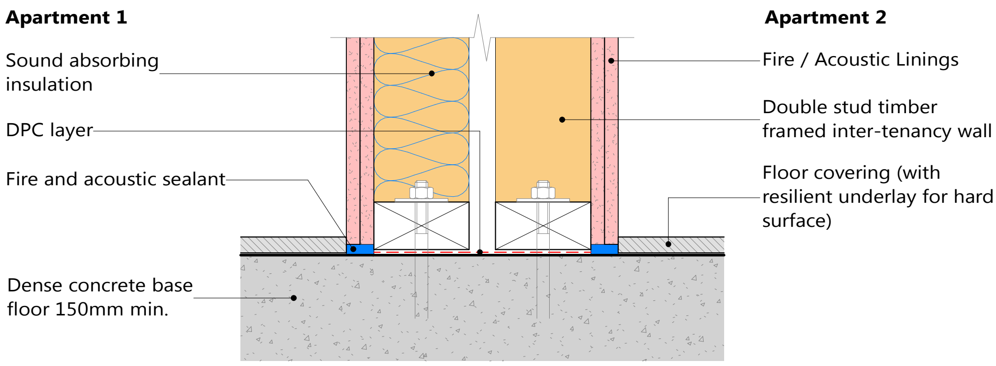


Figure 24. Double stud wall on ground-floor concrete base.

Intertenancy wall / internal floor (terraced house)

When connecting an internal floor to an intertenancy wall do not run rigid structural connections (e.g. a floor diaphragm) across to the neighbouring tenancy (Figure 25). Such continuous structural floor diaphragms will become sound bridges, and the internal floors will become flanking sound paths, compromising the acoustic insulation of the intertenancy wall. Structural diaphragms can be discontinued across intertenancy walls if the amount of bracing within each tenancy is greatly increased.

If a continuous floor diaphragm is required, then intertenancy floor designs should be used for the adjacent internal floors. Alternatively, a suitable acoustically isolating structural connection will be required near the floor diaphragm to transfer structural forces while minimising sound transfer.

The most common application for this sort of junction detail is a terraced house, in which case barrier systems would also be an increasingly common system to use (Figure 26).

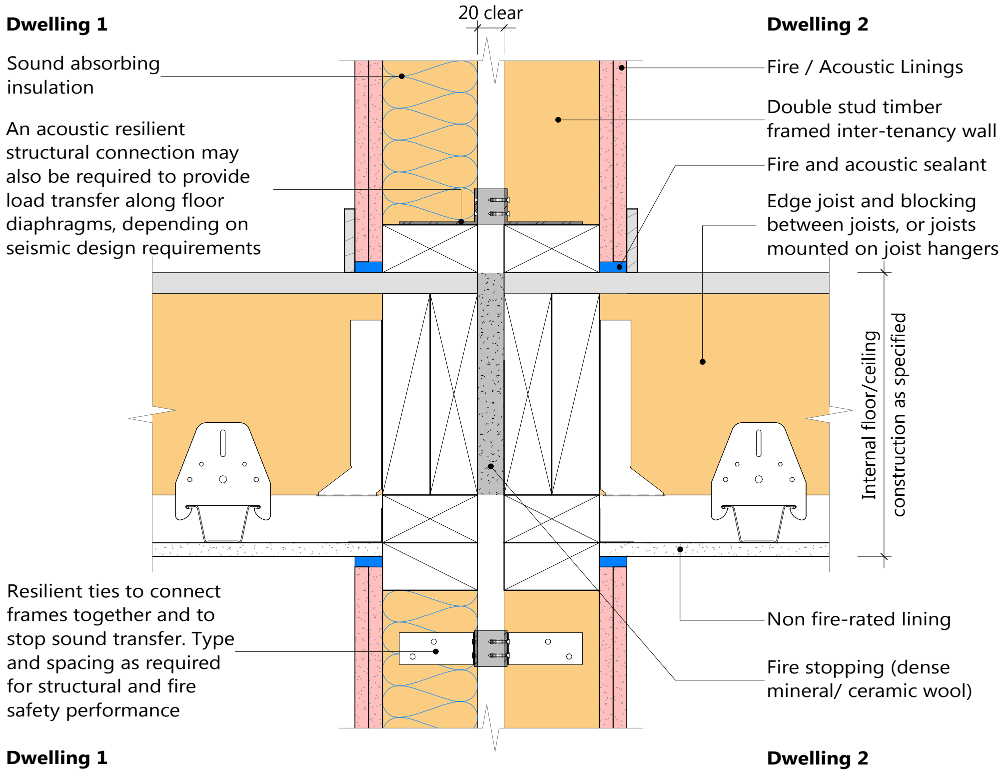


Figure 25. Double-stud intertenancy wall / internal floor junction.

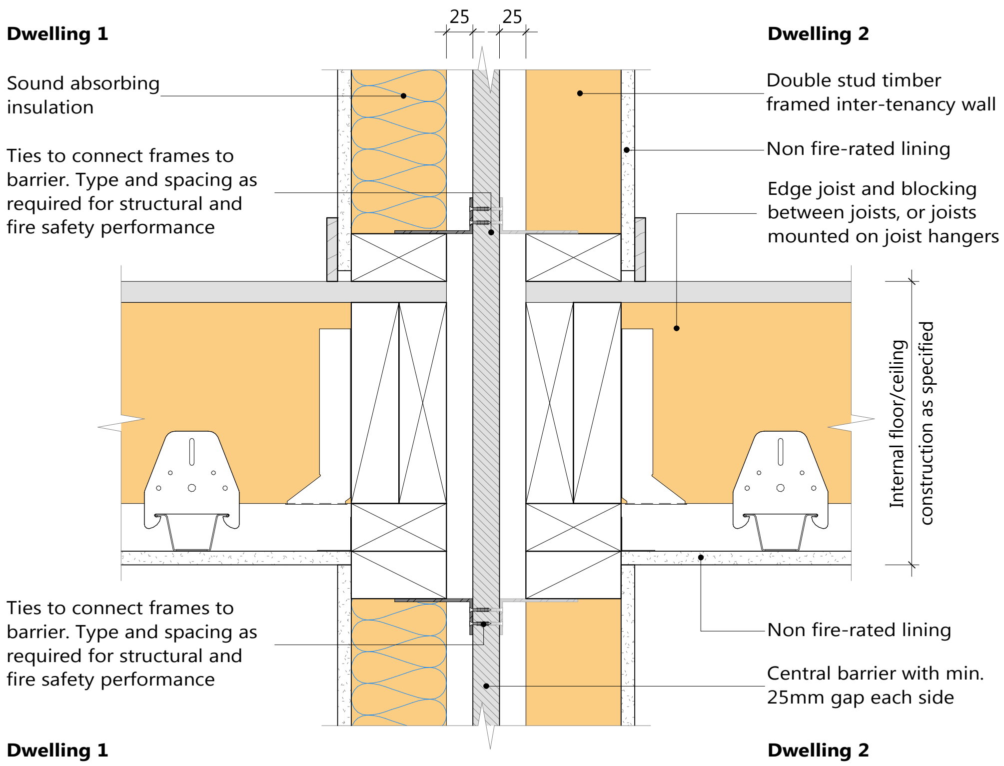


Figure 26. Double stud intertenancy barrier system for terraced housing designs.

Intertenancy floor / loadbearing internal wall

A load bearing internal wall may be required to support intertenancy floor joists, or to add bracing to the structure. Flanking sound will travel from the joists down the internal wall. For this reason, a loadbearing internal wall system may need to have two layers of plasterboard or have the linings resiliently attached to the frame and insulation inserted to reduce flanking sound issues (Figure 27). The use of floating floors in the apartment above will reduce the level of flanking sound passing into the wall and one layer of plasterboard will be probably be enough for minimal G6 performance. The linings of the internal will need to be fire rated to provide structural support and prevent fire spread into the floor system.

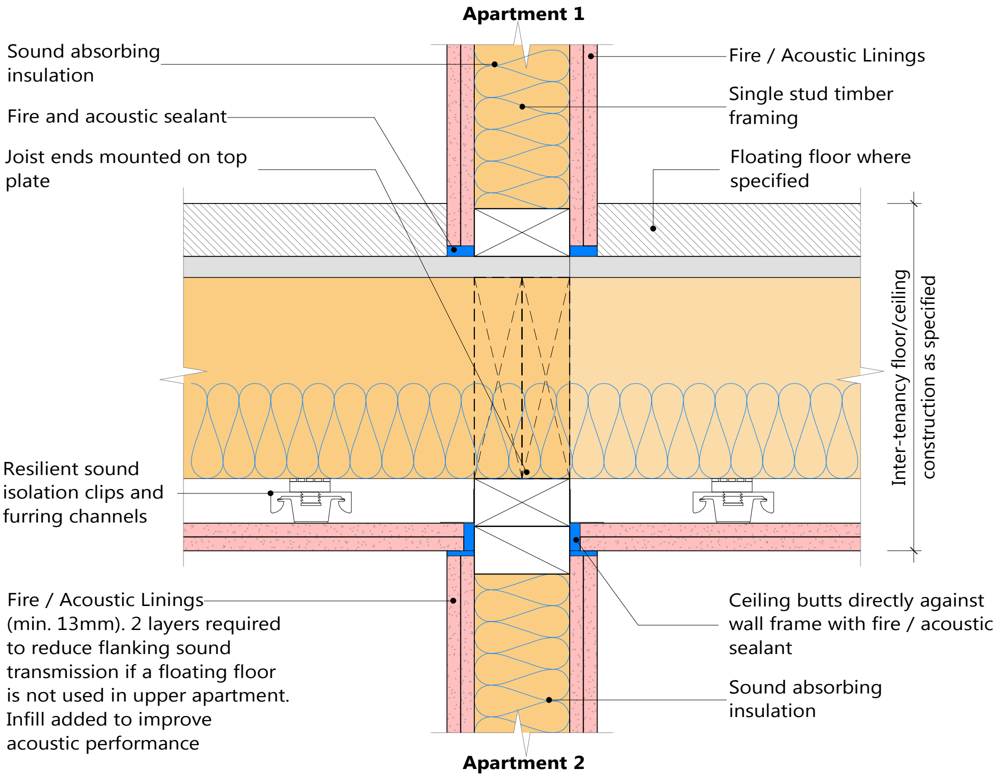


Figure 27. Internal load bearing wall top plate attached directly to joists. Joists running perpendicular to wall.

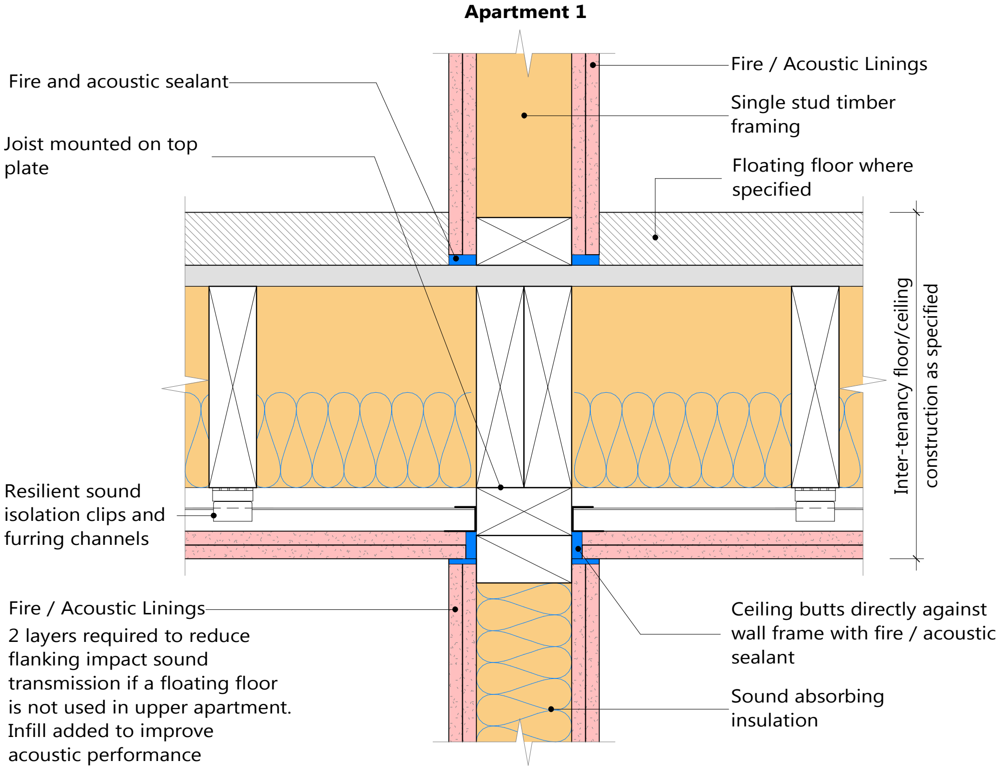


Figure 28. Internal load bearing wall top plate attached directly to joists. Joists running parallel to wall.

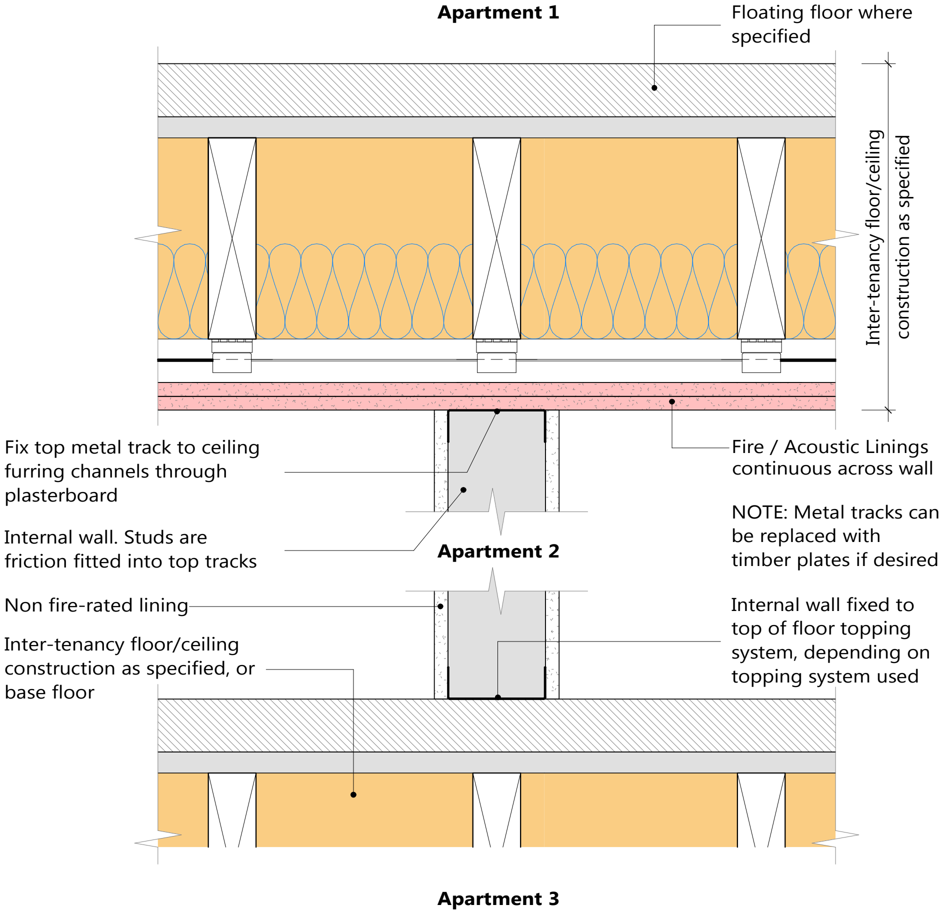


Figure 29. Non-structural internal wall using metal tracks or timber plates attached to ceiling furring channels and sitting on floating floor

Intertenancy floor / non-loadbearing internal wall

If the internal wall is non-loadbearing the floor system ceiling can run continuously above the wall, and the internal wall top plate can be attached directly to the ceiling furring channels through the ceiling plasterboard (Figure 29). This will simplify ceiling construction and improve acoustic and fire performance by eliminating flanking paths for sound and a penetration into a fire-rated ceiling. The non-loadbearing internal wall should ideally be mounted on the floating floor system to simplify the floating floor construction and reduce sound transmission flanking paths.

The timber plates may optionally be replaced with metal tracks and the timber studs friction fitted into place.

Intertenancy wall / internal wall (vertical T junction)

Care is also needed when connecting internal walls to intertenancy walls to ensure sound bridges are not created at the junctions and to ensure fire resistance integrity is maintained. Figure 30 illustrates a junction for loadbearing walls and Figure 31 a junction for non-loadbearing walls.

Identical junctions can be used for exterior wall / internal wall connections.

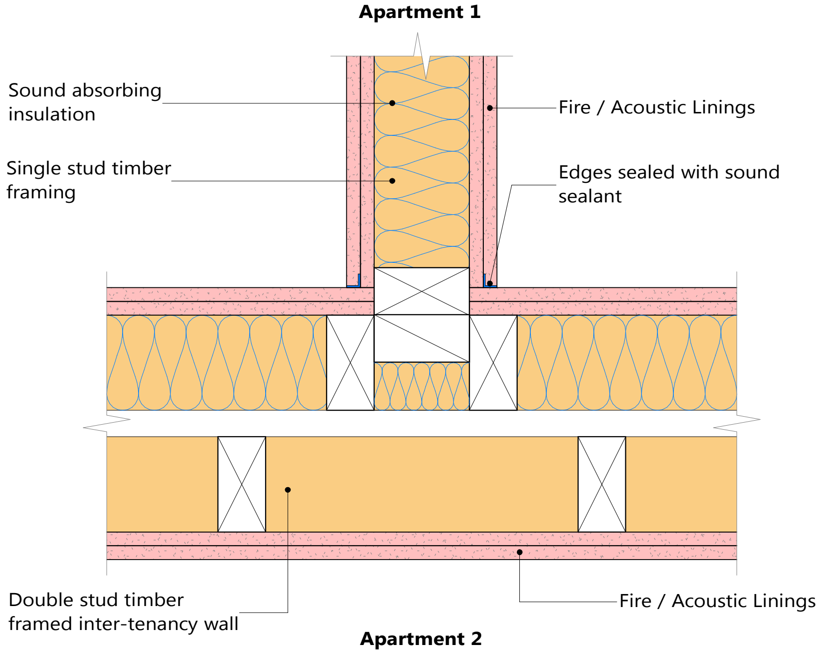


Figure 30. Double-stud intertenancy wall / loadbearing internal wall junction.

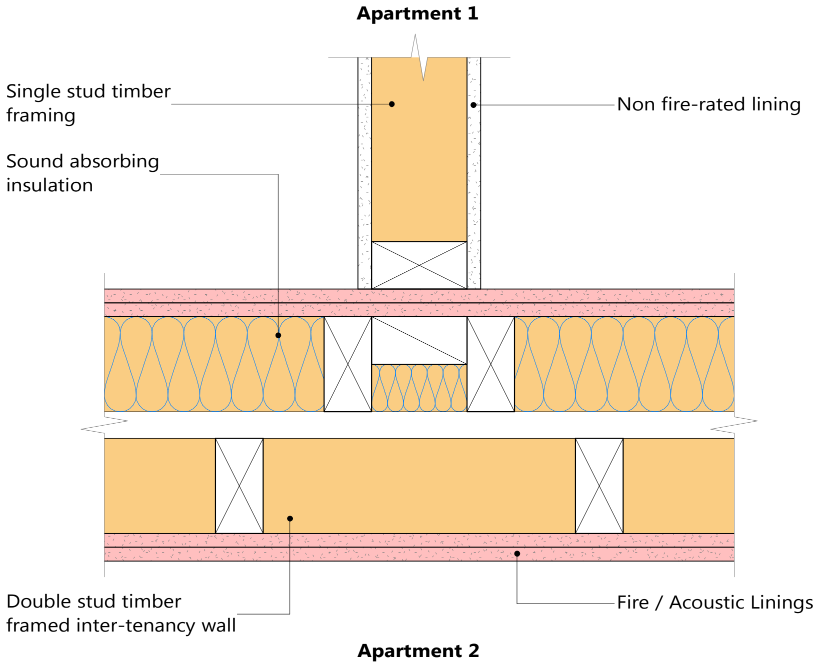


Figure 31. Double-stud intertenancy wall / non-loadbearing internal wall junction

Intertenancy floor / exterior wall (horizontal T junction)

An exterior wall system will need to be selected to provide enough acoustic insulation to meet any requirements imposed by local authorities. Two layers of plasterboard will be required for the linings to reduce flanking sound travelling vertically, particularly for impact sound if a floating floor is not used. Horizontal expansion gaps and systems to prevent water ingress at floor level will be useful to reduce flanking sound transmission (Figure 32).

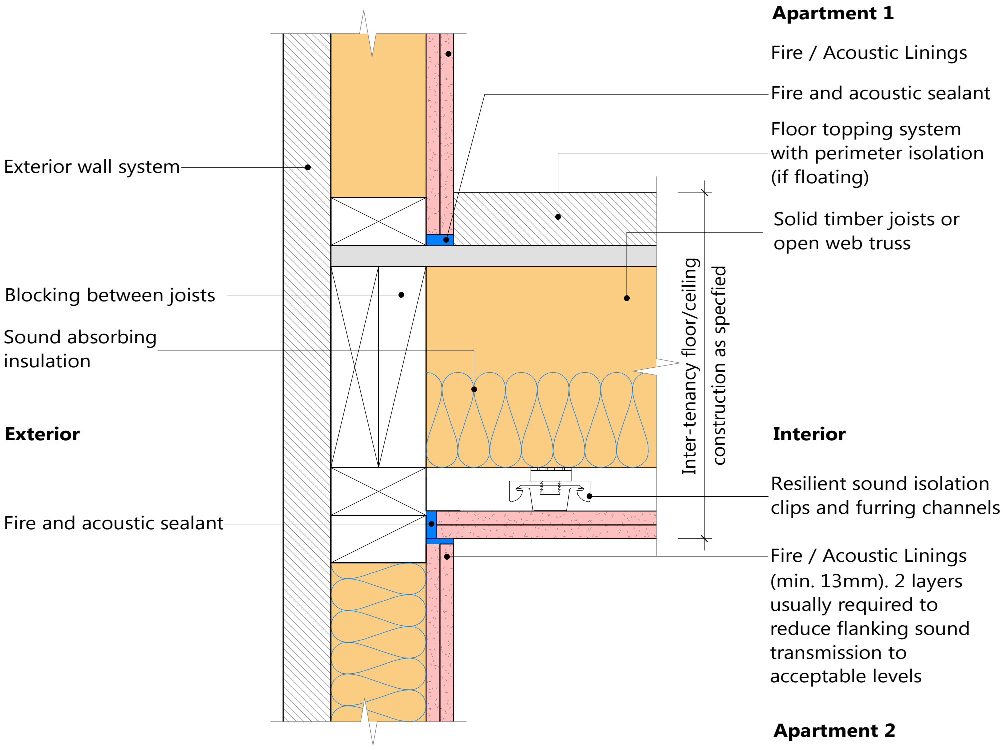


Figure 32. Conceptual details for intertenancy floor / exterior wall junction.

Intertenancy wall / exterior wall (vertical T junction)

In most wall systems little sound will travel along the façade and it will be acceptable to have a continuous external façade spanning across the gap between the double-stud frames. However, if a rigid air barrier is used ideally a barrier sheet join should be located near the double stud wall gap (Figure 33).

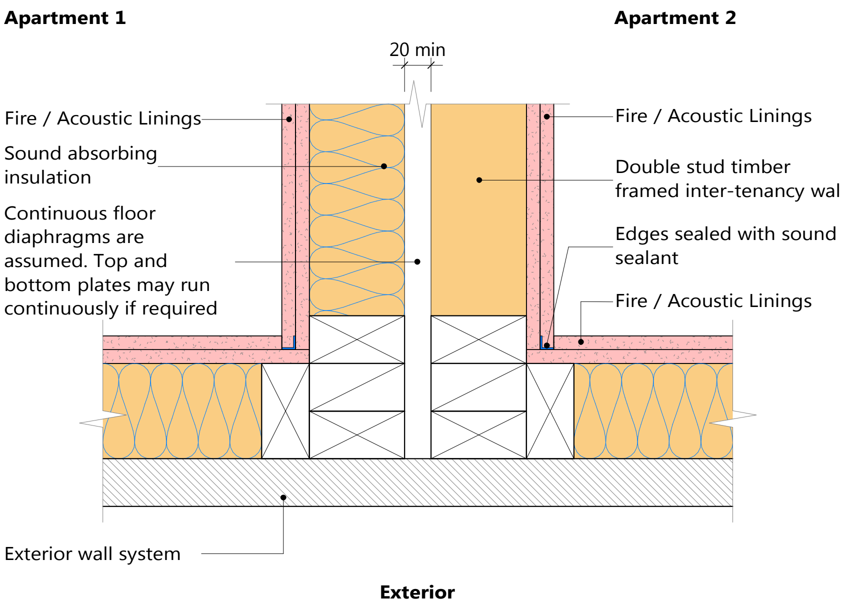


Figure 33. Conceptual details for intertenancy wall / exterior wall junction (plan view)

Intertenancy wall / Roof

In general, the intertenancy walls will need to be brought all the way up to the underside of the roofing material and sealed around rafters. This will reduce sound transmission through the roof cavity and is usually required for fire resistance. Only one layer of lining is necessary in the roof void to achieve acoustic (and fire) requirements. Any gaps will need to be filled with acoustics rated fire sealant or with fire stopping material. Figure 34 shows an example using a metal roofing material, where the wall is running parallel to the rafters, and Figure 35 shows the case where the wall runs perpendicular to the rafters.

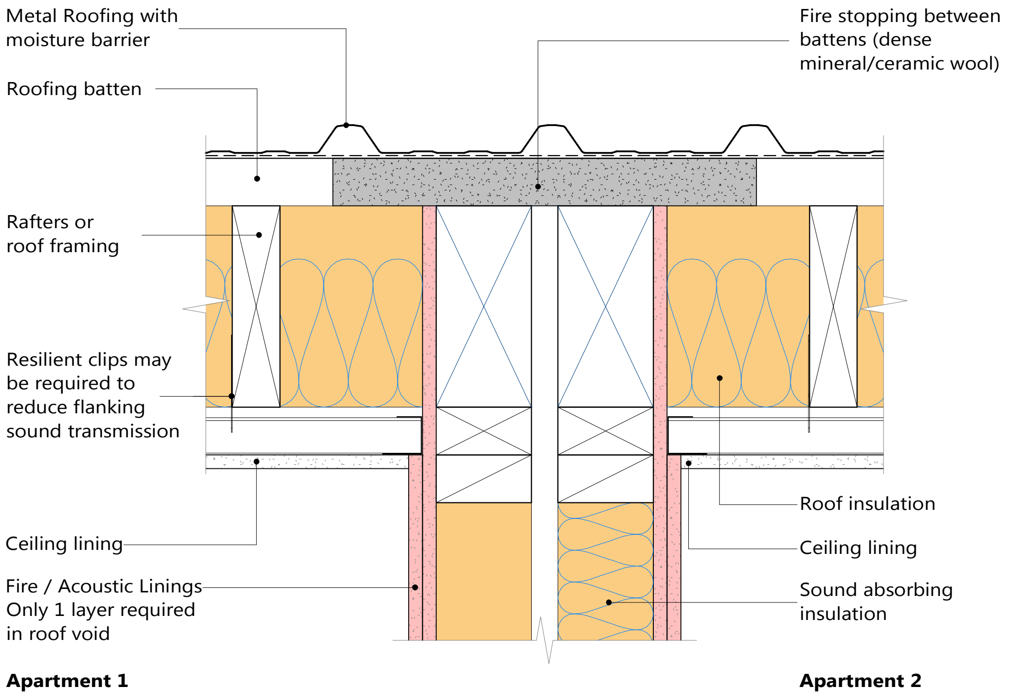


Figure 34. Typical detail for intertenancy wall at underside of roof (wall running parallel to rafters).

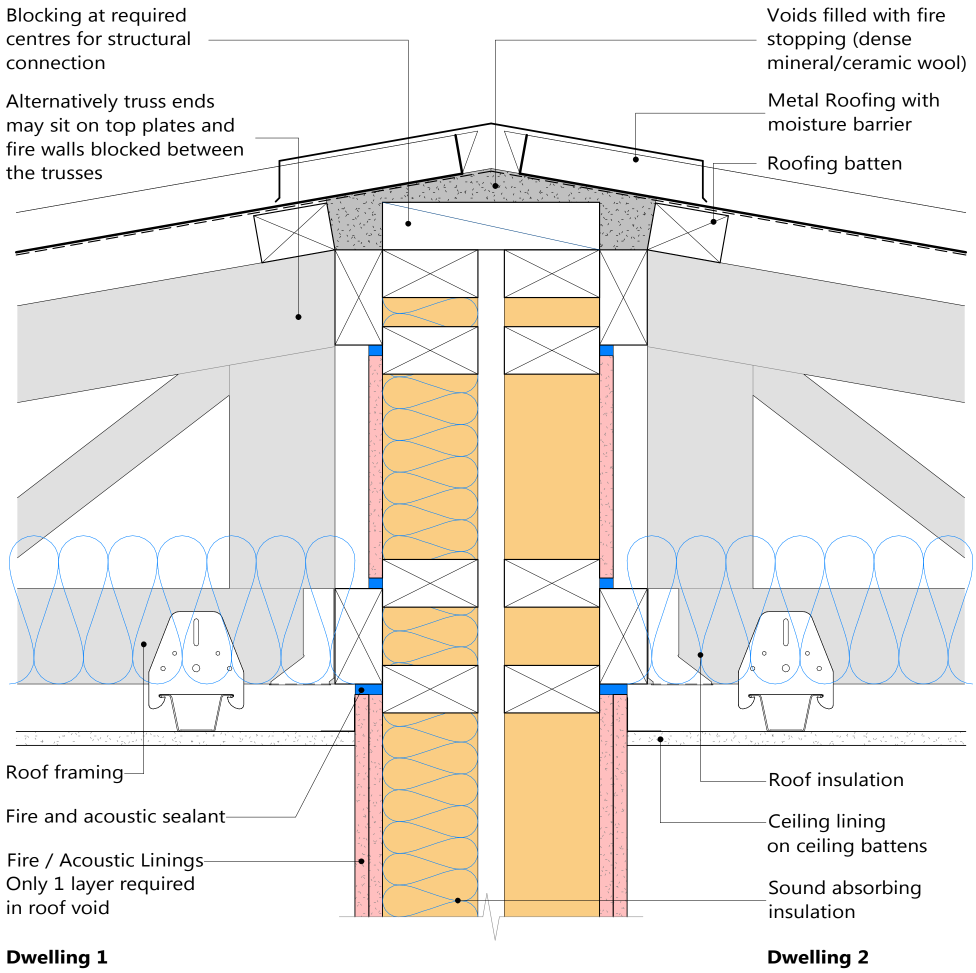


Figure 35: Typical detail for intertenancy wall at underside of roof (wall running perpendicular to rafters).

Cross-laminated timber construction

While timber frame construction is the most commonly used timber construction system in New Zealand, advances in engineered timber production methods have made more products readily available. One more recent engineered wood product is cross-laminated timber. Cross-laminated timber (CLT) is a pre-fabricated solid engineered wood product made of several layers of timber boards stacked crosswise (at 90 degrees) and glued (or stapled) under pressure together to form a solid rectangular panel. CLT panels can then be machined to cut out windows, provide cable channeling, and provide engineered connections. Cross-laminated timber (CLT) has been produced in Europe for about 20 years and is now making its way to the rest of the world.

In New Zealand a few wood product manufacturers have tooled up to fabricate and finish CLT panels, giving more options for the use of CLT in New Zealand. CLT is a high-strength product and can be used to create low to high-rise buildings from prefabricated panels. Since CLT is already prefabricated expect to see more prefabrication steps added to the process in the future.

Intertenancy wall designs

CLT is a medium weight, stiff and solid construction material. These properties mean it is more challenging to make effective sound insulated building elements from CLT. The designer usually needs to make extra cavity spaces using other materials.

Fixing linings on each side of a CLT core to a separate frame or through resilient connections is one way to create extra cavity spaces for improved sound insulation performance. Sound absorbing infill is required for all cavities. As with frame construction, greater cavity depths and more massive linings will improve performance. In the case of CLT this can be balanced against the use of thicker CLT panels. Wall perimeter and junction details are very important since once sound and vibrations get into CLT panels they will travel easily along the CLT panel into neighbouring rooms, resulting in flanking sound paths.

Linings can be also be fixed directly to the CLT, but any air gaps between the plasterboard and CLT when plasterboard is direct fixed to the CLT can reduce the acoustic performance. This can happen with the dabbed glue fixing method. To ensure that no gaps are present between the direct fix lining and CLT, the fire-rated plasterboard should be directly fixed with screws at a maximum of 300mm centres. If glue is to be used it must be applied evenly which typically requires a notched applicator. [Ref. Australian WoodSolutions Timber Design Guide #44]

Double CLT panel walls (> STC 55)

Sound insulation performance of fire rated double CLT core walls generally range from STC 55 to STC 67, depending on the linings, cavity depth and infill. Structural bridging at the perimeter (e.g. top and bottom plates) and non-acoustic ties will degrade performance. If linings are added to the CLT care need to be taken to ensure there are no gaps between the lining and the CLT as small gaps can degrade acoustic performance.

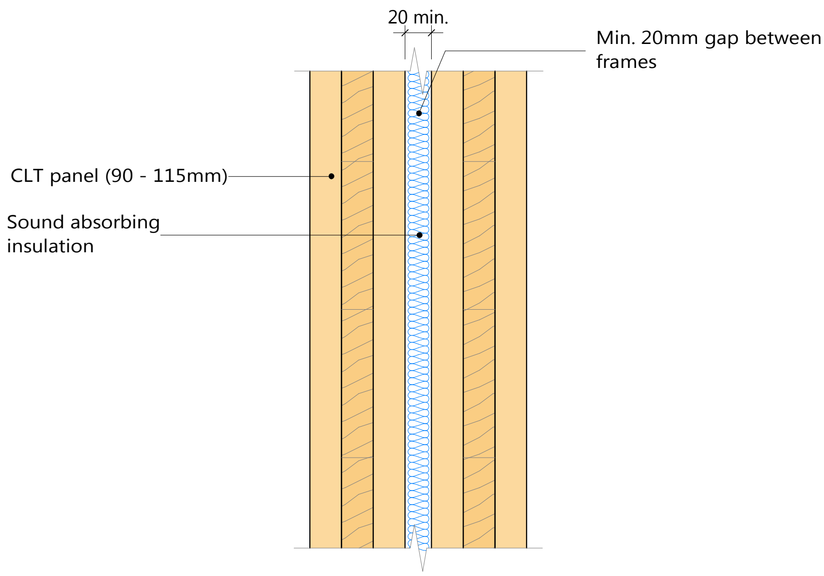


Figure 36. Double CLT panel wall.

Single-CLT panel with spaced linings (> STC 58)

Rather than using double layers of CLT, it may be necessary to use a single CLT panel which is lined on both sides of the panel. The linings need to be acoustically separated from the CLT panel by either mounting on a separate frame (Figure 37) or by using furring channels and resilient sound isolation clips (Figure 38). The sound insulation performance of such a wall will be STC 58 or more depending on the depth of the cavities and the number and density of the linings.

Using linings mounted on furring channels and resilient sound isolation clips makes it easier to solve potential flanking transmission issues; however, reliable buildability can be an issue with such systems, and care must be taken to select sound isolation clips that are effective and easy to install on CLT.

If fire-rated linings are required, using a fire-rated plasterboard for the outer linings does mean extra care is needed with penetrations through the fire rated linings. An alternative approach to avoid such fire rating issues is to fix the fire-rated plasterboard (thickness as required for appropriate fire ratings) directly to the CLT core and to use standard plasterboard on the outer, separated linings to give the acoustic performance required (Figure 39). However, any air gaps between the plasterboard and CLT when plasterboard is direct fixed to the CLT can reduce the acoustic performance. One layer of 13mm standard plasterboard for the outer linings will give an STC rating of 55 or better. Increasing the number, density and thickness of linings will increase the sound insulation performance (E.g. 2x13mm standard plasterboard on both sides will give approximately STC 60 or more).

Optionally the outer linings on one side of the wall may be dispensed with if two layers of 13mm standard plasterboard is used (Figure 40) and only a minimally acoustically performing wall is required (STC 55). Care has to be taken with orientation of such a wall as flanking sound transmission may be a problem on the side of the wall without the outer, detached plasterboard linings.

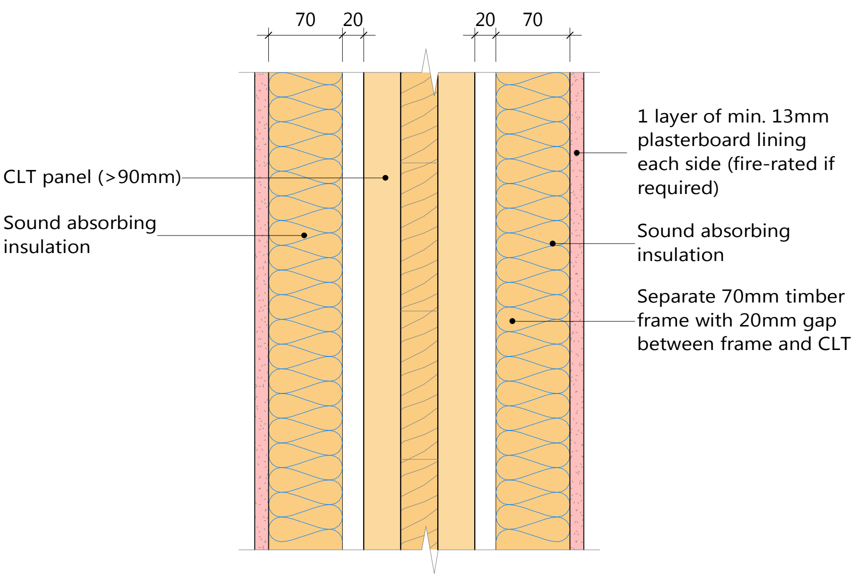


Figure 37. Single CLT panel wall with fire-rated linings mounted on separate timber frames.

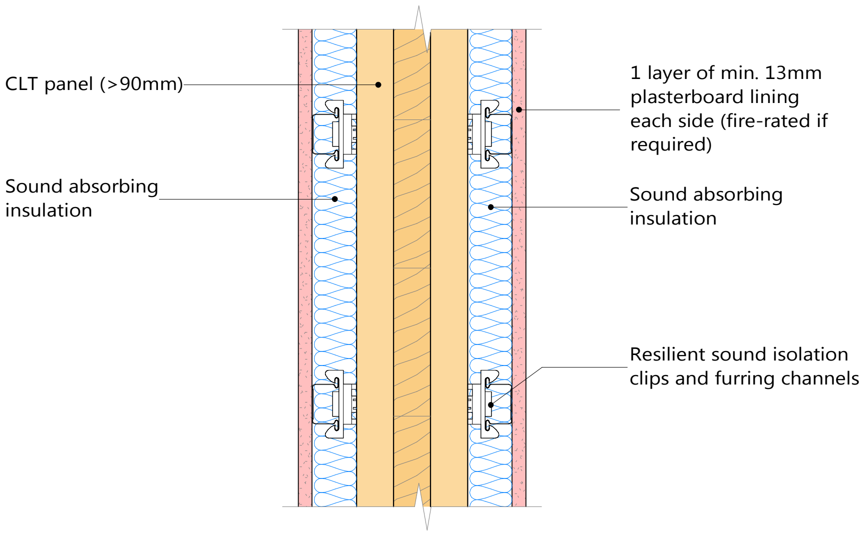


Figure 38. Single CLT panel wall with fire-rated linings mounted on resilient acoustic clips and furring channels.

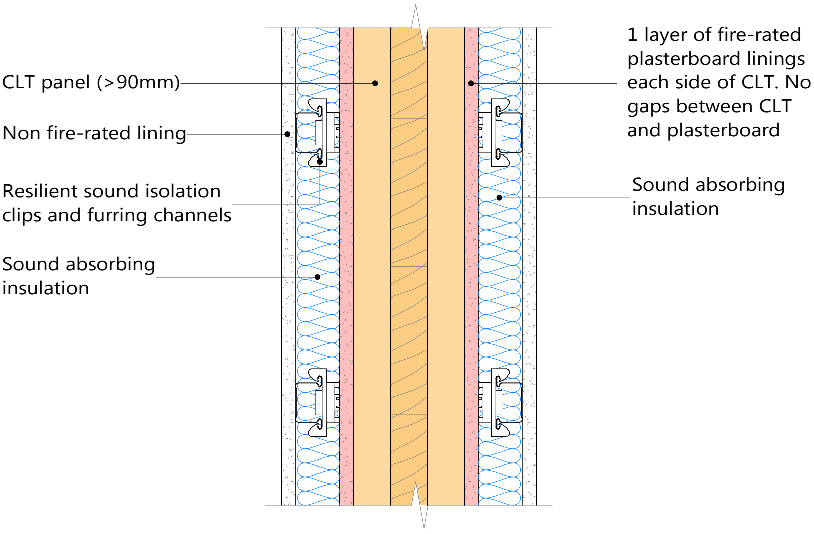


Figure 39. Single CLT panel wall with fire-rated linings mounted directly on CLT. Standard plasterboard mounted on resilient acoustic clips and furring channels.

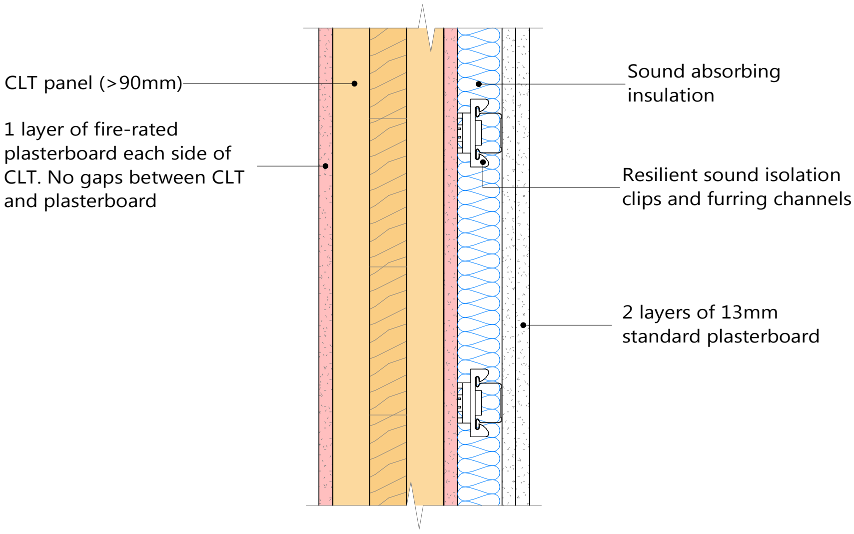


Figure 40. Single CLT panel wall with fire-rated linings mounted directly on CLT. Two layers of standard plasterboard mounted on furring channels and resilient acoustic clips on one side only.

Intertenancy floor designs

As is the case with timber-framed intertenancy floors, CLT floors usually have good airborne sound insulation but ensuring acceptable impact sound insulation performance can be challenging. Nevertheless, low-frequency impact sounds (such as footsteps) are reduced in CLT floors compared to timber frame floors due to the greater mass of CLT.

A basic CLT floor system will consist of a CLT slab with a resiliently attached suspended ceiling with mineral fibre insulation in the ceiling cavity. In the case of 120mm thick 5-ply CLT, with a cavity depth of at least 180mm and two layers of 13mm fire-rated plasterboard (Figure 41) we would expect an impact sound insulation rating of at least IIC 50 for the bare upper surface, and an airborne sound insulation rating of STC 56.

Carpet on a foam underlay can be used to obtain an IIC rating well above 55. Such a solution may not acceptable for some areas of an apartment with hard covering surfaces (e.g. tiles or laminate flooring) and will require the addition of resilient underlays under the floor covering to obtain a suitable impact sound insulation rating (IIC 55 or more in the laboratory or FIIC 50 on site).

One of the challenges with CLT constructions is that sound can easily travel along a continuous CLT floor leading to flanking sound problems. The addition of a floating floor is a way to reduce sound flanking sound.

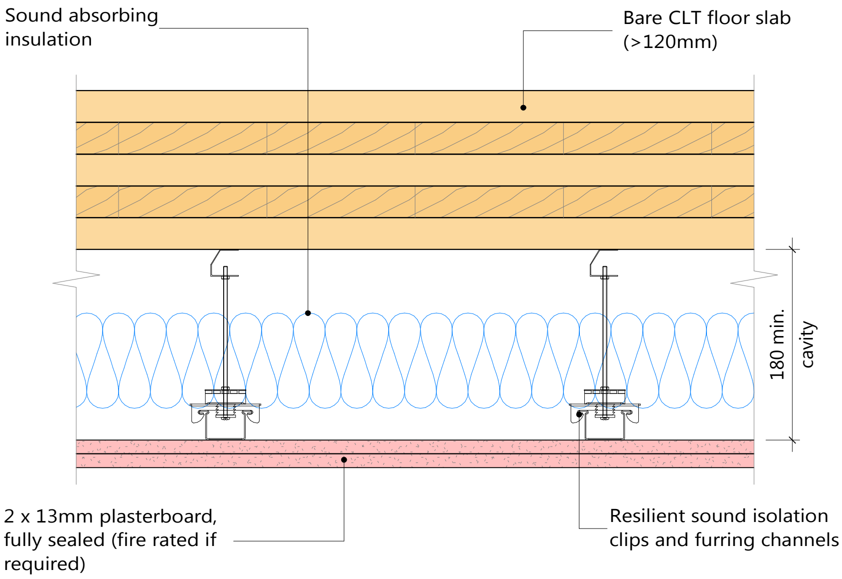


Figure 41. Basic CLT floor with resiliently attached suspended ceiling.

Floating floor topping systems

Floating floor systems are a type of floor topping system which consist of a rigid, heavy flooring layer lying on top of soft, resilient layers or connectors. Floating floor systems are used to create floor systems that achieve good impact sound insulation performance, regardless of the surface finish of the floor. They also reduce flanking sound problems for horizontal airborne sound transfer, enabling the use of continuous floor diaphragms. Increasing the mass of the flooring surface upper layers and increasing the resilience of the connections to the floor underneath will result in better performance. The perimeter of the floating floor must be surrounded with a foam layer to prevent the floating floor upper surface from directly contacting the perimeter walls.

Lightweight floating floor systems can consist of battens sitting on resilient holders with a flooring surface fixed to the battens and sound absorbing fibre within the cavities (Figure 42). There are proprietary systems readily available in New Zealand and their impact sound insulation performance is approximately IIC 55 or more for hard flooring finishes, depending on the system. Such floating floor systems also improve the airborne sound insulation rating, the one shown in Figure 18 with a 60mm deep cavity has an airborne insulation rating of STC 63.

As is the case with timber frame systems, floating floor systems can also consist of panels or concrete screeds laid on resilient underlays.

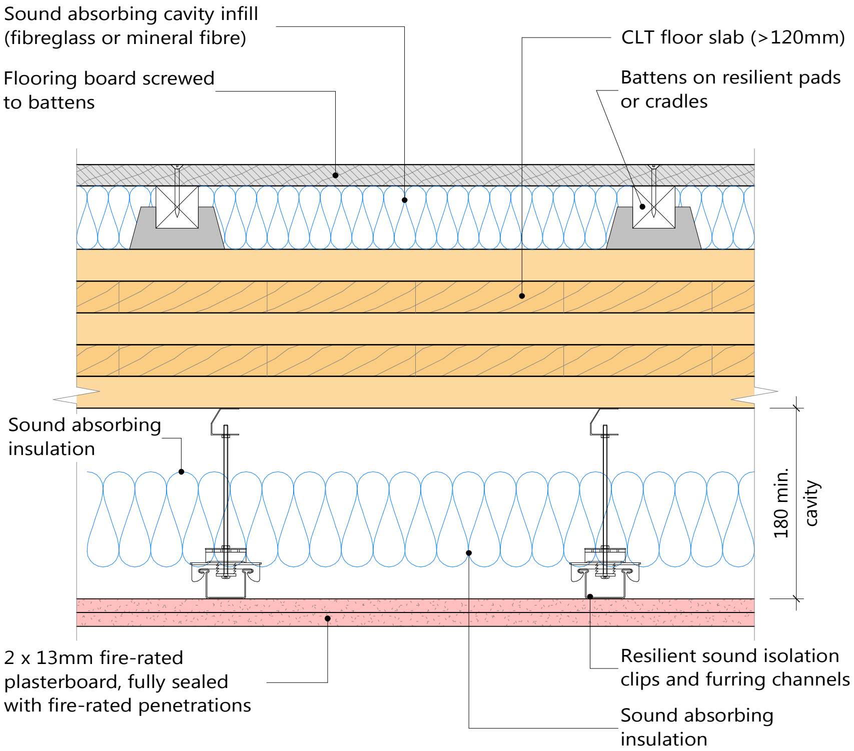


Figure 42. A generic lightweight floating floor system on CLT.

Achieving a suitable fire rating performance of the CLT floor by directly lining the underside of the CLT floor slab with fire-rated plasterboard is also an option (Figure 43). In such a case, penetrations through the ceiling will be easier as they probably do not need to be fire-rated. However, any air gaps between the plasterboard and CLT when plasterboard is direct fixed to the CLT can reduce the acoustic performance. Using 13mm standard plasterboard for the ceiling can give IIC 56 and STC 62 with no floor covering. Using more and denser layers of plasterboard in the ceiling will give better acoustic performance.

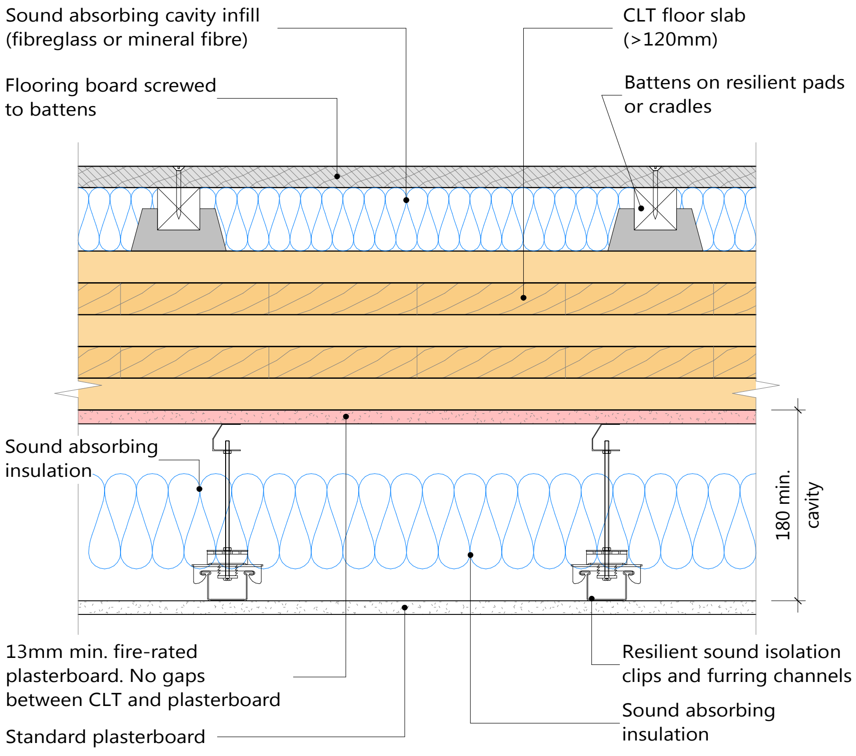
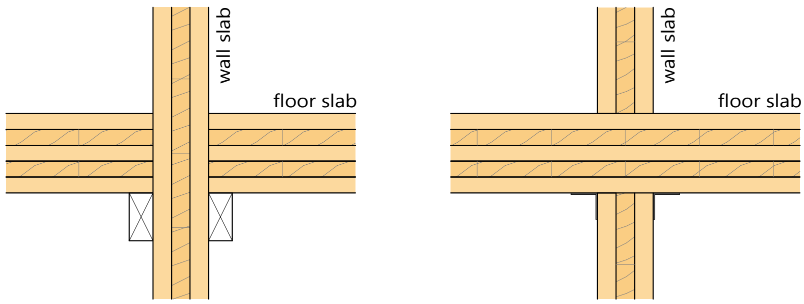


Figure 43. A generic lightweight floating floor system on CLT. Additional fire rating of the CLT floor is achieved by direct fixing fire-rated plasterboard to CLT underside.

Junction details

Flanking sound can be more of a problem in CLT systems compared to timber frame systems due to the strong mechanical coupling that occurs between CLT slabs at joints (using long screws, brackets and tie downs), and due to the continuous nature of CLT slabs.

The flanking sound transmission through a junction depends on the exact configuration of the junction, whether the CLT is continuous across the junction or whether the CLT slab is connected to another CLT slab. Two example floor-wall junctions are shown in Figure 44; the acoustic transmission through the continuous wall slab of Example A can be 15dB higher compared to the discontinuous wall slab of Example B. Judicious use of the appropriate type of junctions can reduce sound transmission to sound sensitive areas.



A. Continuous CLT wall and suspended CLT floor. Greater wall flanking sound transmission

B. Continuous CLT floor and discontinuous CLT walls. Greater floor flanking sound transmission.

Figure 44. Two examples of CLT floor-wall junctions. Discontinuities provide greater acoustic isolation and reduced flanking sound transmission.

In countries with little seismic risk CLT junctions often consist of resilient interlayers to reduce the levels of flanking sound by reducing sound transmission across building element junctions. However, in high seismic risk zones, such as those found in New Zealand, resilient interlayers can't always be easily used. As a result of the greater structural connection required in CLT junctions, we usually need to resiliently attach linings to the CLT structure to reduce flanking sound to acceptable levels.

Intertenancy wall / Intertenancy floor (horizontal cruciform junction)

Acoustically, it is most desirable to have a structural break in a CLT floor when spanning across separate tenancies. Such a structural break minimises horizontal sound transmission by reducing flanking sound travelling along the floor. This type of floor design is most likely used in conjunction with double layer CLT walls to create isolated apartment boxes.

However, in New Zealand it may be difficult to structurally brace each unit sufficiently to enable breaks in the CLT floor. In such cases a continuous floor diaphragm is desirable (Figure 45). However, horizontal sound insulation will be compromised due to flanking sound traveling along the floor, and it will be necessary to include a floating floor on the intertenancy floor CLT in order to achieve the required G6 field sound insulation. Even with a floating floor installed the airborne sound insulation performance of a double CLT layer wall will still be compromised due to sound vibrations travelling through the floor diaphragm at the bottom and top of the CLT walls. It is therefore best to use a single CLT panel wall with resiliently attached linings or with linings attached to separate frames.

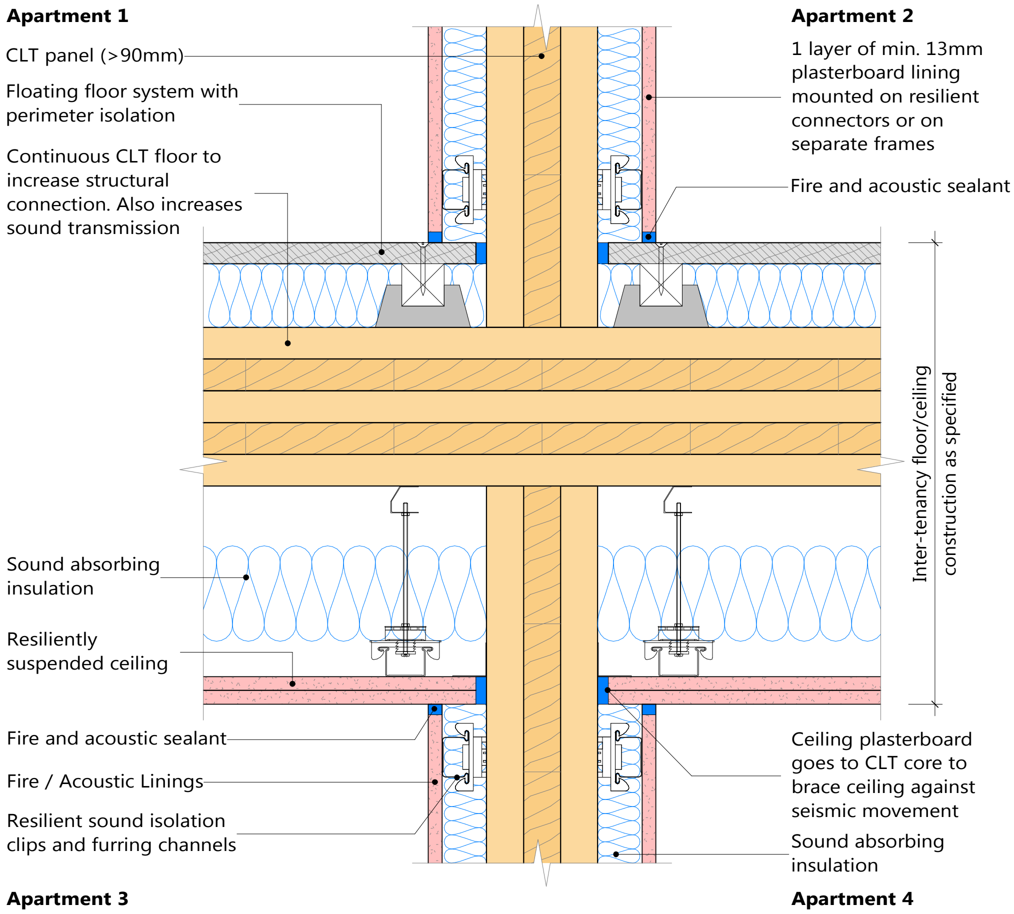


Figure 45. Floor junction detail with continuous CLT floor and discontinuous walls.

Intertenancy wall / intertenancy wall (vertical T-junction)

Intertenancy wall junctions for double stud walls must have isolated studs at the junction to ensure there is no acoustic bridging across separate tenancies. Fire resistant components must also be flexible to ensure no acoustic transmission. This structural isolation is particularly important when the floor diaphragm is not continuous. Figure 46 shows an example of an intertenancy T-junction.

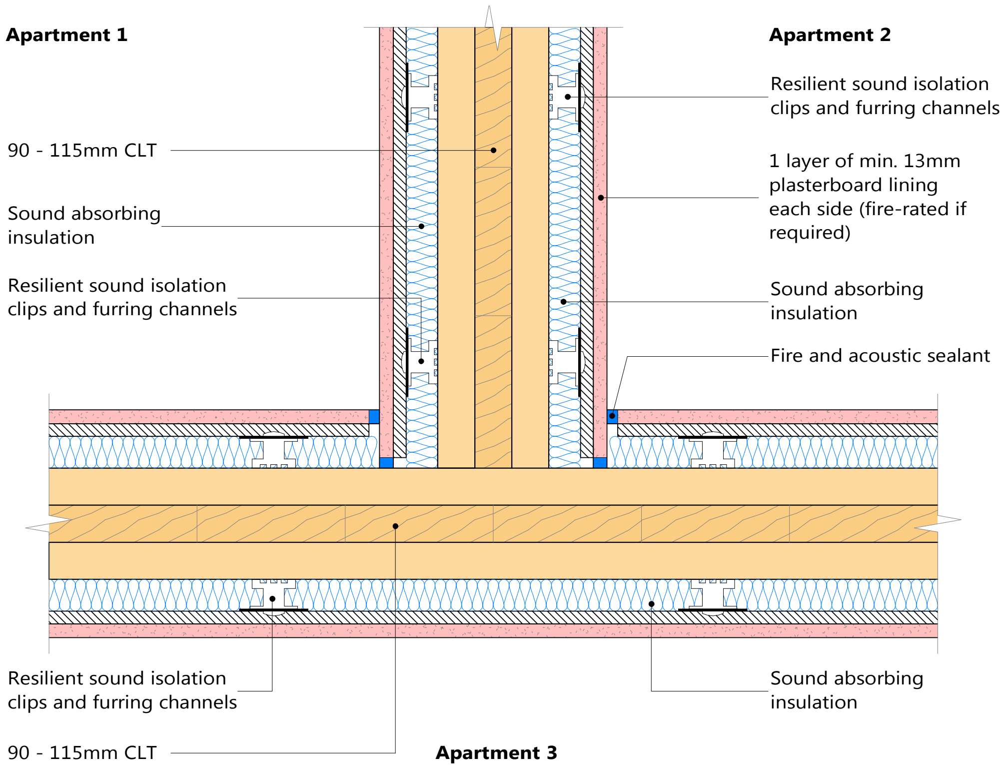


Figure 46. Apartment inter-tenancy or loadbearing CLT wall T-junction (plan view). Resiliently attached linings to minimise acoustic flanking transmission.

Intertenancy wall / Internal load bearing wall

It should be noted that when CLT cores are structurally connected to create a load bearing internal walls flanking sound will pass into the internal wall. To achieve G6 requirements it may be acceptable to directly line the CLT with plasterboard. However, superior and reliable acoustic performance can be obtained by mounting the lining on the internal wall using resilient connectors and furring channels (in the same way as an intertenancy wall – Figure 46).

Intertenancy floor / exterior wall (horizontal T junction)

An exterior wall system will need to be selected to provide enough acoustic insulation to meet any requirements imposed by local authorities. To achieve superior acoustic isolation of flanking transmission travelling vertically, the plasterboard wall linings will need to be separated from the CLT core using resilient acoustic connectors and furring channels or be mounted on a separate frame (Figure 47).

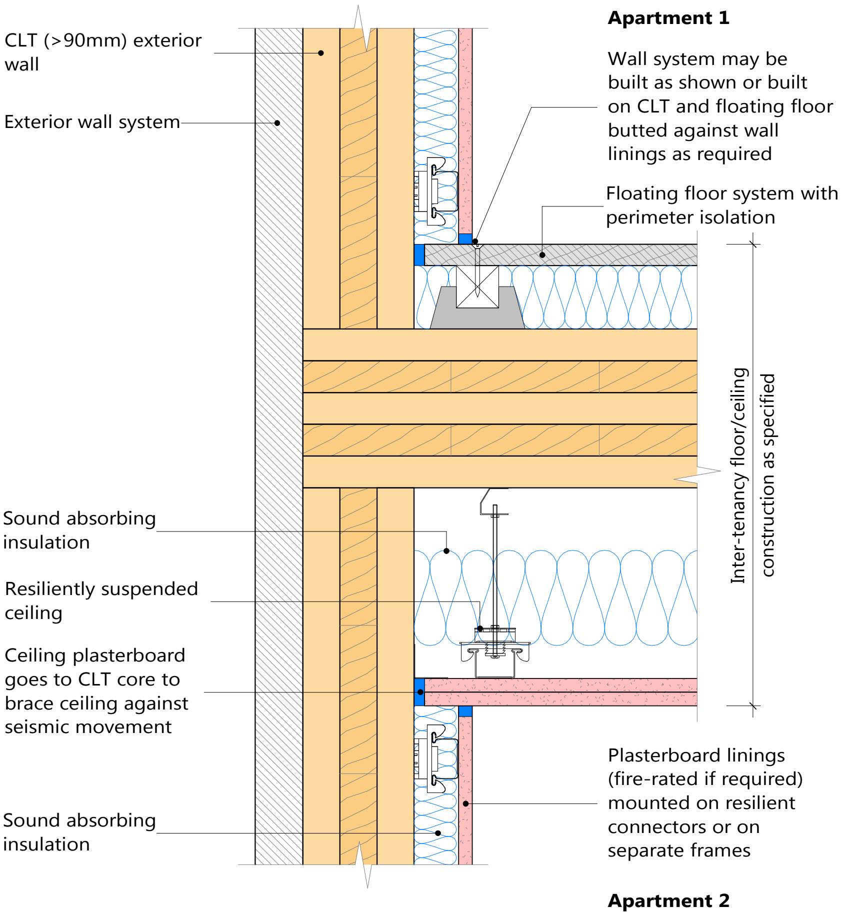


Figure 47. Conceptual details for intertenancy floor / exterior wall junction.

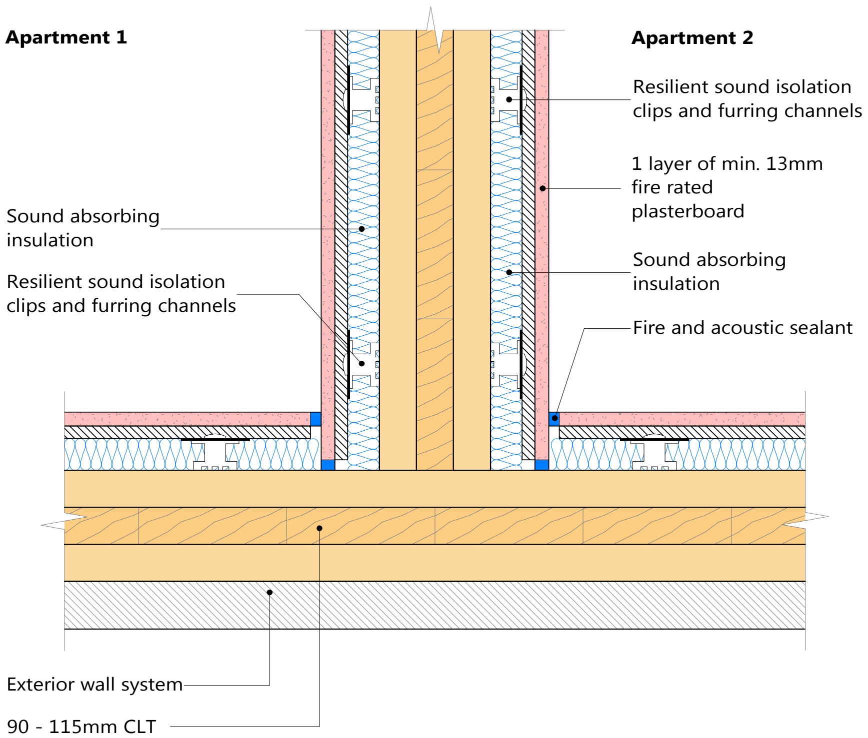


Figure 48. Plan view of intertenancy wall / exterior wall junction.

Intertenancy wall / exterior wall (vertical T junction)

If the exterior CLT wall is continuous across the junction then this will make an excellent flanking sound path for airborne sound transmission and produce unacceptable sound insulation results. To alleviate this issue and produce an acceptable result the plasterboard linings will need to be resiliently attached or mounted on separate frames (Figure 48).

Intertenancy wall / roof

In general, the intertenancy CLT walls will need to be brought all the way up to the underside of the roofing material. Rafters can be hung on hangers attached to the CLT or to a capping beam with solid timber blocking to give appropriate fire resistance. Plasterboard linings will need to be brought up to the underside of the roof and sealed around rafters. This will reduce sound transmission through the roof cavity and is usually required for fire resistance. Any gaps between the will need to be filled with acoustics rated fire sealant or with fire stopping material. Figure 49 shows an example where the wall is running perpendicular to the rafters.

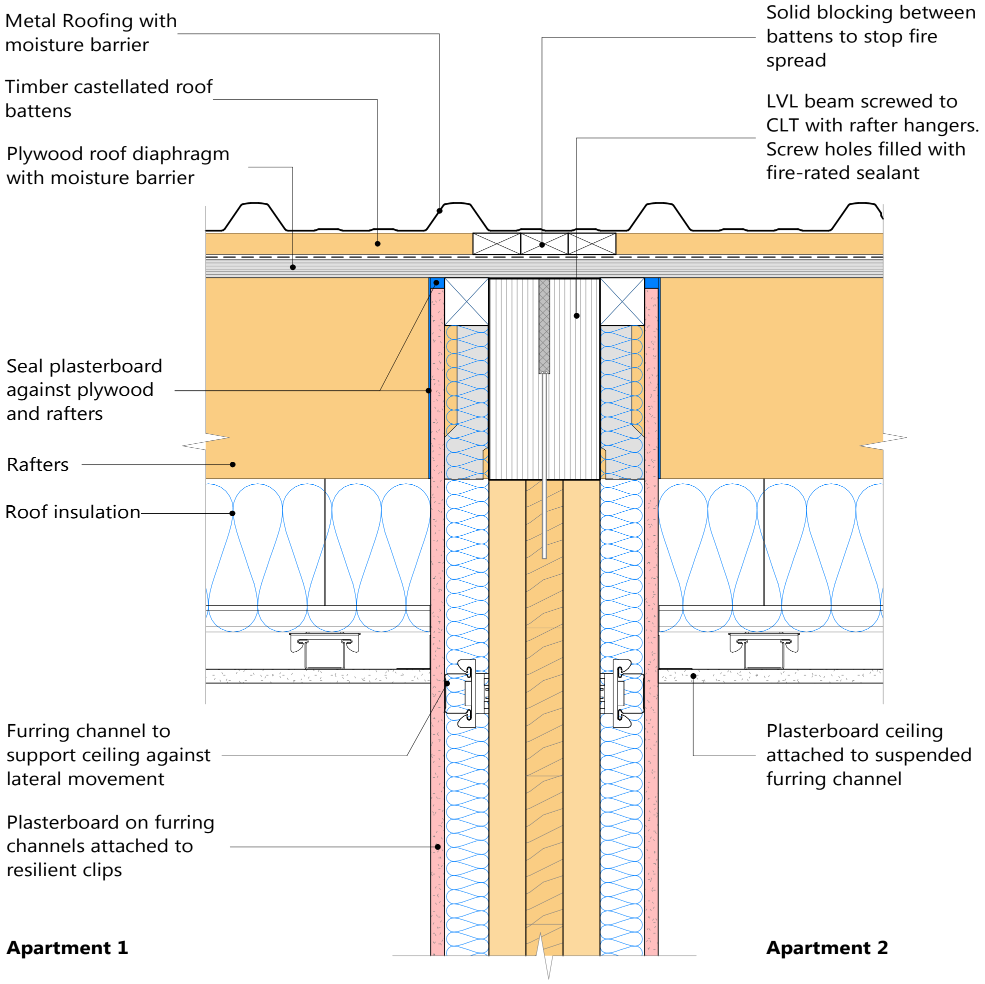


Figure 49. Typical detail for CLT intertenancy wall at underside of roof (rafters perpendicular to wall).

Exposing or directly lining CLT surfaces.

If only minimal acoustic performance is required (FSTC ≥ 50 and IIC ≥ 50) then the fire-rated plasterboard linings can be mounted directly on the CLT, ensuring that there are no gaps between CLT and plasterboard. However, care must be taken to ensure the floating and floor coverings will achieve the required airborne and impact insulation ratings with the additional flanking sound coming from the walls. If the CLT walls do not require additional fire protection, then the CLT may be left exposed to reveal the wood. The designer, however, is strongly advised to obtain expert acoustic advice before attempting to use CLT walls without the addition of acoustically isolated plasterboard linings, as there are a number of factors which need to be considered to produce acceptable acoustic results.

Summary

This design guide has introduced the reader to acoustics as related to sound insulation in timber buildings. The following areas have been covered:

- Principals of sound and its transmission through building elements.
- Standard methods of sound insulation measurement and ratings.
- New Zealand building code and local authority requirements.
- Principals used to reduce sound transmission through building elements.
- Designing for sound isolation in timber frame and CLT buildings.

This guide has only been introductory and has focused on the sound insulation aspects of timber building design. It is important to obtain expert advice and to co-ordinate acoustic advice with structural, seismic and fire safety advice.

About the Author

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Grant obtained his PhD in acoustics from The University of Auckland in 2001. Subsequent to that he was a researcher for 17 years in the New Zealand Forest Research Institute. His research focussed on building acoustics in timber buildings, and the use of acoustics for non-destructive assessment. He has authored and co-authored over 30 papers in international journals and conferences. He currently applies his expertise to assist Marshall Day Acoustics deliver acoustic software and services.

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Building Acoustics Prediction Software

Insul, Marshall Day Acoustics, www.insul.co.nz

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MBIE-Building Performance	www.building.govt.nz
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Wood Processors and Manufacturers Association	www.wpma.co.nz
Acoustics Society of New Zealand	www.acoustics.org.nz
Association of Australasian Acoustic Consultants	www.aaac.org.au
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TRADA (UK)	www.trada.co.uk
NRCC (Canada)	www.nrc.canada.ca/en
FPInnovations (Canada)	www.web.fpinnovations.ca
Wood Solutions (Australia)	www.woodsolutions.com.au

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