ABCB

National Construction Code

Handbook

Sound transmission and insulation in buildings

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Preface

The Inter-Government Agreement (IGA) that governs the Australian Building Codes Board (ABCB) places a strong emphasis on reducing reliance on regulation, including consideration of non-regulatory alternatives such as non-mandatory handbooks and protocols.

This handbook is one of a series produced by the ABCB developed in response to comments and concerns expressed by government, industry and the community that relate to the built environment. The topics of handbooks expand on areas of existing regulation or relate to topics which have, for a variety of reasons, been deemed inappropriate for regulation. They provide non-mandatory advice and guidance.

The Handbook: Sound transmission and insulation in buildings has been developed to provide additional information, detail and advice relating to the Building Code of Australia[1] (BCA) sound transmission and insulation requirements.

This handbook assists in understanding the application of the existing provisions, including outlining the intent of the requirements, defining key terms, clarifying the difference between airborne and structure-borne noise, describing options to satisfy requirements, and explaining the process from design through to certification. It addresses issues in generic terms. It is expected that this handbook will be used to guide solutions relevant to specific situations in accordance with the generic principles and criteria contained herein.

[1] The BCA comprises Volume One and Two of the National Construction Code (NCC). The Plumbing Code of Australia (PCA) comprises Volume Three of the NCC. The NCC was introduced in 2011 with the addition of the PCA.

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REMINDER

This handbook is not mandatory or regulatory in nature and compliance with it will not necessarily discharge a user's legal obligations. The handbook should only be read and used subject to, and in conjunction with, the general disclaimer at page i.

The handbook also needs to be read in conjunction with the relevant legislation of the appropriate state or territory. It is written in generic terms and it is not intended that the content of the handbook counteract or conflict with the legislative requirements, any references in legal documents, any handbooks issued by the Administration or any directives by the appropriate authority.

1 Background

The NCC is a performance-based code containing all Performance Requirements for the construction of buildings. A building, plumbing or drainage solution will comply with the NCC if it satisfies the Performance Requirements, which are the mandatory requirements of the NCC. To comply with the NCC, a solution must achieve compliance with the Governing Requirements and the Performance Requirements. The Governing Requirements contain requirements about how the Performance Requirements must be met.

The BCA underwent a major amendment in 2004 in response to increasing evidence that earlier BCA sound insulation requirements were not meeting community expectations. The purpose of the sound insulation requirements is to reduce noise transmission between attached dwellings and units and also between dwellings or units and other areas within the building.

This handbook was written primarily to support the sound insulation provisions introduced in BCA 2004 and has been updated to align with NCC 2019. It is intended that this handbook be read in conjunction with the provisions contained within the BCA. The BCA has sound insulation provisions for residential buildings in the following parts -

- Part F5 'Sound transmission and insulation' in Volume One for Class 2, 3 and 9c buildings.
- Part 2.4 'Health and amenity' in Volume Two for Class 1 buildings.
- Part 3.8.6 'Sound insulation' in Volume Two for Class 1 buildings.

This handbook is not intended to replace or supersede the BCA but rather provide additional information to aid the user in the application of the sound insulation provisions of the BCA.

The objectives of this handbook are to -

- provide guidance on the acoustic design process
- provide guidance on methods of compliance with the BCA
- provide guidance on the installation of acoustic elements
- help achieve acceptable acoustic outcomes within buildings.

It is the intention for this handbook to provide a link between the BCA provisions and the needs of users including architects, builders, engineers, certifiers, project managers, acoustic consultants, subcontractors and the public.

The BCA requires a level of sound insulation that represents the minimum acceptable building standard. This was determined through wide consultation with the community and industry. An owner or designer can always go beyond the minimum requirements in the BCA if they choose in which case, the information provided in this handbook may need to be supplemented to suit the specific project.

Alert:

The scope of this handbook is restricted to the sound transmission and isolation requirements within the BCA (Part F5). It does not cover the excess noise requirements of the PCA (Section D).

1.1 Scope

This handbook has been developed to assist NCC users in understanding and applying the acoustic design process. It will be of interest to all parties who are involved in selecting or assessing elements of buildings that must comply with the NCC. The concepts and principles within this document can be used to -

- assist in the design of structures and partitioning
- review different methods of BCA compliance
- assist in the establishment of compliance with the BCA sound insulation provisions.

This handbook is intended to provide guidance to all users of the BCA, whether involved in design, construction, development, certification or approval, as they work to develop, implement or review solutions that provide acceptable levels of sound insulation. Any acoustic design should be conducted in conjunction with the design of all other building requirements including, but not limited to, structural loading, wind loading, fire safety, earthquake design, ventilation requirements and buildability.

Designers need to interpret the guidance given in this handbook flexibly and use it as a tool for responsible acoustic design.

1.2 Design and approval of Performance Solutions

The design and approval processes for sound insulation solutions is expected to be similar to that adopted for demonstrating compliance of other NCC Performance Solutions. Since the design approval process for Performance Solutions varies between the responsible state and territory governments it is likely to also be the case with sound insulation and requirements should be checked for the relevant jurisdiction.

Notwithstanding the quantified input and acceptance criteria, other qualitative aspects of sound insulation, which are discussed in this document, require assessment and analysis throughout the design and approval process. The advice of an appropriately qualified person should be sought to undertake this assessment and analysis where required, and may be aided by the early and significant involvement from regulatory authorities, peer reviewer(s) and / or a technical panel as appropriate to the state or territory jurisdictions.

1.3 Using this document

General information about complying with the NCC and responsibilities for building regulation are provided in 0 of this document.

Acronyms and symbols used in this document are provided in Appendix B.

Defined terms are used in this document. They may align with a defined term in the NCC or be defined for the purpose of this document. See Appendix C for further information.

Additional information about Laboratory and Field testing is provided in Appendix D.

A list of further reading is also provided.

NCC extracts

Examples

Alerts

Reminders

2 BCA sound transmission and insulation requirements

2.1 Objectives of the BCA

The BCA has the objective of safeguarding occupants in residential buildings from illness or loss of amenity resulting from excessive noise. The noise of concern is:

- noise transmitted between adjoining dwelling or units containing sleeping facilities;
- noise transmitted from common spaces into adjoining units; and
- noise transmitted from parts of the building with a different classification into adjoining units.

To meet the objectives outlined above, the BCA has detailed sound insulation provisions in Part F5 of Volume One (‘Sound transmission and insulation’) and Parts 2.4 and 3.8.6 of Volume Two (‘Health and amenity’ and ‘Sound insulation’). The types of buildings these clauses relate to is summarised below. Refer to the BCA for exact definitions of the different building classifications.

2.1.1 Volume One, Part F5

Class 2 building	A building containing two or more separate units (i.e. apartment building, block of flats, etc.).
Class 3 building	A residential building other than Class 1 or 2 (i.e. hotel, motel, etc.).
Class 9c building	An aged care building.

2.1.2 Volume Two, Parts 2.4 and 3.8.6

Class 1 building	A single dwelling or more attached dwellings separated by a fire resisting wall.

2.2 Acoustic issues covered by the BCA

The BCA deals only with the sound insulation between dwellings or units as outlined above. It does not address issues such as:

- noise entering the building from outside, for example from industrial processes, vehicle traffic, trains, aircraft or animals
- environmental noise emission from the building to surrounding areas
- air conditioning or other plant noise within a unit
- domestic appliance noise within a unit
- room acoustic design for home entertainment systems
- noise transfer within a unit.

The options for designers, builders and certifiers which can satisfy the provisions of the BCA are summarised below in Section 2.4.

2.3 BCA compliance process

Anyone who constructs a building covered by the sound insulation provisions of the BCA should consider the issues outlined below:

- establish which approach outlined in Section 2.4 of this handbook is to be used to comply with the BCA
- design and document a system to comply with the BCA
- construct the building elements taking account of all relevant detailing and construction techniques
- inspect and document the construction works at suitable intervals during the construction period.

Field testing may be used to demonstrate BCA compliance. The work should be inspected and tested and any non-compliance rectified.

In some cases the builder may undertake all design, inspection and testing in-house. In other cases, the builder may form a design team and/or use external consultants.

2.4 Options to satisfy the BCA

The sound insulation provisions of the BCA can be satisfied by adopting one or more of the options outlined below:

Option 1 DTS Solution – Laboratory tested systems.
Option 2 Performance Solution – Verification Methods – Field test.
Option 3 Performance Solution – Expert Judgement.
Option 4 Performance Solution – Comparison with DTS Provisions.
Option 5 Performance Solution – Evidence of Suitability.

In adopting a solution, it is essential that appropriate documentation is produced and subsequently maintained for the installed systems.

The options for determining compliance are summarised as follows:

2.4.1 Option 1 DTS Solution – Laboratory tested systems

- Identify and use building element systems which have been tested in a laboratory and meet the nominated acoustic standards.
- Develop designs which reduce noise leakage through flanking paths.
- Build and install each building element so that its performance is not degraded, i.e. in accordance with the requirements of the tested system.
- Inspect during construction and identify non-compliance.
- Rectify any defects.
- Document compliance with the BCA.

This option uses only systems which have been verified by testing in an approved testing laboratory. The acceptable level of construction described in the DTS Provisions of the BCA generally fall under this category.

These building elements would be constructed and installed in the same manner as those systems tested in the laboratory or, as for the systems described in DTS Provisions of the BCA. The construction of these building elements should be inspected and evidence documented that the building elements are in accordance with the tested systems. The evidence can be in the form of a summary of building materials used on site, regular memorandum of inspections, overall list of defects, construction photographs of key elements and a summary of the rectification measures undertaken on the project.

2.4.2 Option 2 Performance Solution – Verification Methods – Field testing

- Identify building elements and systems that are likely to meet the requirements.
- Develop designs which reduce noise leakage through flanking paths.
- Build and install each element in accordance with the requirements.
- Inspect during construction and identify any non-compliance.
- Rectify any defects.
- Document compliance with recommended construction measures.

- Conduct a risk assessment to establish how many building elements are involved, which building elements are to be tested, and for which other building elements the test results are valid.
- Field test performance of building elements.

For this option, it is expected that only systems that are likely to comply when tested on site would be used. In this instance there should be some form of evidence of suitability, such as a test result or other documentation.

The building elements should be constructed as recommended including any additional detailing to limit flanking noise. Inspections would normally be conducted, defects rectified and documentation produced which demonstrate compliance with the construction requirements.

Testing is then conducted on a suitable number of building elements. Typically at least 10% of all wall systems should be tested. For some complicated designs the number may be 40% to 50%.

The documentation can be in the form of a summary of building materials used on site, regular memorandum of inspections, overall list of defects, construction photographs of key elements, a summary of the rectification measures undertaken on the project and a copy of the results of acoustic testing.

Acoustic certification is issued when all defects have been satisfactorily rectified.

2.4.3 Option 3 Performance Solution – Expert Judgement

- Identify building element systems.
- Develop designs which reduce noise leakage through flanking paths.
- Build and install each element in accordance with the requirements.
- Inspect during construction and identify any non-compliance.
- Rectify any defects.
- Document compliance with recommended construction measures.

This option uses only systems which in the opinion of an expert would meet the required performance scheduled in the BCA. The basis of the expert's judgement needs to be documented in order to allow traceability of the expert's decision-making process and provide evidence that the systems meet their predicted performance.

The building elements should be constructed as required. Inspections should be conducted, defects rectified and documentation produced which demonstrates compliance with the construction requirements.

2.4.4 Option 4 Performance Solution – Comparison with DTS Provisions

- Identify building element systems.
- Develop designs which reduce noise leakage through flanking paths.
- Build and install each element in accordance with requirements.
- Inspect during construction and identify any non-compliance.
- Rectify any defects.
- Document compliance with recommended construction measures.

This option uses only systems which, in the opinion of an expert would match the performance as required by the DTS Provisions. The ability of an expert to make their judgement needs to be documented. There needs to be traceability of the expert's decision-making process and evidence that the systems suitably meet or exceed the level required by the DTS Provisions.

The building elements would be constructed as required. Inspections would be conducted, defects rectified and documentation produced which demonstrates compliance with the construction requirements.

This approach could be used to consider treatments for services noise insulation and for impact rating of walls. An example would be to measure the noise intrusion level from waste pipes or other services adjoining a room and comparing these levels with the equivalent level from a system meeting the BCA DTS Provisions. The impact rating of walls is a more difficult undertaking as no test method is universally acceptable.

2.4.5 Option 5 Performance Solution - evidence of suitability

- Use building element systems deemed suitable under Part A5 of the BCA, depending on the building classification.
- Develop designs which reduce noise leakage through flanking paths.

- Build and install each element in accordance with requirements.
- Inspect during construction and identify any non-compliance.
- Rectify any defects.
- Document compliance with the required construction measures.

This option allows the use of building element systems where evidence has been provided under Part A5 of the BCA which deems that the building element system meets the relevant Performance Requirements or a DTS Provision. The evidence can be in a number of forms such as a:

- CodeMark or CodeMark Australia Certificate of Conformity.
- Certificate of Accreditation.
- certificate from a certification body
- report issued by an Accredited Testing Laboratory
- certificate or report from a professional engineer or other appropriately qualified person
- another form of documentary evidence, such as a Product Technical Statement.

Practitioners should consult the Evidence of Suitability requirements in Part A5 of the NCC as the forms of evidence listed vary between Volumes.

The building elements should be constructed as required. Inspections should be conducted, defects rectified and documentation produced which demonstrates compliance with the construction requirements.

3 Design practices

Good design practices should minimise the amount of noise entering a dwelling or unit from adjoining dwellings or units and also minimise the cost of construction.

Noise intrusion can be limited by considering a range of factors. A list of good and bad design practices is presented below. These are described in more detail in the remainder of this section.

The following outlines a series of items to consider during the design process that will assist in the management of risk during construction.

3.1 Good design practices

3.1.1 Strategy:

- ✓ Decide on a strategy and plan for the approach to be adopted for BCA compliance.
- ✓ Use wall, floor, ceiling, bulkhead and riser systems which have been tested and documented.

3.1.2 Planning:

- ✓ Plan quiet areas in a unit adjacent to quiet areas in adjoining units.
- ✓ Plan quiet areas in a unit away from services.
- ✓ Plan buffer areas between units where possible.
- ✓ Locate services away from sensitive areas in a unit.
- ✓ Consult the body corporate if intending to modify or renovate existing units.

3.1.3 Walls and floors:

- ✓ Allow for sufficient width for walls and sufficient depth for floor and ceilings in initial planning.
- ✓ Provide clear construction drawings detailing junctions of walls, ceilings and floors.
- ✓ Indicate where impact-rated wall systems are required.
- ✓ Design walls to be full height, to underside of soffit or roof above, where an acoustically rated ceiling is not used (refer to Figure 7).
- ✓ Choose wall systems which are simple to build and reliable.
- ✓ Design a break in the floor boards under the boundary walls of a unit.

- ✓ Develop alternative floor designs which are impact-rated and not reliant on carpet and underlay alone.
- ✓ Ensure that discontinuities in walls and floor/ceilings can be maintained.
- ✓ Use acoustic grade insulation in sound-rated walls and ceiling cavities.
- ✓ Design acoustic seals for joints to remain effective over the life of the building.

3.1.4 Penetrations:

- ✓ Design penetrations in acoustically-rated building elements, such as ceilings, floors, walls, bulkheads and risers, so as not to reduce the sound rating of the building element.
- ✓ Design acoustic seals at penetrations to last as long as the building design life.
- ✓ Minimise the incidence of penetrations in sound-rated walls and floors.
- ✓ Minimise the incidence of other flanking paths in the design.
- ✓ Design for the sealing of all gaps at building element perimeters and penetrations, including gaps behind skirting boards and cornices.

3.1.5 Building movement:

- ✓ Maintain acoustic ratings by using a design which allows for building movement, especially at penetrations and junctions.
- ✓ Design for a flexible acoustic seal between internal walls.
- ✓ Design for a flexible acoustic seal between common walls and the adjoining façade.
- ✓ Design for a flexible acoustic seal between walls and floors/ceilings.

3.1.6 Doors and windows:

- ✓ Use full perimeter acoustic seals on doors and sensitive windows.
- ✓ Allow for the adjustment and maintenance of acoustic seals on doors and windows.

3.1.7 Services:

- ✓ Design for sufficient noise isolation in common ventilation ducts and risers.
- ✓ Use flexible connectors on pipes to pumps.
- ✓ Reduce the number of bends and elbows in pipes and ducts.
- ✓ Reduce the flow velocity in pipes and ducts.
- ✓ Resiliently fix pipes and ducts to walls and structures.

- ✓ Use quieter pipe constructions to reduce noise generated by pipes.
- ✓ Design pipe treatment using acoustic wrapping where necessary.

3.2 Bad design practices

3.2.1 Walls and floors:

- ✗ Substituting materials in building elements without proper testing and documentation.
- ✗ Short circuiting bracing between separate stud systems (refer to Section 3.14).
- ✗ Fixing together discontinuous elements of a sound-rated wall or ceiling.
- ✗ Designing wall-mounted furniture to be fixed across wall discontinuities for support.
- ✗ Replacing carpet with acoustically non-compliant hard floor coverings.

3.2.2 Penetrations:

- ✗ Using non-sound rated downlights or other fittings in sound-rated ceilings.
- ✗ Installing return air grilles on sound-rated doors.
- ✗ Leaving untreated penetrations in sound-rated walls above ceilings.

3.2.3 Doors and windows:

- ✗ Locating windows and doors of a unit adjacent to those of the adjoining unit.
- ✗ Undercutting sound-rated doors.

3.2.4 Services:

- ✗ Providing insufficient space which causes pipes or lagging to contact ceilings, hangars, bulkheads or risers.
- ✗ Acoustically sealing around fire collars without regard for the fire rating.
- ✗ Fixing pipes or ducts to the neighbouring side of a common wall.
- ✗ Chasing pipes into common walls.
- ✗ Design air grilles into bulkheads which contain hydraulic services or ductwork.
- ✗ Design power outlets and light switches to be installed back-to-back.
- ✗ Design for non-rated (acoustic) power outlets and switches to be installed in sound-rated walls.

3.3 Building plan layout

It is good design practice to locate noise-sensitive rooms away from noisy areas where possible, both within each unit and also between adjoining units.

Noisy areas such as living rooms, kitchens, laundries and bathrooms should be grouped together possibly sharing common walls. Quiet areas such as studies and bedrooms should be grouped away from noisy areas (refer to Figures 1 and 2).

Locating wet areas above one another can result in significant cost savings in relation to sound insulation requirements, particularly where pipes penetrate the separating slab.

Buffer spaces can be set up on each side of common walls, for example garages, wardrobes, store rooms and closets.

Noisy areas external to a unit such as plantrooms, lift shafts, garbage chutes, spa baths, pools, gymnasiums, entertainment rooms and other communal areas or public areas should be located as far away as possible from noise-sensitive areas of a unit.

Figure 1 Example of layout planning - Good acoustic practice.

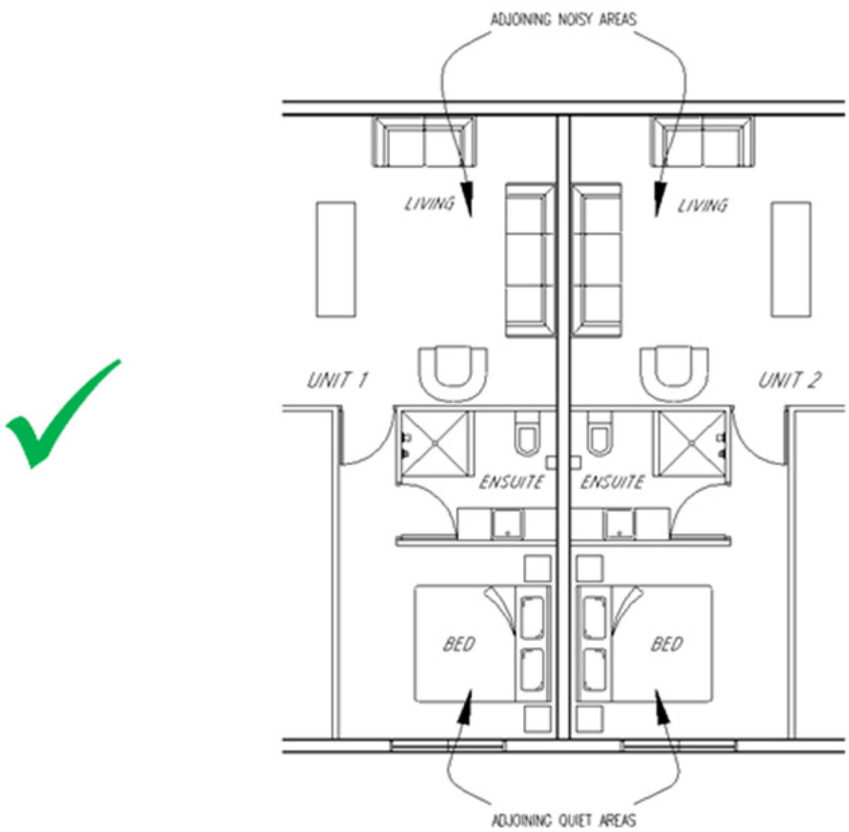
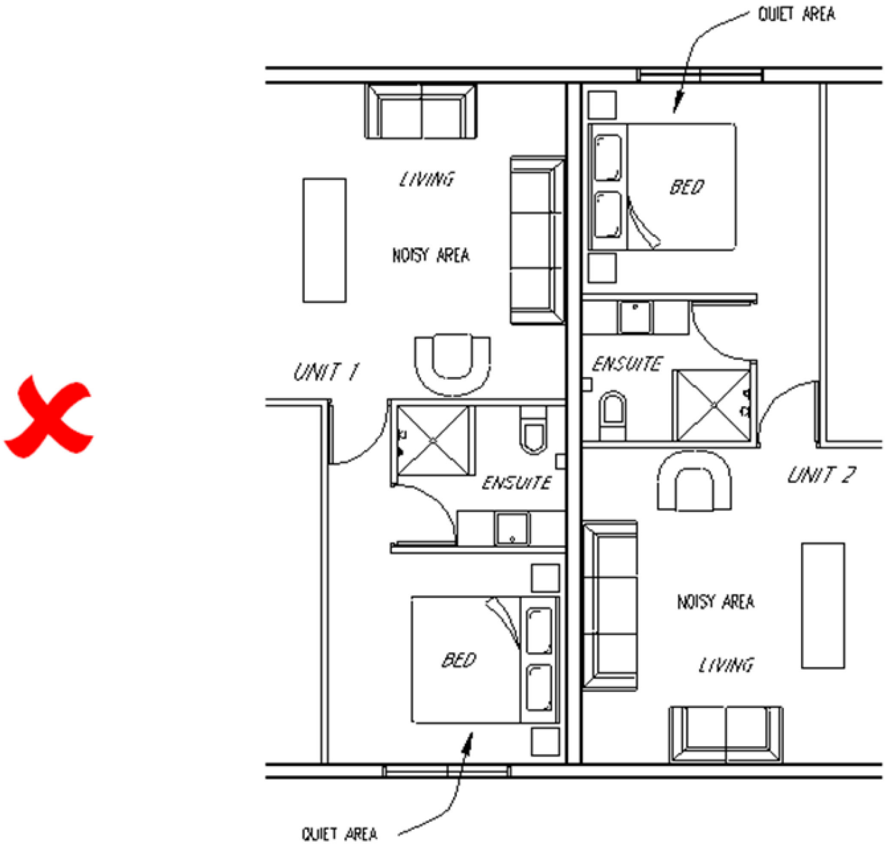


Figure 2 Example of layout planning - Bad acoustic practice



3.4 Buffer distance around doors & external windows

The distance between the doors of adjoining units should be maximised. This will limit potential flanking noise through the doors.

The distance between external windows of adjoining units should also be maximised. This will limit potential flanking noise through the windows especially where there is a common light well, shared courtyard or atrium (refer to Figures 3 and 4).

Figure 3 Example of layout planning - Good acoustic practice to minimise flanking via external glazing and entrance doors by maximising distance between windows and doors.

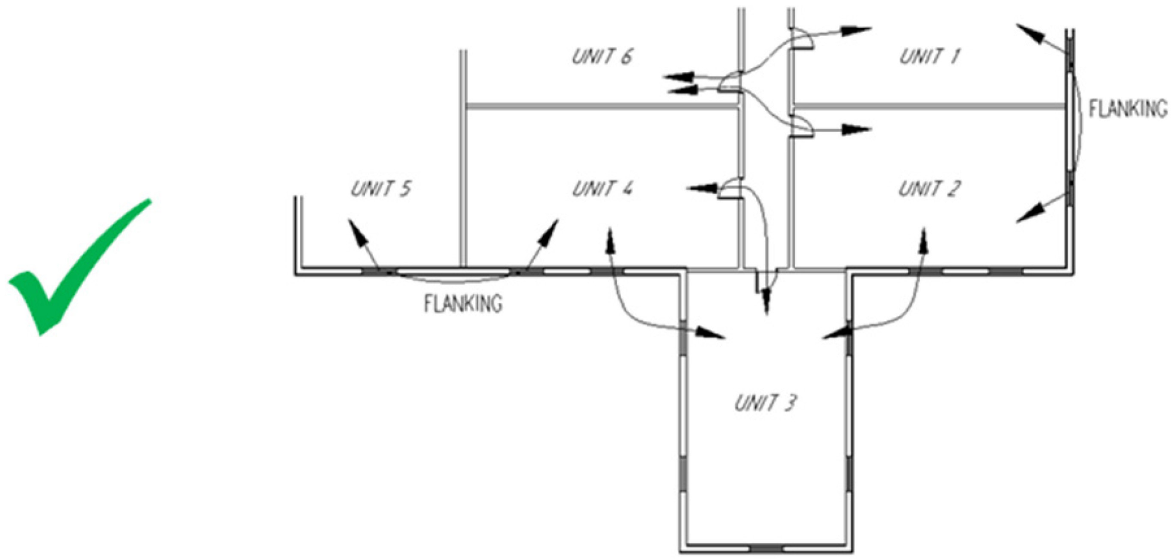
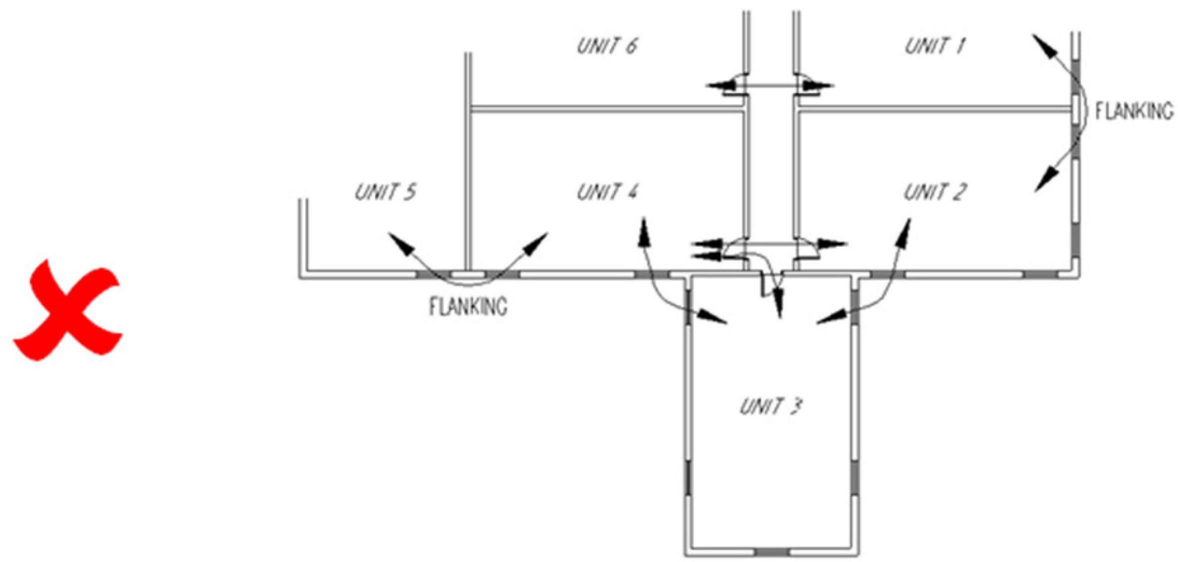


Figure 4 Example of layout planning - Bad acoustic practice to minimise flanking via external glazing and entrance doors, by not ensuring maximum distance between windows and doors.

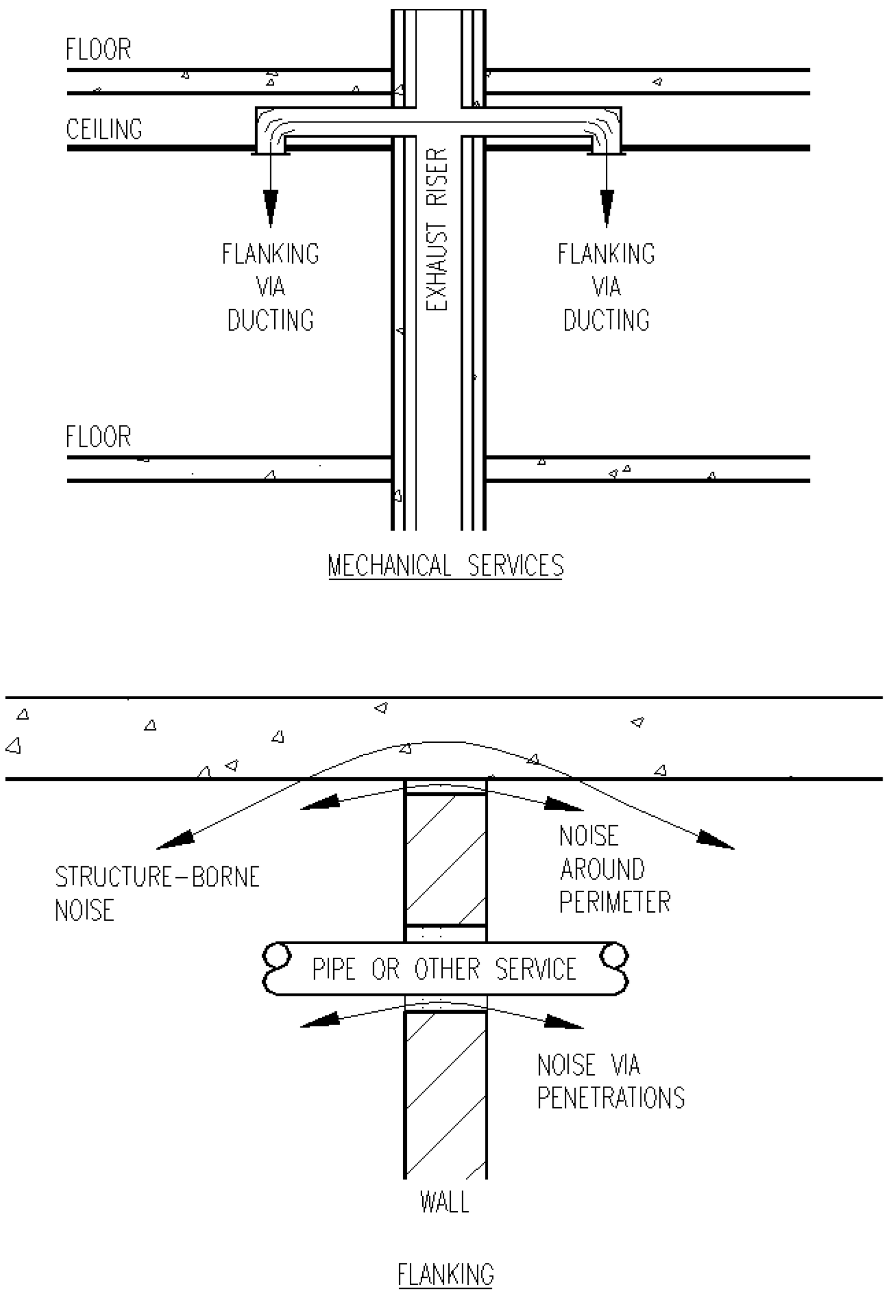


3.5 Avoidance of sound leakage

3.5.1 Flanking

Flanking reduces the effectiveness of acoustically rated building elements that separate spaces. Flanking should be minimised to ensure that the element performs to the desired level. Some flanking paths are presented in Figure 5.

Figure 5 Internal flanking paths



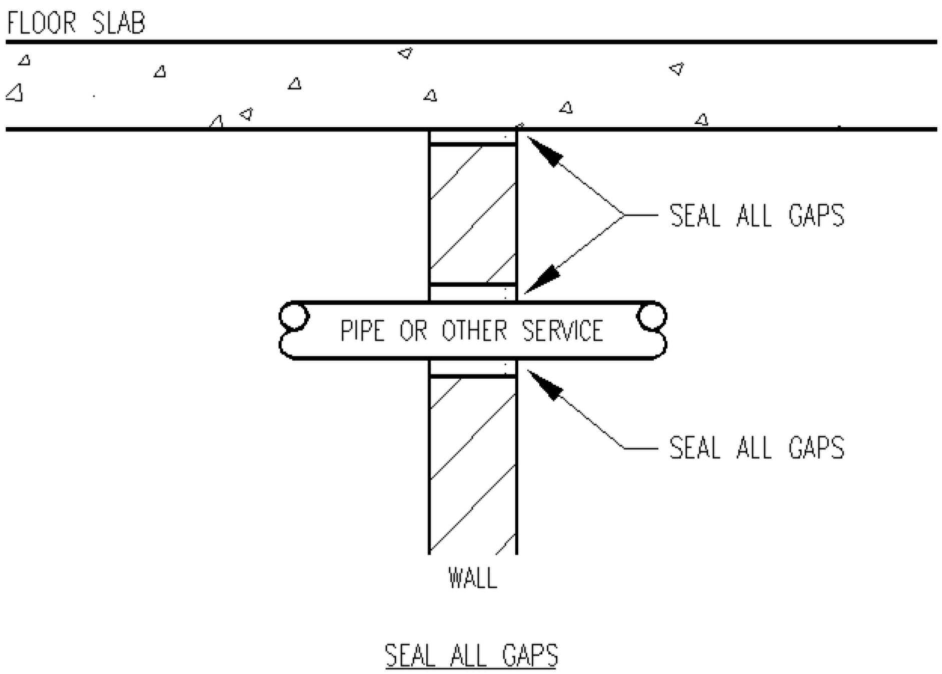
Typical problem flanking paths in units include:

- noise travelling through air conditioning ducting
- noise travelling through kitchen or toilet exhaust ducting
- noise passing through gaps and weaknesses around building elements
- structure-borne noise passing through perimeter building elements, such as floors, ceilings and façade walls which pass across a sound-rated wall
- noise passing through gaps and penetrations associated with building services penetrations
- noise travelling through lift shafts or garbage chutes.

3.5.2 Sealing of penetrations

The acoustic performance of a system is severely degraded by the presence of gaps. All gaps in acoustically rated walls and floors, especially around penetrations should be acoustically sealed to minimise flanking (refer to Figure 6).

Figure 6 Sealing of flanking paths



The method of sealing should reflect the environment where the penetration occurs. The seal normally has to remain effective over the life of the building. Sealing is best performed on both sides of the element. The sealing treatments are most effective where the penetrations are cut neatly and are not any larger than necessary.

To maintain suitable long-term performance an acoustic seal may need to be:

- fire-rated
- heat and temperature resistant
- weather proof
- remain flexible over the life of the building
- able to withstand movement
- resistant to chemicals.

3.5.3 Joints

Joints are a prime source of noise intrusion in buildings. Buildings have the potential to move over time and any settling of the building can translate into movement at the joints. Set plaster joints on concrete, or set mortar joints have the potential to crack with movement over time. The residual noise intrusion can be excessive through such joints. Accordingly, the joints should be properly designed to reduce flanking.

The sealant or mastic applied at joints should be suitably dense, sufficiently flexible and maintain this flexibility over time.

Where joints are sealed with mastic, it is not good practice to smear the mastic on in a thin layer. The depth of the mastic in the joint should be sufficient to provide the movement and strength needed while maintaining the acoustic rating of the construction.

Typically, the depth of mastic should be equal to or greater than the width of the joint. Suitable backing rods are also generally required.

The manufacturer’s installation instructions should be followed to ensure products work as designed.

3.6 Designing with building elements

It is good practice to use systems which have been laboratory tested and have been demonstrated to be BCA compliant.

Where a building material supplier is proposing specific building elements for the project, it is preferable to receive a valid test certificate on the system as well as a clear statement on the requirements and techniques for working with the particular system.

3.7 Walls

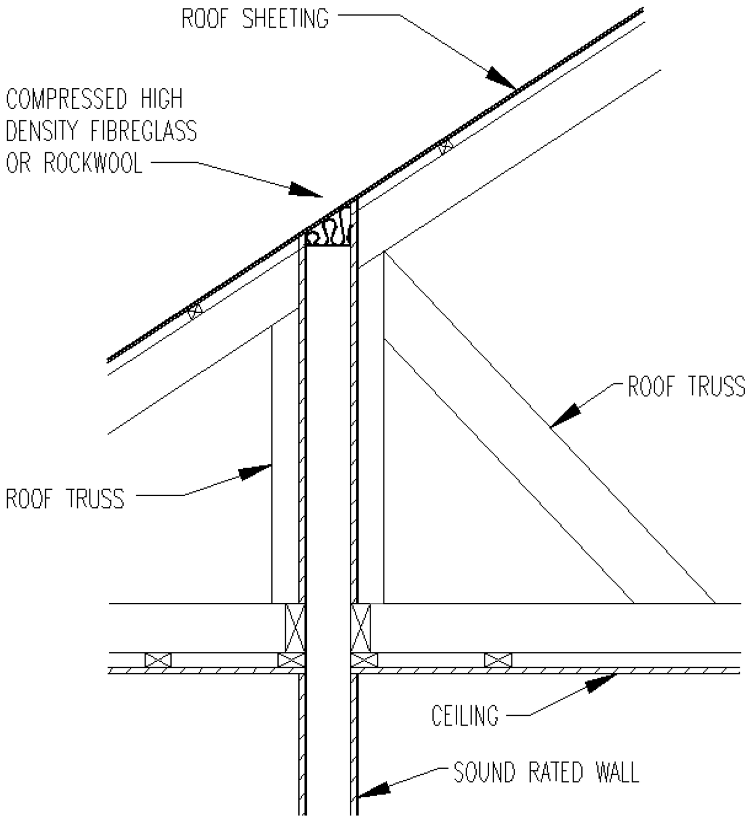
Wall design is principally concerned with ensuring high acoustic performance for minimal thickness, minimal weight and minimal cost. It is not easy to simultaneously meet all these conditions and therefore close attention to design is required.

The acoustic performance of wall systems is generally improved by substituting either thicker/heavier wall systems or substituting systems with larger cavities and moderate cladding thicknesses.

To save weight, some heavy single-leaf wall systems can be replaced by lightweight constructions using thinner leaves of material and insulation filled cavities.

To control noise transfer, it is good design practice to extend walls to full-height, from slab to soffit, or slab to roof (refer to Figure 7). Wall partitions should be selected which allow for a margin of safety in the construction to reduce the risk of non-compliance.

Figure 7 Sound-rated wall penetration to roof



There are additional factors which also should be considered in relation to walls.

- Reliability in the field – is it possible to easily reproduce the laboratory acoustic performance for a sound-rated wall?
- Walls which are impact-rated or discontinuous require more attention to detail.
- In the event that the acoustic performance of the wall fails, is there sufficient space to allow rectification and a further upgrade to the wall?
- For wall designs which rely on sound-rated ceilings, has detail been developed to control noise intrusion through ceiling penetrations such as downlights, mechanical ventilation grilles, fire service penetrations and ceiling speakers? (refer to Section 3.8)
- Buildability – is it possible to easily build the walls to the same standard as in the laboratory thus maintaining the acoustic rating? Simple systems will tend to be more reliable than complex systems.
- Has the wall been designed to comply with other BCA requirements such as fire or structural requirements?

3.8 Floors/ceilings

Some designs require both floors and ceilings to be sound-rated to meet the BCA provisions. Some floor designs require carpet and underlay to meet the BCA provisions. The following factors also need to be considered.

- For sound-rated ceilings, have details been developed to control noise intrusion through ceiling penetrations such as downlights, mechanical ventilation grilles, fire service penetrations and ceiling speakers? (refer to Section 3.12)
- Is the break at the boundary in the floor boards and/or joists sufficient to isolate horizontally adjacent units and control structure-borne noise intrusion from footsteps? (refer to Figure 8 & Figure 9)
- For design solutions for both carpet and hard floor coverings (refer to Section 3.16).

Figure 8 Floor lateral vibration isolation - Good design practice

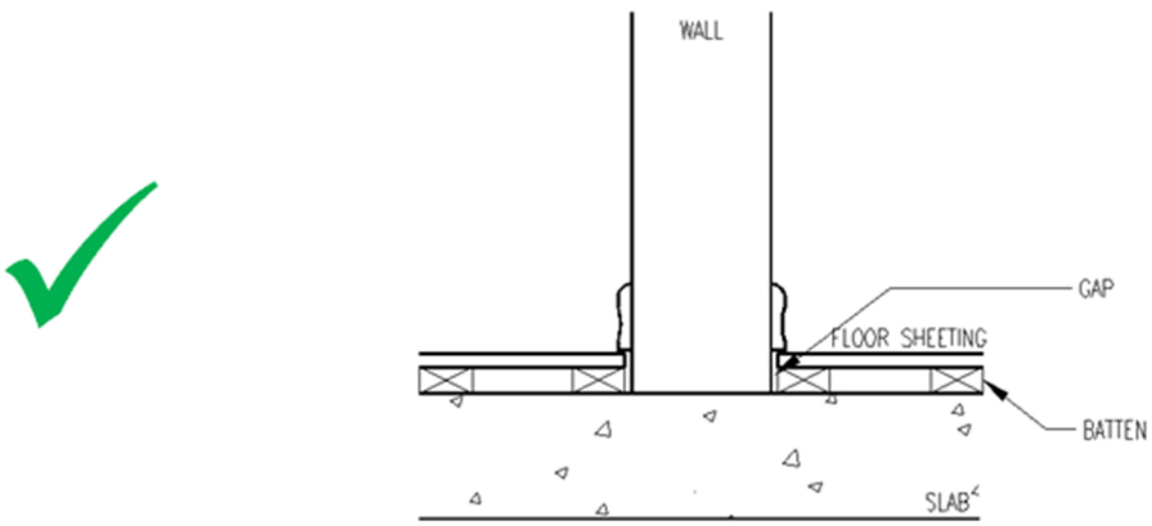
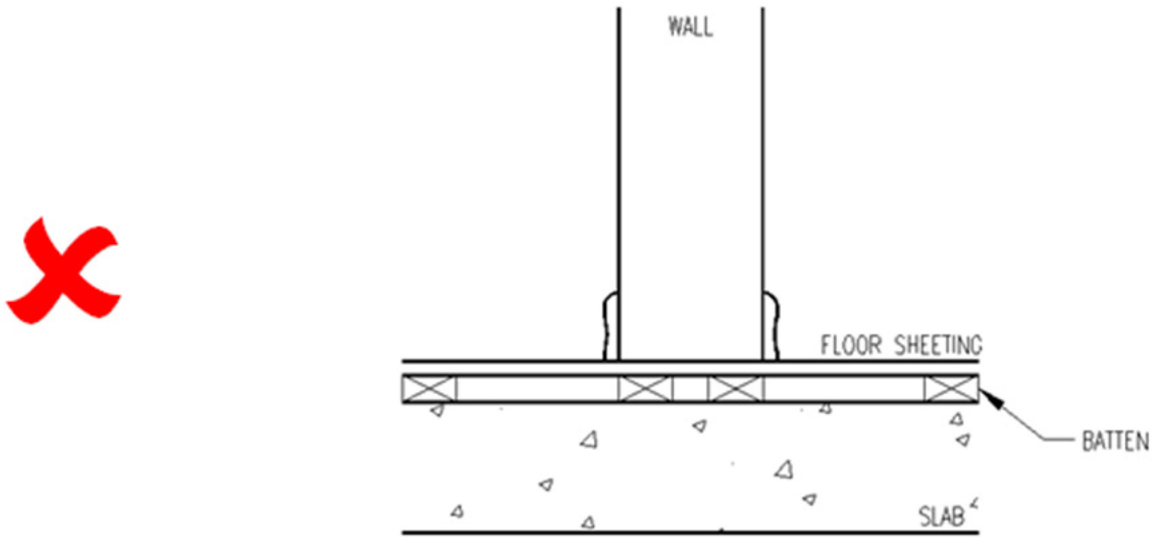


Figure 9 Floor lateral vibration isolation - Bad design practice



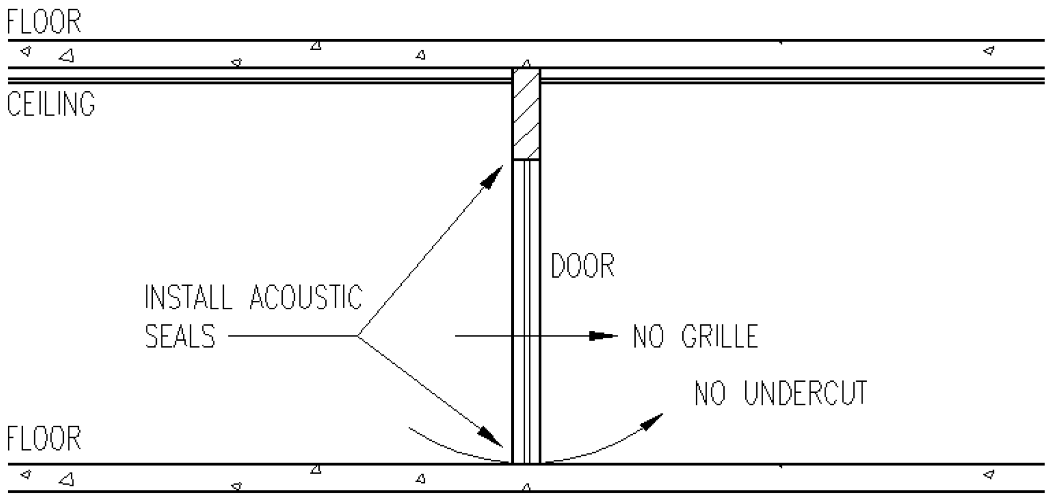
3.9 Doors

Doors are an acoustic weak link and invariably reduce the acoustic performance of walls. To counter this weakness, the BCA requires doors from corridors to units to be sound-rated.

Doors may be either thick solid-core doors or proprietary systems. Most sound-rated doors require full acoustic seals around the head, jamb and foot to limit flanking. In addition, the following points should be addressed:

- For return air flow, it is preferable to use transfer ducts with fire dampers rather than undercut sound-rated doors.
- Air grilles should not be installed in sound-rated doors (refer to Figure 10).

Figure 10 Treatment around sound-rated doors



- Acoustic seals do not provide suitable performance if they are not properly adjusted. Seals should be selected based on their performance, simplicity of use, and they should be low maintenance and durable.
- Maximise the buffer distance between entrance doors to limit noise flanking via the doors (refer to Figure 3).
- Doors may be installed in sound-rated walls, for example between hotel or resort guestrooms. The acoustic performance of the wall can be degraded where doors are installed. Careful design is required to maintain the sound-rating of the wall/door combination.
- The performance of an acoustic seal can be limited if it seals onto carpet or onto non-smooth materials such as tiles or pavers.
- Consideration should also be given for other seal performance requirements such as fire resistance, smoke resistance, chemical resistance, weather resistance, dust resistance and vermin proofing.

3.10 Façade

Façade walls can reduce the performance of sound-rated common walls. They can produce a flanking path for noise transfer as shown in Figure 11 & Figure 12. Detailed design measures and the use of sound absorption materials may be required to overcome this flanking.

Figure 11 External wall flanking control – Good design practice

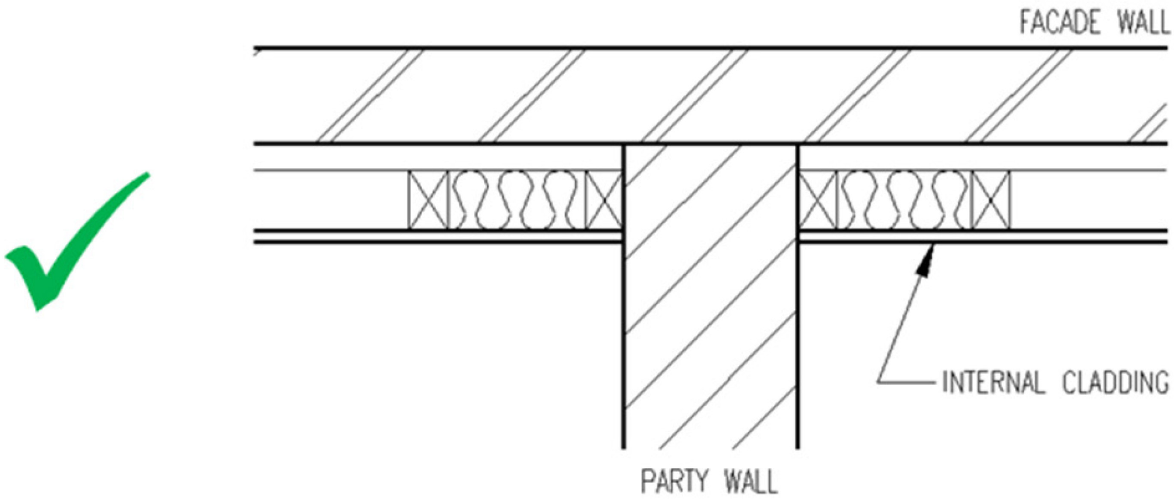
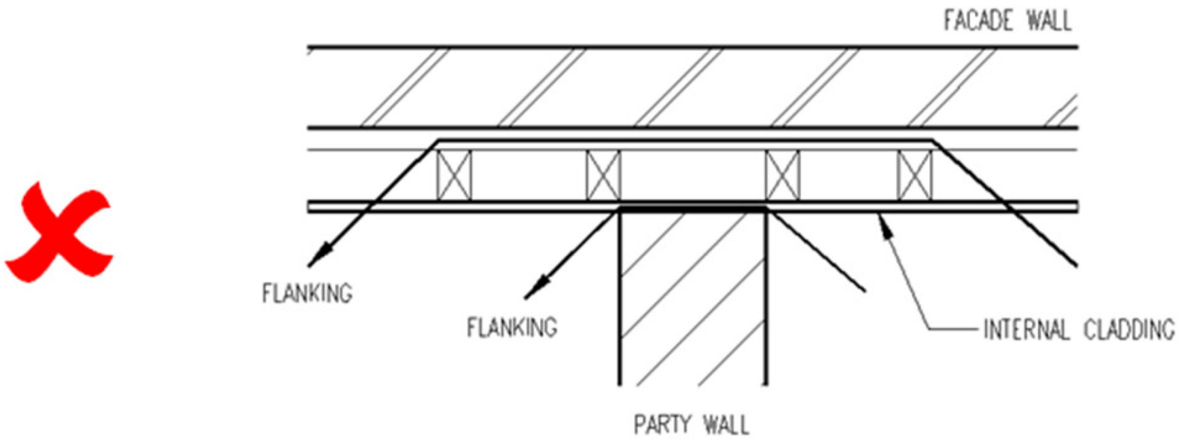


Figure 12 External wall flanking control – Bad design practice



The design measures may need to be applied to the entire façade wall at the time of construction so as to allow suitable flexibility for the location of common walls. For instance, common walls should align at structural columns in the façade where possible and should not be bridged by common air supply grilles or by windows in the façade.

3.11 Windows

Façade glazing and glazing installed in walls of units can reduce the acoustic performance of the sound-rated common walls. They can produce a flanking path for noise transfer as shown in Figure 4. Like the doors in Section 3.9 above, glazing requires careful design to limit noise transfer. Refer also to the façade design in Section 3.10 above.

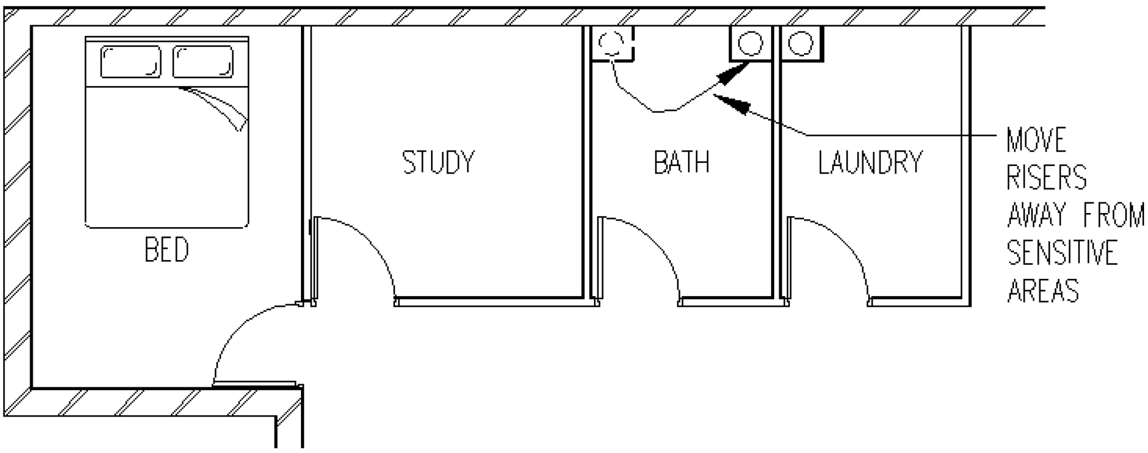
3.12 Treatment of services

Historically, noise generated by building services and flanking around building services have been significant problems. Building services can generate noise via airborne or structure-borne paths or both. The main issues are summarised below.

3.12.1 General design principals

- Flexible connectors should be installed for pipes and ducts to limit structure-borne noise transfer.
- Fixing of plumbing and ducting should be via resilient mounts.
- Mechanical and hydraulic services should be located away from sensitive areas within the unit (refer to Figure 13).
- Services such as power outlets, light switches, plumbing pipes and fittings, and ducts should preferably not be fixed to common walls.
- Services such as plumbing pipes and fittings should not be chased into common walls.

Figure 13 Location of services



3.12.2 Hydraulic services

- Where a sound-rated building element is required to isolate noise from pipes, a lighter building element could be constructed if a suitable pipe lagging is also incorporated and sufficient space is retained around the pipes to ensure there is no contact with ceilings, risers or supports.

- Where pipe lagging is required to isolate noise, sufficient space should be retained around the pipe and lagging to ensure there is no contact with ceilings, ceiling supports or risers.
- Waste and stormwater can generate noise from turbulent flow within the pipes. Pipe suppliers can supply quiet proprietary pipe systems which reduce noise. Care should also be exercised as additional treatment may still be required to meet the BCA provisions.
- Waste pipes and stormwater pipes should pass above non-habitable areas where possible.
- Sharp bends, elbows and take off points exacerbate pipe noise, so should be minimised.
- Reducing water flow velocity and pressure within pipes to the rated specification can reduce noise.
- Pumps and other plant should have flexible couplings to the services pipes. This is required for pumps in F5.7 ‘Sound isolation of pumps’ in Volume One.
- Avoid the installation of hydraulic services in plenums containing air grilles.
- Supply pipes should be resiliently fixed to wall structures and not fixed to the neighbour’s side of a cavity wall system.
- Pipes should not be lagged at the fire collar.

3.12.3 Mechanical services

- Where a sound-rated building element is required to isolate noise from ducts, a lighter building element can be constructed where suitable duct lagging is also incorporated. Sufficient space should be retained around the duct to ensure there is no contact with ceilings, risers or supports.
- Design smooth duct runs and transitions and large radius bends to maintain smooth airflow and reduce the likelihood of generating noise.
- Lower air velocities generate less noise.
- Bends with turning vanes limit turbulent noise generation.
- Doors with undercuts allow flanking noise. Such doors would not meet the BCA provisions. Fit acoustic seals onto doors and design return air paths via acoustically treated transfer ducts.
- Where ducts penetrate sound-rated walls, acoustic treatment is required around the ducts, especially between the duct and the slab soffit above.

3.12.4 Electrical services

- Sound barriers should be provided to control noise from cooling fans, transformers and other noise producing electrical equipment in electrical plantrooms and from the regular operation, servicing and testing of stand-by generators.
- Sound-rated electrical outlets and switches should be used, or outlets and switches should be surface mounted on sound-rated walls.
- Note also the BCA also requires electrical outlets in a wall to be offset.

3.12.5 Lift services

- To limit noise intrusion from lift shafts, it may be useful to isolate the lift rails from the surrounding structure.
- Control air-rush whistle noise through doors.
- Slower travelling cars make less noise than faster travelling cars.
- Minimise the call signal volume as much as practical.

3.12.6 Fire services

- Where sprinklers are located in sound-rated ceilings, the penetrations are to be treated to control noise transfer.
- Gaps and penetrations around fire collars need to be acoustically sealed while maintaining their fire rating.

3.12.7 Penetrations

- Penetrations in sound-rated ceilings, for example downlights and other recessed lights, air grilles, fire services sprinklers and speakers, need to be acoustically treated to maintain the overall acoustic rating of the ceiling.

3.13 Refurbishing existing buildings

Refurbishments have the potential to severely compromise the acoustic ratings within a building. Furthermore, most buildings undergoing refurbishment were built at a time when lower acoustic standards prevailed in previous regulatory regimes.

Great care must be exercised during the building renovation process to ensure that the new building work complies with the current BCA. To this end, the following areas may require extra detailing and attention.

- Wall constructions (refer to Section 3.7).

- Limiting flanking paths around the walls, ceilings and floors (refer to Figure 5).
- The treatment applied to seal gaps should be sufficiently flexible to allow for building movement.
- Controlling noise and vibration travelling through timber floorboards, joists, beams, external walls or ceilings (refer to Figure 8).
- The avoidance of fire hazards from the acoustic treatment, for example by covering electrical wiring or lighting with acoustic insulation.
- Gaps opening up over time from building movement. This limits the sound isolation and may lead to non-compliance with the BCA.
- Robust acoustic design to allow for site conditions where surfaces may not be straight, true or square. This is especially an issue around joints, walls, floors, ceiling junctions and penetrations.
- Adding mass to building elements where upgrading acoustic ratings without exceeding maximum acceptable structural loading.
- Variations in the building fitout driven by unexpected site conditions which may require revised designs.
- Where renovation is performed, for example in a unit, it is advisable to ensure that sufficient detail is readily available to the future occupants via the body corporate for any floor, ceiling and wall modifications made (refer to Section 3.14).

3.14 Floor, ceiling and wall modifications

3.14.1 Floor design

Some designs require floors to be sound-rated to meet the BCA provisions. Carpet may only be one option to meet the impact rating on floors. Alternative hard-floor systems also need to be considered. This is the case whether the hard floor covering is installed as part of the initial fitout or as part of a future occupant upgrade. The design for both the hard floor covering and carpet options should allow for:

- sufficient ceiling height being maintained in all rooms
- an excessively high step is not formed between carpet and hard floor covering systems within the unit.

Where carpet is replaced during renovation works by hard floor finishes, the impact isolation performance of the floor will invariably reduce. This reduction can be as high as 25 to 30 dB. This level of reduction is difficult to recover and the use of resiliently suspended ceilings becomes an important part of any design solution.

After the installation of resilient ceilings and floors, a BCA compliant floor/ceiling system may still be 15 to 20 dB lower than the original carpet design. It is not unusual for complaints to be registered by the neighbour in the unit underneath in this situation.

3.14.2 Ceiling design

Where carpet is installed on the floor above a ceiling to comply with the floor impact requirements, consideration should be given to the potential of occupants to upgrade their own carpets to hard floor coverings.

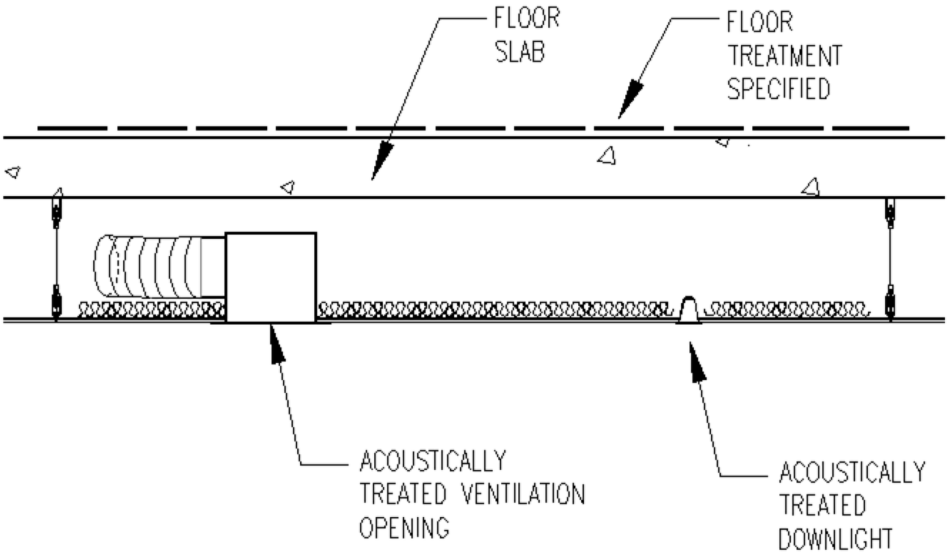
The replacement of carpet with hard floor coverings in the unit or dwelling above can cause a reduction in acoustic performance and this may require an acoustically-rated ceiling to be installed underneath. The ceiling would need to be installed at the time of building construction as there is no guarantee of access to the unit or dwelling underneath to retrofit later.

Penetrations in sound-rated ceilings which require acoustic detail to be developed include:

- downlights
- mechanical ventilation
- air conditioning
- ceiling speakers
- fire sprinklers.

This detail should be made available to the occupants as part of the body corporate approval for these works. The combined ceiling and floor treatments should be covered (refer to Figure 14).

Figure 14 Sound-rated treatments for ceilings and floors

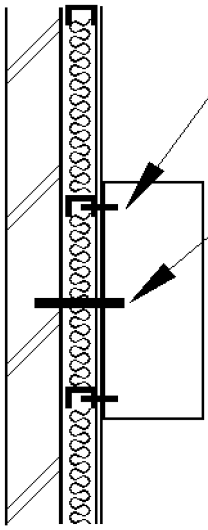


3.14.3 Wall design

Sufficient space should be provided to allow construction of suitable sound-rated walls.

Wall furniture shouldn't be fixed so that its supports bridge across vibration isolation elements in walls. This is particularly the case for fixing of cupboards, toilet bowls, clothes dryers and other appliances to drywall cladding or its associated stud work rather than to any free-standing masonry or the separate studs forming the discontinuous wall behind the cladding (refer to Figure 15).

Figure 15 Mounting of wall furniture



3.15 Substitution of materials

The sound insulation performance of modern, high-performance building elements is particularly sensitive to the materials used. Extensive testing by product suppliers of different elements of the systems has established the most efficient manner of meeting the nominated performance standards.

Substitution of materials should be avoided unless it has been demonstrated that the new material will not degrade the overall building element insulation performance. Any substitution can reduce the level of sound insulation and potentially jeopardise compliance with the BCA. Accordingly, substitutions should only be considered based on expert advice, where testing demonstrates the residual performance is acceptable, and where it is documented with the necessary approval. This applies to all aspects of the design, especially to cavity insulation materials, the cladding or masonry products to be used in the wall, vibration isolation products for resilient floor, wall and ceiling systems and to acoustic sealants.

3.16 Improving sound insulation of building elements

3.16.1 Additional material

The sound insulation performance of building elements can be improved by:

- increasing the mass of the material
- the use of additional skins of material, typically with a cavity
- increasing the depth of cavities
- the use of limp materials or materials with low stiffness
- the addition of damping, especially to thin stiff elements in a partition system.

3.16.2 Sound absorption

The sound insulation of a lightweight building element can be improved by introducing sound absorption into cavities. Where absorption is already present, some marginal improvements can be achieved by upgrading the sound absorption material.

The sound absorption performance of a material can be quantified by its noise reduction coefficient (NRC). Different materials such as glass wool, rock wool, polyester fibre, natural wool or cellulose fibre are sound absorptive. The sound absorption performance can be marginally improved by:

- using thinner fibres within a material
- increasing the density of, and hence number of fibres within a given material
- increasing the thickness of the absorbing material itself.

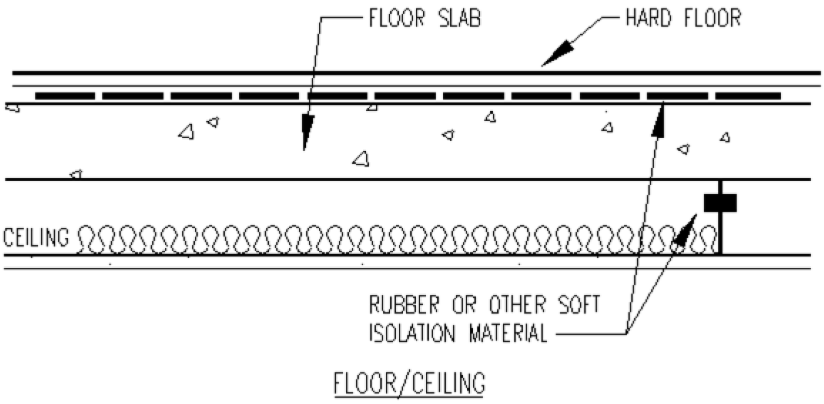
3.17 Structure-borne noise insulation

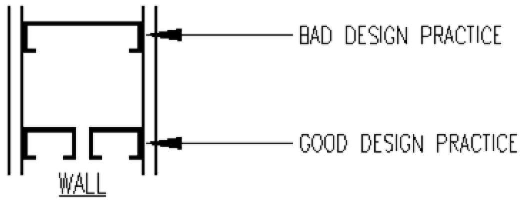
The amount of structure-borne noise can be reduced by increasing the vibration isolation in a system. This can be done by:

- using a suitably soft connecting material such as rubber, neoprene or isolation springs between the elements within a building element
- designing and installing a break in continuity of a panel, for example using double studs (not touching) instead of large single studs (refer to Figure 16)
- increasing the size of the air gap or cavity between the panels

- introducing vibration isolated floors to adjacent rooms located on a common slab.

Figure 16 Vibration isolation treatments





3.18 Pipe lagging

The amount of pipe noise can be reduced by using lightweight barriers such as plasterboard linings and sound insulation for both risers and bulkheads, along with acoustic lagging of pipes. Effective acoustic lagging is characterised by the following:

- uses a heavy barrier such as loaded vinyl, isolated from the pipe with foam rubber or fibreglass
- extends gap-free along the full length of a pipe
- the lagging and pipe do not contact ceilings, walls or supports
- the pipe mounts and supports do not contact the surrounding bulkheads or risers.

Care must be exercised with lagging to make sure that the performance of any fire collar, and the like, on the pipe is not impeded by the lagging. In all cases refer to the manufacturer's specific recommendations.

Refer also to Section 3.12 for additional advice regarding hydraulic services noise control.

4 Construction

The following good practice tips for construction should be applied during the building phase.

4.1 General

- When using proprietary building elements, the specific installation instructions from suppliers should be accurately followed.
- No substitutions should be permitted which have not been thoroughly documented and approved by an acoustic consultant, manufacturer, supplier or testing authority.
- All building element systems should be constructed and installed in accordance with manufacturing requirements.
- Design drawings should be followed.
- Where clashes occur which have not been documented, designers should be consulted.
- Thorough inspections should be conducted and documented during construction.

4.2 Windows and doors

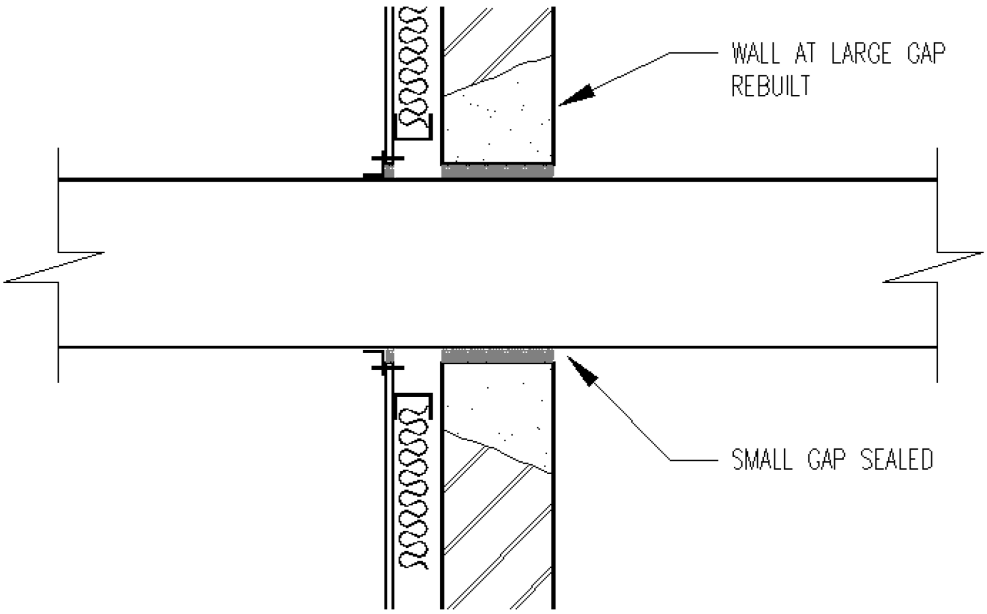
- Seals should not be removed from sound-rated doors or windows.
- Acoustic seals on all sound-rated doors should be properly adjusted and operational.

4.3 Penetrations and gaps

- There should be no residual gaps around full-height walls.
- Joints at wall and floor perimeters should be sealed and airtight, using approved mastic.
- The depth of mastic in joints should be equal to or greater than the depth of the joint.
- Joints in dissimilar materials may open up if there is building movement. It is important that the acoustic seal in joints will accommodate building movement.
- Gaps around all penetrations in sound-rated walls, floors and ceilings should be treated and sealed to maintain acoustic ratings. This includes around bundles of cables as well as around and above ducts installed close to a slab soffit overhead.
- All penetrations in sound-rated building elements should be neatly cut or drilled. Avoid excessively sized penetrations.

- The wall/floor around any large penetration should be rebuilt with the same material. Small residual gaps at penetrations can be sealed with a suitable mastic (refer to Figure 17).
- Sealing should be effective, resilient, resistant to the surrounding environment and designed to last for the life of the building.
- It is not good practice to install insulation in small gaps over wide elements after installation. The insulation should be planned and applied prior to installation.
- The normal tolerance in building construction should be considered when installing penetrations and at wall/floor junctions. Revised detailing may be needed where residual gaps are too large to allow effective sealing with mastic.
- It is good practice to cut sizes of holes to suit. It is not advisable to knock large holes into walls by using a sledge hammer or other similar method.

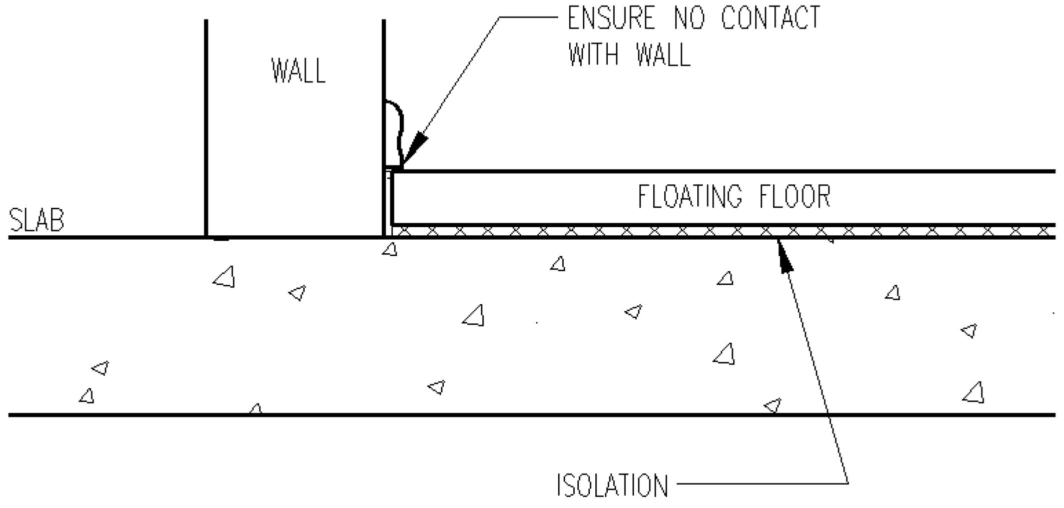
Figure 17 Treatment of gaps around penetrations



4.4 Floors/ceilings

- It should be ensured that the resilient rubber underlay used for isolated floors is not 'bridged' or short circuited by nails and screws connecting the floor to the slab underneath. These penetrate the rubber underlay and diminish its performance.
- Isolated floors should not be installed in contact with side walls. Isolation is also important between the floor and side wall (refer to Figure 18).
- It is not good practice to bridge across breaks or vibration isolation joints in floor and ceiling construction.
- Any penetrations in a sound-rated ceiling should be acoustically treated.

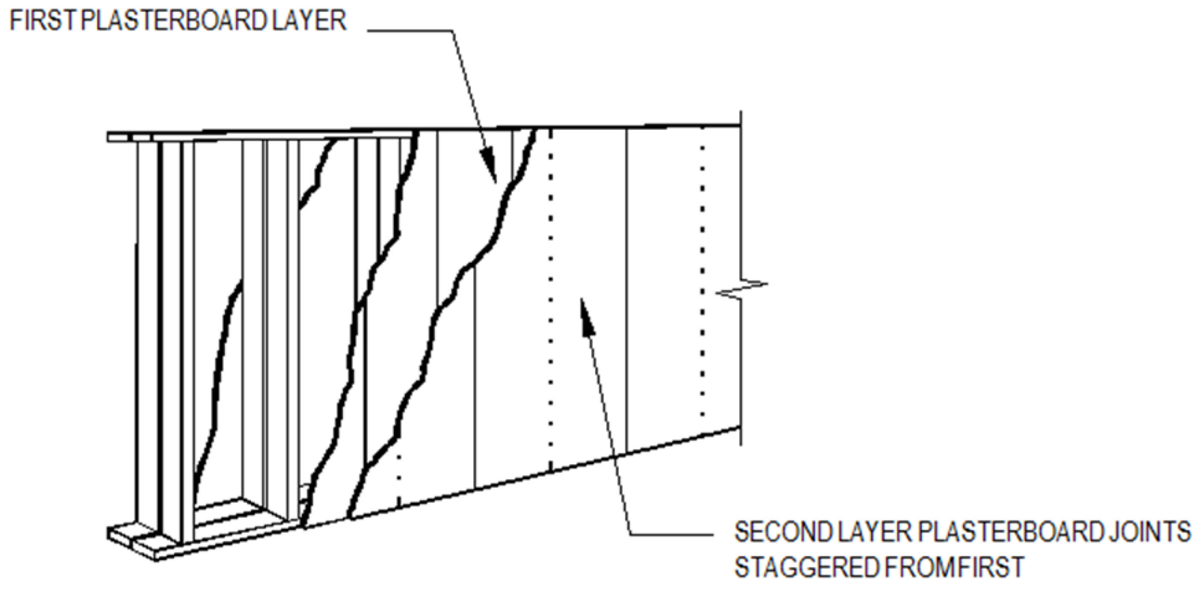
Figure 18 Treatment around the perimeter of isolated floors



4.5 Sheeted walls

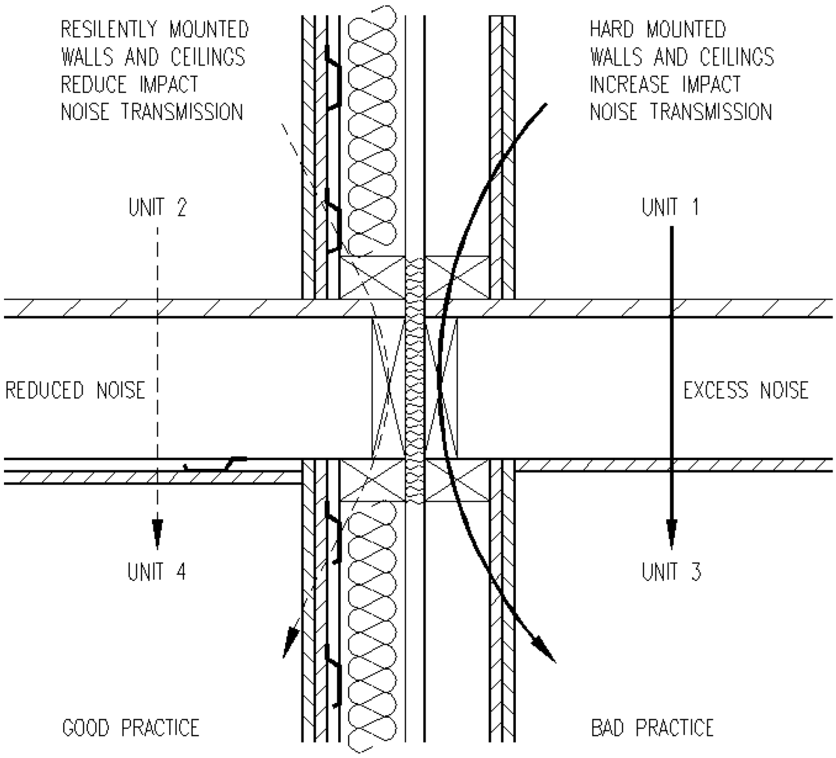
- Joints in sheeting systems, including plasterboard systems, should be staggered and, where multiple layers of material are used on walls, the joints must not overlap (refer to Figure 19).

Figure 19 Optimum plasterboard sheeting configuration



- Full height walls should not stop short of the slab soffit or roof above.
- There should be no residual gaps around full-height sound-rated walls, especially around roof structure such as rafters and purlins (refer to Figure 7).
- Any discontinuity in isolated walls should not be ‘bridged’ or short circuited by nails or screws.
- Any discontinuity in isolated walls should not be ‘bridged’ or short circuited by noggins, battens or packers.
- Any discontinuity in isolated walls should not be ‘bridged’ or short circuited by joists or floor boards on the floor supporting the wall (refer to Figure 8 & Figure 9
- Building debris or rubbish should not be left in wall or ceiling cavities. This material can span the discontinuity causing bridging or short circuiting.
- When installing sanitary fixtures onto walls, noggins which span across the discontinuous studs on both sides of the wall should not be installed.
- Cupboards, wall furniture, appliances and toilet cisterns should be mounted onto the cladding/supports of the front wall only.
- In timber construction, it is good practice to install walls and ceilings on isolation mounts to improve impact isolation between floors (refer to Figure 20).
- Insulation should be evenly spaced throughout the entire cavity where needed.

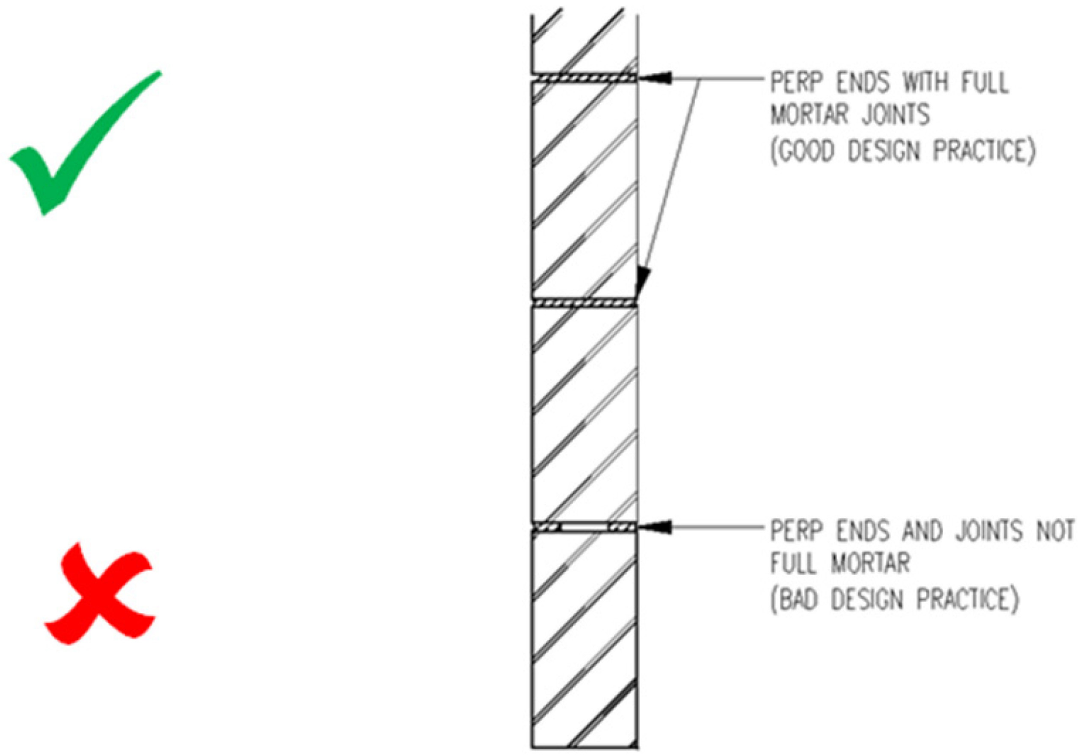
Figure 20 Wall and ceiling isolation in timber construction



4.6 Masonry walls

- Joints in sheeting in dry wall/masonry combination systems should be staggered and, where multiple layers of material are used on walls, the joints should not overlap.
- Full height walls should not stop short of the slab soffit or roof above.
- There should be no residual gaps around full-height sound-rated walls, especially around roof structure such as rafters and purlins (refer to Figure 7).
- Discontinuity in isolated walls should not be ‘bridged’ or short circuited by noggins, battens or packers of plaster linings.
- There should be no building debris or rubbish left in wall or ceiling cavities. This material can span the discontinuity causing bridging or short circuiting.
- Cupboards, wall furniture, appliances and toilet cisterns should be mounted onto the cladding/supports of the front wall only. Wall elements should not be supported behind a wall discontinuity (refer to Figure 16).
- Services should not be chased into masonry or concrete walls.
- Full-mortar joints should be used where a sound-rated masonry wall system is used. Special care is required at perpends to ensure full-mortar joints (refer to Figure 21).
- Insulation should be evenly spaced throughout the entire cavity where needed.

Figure 21 Treatment of joints in masonry walls



Note: Perp = Perpendicular

2.1 Services

- Waste pipes, water supply pipes, stormwater pipes and ductwork in ceiling cavities and risers should be acoustically treated. Alternatively, acoustically treat the ceilings and riser walls themselves as well as any penetrations in these elements.
- Installation of pipe/duct lagging should be gap-free and in strict accordance with the manufacturer's requirements.
- Electrical wiring or lighting should not be covered with acoustic blankets if not designed to be covered.
- Flexible connectors in pipes should be operational and not "bridged."
- Unnecessary bends and elbows in pipes and ducts should be avoided.
- Resilient fixings of pipes and ducts to party-walls should be used.
- Pipes and ducts should only be attached to the side of the wall to which the services belong. It is not good practice to bridge across wall discontinuities.

5 Further reading

5.1 Australian & International Standards

The following Australian & International Standards may be applicable when measuring the acoustic performance of building elements.

- AS 1045 - 1988[2]: "Acoustics - Measurement of sound absorption in a reverberation room".
- AS 1191 - 2002: "Acoustics – Method for laboratory measurement of airborne sound transmission loss of building partitions".
- AS 2253 - 1979[3]: "Methods for field measurement of the reduction of airborne sound transmission in buildings". This standard has been superseded by AS ISO 140.4:2006.
- AS/NZS 1276 - 1999[4]: "Rating of sound insulation in buildings and of building elements – Part 1 – Airborne sound insulation.
- AS/NZS ISO 717.1 - 2004: "Acoustics - Rating of sound insulation in buildings and of building elements - Airborne sound insulation"
- AS ISO 140.4 – 2006: "Acoustics – Measurement of sound insulation in buildings and of building elements – Part 4 – Field measurements of airborne sound insulation between rooms".
- AS ISO 140.6 – 2006: "Acoustics – Measurement of sound insulation in buildings and of building elements – Part 6 – Laboratory measurements of impact sound insulation of floors."
- ISO 717.2 – 2014: "Acoustics – Rating of sound insulation in buildings and of building elements – Part 2 – Impact sound insulation".

5.2 Other sources

5.2.1 Useful text books

"Engineering Noise Control" by Bies & Hansen
"Noise and Vibration Control" by Beranek
"Detailing for Acoustics" by Lord & Templeton

[2] Available superseded
[3] Available superseded
[4] Available superseded

5.2.2 Associations and Professional Bodies

The following organisations (listed alphabetically) can provide additional information on acoustic issues related to building construction:

Association of Australian Acoustical Consultants	aaac.org.au
Association of Wall and Ceiling Industries – Aus & NZ	awci.org.au
Australian Acoustical Society	acoustics.org.au
Australian Institute of Refrigeration, Air Conditioning & Heating	airah.org.au
Australian Glass and Window Association	agwa.com.au
Cement, Concrete and Aggregate Australia	ccaa.com.au
Concrete and Masonry Association of Australia	cmaa.com.au
Wood Solutions	woodsolutions.com.au

APPENDICES

Appendix A Compliance with the NCC

A.1 Responsibilities for regulation of building and plumbing in Australia

Under the Australian Constitution, state and territory governments are responsible for regulation of building, plumbing and development / planning in their respective State or Territory.

The NCC is an initiative of the Council of Australian Governments and is produced and maintained by the ABCB on behalf of the Australian Government and each state and territory government. The NCC provides a uniform set of technical provisions for the design and construction of buildings and other structures, and plumbing and drainage systems throughout Australia. It allows for variations in climate and geological or geographic conditions.

The NCC is given legal effect by building and plumbing regulatory legislation in each state and territory. This legislation consists of an Act of Parliament and subordinate legislation (e.g. Building Regulations) which empowers the regulation of certain aspects of buildings and structures, and contains the administrative provisions necessary to give effect to the legislation.

Each state's and territory's legislation adopts the NCC subject to the variation or deletion of some of its provisions, or the addition of extra provisions. These variations, deletions and additions are generally signposted within the relevant section of the NCC, and located within appendices to the NCC. Notwithstanding this, any provision of the NCC may be overridden by, or subject to, State or Territory legislation. The NCC must therefore be read in conjunction with that legislation.

A.2 Demonstrating compliance with the NCC

Compliance with the NCC is achieved by complying with the Governing Requirements of the NCC and relevant Performance Requirements.

The Governing Requirements are a set of governing rules outlining how the NCC must be used and the process that must be followed.

The Performance Requirements prescribe the minimum necessary requirements for buildings, building elements, and plumbing and drainage systems. They must be met to demonstrate compliance with the NCC.

Three options are available to demonstrate compliance with the Performance Requirements:

- a Performance Solution
- a DTS Solution, or
- a combination of a Performance Solution and a DTS Solution.

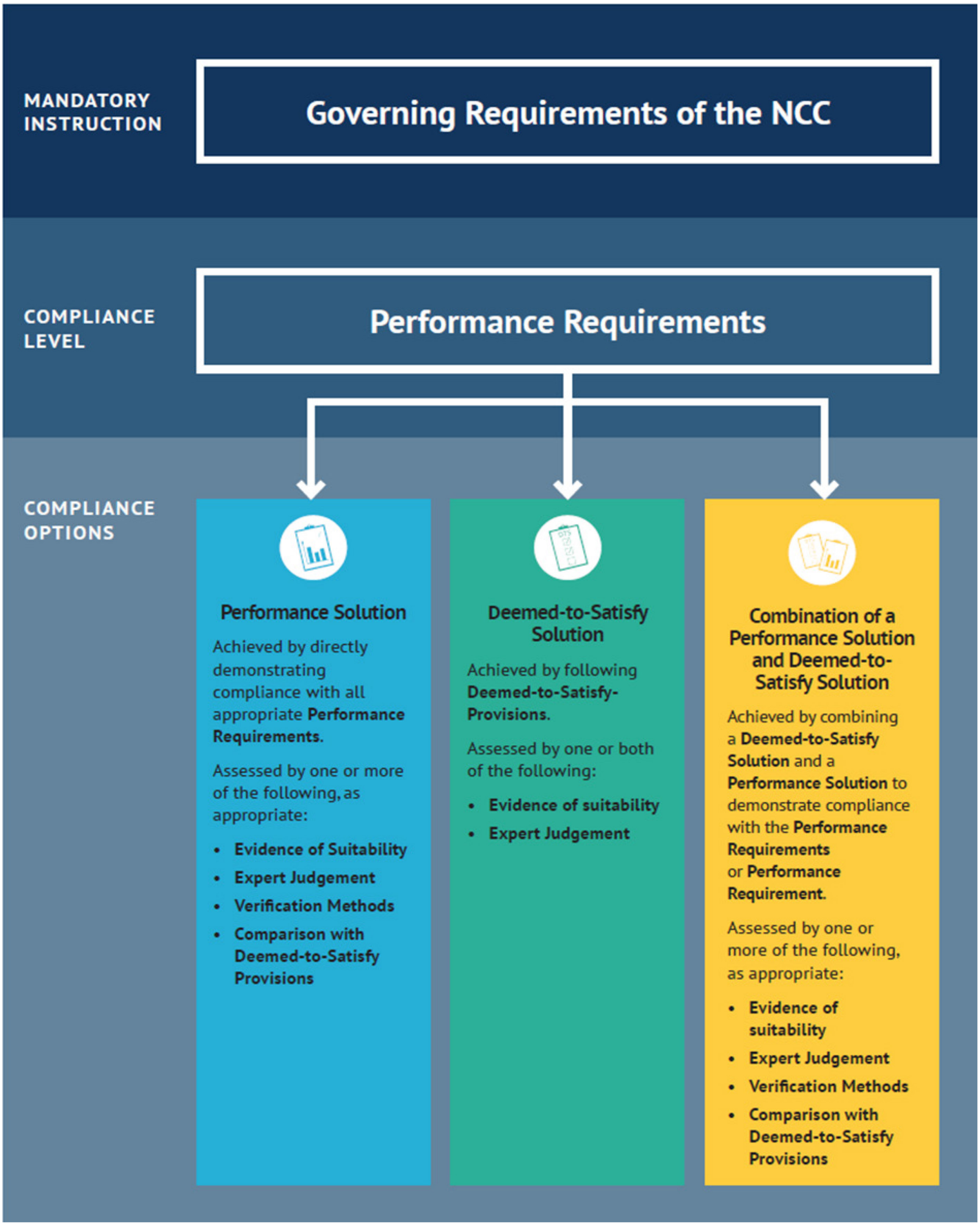
All compliance options must be assessed using one or a combination of the following Assessment Methods, as appropriate:

- Evidence of Suitability
- Expert Judgement
- Verification Methods
- Comparison with DTS Provisions.

A figure showing hierarchy of the NCC and its compliance options is provided in Figure A.1. It should be read in conjunction with the NCC.

To access the NCC or for further general information regarding demonstrating compliance with the NCC visit the ABCB website (abcb.gov.au).

Figure A.1 Demonstrating compliance with the NCC



Appendix B Acronyms and symbols

The following table, Table B.1 contains acronyms and symbols used in this document.

Table B.1 Acronyms and symbols

Acronym/Symbol	Meaning
ABCB	Australian Building Codes Board
AS	Australian Standard
BCA	Building Code of Australia
C_I	Spectrum adaptation value
C_{tr}	Spectrum adaptation value
dB	decibels
$D_{nT,w}$	Weighted standardised level difference
DTS	Deemed-to-Satisfy
Hz	Hertz
IGA	Inter-government agreement
ISO	International Organisation for Standardisation
$L'_{nT,w}$	Weighted standardised field impact sound pressure level
$L_{n,w}$	Weighted normalised impact sound pressure level
NCC	National Construction Code
NRC	Noise reduction coefficient
NZS	New Zealand Standard
PCA	Plumbing Code of Australia
R_w	Weighted Sound Reduction Index
STC	Sound Transmission Class

Appendix C Defined terms

C.1 NCC defined terms

NCC definitions for the terms used in this handbook can be found in:

- Schedule 3 of NCC 2019 Volumes One, Two and Three.

Building classifications can be found in:

- Part A6 Building Classifications of NCC 2019 Volumes One, Two and Three.

C.2 Other terms

C_{tr}: A value used to modify the measured sound insulation performance of a wall or floor. This sound insulation performance can be described by the R_W or the $D_{nT,w}$ terms. However, these are not accurate for all noises, especially for low frequency bass noise from modern stereo systems.

The value is referred to as a “spectrum adaptation value” and is added to either the R_W or $D_{nT,w}$.

AS/NZS 1276 sets out testing methodologies for the sound insulation properties of building elements and spectrum adaptation values, and explains their use.

The C_{tr} for a building element varies according to the insulating material employed. For example, a 90 mm cavity brick masonry wall has a C_{tr} value of -6, as does a wall constructed of 150 mm core-filled concrete blocks. By contrast, a brick veneer wall may have a C_{tr} of -12.

Smaller negative C_{tr} values are more favourable than large negative values.

dB(A): A unit of measure for decibels. The (A) represents the A-weighted scale which indicates the human ear’s sensitivity to various frequencies. The human ear is not a perfect listening device. It is poor at hearing low frequency noise. The “A”-weighted scale and dB(A) noise level are used to degrade the performance of a sound level meter to simulate what humans hear.

A number of noise criteria refer to, and are measured in, dB(A). The larger the dB(A) level, the louder the noise.

$D_{nT,w}$: A measure of the sound insulation performance of a building element. It is characterised by the difference in noise level on each side of a wall or floor. It is measured in the field and is therefore subject to the inherent inaccuracies involved in such a measurement.

The term is referred to as the "weighted standardised field level difference" and it indicates the level of speech privacy between spaces. It is a field measurement that relates to the R_W laboratory measurement. The higher the number the better the insulation performance.

Field test: A test of the overall building performance, rather than the performance of a building element. See also 'laboratory test'.

The sound insulation performance of a building can be measured by conducting a field test. The field test is a test which is conducted, typically at the construction site when the spaces are ready for testing.

A field test is conducted in a non-ideal acoustic environment. It is generally not possible to measure the performance of an individual building element as the results can be affected by numerous field conditions (refer to Appendix D.1).

Flanking: The mechanism of sound passing from one space to another through paths around a building element rather than through the building element material directly (refer to Section 3.5.1).

Frequency: All sounds can be described by their frequency or their mix of frequencies. Sounds have a mix of frequencies which are peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a mix of predominantly high frequencies and the sound of a bass drum or large truck has a mix of predominantly lower frequencies. Frequency can be measured on a scale in units of Hertz (Hz).

Impact noise: The noise in a room, caused by impact or collision with the perimeter walls or floor of the room. The impact noise of interest to the BCA occurs in the adjoining tenancy and occurs on the floor or common wall of that tenancy. Typical sources of impact are footsteps on the floor above a tenancy and the slamming of doors on cupboards mounted on the common wall between tenancies.

$L'_{nT,w}$: A measure of the noise impact performance of a floor. It is characterised by how much sound reaches the receiving room from a standard tapping machine. It is measured in the field and is therefore subject to the inherent inaccuracies involved in such a measurement.

The term is referred to as “weighted standardised field impact sound pressure level”. It is a field measure of the amount of impact sound reaching a space via a floor. It is the equivalent field measurement to the $L_{n,w}$ laboratory measurement. The lower the number the better the performance.

$L_{n,w}$: A measure of the noise impact performance of a floor. It is measured in very controlled conditions in a laboratory and is characterised by how much sound reaches the receiving room from a standard tapping machine.

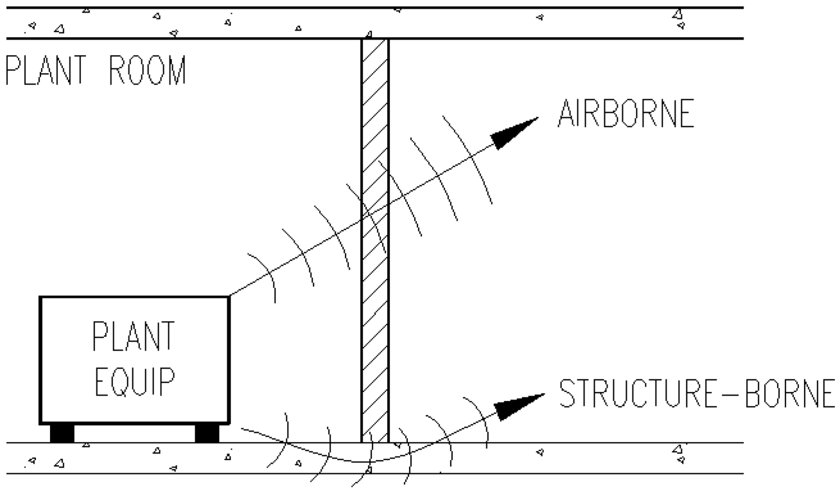
The term is referred to as the “weighted normalised impact sound pressure level”. It is a laboratory measure of the amount of impact sound reaching a space via the ceiling/floor overhead. The lower the number the better the performance.

Laboratory test: The sound insulation performance of a building element can be accurately measured in a laboratory. The sound insulation performance of the entire building cannot. This is because laboratory tests are not subject to the same site conditions as building elements installed in the field (refer to Appendix D1 and ‘field test’).

Noise: Noise can be classified into airborne and structure-borne components to identify the two mechanisms by which noise is transferred.

> **Airborne noise:** Airborne noise is noise that travels through air, generally through a direct or open path between the noise source and the listener (refer to Figure C.1).
>
> **Structure-borne noise:** Audible noise which is generated by vibrations induced in the ground and/or a structure. Vibration can be generated by impact or by direct contact with a vibrating machine (refer to Figure C.1).

Figure C.1 Airborne and structure-borne noise



Structure-borne noise cannot be attenuated by barriers or walls but requires the isolation of the vibration itself. Isolation is improved by using a resilient element such as rubber, neoprene or springs in the structure, or by a gap in the structure through which the vibration cannot pass. Examples of structure-borne noise include the noise of air-conditioning plant in a plant room, the sound of footsteps on the floor above a listener and the sound of a lift car passing in a shaft. See also 'impact noise'.

Normalising: A method of adjusting the measured noise results so that they are independent of the measuring space. The normalising of results is the BCA required method of adjusting laboratory measured results to give consistency. This relates to the DTS Provisions in BCA Volume One.

The noise level in a room is affected by the amount of noise entering the room as well as by the acoustic behaviour of the room. For example, the $L_{n,w}$ impact sound pressure level measured in a laboratory is dependent on the amount of noise entering through the floor and also the amount of absorptive material in the receiving room. Impact sound pressure level results are normalised when the area of sound absorption in the receiving room is set at 10 m^2. See also 'standardised'.

Noise reduction coefficient (NRC): A measure of the ability of a material to absorb sound. The NRC is generally a number between 0 and 1. A material with an NRC rating of 1 absorbs 100 % of incoming sound, that is, no sound is reflected back from the material.

R_W: A measure of the sound insulation performance of a building element. It is measured in very controlled conditions in a laboratory.

The term symbolises the “weighted sound reduction index” and is a laboratory measurement similar to STC. R_W is measured and calculated using the procedures from AS/NZS 1276 and AS 1191. The related field measurement is the $D_{nT,w}$. The higher the number the better the performance.

Sound absorption: The ability of a material to absorb sound. In doing so, the sound energy is converted to heat energy. Sound absorptive materials are useful within internal cavities of double skin partitions as they help absorb sound within the cavity and hence improve the acoustic performance of the building element. A measure of sound absorption is the NRC.

Efficient sound absorbers are typically made from glass wool, rock wool, polyester fibre, natural wool or cellulose fibre.

Sound insulation: Sound Insulation refers to the ability of a construction or building element to limit noise transmission through the building element. The sound insulation of a material can be described by the R_W or $D_{nT,w}$ of the system.

Sound Transmission Class (STC): A measure of the sound insulation performance of a building element. It is measured in very controlled conditions in a laboratory.

Standardising: A method of adjusting the measured noise results so that they are independent of the measuring space. The standardising of results is the BCA required method of adjusting field measured results to give consistency. This relates to the Verification Methods in BCA Volume One and Two.

The noise level in a room is affected by the amount of noise entering the room as well as by the acoustic behaviour of the room. For example the standardised $L'_{nT,w}$ impact sound pressure level measured in the field is dependent on the amount of noise entering through the floor and also the amount of absorptive material in the receiving room. Impact sound pressure level results are standardised when the reverberation time within the receiving room is set to half a second. See also ‘normalising’.

Appendix D Background information

D.1 Difference between laboratory and field testing results

The airborne sound insulation performance of walls is characterised by the “weighted sound reduction index”, R_W, which may be modified to give $R_W + C_{tr}$, to account for low frequency sound energy. In a similar way, the measured floor impact performance, $L_{n,w}$ can also have a spectrum correction, C_I applied to it and, up to 2015 this was an option in the BCA. However, while the ISO 717-2 (2014) standard from the International Standards Organisation has retained this option, it was removed from the BCA in 2016 at the request of industry.

The terms R_W and $L_{n,w}$ describe acoustic properties of a material or building element. They are only measurable in a laboratory where accurate measurements are conducted with precise techniques and equipment and where noise travelling via flanking paths has been minimised in vibration isolation chambers.

The measured performance of a floor or wall panel in the field can be affected by flanking paths and non-ideal measurement conditions as outlined below:

- the size or volume of the test rooms being too small to allow uniform sound distribution at all frequencies
- the size of the building element under test not being uniform. Variations in the size can give both higher and lower readings when compared to standard panel sizes in laboratories
- absorption in the field space not being uniform and invariably being greater than that in a laboratory. Noise measurements in such environments can have a reduced accuracy
- flanking paths via floors, ceilings, penetrations and external walls could reduce the element’s apparent performance
- flanking via structure-borne noise may reduce the element’s apparent performance
- background noise within field spaces are generally higher than in laboratories, potentially reducing the accuracy of tests.

Based on advice from industry and from other countries, the BCA allows a 5 dB concession for wall/floor elements tested in the field. Therefore the $D_{nT,W} + C_{tr}$ may be up to 5 dB less than the R_W + C_{tr}. The BCA does not permit variations between $L_{n,w}$ /$L'_{nT,w}$ tests.

Other factors can also reduce the performance of wall and floor systems. These include:

- insufficient acoustic treatment around penetrations;
- insufficient acoustic sealing at the wall junctions with surrounding walls, floors, ceilings; or
- substandard wall/floor construction.

D.2 Acoustic specification

An acoustic specification is recommended for each project undertaken. The following information summarises the necessary elements of the specification. Additional requirements should be incorporated as needed.

- Nominate the acoustic performance rating for all building elements between adjoining units.
- Nominate the materials and building systems that have to meet the acoustic performance requirements. This includes all systems proposed for construction and also where alternative systems are available to the building occupants, for example changing from carpet to hard floor finishes by building occupants.
- Nominate that, where a proprietary system is used, the manufacturer's installation instructions should be strictly followed.
- Nominate the procedure for reviewing and approving alternative construction techniques.
- Nominate details on construction techniques, for example penetrations, building element constructions and the treatment of services.
- Specifying the process for establishing compliance, i.e. whether laboratory tested results or field tested results take precedence.
- Nominate who is responsible for, and the frequency of periodic inspections.
- Nominate the procedure for rectifying defects.
- Nominate who is responsible for, and the extent of, any compliance measurements to be conducted at the site.
- Nominate the maximum acceptable deviation in performance between field and laboratory results.
- Address whether the sound insulation performance of the walls or floors relies on an installed acoustic ceiling system and the minimum current and future

requirements of that ceiling, i.e. what treatments are required to modify the ceiling.

- Specifying how many penetrations are permitted in the wall or floor/ceiling to maintain the acoustic rating. Consider alternative forms of treatment where excessive numbers of penetrations are proposed.
- Specifying the method of treatment and support for services within wall and ceiling cavities.
- Reference to acoustic compliance does not necessarily provide compliance within other BCA requirements, for example fire-rating, structural loading, wind loading, weather proofing and energy efficiency.

D.3 Testing

A testing regime is required when the BCA sound insulation Verification Methods are used to demonstrate compliance. The main features of acoustic testing are outlined below.

D.3.1 Regime of testing

A selection of randomly chosen building elements should be tested. A risk assessment should be performed to determine:

- how many building elements need to be evaluated
- which building elements require evaluation
- for which building elements are the test results valid.

As a minimum, the following testing is recommended:

- representative walls and floors/ceilings of all different types
- any building element which had faults or defects during construction
- at least one test on each storey
- 10% of the common walls and separating floors/ceilings on a project should be tested, as well as more for difficult or complex projects.

Other building elements should also be tested where there is a higher risk of non-compliance. Note that the higher the building element acoustic performance, or the more complex the structure, the greater the risk of failure.

It is worth noting that the building occupants themselves can commission acoustic testing on their own elements. Where such testing demonstrates failure with the BCA field performance requirements, then the procedures outlined in Section 2.4 should be used to resolve disputes.

D.3.2 Testing of completed units

Acoustic testing can be conducted in rooms before they are fully complete. For example it is not necessary to have a room which is fully carpeted and furnished. The minimum room requirements are as follows.

- The room to be tested is to be a defined volume, preferably rectangular in shape with all four (or more) walls complete and fully sealed. The building element under test is to be complete. The preferred size of floors and walls is 10 m^2.
- Both external and any internal glazing, and all doors, access panels and hatches to the rooms under consideration are to be installed and complete.
- No furniture or building materials should cover or shield the building element under test, on either side of the building element. All penetrations to the building element, and fittings, such as general purpose outlets, light switches, fire sprinklers, and mechanical registers, are to be installed and complete.
- Where testing sound-rated doors, then a comparative test should be conducted with the door open and closed. The overall performance of the wall/door combination is evaluated and the performance of the door itself deduced from the results.

D.3.3 Reporting requirements

Any test results should, as a minimum, state the following:

- the name of the organisation and test officer who conducted the tests
- the name of the organisation and the person who commissioned the tests
- the date and place of the testing
- which standards were used as references for the test procedure. Where departure from the standards was necessary, a statement on the effect of this departure on the results
- a description of the test sample including age, size, weight and composition
- a description of the test rooms including dimensions, volumes and finishes within the spaces
- a description of the test procedure and equipment used for testing
- a description of the microphone locations and source speaker/tapping machine locations

- a description of the test sound and how it was produced
- an indication of results which have been affected by the test conditions, and a statement of the effect, for example, of a high background noise during the testing, noise via flanking paths, etc.
- a summary of the measured reverberation times, source room noise levels and receiver room noise levels in each frequency band
- the overall weighted standardised results and third-octave band frequency results, both tabulated and graphed
- an indication of the overall precision of the results.