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CLT Acoustic Performance



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Contents

1	Introduction	4
2	Executive Summary	5
2.1	Sound Insulation Criteria	5
2.2	Complying Systems	5
2.2.1	Dividing Walls	6
2.2.2	Dividing Floors	8
2.3	Limitations	8
3	Cross-Laminated Timber (CLT)	9
3.1	CLT Description	9
3.2	CLT Connections	9
3.3	CLT Build-Up	10
4	Assessment Methodology	11
5	Explanation Of Acoustic Terms	12
6	Sound Insulation Criteria	14
6.1	NCC Criteria For Assessment In An Acoustic Laboratory	14
6.2	NCC Criteria For Assessment In-Situ Verification	15
6.3	NCC Criteria Discussion	15
7	Acoustic Laboratory Testing Program	16
8	Summary Acoustic Assessment	19
8.1	Complying CLT Wall Systems	19
8.2	Assessment of Acoustic Laboratory Test Results - Wall Configurations	20
8.3	Complying CLT Floor/Ceiling Systems	26
8.3	Assessment of Acoustic Laboratory Test Results - Floor Configurations	27

1 Introduction

Cross Laminated Timber (CLT) is a modified timber building product in widespread use internationally. While its use in Australia is currently not widespread, the potential of the product for using in dividing walls, floors and ceilings is increasingly evident, particularly for multi storey residential buildings. Such buildings have particular acoustic requirements, mandated in Australia by the National Construction Code, Building Code of Australia (BCA).

Extensive acoustic research programs have been conducted across Europe and in North America on CLT's acoustic properties. The particulars, designed to meet local building codes, building practises and local materials, mean that it is not always possible to compare the results to the NCC's acoustic requirements.

PKA Acoustic Consulting (PKA) was commissioned by FWPA and the NSW Timber Development Association (TDA), to conduct and coordinate a research program into the acoustic performance of CLT products in various system configurations with the aim of compliance with the NCC.

CLT is available from a number of manufactures and suppliers. The study co-ordinated the supply of CLT panels from various suppliers for the acoustic assessment and testing. Information on the specific suppliers and products is set out in the table below.

Table 1.1: List of CLT and acoustic system suppliers.

Company	PKA Reference	Material Supply
Strongbuild Commercial Pty. Ltd.	Strongbuild	Binderholz CLT
Meyer Timber NSW Pty. Ltd.	Meyer Timber	Meyer Timber CLT
Stora Enso Australia Pty. Ltd.	Stora Enso	Stora Enso CLT
Xlam Australia Pty. Ltd.	Xlam	Xlam CLT
Dynamic Composite Technology Pty. Ltd.	DCTech	Proctor Q-Silence Floor Battens Proctor Q-Silence Floor Underlay DCT SolidEX Floor Screed DCT URSAcoustic

PKA cautions that this research program is limited to the sound insulation performance of CLT in an acoustic laboratory. The achievement of an acoustic result in an acoustic laboratory that complies with a particular code does not mean that compliance is automatically achieved on site.

Constructing buildings exclusively using CLT as load-bearing elements will require additional acoustic detailing of potential sound flanking paths to ensure compliance with the NCC's verification criteria when measured in- situ. Further acoustic testing may also be required in order to fully examine these issues.

Particular information on sound flanking in CLT constructions is available from the National Research Council of Canada: "Report to Research Consortium for Wood and Wood-Hybrid Mid-rise Buildings, Acoustics – Sound Insulation in Mid-Rise Wood Buildings" (2014) (Schoenwald, S.)

2 Executive Summary

Cross Laminated Timber (CLT) is a prefabricated solid engineered wood product made of several layers of timber boards stacked crosswise (at 90 degrees) and glued under pressure together to form a solid rectangular panel.

The Australian wood products industry, in conjunction with the Forest and Wood Products Australia Limited (FWPA), envisage considerable potential for the CLT as a construction material in amongst other areas, residential developments.

Such buildings normally have particular acoustic requirements, normally mandated in Australia by the National Construction Code, Building Code of Australia (NCC) or by a relevant Local Government Authority.

Previous acoustic research programs of CLT have been conducted across Europe and in North America. The applicability of this data to the local market is however limited due to the design of the testing to address codes that are not relevant to Australia. Further, the test elements often include construction materials that are not available or not in widespread use in Australia.

PKA Acoustic Consulting (PKA) was commissioned to coordinate a research program into the acoustic performance of CLT in various system configurations with the aim of compliance with the NCC.

The acoustic testing was carried out at New Zealand's Auckland University Acoustic Laboratory.

CLT panels are available from a number of different suppliers. This study coordinated the supply of test panels from various manufacturers. The same CLT panel configuration from multiple suppliers was tested in order to consider the variability of CLT products.

2.1 Sound Insulation Criteria

The use of the NCC is mandated for attached and multistorey residential buildings in Australia.

Section F5 "Sound Transmission and Insulation" includes acoustic requirements for internal dividing elements as follows:

- F5.4 Dividing Floors
- F5.5 Dividing Walls
- F5.6 Services Isolation

Any CLT system configuration must, as a minimum, primarily address these requirements within the NCC.

Some Local Government Authorities consider that parts of Section F5 do not offer adequate amenity to occupants and have adopted more stringent acoustic requirements. Where possible CLT acoustic building systems should be designed or developed in recognition of the local government requirements. This report includes the Association of Australian Acoustical Consultants (AAAC) Star Rating system that is widely used as a preferred impact sound insulation rating of floors.

2.2 Complying Systems

The test program successfully identified various CLT systems that would meet the acoustic requirements of the NCC and the AAAC.

2.2.1 Dividing Walls

The acoustic research program identified that CLT panel in conjunction with plasterboard wall systems can comply with the Part F5.5 of the NCC pertaining to dividing walls separating sole-occupancy units (SOUs). The various wall configurations and applications are summarised as follows:

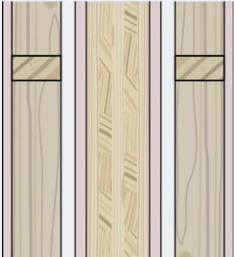
Criteria	Graphic	Brief Description	Thickness
$R_w + C_{tr} \geq 50$ Separating SOUs No cavity services Discontinuous construction		Separate stud one side Cavity insulation CLT panel with linings	219-238mm
$R_w + C_{tr} \geq 50$ Cavity services Discontinuous construction		Separate stud both sides Cavity insulation CLT panel with linings	328-354mm
$R_w + C_{tr} \geq 50$ Cavity services Discontinuous construction		Furring channel one side Separate stud one side Cavity insulation CLT panel with linings	296mm
$R_w + C_{tr} \geq 50$ Separating SOUs No cavity services Discontinuous construction		Double CLT panel with linings Cavity insulation	232mm
$R_w \geq 50$ Common wall* $R_w \geq 45$ Aged Care $R_w + C_{tr} \geq 40$ Shaft wall No cavity services Not discontinuous		Furring channel one side Cavity insulation CLT panel with linings	180-193mm

Figure 1.1: Complying dividing walls

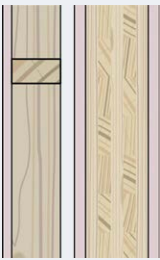
Criteria	Graphic	Brief Description	Thickness
$R_w \geq 50$ Common wall* $R_w \geq 45$ Aged Care No cavity services Discontinuous construction		Separate stud one side Cavity insulation CLT panel with linings	219-225mm
$R_w \geq 50$ Common wall* $R_w \geq 45$ Aged Care No cavity services Discontinuous construction		Double CLT without linings Cavity insulation	200mm
$R_w + C_{tr} \geq 25$ Service Shaft wall Not discontinuous		CLT panel with or without linings	90-122mm

Figure 1.1: Complying dividing walls (continued)

* Common walls are walls separating SOUs from plant room, lift shaft, stairway, public corridor, lobbies or different building classifications.

2.2.2 Dividing Floors

The acoustic research program identified that CLT panel in conjunction with floor toppings and plasterboard ceilings systems can comply with the Part F5.4 of the NCC pertaining to dividing floors separating sole-occupancy units (SOUs). The various floor configurations and applications are summarised as follows:

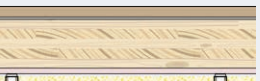
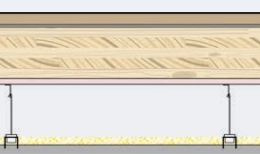
Criteria	Graphic	Brief Description	Thickness
$R_w + C_{tr} \geq 50$		Bare CLT panel with lining Cavity insulation Suspended or furring ceiling	249-367mm
$R_w + C_{tr} \geq 50$ $L_{nT,w} \leq 55$ (AAAC 3 Star)		Floor with acoustic underlay CLT panel with lining Cavity insulation Furring or suspended ceiling	286-404mm
$R_w + C_{tr} \geq 50$ $L_{nT,w} \leq 50$ (AAAC 4 Star)		Floor with acoustic underlay CLT panel with lining Cavity insulation Suspended ceiling	400-427mm
$R_w + C_{tr} \geq 50$ $L_{nT,w} \leq 50$ (AAAC 4 Star)		Resilient batten floor Cavity insulation CLT panel with lining Cavity insulation Suspended ceiling	417-443mm
$R_w + C_{tr} \geq 50$ $L_{nT,w} \leq 50$ (AAAC 5 Star)		Floor with resilient battens Cavity insulation CLT panel with lining Cavity insulation Suspended ceiling	453mm

Figure 1.2: Complying dividing floors.

2.3 Limitations

The acoustic research program identified that CLT panel in conjunction with floor toppings and plasterboard ceilings systems can comply with the Part F5.4 of the NCC pertaining to dividing floors separating sole-occupancy units (SOUs). The various floor configurations and applications are summarised in Section 8 of this guide.

3 Cross-laminated Timber (CLT)

3.1 CLT Description

Cross-laminated timber (CLT) typically refers to a prefabricated solid engineered wood product made of several layers of timber boards stacked crosswise (at 90 degrees) and glued under pressure to form a solid rectangular panel.

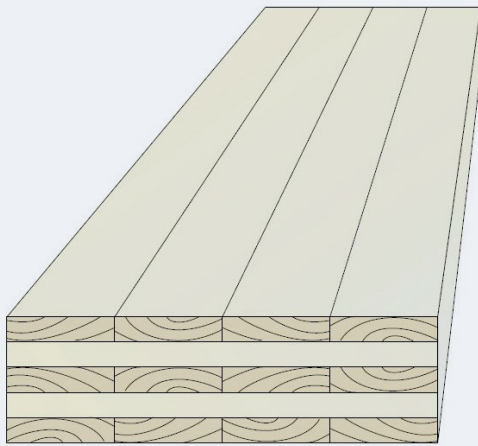


Figure 3.1: Cross-laminated timber (CLT) Sources: Left - CLT Handbook: Cross-laminated Timber (U.S. Edition 2013) FP Innovations, Right - Massive Timber Construction Systems – Cross-laminated Timber (CLT) (2012) Forest and Wood Products Australia Limited

A summary of the physical properties of CLT panels tested in this acoustic research program is set out in the table below.

Table 3.1: Physical properties of CLT panels.

Type	Product	Thickness mm	Layers	Density kg/m3	Mass kg/m2
Wall	Xlam	90	3 ply	472	42.5
Floor	Binderholz	140	5 ply	456	63.9
	Meyer			458	64.1
	Stora Enso			444	62.2
	Xlam			464	65.0
	Xlam	200	5 ply	464	92.8

3.2 CLT Connections

CLT panels are typically connected together on site due to production and transport limitations. There are several possible panel-to-panel connection options however in the preliminary discussions with the CLT suppliers it was determined that the most typical is the “cover-board” method which was used almost exclusively throughout the acoustic research program.

Cover-board connections involve the CLT panel edges profiled to take a strip of timber fastened with screws. During the acoustic testing it was apparent that sound leakage was occurring between the CLT panel connections. It was deemed necessary to seal the gap between the panels with sound- rated sealant prior to the installation of the cover-board to ensure the acoustic integrity of the CLT system was maintained.

For comparison purposes acoustic testing was performed of a CLT floor that was connected using a “half-lapped” method. This involves milling half of the connecting edge on both panels to allow an overlap. The panel edges are then typically fixed together with long self-tapping screws.

The two methods adopted in this acoustic research program are shown below.

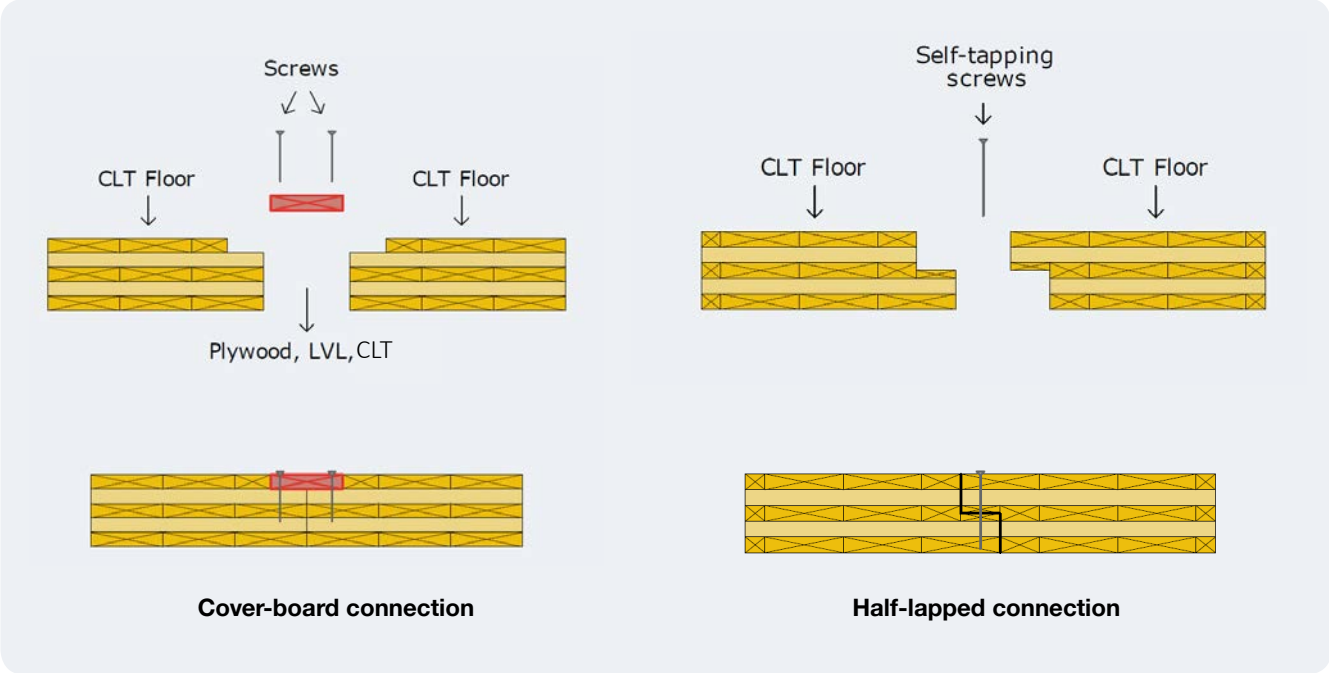


Figure 3.2: CLT connection types. Source: *CLT Handbook: Cross-laminated Timber (U.S. Edition 2013) FP Innovations*

3.3 CLT Build-up

NCC 2016 introduced a new deemed to satisfy solution for timber based building systems, called fire protected timber. One of the elements to fire protected timber is direct fixed fire rated plasterboard.

The acoustic research program adopted the direct fix fire-rated plasterboard approach as the default for CLT system configurations as follows:

Building Element	Graphic	CLT Build-up
Wall		16mm fire-rated plasterboard screw fixed 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard screw fixed
Floor		140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard screw fixed

Figure 3.3: Fire protected timber

There were a few wall systems where one or both fire-rated plasterboard linings were removed to provide additional data on which future acoustic assessments could be based if fire rating is desired at the stud lining position. This data is detailed in Appendix A.

This report cautions that any air gaps or cavities that might arise from the direct fix lining being applied to the CLT has the potential to deteriorate the acoustic performance of the system. This can happen with the dabbed glue fixing method. If glue is to be used it must be applied evenly which typically requires a notched applicator.

To ensure that no gaps were present between the direct fix lining and CLT, the fire-rated plasterboard was directly fixed with screws at a maximum of 300mm centres throughout the entire acoustic testing program.

4 Assessment Methodology

PKA and TDA collaborated during the preliminary stages of the acoustic research program. The aim was to develop a comprehensive acoustic laboratory testing schedule of CLT wall and floor/ceiling systems that would allow the following:

- Compliance with the sound insulation criteria required by the relevant Australian codes
- Installation using building materials and practices typically employed in Australia
- A comparison of the test results for multiple CLT products to determine variability between manufacturers
- Compilation of comprehensive data for future acoustic assessments. This was achieved using a staged testing approach.

New Zealand's Auckland University Acoustic Laboratory (Auckland Laboratory) was selected as the location for the acoustic testing as it fulfilled the following principle requirements:

- Laboratory conforms to ISO 10140-5 (2010) *Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment*
- Laboratory equipment calibrated by an accredited association
- Ability for wall (airborne) and floor/ceiling (airborne and impact) acoustic testing
- Accessibility for chief CLT supplier Xlam, whose factory is based in New Zealand
- Affordable laboratory hire and reporting costs due to comprehensive testing regime

The acoustic testing was conducted over the period 26th April to 10th June 2016. The results were collated from over 107 separate airborne/impact tests involving 25 walls and 41 floor/ceiling configurations.

One of the aims was to determine the variability of multiple CLT products. It was deemed impractical, in both cost and time, to construct replica system configuration 4 times over only to change the CLT panel type. Instead, the test schedule was conducted entirely from one CLT supplier. The remaining CLT products were then tested in a round robin fashion as a floor panel.

PKA has assessed the variance between CLT products, in terms of both airborne and impact sound insulation performance, and provided the CLT suppliers with individualised assessments relating to each system configuration tested.

This report does not contain the individualised data sets due to protection of individual supplier's intellectual property. Instead this report provides generic test results derived from the range of CLT acoustic performance relating to each system configuration tested.

PKA notes that although the system configurations were designed with assistance from TDA to be practically buildable, the aim of this CLT research program relates to acoustic considerations only. Qualified personnel should be consulted with regard to specific requirements for other non-acoustic considerations.

5 Explanation of Acoustic Terms

The following definitions have been simplified to convey a practical meaning of the technical acoustic terms used throughout this assessment.

Sound Level

A perceptible sound level is a result of a pressure variation in the air generally between the source and the ear. Sound levels are expressed as decibels (dB).

Sound pressure level (SPL) is effectively the loudness of a sound from a particular sound source measured at a particular distance.

Decibel (dB)

A unit of measurement that represents sound levels. The human ear can perceive a large range of sound levels, however it responds to the change in sound levels in a non-linear fashion, therefore for convenience the decibel is a logarithmic unit of measurement.

The table below sets out the subjective effect of changes in sound level:

Table 5.1: Subjective effect of changes in sound level.

Change in Sound Level	Change in Acoustic Energy	Change in Loudness
3 dB	2 times	Just Perceptible
5 dB	3 times	Clearly Perceptible
10 dB	10 times	Double/Half the Loudness
20 dB	100 times	Much Louder/Quieter

For example a 1-2dB change is unlikely to be perceptible, however a change of 5-10dB will be a significant increase or decrease in loudness.

Airborne Sound Insulation (R_w , $D_{nT,w}$, STC)

Airborne sound is a sound source that originates in the air such as a person talking or a loudspeaker, as opposed to impact sound which strikes a surface such as footsteps.

Airborne sound insulation is the difference in sound pressure level between the sound entering and sound leaving a building element. The higher the value the better the sound insulation.

The R_w rating, defined as a “Weighted Sound Reduction Index”, is an acoustic laboratory measurement that determines the effectiveness of a building element’s airborne sound insulation over a range of frequencies (100Hz to 3150Hz) in a single number quantity. The R_w value, expressed in dB, is corrected for room volume and reverberation time but does not take into account sound flanking paths associated with in-situ installations.

The $D_{nT,w}$ rating, defined as “Weighted Standardised Level Difference”, is similar to R_w but is measuring the building element’s airborne sound insulation in-situ rather than an acoustic laboratory. The $D_{nT,w}$ is more indicative in determining the actual airborne sound insulation between spaces as it accounts for sound flanking paths and construction quality.

The **STC** rating, defined as “Sound Transmission Class” adopted in North America and New Zealand, is an acoustic laboratory measurement similar to R_w , however the range of assessing frequencies is shifted upwards to 125Hz to 4000Hz. For typical building elements the STC and R_w ratings are largely similar except where there is a significant decrease in performance at 100Hz which results in the R_w rating decreasing from the STC.

Spectrum Adaption Term (C_{tr})

The C_{tr} term is an airborne low frequency adjustment factor that helps quantify the low frequency performance of the building element from sources such as traffic, music, televisions etc. C_{tr} is a negative value that is added to an R_w or a $D_{nT,w}$ rating.

Impact Sound Insulation ($L_{n,w}$, $L_{nT,w}$, IIC)

Impact sound is a sound source that typically originates by striking a floor surface such as footsteps or moving furniture. Impact sounds can be transmitted through walls via lifts, plantrooms, washing machines, service pipes etc. however there is no functioning criteria for assessing these structure-borne sounds except for adopting discontinuous constructions.

Impact sound insulation is the resultant sound pressure level measured in the receive space when an ISO standard tapping machine is placed in the source space on the separating floor/ceiling. The lower the value the better the sound insulation.

The $L_{n,w}$ rating, defined as “Weighted Normalised Impact Sound Pressure Level”, is an acoustic laboratory measurement to determine the effectiveness of a building element’s impact sound insulation over a range of frequencies (100Hz to 3150Hz) in a single number quantity. The $L_{n,w}$ value, expressed in dB, is corrected for room volume and reverberation time but does not take into account sound flanking paths associated with in-situ installations.

The $L_{nT,w}$ rating, defined as “Weighted Normalised Impact Field Sound Pressure Level”, is similar to $L_{n,w}$ however measures the building element’s impact sound insulation in-situ rather than an acoustic laboratory. The $L_{nT,w}$ is more indicative in determining the actual impact sound insulation between spaces as it accounts for sound flanking paths and construction quality.

The IIC rating, defined as “Impact Insulation Class” adopted in North America and New Zealand, is an acoustic laboratory measurement that is derived from the sound pressure levels measured as described above. The IIC rating is not related to the $L_{n,w}$ rating as a higher IIC equates to a better sound insulation, however an approximate conversion is typically applied whereby the $L_{n,w} = 110 - \text{IIC}$.

Spectrum Adaption Term (C_i)

The C_i term is an impact adjustment factor which is typically a negative value effectively improving the impact rating of the floor/ceiling system. The C_i term was included in the BCA 2004 following its adoption in the UK building code, but was soon discarded in the UK when it was found that known deficient constructions were achieving compliance. The C_i term was finally removed in the BCA 2016 due to pressure from the Association of Australian Acoustical Consultants (AAAC). The detailed test data state the C_i term for information purposes only.

6 Sound Insulation Criteria

6.1 NCC Criteria For Assessment in an Acoustic Laboratory

The NCC 2016, in Volume 1 Section F5 “Sound Transmission and Insulation” states that walls and floors separating places of occupancy “*must provide insulation against the transmission of airborne and impact generated sound sufficient to prevent illness or loss of amenity to the occupants*”.

The following summarises the acoustic laboratory design requirements, brevity necessitates detail in the NCC taking precedence over the tables below.

Table 6.1: NCC sound insulation acoustic laboratory criteria for walls.

Wall Description	BCA Reference	Sound Insulation Requirements	
		Airborne	Impact
Separating sole-occupancy units (SOUs) habitable areas	F5.5(a)(i)	$R_w + C_{tr} \geq 50$	
Separating SOUs wet to habitable areas	F5.5(a)(i) F5.5(a)(iii)	$R_w + C_{tr} \geq 50$	Discontinuous Construction
Separating SOUs with corridor, stairway, lobby or different classification	F5.5(a)(ii)	$R_w \geq 50$	
Separating SOUs with plantroom or lift shaft	F5.5(a)(ii) F5.5(a)(iii)	$R_w \geq 50$	Discontinuous Construction
Separating Class 9c aged care SOU generally	F5.5(c)	$R_w \geq 45$	
Separating Class 9c aged care SOU with kitchen or laundry	F5.5(c)	$R_w \geq 45$	Discontinuous Construction
Separating SOU habitable area with services from another SOU	F5.6(a)(i)	$R_w + C_{tr} \geq 40$	
Separating SOU wet area with services from another SOU	F5.6(a)(ii)	$R_w + C_{tr} \geq 25$	

The NCC denotes “Discontinuous Construction” as follows:

Wall Type	Reference	Discontinuous Construction Requirement
Masonry	F5.3(c)(i)	Wall having a minimum 20mm cavity between the 2 separate leaves, with resilient wall ties if necessary
Other than masonry	F5.3(c)(ii)	Wall having a minimum 20mm cavity with no mechanical linkage except at the periphery

Table 6.2: NCC sound insulation acoustic laboratory criteria for floors.

Floor Description	BCA Reference	Sound Insulation Requirements	
		Airborne	Impact
Separating sole-occupancy units (SOUs)	F5.4(a)(i)	$R_w + C_{tr} \geq 50$	$L_{n,w} \leq 62$
Separating SOUs with plantroom, lift shaft, corridor, stairway, lobby or different classification	F5.4(a)(ii)	$R_w + C_{tr} \geq 50$	$L_{n,w} \leq 62$
Separating Class 9c aged care SOU generally	F5.4(b)	$R_w \geq 45$	
Separating SOU habitable area with services from another SOU	F5.6(a)(i)	$R_w + C_{tr} \geq 40$	
Separating SOU wet area with services from another SOU	F5.6(a)(ii)	$R_w + C_{tr} \geq 25$	

6.2 NCC Criteria for Assessment In-Situ Verification

The aim of the NCC acoustic laboratory design requirements is to allow compliance with the verification criteria FV5.1 and FV5.2 when measured in-situ. In most cases the verification criteria allows for a 5dB reduction in sound insulation performance between an acoustic laboratory test and a field test on site. This is due to sound flanking paths and variation of quality workmanship in construction.

Table 6.3: NCC sound insulation in-situ verification criteria: walls.

Wall Description	NCC Reference	Sound Insulation Requirements	
		Airborne	Impact
Separating sole-occupancy units (SOUs)	FV5.2(a)	$D_{nT,w} + C_{tr} \geq 45$	
Separating SOUs with plantroom, lift shaft, corridor, stairway, lobby or different classification	FV5.2(c)	$D_{nT,w} \geq 45$	

Table 6.4: NCC sound insulation in-situ verification criteria: floors.

Floor Description	NCC Reference	Sound Insulation Requirements	
		Airborne	Impact
Separating sole-occupancy units (SOUs)	FV5.1(a) FV5.1(b)	$D_{nT,w} + C_{tr} \geq 45$	$L_{nT,w} \leq 62$

6.3 NCC Criteria Discussion

The goal of the NCC is to “enable the achievement of nationally consistent, minimum necessary standards”. PKA considers the various airborne sound insulation criteria in the NCC to be of a high standard, which accordingly achieves a 4 Star Rating by the Association of Australian Acoustical Consultants (AAAC) in their document “Guideline of Apartment and Townhouse Acoustic Rating 2010”.

However, along with the vast majority of Australian acoustic consultants, PKA considers the floor impact sound insulation verification criterion of $L_{nT,w} \leq 62$ to be of a poor standard resulting in a AAAC 2 Star Rating.

In PKA's experience, a typically non-carpeted floor/ceiling installation that simply complies with the NCC impact sound insulation criterion often leads to noise complaints from adjoining occupants. Impact generated sounds, such as footsteps and moving furniture, result in disturbances that cause significant anguish to occupants often leading to costly legal battles in consumer tribunals.

Therefore it is PKA's opinion that the NCC is in direct conflict with its own performance requirements to “provide insulation against the transmission of airborne and impact generated sound sufficient to prevent illness or loss of amenity to the occupants”.

The following table demonstrates the AAAC Star Rating improvement over the NCC floor impact criterion and provides comments as to PKA's typical recommendation for floor/ceiling constructions involving hard surfaces:

Table 6.5: AAAC Star Rating improvement over the NCC floor impact criterion.

AAAC Star Rating	AAAC Criteria	Improvement over NCC Criterion of $L_{nT,w} \leq 62$	PKA Advice For Hard Surface Floor/Ceiling Constructions
3	$L_{nT,w} \leq 55$	7dB	Recommended as minimum for standard residential apartments
4	$L_{nT,w} \leq 50$	12dB	Recommended as minimum for luxury residential apartments
5	$L_{nT,w} \leq 45$	17dB	Recommended for luxury residential apartments
6	$L_{nT,w} \leq 40$	22dB	Recommended where hard floor is to have comparable high performance to a carpeted floor. This is generally not feasible

We note certain Councils require superior impact sound insulation beyond the NCC criteria. In PKA's experience this can range from 3 Star to 5 Star Ratings. When designing floor/ceiling systems, acoustic advice should be sought to determine the appropriate criteria taking into account location and intended quality of the development.

7 Acoustic Laboratory Testing Program

The acoustic research program was conducted at New Zealand's Auckland University Acoustic Laboratory (Auckland Laboratory). As listed in Section 4 Assessment Methodology the Auckland Laboratory was selected as it fulfilled the following principle requirements:

- Laboratory conforms to ISO 10140-5 (2010) *Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment*
- Laboratory equipment calibrated by an accredited association (Electroacoustic Calibration Services (ECS), an International Accreditation New Zealand (IANZ) registered laboratory)
- Ability for wall (airborne) and floor/ceiling (airborne and impact) acoustic testing
- Accessibility for chief CLT supplier Xlam, whose factory is based in New Zealand
- Affordable laboratory hire and reporting costs due to comprehensive testing regime

The acoustic testing was conducted over the period 26th April to 10th June 2016. The results were collated from over 107 separate airborne/impact tests involving 25 walls and 41 floor/ceiling configurations.

A representative of TDA attended the Auckland Laboratory for the duration of the acoustic testing program to ensure that the CLT system configurations were being installed correctly by the resident tradespeople and to document the building material properties.

A representative of PKA, Joel Parry-Jones, attended the Auckland Laboratory during the first few days of acoustic testing to inspect the CLT panel constructions and provide advice regarding installation of specific acoustic products.

The testing was conducted by Gian Schmid of Auckland University who has over 15 years of experience in acoustic laboratory testing.

The following standards are adopted by the Auckland Laboratory:

Table 7.1: Auckland acoustic laboratory standards.

Type	Standard	Description
Airborne testing	ISO 10140-2:2010	Laboratory measurement of sound insulation of building elements Part 2: Measurement of airborne sound insulation
Impact testing	ISO 10140-3:2010	Laboratory measurement of sound insulation of building elements Part 3: Measurement of impact sound insulation
Airborne testing	ISO 717-1:2013	Acoustics – Rating of sound insulation in building and of building elements Part 1: Airborne sound insulation
	ASTM E413	Classification for Rating Sound Insulation
Impact testing	ISO 717-2:2013	Acoustics – Rating of sound insulation in building and of building elements Part 2: Impact sound insulation
	ASTM E989	Standard Classification for Determination of Impact Insulation Class (IIC)

The Auckland Laboratory has three large interconnected reverberation chambers. The chambers are shaped as asymmetrical hexagonal prisms that employ fixed and rotating diffusers to evenly distribute the sound field.



Figure 7.1: Reverberation Chamber A with bare CLT wall and floor installed.



Figure 7.2: Reverberation Chamber B with CLT floor and direct fixed plasterboard installed.

The reverberation chambers details and arrangements are as follows:

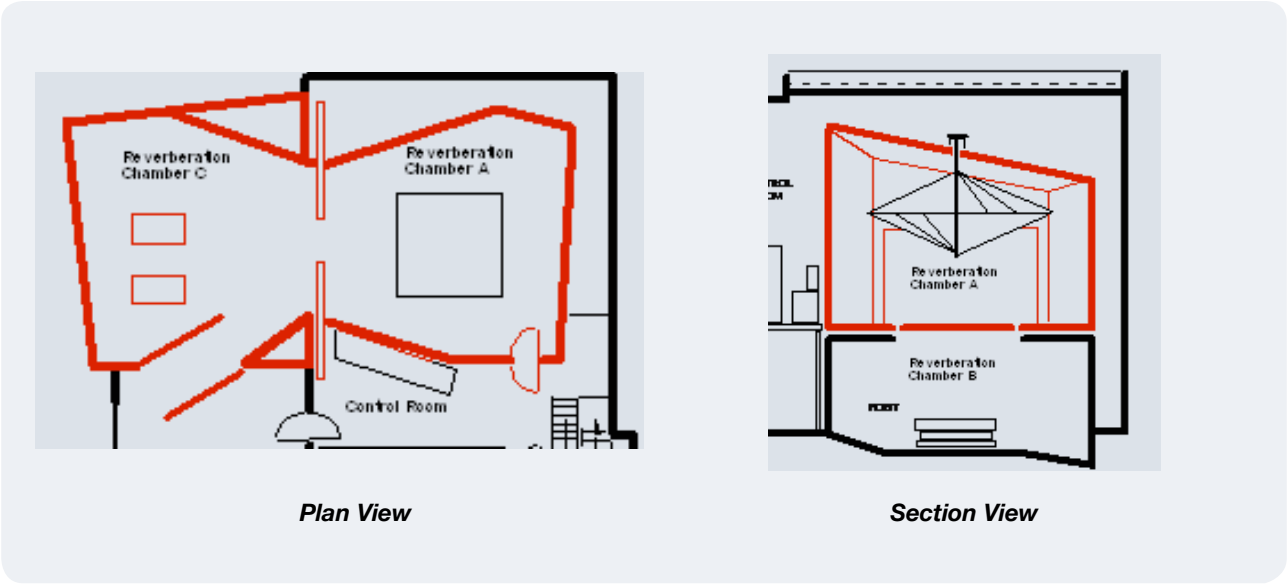


Figure 7.3: Auckland Laboratory Reverberation Chamber details.

Element	Test Type	Source	Receive
Floor/Ceiling	Airborne and Impact	Chamber A	Chamber B
Wall	Airborne	Chamber C	Chamber A

Description	Location	Volume
Chamber A	Ground	202m³ ± 3
Chamber B	Basement	153m³ ± 2
Chamber C	Ground	209m³ ± 4

8 Summary of Acoustic Assessment

As detailed in Section 4 Assessment Methodology, PKA have assessed the range of acoustic performance expected in each CLT system configuration based on the Auckland University test data which incorporated a round robin of four different CLT products.

The following tables present the CLT system configurations organised into each BCA sound insulation criteria listed in Section 6.

8.1 Complying CLT Wall Systems

The complete descriptions of the building materials and system configurations tested are provided in Appendix A Detailed Test Data. For this summary the system configurations have been abbreviated as follows:

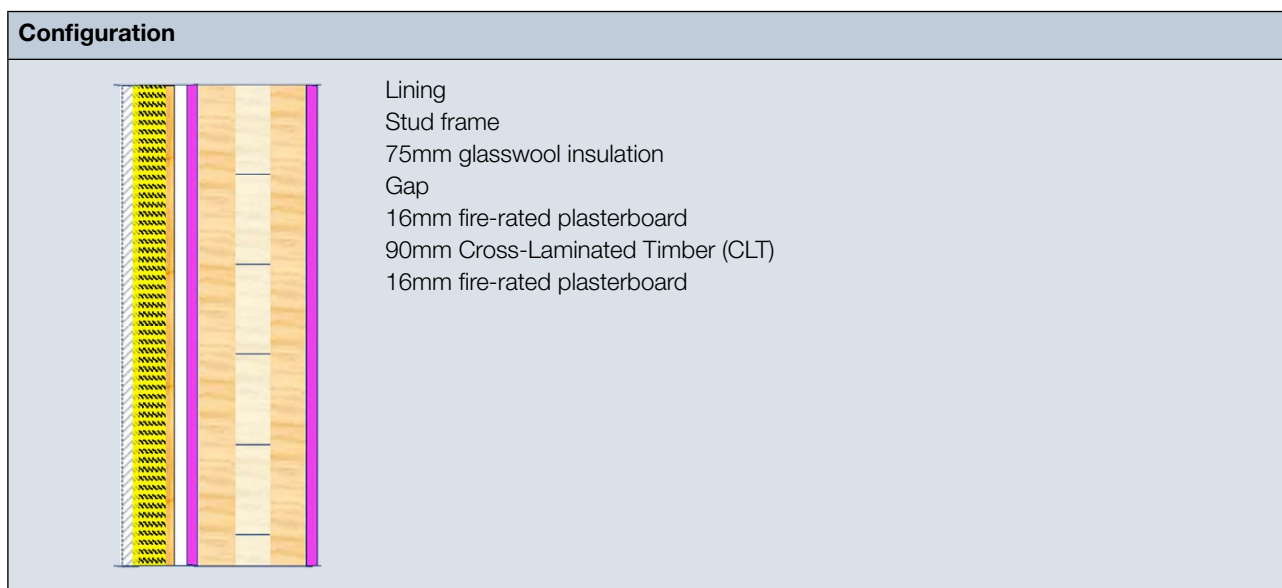
Table 8.1: Abbreviations and their meaning.

Abbreviation	Detailed Description
90mm Cross-Laminated Timber (CLT)	90mm Cross-Laminated Timber (CLT) wall 3 ply (40.0 – 42.5kg/m ²)
13mm standard plasterboard	13mm GIB standard plasterboard (min. 8.6kg/m ²)
13mm sound-rated plasterboard	13mm GIB Noiseline sound-rated plasterboard (min. 12.5kg/m ²)
16mm fire-rated plasterboard	16mm GIB Fyreline fire-rated plasterboard (min. 13.7kg/m ²) *
9mm fibre cement sheet	9mm fibre cement sheet (min. 13.5kg/m ²)
50mm glasswool insulation	50mm DCT URSAcoustic glasswool insulation R1.4 (min. 18kg/m ³) or 50mm Bradford Acoustigard glasswool insulation R1.3 (min. 14kg/m ³)
50mm glasswool insulation	50mm Bradford Acoustigard glasswool insulation R1.3 (min. 14kg/m ³)
75mm glasswool insulation	75mm DCT URSAcoustic glasswool insulation R1.8 (min. 17kg/m ³) or 75mm Bradford Acoustigard glasswool insulation R1.8 (min. 14kg/m ³)
70mm timber stud	70mm x 45mm timber stud (cc 600mm)
64mm steel stud	64mm Rondo steel stud 0.50BMT (cc 600mm)
28mm furring channel	28mm Rondo 129 furring channel (cc 600mm)
Adjustable clip	30mm Rondo BETAGRIP1 BG01 adjustable clip (cc 1200mm)
Resilient mount	Rondo STWC resilient mount (cc 1200mm)

* The 16mm fire-rated plasterboard available for the acoustic laboratory testing in New Zealand is manufactured by GIB and is approximately 1kg/m² heavier at 13.7kg/m² than the leading Australian fire-rated plasterboard products averaging at 12.5kg/m². For the research program fire-rated plasterboard was exclusively used direct fix to the CLT panel and resulted in a maximum of 3dB improvement compared to the bare CLT panel. It is PKA's opinion that substituting Australian fire-rated plasterboard at nominal 12.5kg/m² as a direct fix lining would not deteriorate the acoustic performance of the wall beyond expected tolerances.

We note that any other deviations from the specific material properties tested may affect the acoustic performance of the CLT system. Advice must be sought from a qualified acoustic consultant as well as specific requirements for other non-acoustic considerations.

Figure 8.1: $R_w + C_{tr} \geq 50$ Discontinuous Construction



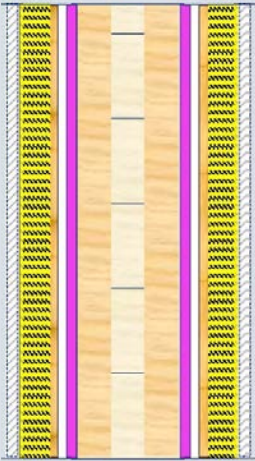
System	Test	Lining	Stud Frame	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W02-05	T1617-89	2x13mm standard plasterboard	70mm timber stud 20mm gap	238	58 - 59	52	58 - 59
W03-04	T1617-44	2x13mm standard plasterboard	64mm steel stud 20mm gap	232	59 - 60	52	60 - 61
W03-05	T1617-46	1x13mm sound-rated plasterboard	64mm steel stud 20mm gap	219	58 - 59	50	59 - 60
W03-06	T1617-47	2x13mm sound-rated plasterboard	64mm steel stud 20mm gap	232	60	53 - 54	60 - 61

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.2: $R_w + C_{tr} \geq 50$ Discontinuous Construction

Configuration	
	Lining Side 1 70mm timber stud 75mm glasswool insulation 20mm Gap 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 20mm Gap 75mm glasswool insulation 70mm timber stud Lining Side 2

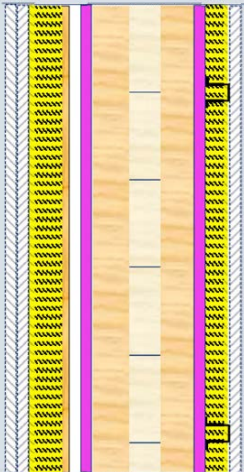
System	Test	Lining Side 1	Lining Side 2	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W07-03	T1617-91	1x13mm standard plasterboard	1x13mm standard plasterboard	328	64 - 65	52 - 53	66
W07-04	T1617-90	2x13mm standard plasterboard	1x13mm standard plasterboard	341	68 - 69	58 - 59	69 - 70
W07-05	T1617-19	2x13mm standard plasterboard	2x13mm standard plasterboard	354	69 - 70	63	70 - 71

Note:

Services are permitted in both cavities when separating habitable areas

Services are permitted in both cavities when separating wet areas

Figure 8.3: $R_w + C_{tr} \geq 50$ Discontinuous Construction

Configuration	
	Lining Side 1 70mm timber stud 75mm glasswool insulation 20mm Gap 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 50mm glasswool insulation Adjustable clip (45mm total cavity) 28mm furring channel Lining Side 2

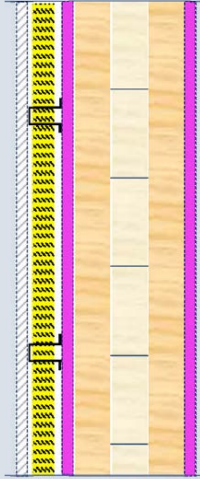
System	Test	Lining Side 1	Lining Side 2	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W08-02	T1617-93	2x13mm standard plasterboard	1x13mm standard plasterboard	296	65 - 66	52 - 53	67

Note:

Services are permitted in both cavities when separating habitable areas

Services are permitted in both cavities when separating wet areas

Figure 8.4: $R_w \geq 50$

Configuration	
	Lining 28mm furring channel Clip or mount (min. 45mm cavity) 50mm glasswool insulation 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard

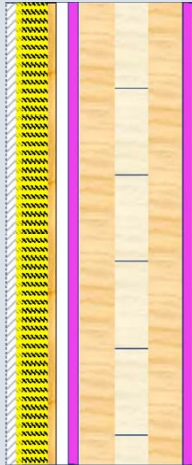
System	Test	Lining	Connection	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W05-02	T1617-94	1x13mm standard plasterboard	Adjustable clip	180	52	42	53 - 54
W06-01	T1617-37	1x13mm standard plasterboard	Resilient mount	180	51 - 52	42 - 43	53
W06-02	T1617-38	2x13mm standard plasterboard	Resilient mount	193	56	47	57 - 58

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.5: $R_w \geq 50$ Discontinuous Construction

Configuration	
	Lining Stud frame 75mm glasswool insulation Gap 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard

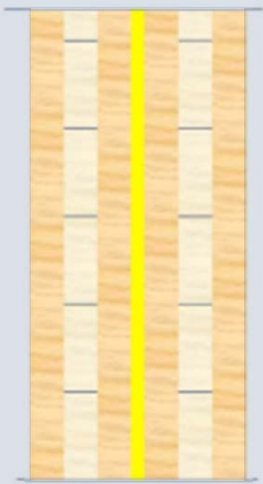
System	Test	Lining	Stud Frame	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W02-02	T1617-88	1x13mm standard plasterboard	70mm timber stud 20mm gap	225	56	48	56 - 57
W04-02	T1617-43	1x13mm standard plasterboard	64mm steel stud 20mm gap	219	58	48 - 49	58 - 59

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.6: $R_w \geq 50$ Discontinuous Construction

Configuration	
	90mm Cross-Laminated Timber (CLT)
	20mm gap 50mm glasswool insulation 90mm Cross-Laminated Timber (CLT)

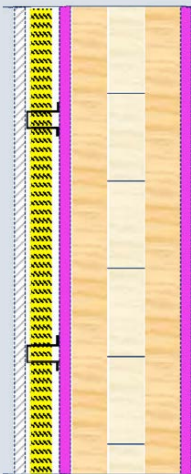
System	Test	Lining Side 1	Lining Side 2	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W09-01	T1617-97	Nil	Nil	200	54 - 55	47	55 - 56

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.7: $R_w \geq 45$ Class 9c - Aged Care

Configuration	
	Lining
	28mm furring channel Clip or mount (min. 45mm cavity) 50mm glasswool insulation 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard

System	Test	Lining	Connection	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W05-02	T1617-94	1x13mm standard plasterboard	Adjustable clip	180	52	42	53 - 54
W06-01	T1617-37	1x13mm standard plasterboard	Resilient mount	180	51 - 52	42 - 43	53

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.8: $R_w \geq 45$ Discontinuous Construction, Class 9c - Aged Care

Configuration							
		Lining Stud frame Cavity insulation Gap 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard					

System	Test	Lining	Stud Frame	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W02-01	T1617-07	1x13mm standard plasterboard	70mm timber stud 20mm gap No cavity insulation	225	47 - 48	41	48 - 49
W02-02	T1617-88	1x13mm standard plasterboard	70mm timber stud 20mm gap 75mm glasswool insulation	225	56	48	56 - 57
W04-02	T1617-43	1x13mm standard plasterboard	64mm steel stud 20mm gap 75mm glasswool insulation	219	58	48 - 49	58 - 59

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.9: $R_w + C_{tr} \geq 40$

Configuration							
		Lining 28mm furring channel Clip or mount (min. 45mm cavity) 50mm glasswool insulation 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard					

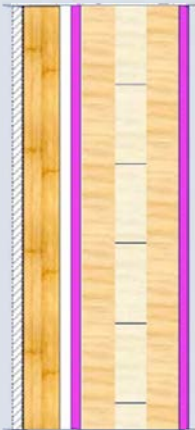
System	Test	Lining	Connection	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W05-02	T1617-94	1x13mm standard plasterboard	Adjustable clip	180	52	42	53 - 54
W06-01	T1617-37	1x13mm standard plasterboard	Resilient mount	180	51 - 52	42 - 43	53

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.10: $R_w + C_{tr} \geq 40$

Configuration							
		Lining Stud frame Gap No cavity insulation 16mm fire-rated plasterboard 90mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard					

System	Test	Lining	Stud Frame	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W02-01	T1617-07	1x13mm standard plasterboard	70mm timber stud 20mm gap No cavity insulation	225	47 - 48	41	48 - 49

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

Figure 8.11: $R_w + C_{tr} \geq 25$

Configuration							
		Lining Side 1 90mm Cross-Laminated Timber (CLT) Lining Side 2					

System	Test	Lining Side 1	Lining Side 2	Thickness (mm)	R_w	$R_w + C_{tr}$	STC
W01-01	T1617-86	Nil	Nil	90	33 - 34	30 - 31	33 - 35
W01-02	T1617-95	16mm fire-rated plasterboard	Nil	106	36 - 38	33 - 34	37 - 38
W01-03	T1617-87	16mm fire-rated plasterboard	16mm fire-rated plasterboard	122	36 - 38	34 - 35	36 - 38

Note:

Services are **not** permitted in the cavity when separating habitable area

Services are permitted in the cavity when separating wet area

8.3 Complying CLT Floor/Ceiling Systems

The complete descriptions of the building materials and system configurations tested are provided in Appendix A Detailed Test Data. For this summary assessment the system configurations have been abbreviated as follows:

Table 8.2: Abbreviations and their meaning.

PKA Abbreviation	Detailed Description
140mm Cross-Laminated Timber (CLT)	140mm Cross-Laminated Timber (CLT) wall 5 ply (62.2 - 65kg/m ²)
13mm standard plasterboard	13mm GIB standard plasterboard (min. 8.6kg/m ²)
16mm fire-rated plasterboard	16mm GIB Fyrelite fire-rated plasterboard (min. 13.7kg/m ²)*
9mm fibre cement sheet	9mm fibre cement sheet (min. 13.5kg/m ²)
20mm strand board floor	20mm Strandboard floor (min. 14.2kg/m ²)
40mm screed	40mm sand-cement screed (min. 80kg/m ²)
25mm DCT SolidEX Screed	25mm DCT SolidEX screed (min. 59kg/m ²)
20mm DCT URSA TerraSol T70P mineral wool	20mm DCT URSA TerraSol T70P Terra Sol T70P mineral wool insulation (7kg/m ³)
50mm glasswool insulation	50mm DCT URSAAcoustic glasswool insulation R1.4 (min. 18kg/m ³) or 50mm Bradford Acoustigard glasswool insulation R1.3 (min. 14kg/m ³)
75mm glasswool insulation	75mm DCT URSAAcoustic glasswool insulation R1.8 (min. 17kg/m ³) or 75mm Bradford Acoustigard glasswool insulation R1.8 (min. 14kg/m ³)
185mm suspended ceiling with Resilient mounts	185mm Rondo suspension ceiling with Rondo STSU resilient mounts (cc 1000mm x 600mm) See test data in Appendix A for detailed description
67mm furring channel ceiling with Resilient mounts	67mm Rondo furring channel ceiling with Rondo STSL resilient mounts (cc 1000mm x 600mm) See test data in Appendix A for detailed description
Adjustable clip	50mm Rondo Betagrip2 BG02 adjustable clip (cc 1000mm)
10mm rubber underlay	10mm Embleton Impactamat rubber acoustic underlay

* As discussed in Section 8.1, it is this report's opinion that the 16mm fire-rated plasterboard with a mass of 13.7kg/m² can be substituted for Australian fire-rated plasterboard at nominal 12.5kg/m².

We note that any other deviations from the specific material properties tested may affect the acoustic performance of the CLT system. Advice must be sought from a qualified acoustic consultant as well as specific requirements for other non-acoustic considerations.

Figure 8.12: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 62$ (BCA) - Not recommended (see page 15)

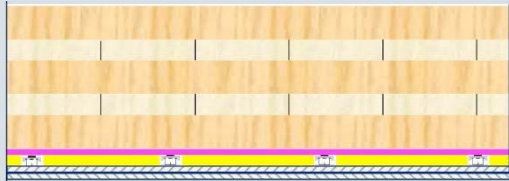
Configuration	
	140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 185mm suspended ceiling with Resilient mounts 75mm glasswool insulation Lining

System	Test	Floor Covering	Lining	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F04-02	T1617-08	Bare CLT	1x13mm standard plasterboard	354	57 - 59	51 - 53	58 - 59	59 - 61	49 - 51
F06-01	T1617-09	Bare CLT	2x13mm standard plasterboard	367	59 - 61	53 - 55	59 - 61	57 - 58	52 - 53

Note:

If CLT floor panels traverse between SOUs without a resilient floor, it is most likely that compliance will not be achieved with BCA sound insulation criteria horizontally due to sound flanking.

Figure 8.13: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 62$ (BCA) - Not recommended (see page 15)

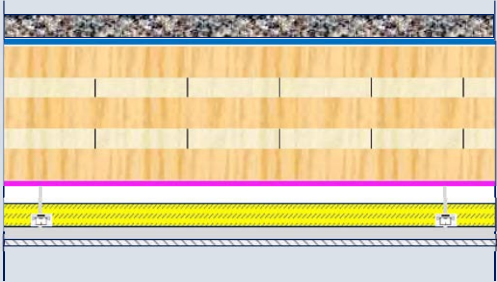
Configuration	
	140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 67mm furring channel ceiling with Resilient mounts 50mm glasswool insulation 2x13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F12-01	T1617-68	Bare CLT	249	57 - 58	50 - 52	57 - 59	61 - 62	48 - 49

Note:

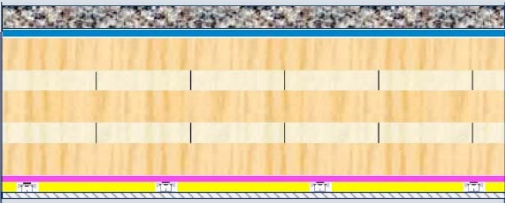
If CLT floor panels traverse between SOUs without a resilient floor, it is most likely that compliance will not be achieved with BCA sound insulation criteria horizontally due to sound flanking.

Figure 8.14: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 55$ (AAAC 3 Star)

Configuration	
	40mm screed 10mm rubber underlay 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 185mm suspended ceiling with Resilient mounts 75mm glasswool insulation 13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F05-01	T1617-42	Bare screed	404	61 - 62	54 - 56	61 - 62	50 - 51	59 - 60

Figure 8.15: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 55$ (AAAC 3 Star)

Configuration	
	Floor 40mm screed 10mm rubber underlay 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 67mm furring channel ceiling with Resilient mounts 50mm glasswool insulation 13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F11-01	T1617-52	Bare screed	286	60 - 61	52 - 54	60 - 62	53 - 55	55 - 57
F11-03	T1617-53	7mm laminate timber floor 3mm foam underlay on Screed	296	60 - 61	51 - 54	60 - 61	52 - 53	54 - 57

Figure 8.16: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 55$ (AAAC 3 Star)

Configuration	
	Floor 40mm screed 10mm rubber underlay 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard Clips or mount (min. 67mm cavity) 50mm glasswool insulation 2x13mm standard plasterboard

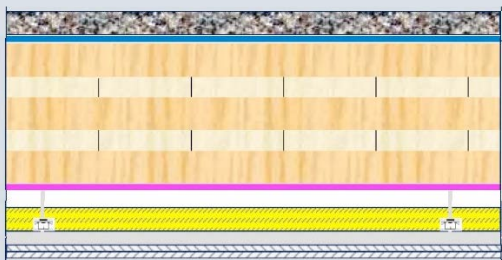
System	Test	Floor Covering	Connection	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F14-01	T1617-49	Bare screed	Adjustable clip	299	60 - 61	51 - 54	60 - 62	54 - 55	55 - 56
F13-01	T1617-56	Bare screed	Resilient mount	299	61 - 62	54 - 56	61 - 62	50 - 52	58 - 60
F13-04	T1617-62	10mm ceramic tiles 8mm adhesive bed Screed	Resilient mount	317	61 - 62	55 - 56	61 - 62	50 - 51	59 - 60

Figure 8.17: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 55$ (AAAC 3 Star)

Configuration	
	Floor 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 67mm furring channel ceiling with Resilient mounts 50mm glasswool insulation 2x13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F12-03	T1617-65	7mm laminate timber floor 3mm foam underlay 2x9mm fibre cement 10mm rubber underlay	287	59 - 60	53 - 54	59 - 60	50 - 51	58 - 59
F12-04	T1617-66	7mm laminate timber floor 3mm foam underlay 2x9mm fibre cement 9.5mm Proctor Q-Silence C40 underlay	286.5	59 - 61	52 - 53	60 - 61	51 - 52	57 - 58

Figure 8.18: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 50$ (AAAC 4 Star)

Configuration	
	Floor 40mm screed 10mm rubber underlay 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 185mm suspended ceiling with Resilient mounts 75mm glasswool insulation 2x13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F07-01	T1617-34	Bare screed	417	61 - 62	55 - 56	61 - 62	49 - 50	60 - 61
F07-03	T1617-36	7mm laminate timber floor 3mm foam underlay on Screed	427	61 - 62	55 - 56	61 - 62	46 - 48	62 - 64

Figure 8.19: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 50$ (AAAC 4 Star)

Configuration	
	Floor 25mm DCT SolidEX screed 7.5mm Proctor Q-Silence P80 underlay 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 185mm suspended ceiling with Resilient mounts 75mm glasswool insulation 2x13mm standard plasterboard

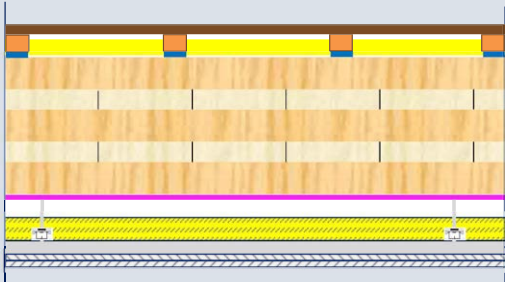
System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F08-01	T1617-25	Bare DCT SolidEX screed	399.5	60 - 61	54 - 55	60 - 61	48 - 49	61 - 62
F08-03	T1617-23	7mm laminate timber floor 3mm foam underlay on DCT SolidEX Screed	409.5	60 - 61	54 - 55	60 - 61	47 - 49	61 - 62

Figure 8.20: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 50$ (AAAC 4 Star)

Configuration	
	Floor 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 185mm suspended ceiling with Resilient mounts 75mm glasswool insulation 2x13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F06-03	T1617-15	7mm laminate timber floor 3mm foam underlay 2x9mm fibre cement 10mm rubber underlay	405	60 - 62	54 - 55	60 - 62	46 - 48	62 - 64
F08-04	T1617-12	7mm laminate timber floor 3mm foam underlay 2x9mm fibre cement 7.5mm Proctor Q-Silence P80 underlay	402.5	60 - 62	54 - 55	60 - 62	47 - 49	62 - 63

Figure 8.21: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 50$ (AAAC 4 Star)

Configuration	
	Floor 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 185mm suspended ceiling with Resilient mounts 75mm glasswool insulation 2x13mm standard plasterboard

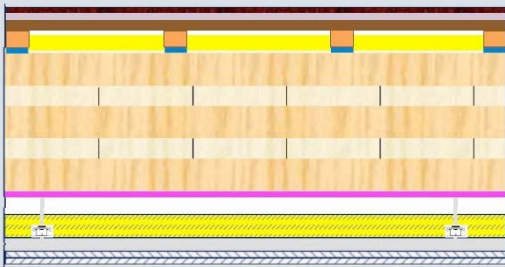
System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F09-01	T1617-16	20mm strand board floor 56mm Proctor Q-Silence Dynamic Batten 20mm DCT URSAcoustic mineral wool in cavity	443	61 - 62	55 - 56	61 - 62	44 - 46	60 - 63
F09-04	T1617-26	20mm strand board floor 30mm Proctor Q-Silence Thin Batten 20mm DCT URSAcoustic mineral wool in cavity	417	60 - 62	52 - 54	61 - 62	46 - 47	60 - 62

Figure 8.22: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 50$ (AAAC 4 Star)

Configuration	
	Floor 40mm screed 10mm rubber underlay 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 67mm furring channel ceiling with Resilient mounts 50mm glasswool insulation 2x13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F13-03	T1617-54	7mm laminate timber floor 3mm foam underlay on Screed	309	61 - 62	54 - 55	61 - 62	48 - 49	59 - 62

Figure 8.23: Airborne $R_w + C_{tr} \geq 50$, Impact $L_{n,w} \leq 45$ (AAAC 5 Star)

Configuration	
	Floor 20mm strand board floor 56mm Proctor Q-Silence Dynamic Batten 20mm DCT URSAcoustic mineral wool in cavity 140mm Cross-Laminated Timber (CLT) 16mm fire-rated plasterboard 185mm suspended ceiling with Resilient mounts 75mm glasswool insulation 2x13mm standard plasterboard

System	Test	Floor Covering	Thickness (mm)	R_w	$R_w + C_{tr}$	STC	$L_{n,w}$	IIC
F09-03	T1617-20	7mm laminate timber floor 3mm foam underlay on Strand board	453	61 - 62	56	61 - 62	41 - 43	63 - 66



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