DESIGN AND INSTALLATION OF WALLS & CEILINGS IN TALL BUILDINGS

RONDO®

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INTRODUCTION

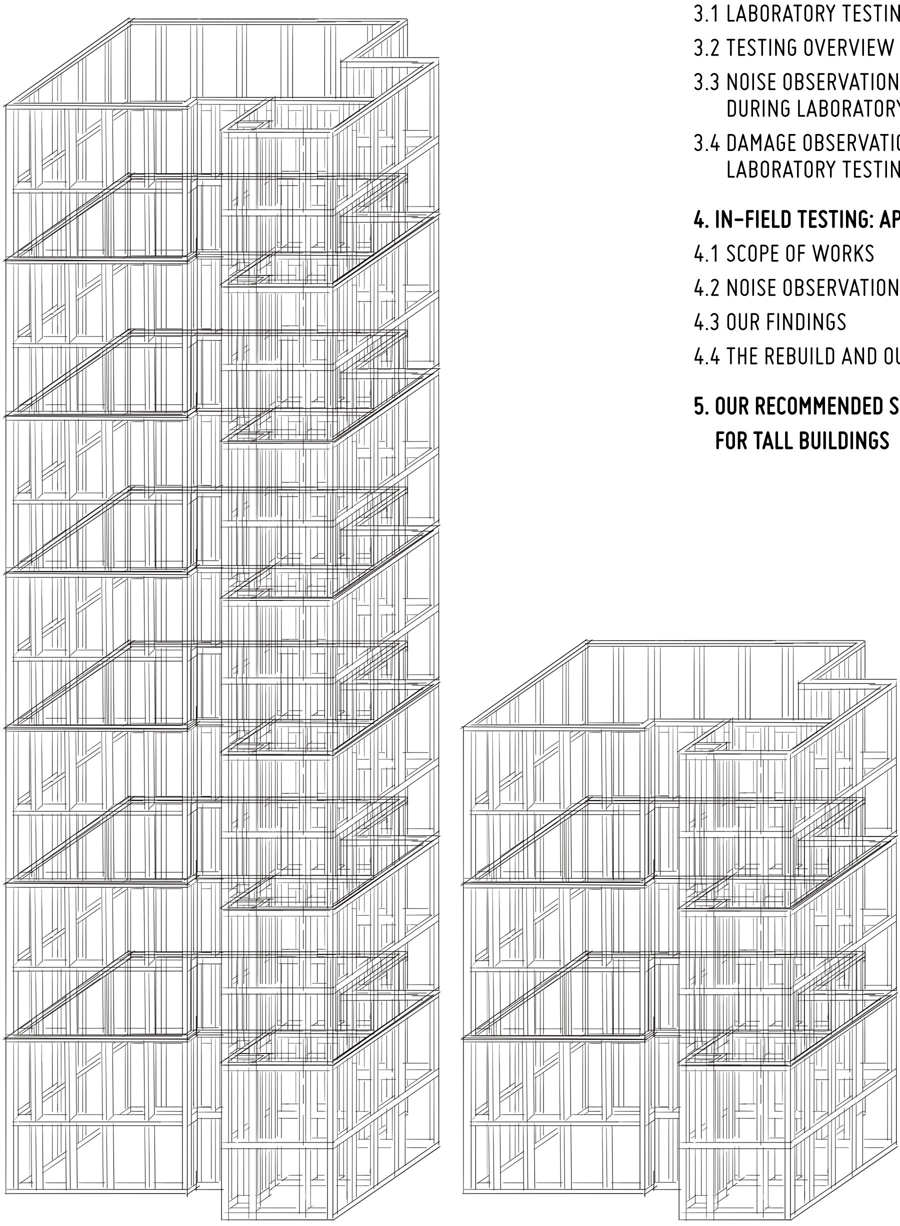
Our cities are getting more populated and with this comes pressure for land space... when the land isn't available, the solution comes from vertical space – taller buildings.

As the market-leading manufacturer and supplier of wall and ceiling systems in Australia, we have the knowledge and expertise to help you design and construct your next tall building.

This manual is intended to provide an overview of the following:

- The design requirements for wall and ceiling systems in tall buildings
- An overview of Rondo's testing program, both in the laboratory and in the field
- What is a tall building?
- Recommendations for Rondo wall and ceiling systems installation

CONTENTS:



1. DESIGN REQUIREMENTS

1.1 NCC REQUIREMENTS

The National Construction Code (NCC) provides the legal framework for all building compliance throughout Australia. Each State or Territory can have variations to some of the NCC requirements however; the NCC is given legal effect through relevant State or Territory legislation.

Whilst the NCC is a performance-based code, the design requirements for walls and ceilings in tall buildings is very specific and stems from the structural requirements documented in Section B of Volume 1 of the NCC. This is where the design process starts:

1. Determine the building Importance Level (IL) per Table B1.2a
2. Determine design events for safety per Table B1.2b

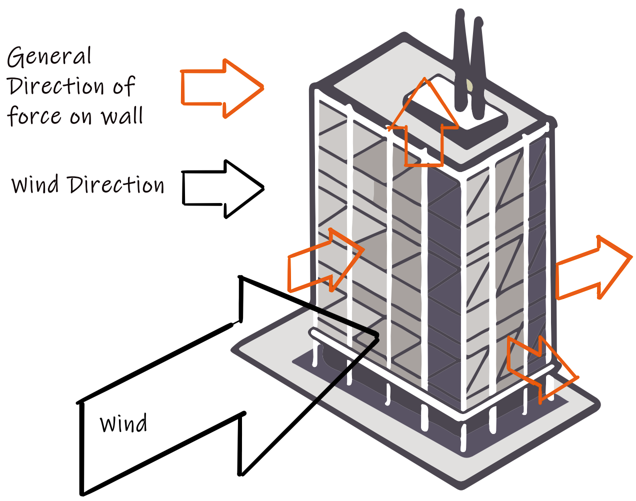
The NCC design events for safety include Wind, Snow and Earthquake actions and is based on an Annual Probability of Exceedance (APE) applicable for the building IL. The design events for safety need to be assessed for each site individually and this is through the referenced Australian Standards such as AS/NZS1170.2 for Wind actions and AS1170.4 for Seismic actions. Snow loading is not considered in this manual as it is not typically applicable for wall or ceiling systems.

1.2 WIND PRESSURES – AS/NZS1170.2

As design experts, we understand that wind loading traditionally governs the design of tall buildings in Australia, and that it is complex with many factors that relate to the site and the building including: the façade system on the building and whether there are operable doors and/or windows within the façade.

The characteristics of wind pressure on a structure and its elements are specific to that structure and are a function of four main variables:

1. Building Importance Level
2. Locality of the building
3. The geometry of the structure under consideration
4. Disturbance of the approaching wind



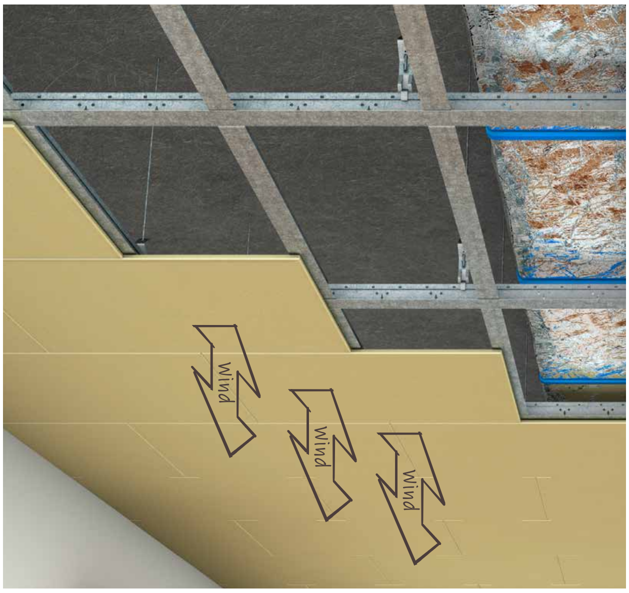
The external wind pressures on a building are not steady, but highly fluctuating, and vary across the building face both laterally and vertically. These external wind pressures, coupled with the façade design, also result in the development of internal pressures within the building.

Internal pressures are determined in accordance with AS/NZS1170.2 Clause 5.3, using the basic external pressures for the building and are applicable for both walls and ceilings. The internal pressures cannot be ignored, and in some situations can be upwards of 1.0kPa.

Using internal pressures along with system testing as applicable, Rondo provide design solutions for wall and ceiling systems to accommodate the site wind loads. This ensures the client's requirements are satisfied, whilst simultaneously complying with the Building Codes requirements.

For more information, download our Contractor R-Series; *"Quick & Simple Guide to the Importance of Site Wind Speed"*

WIND LOAD ON WALLS



WIND LOAD ON CEILINGS

1.3 SEISMIC CONSIDERATIONS – AS1170.4

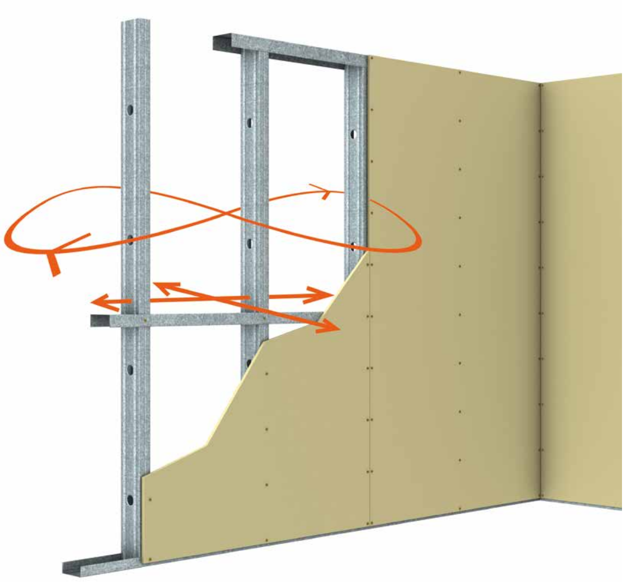
All buildings and their parts need an assessment of their seismic requirements, in accordance with the NCC and AS1170.4. Each building's Importance Level (IL) determines the extent of the seismic design requirements.

For structures of IL2 or greater, the seismic actions on the walls and ceilings in all buildings needs to be considered, in conjunction with any other expected actions, such as wind loading, as discussed previously.

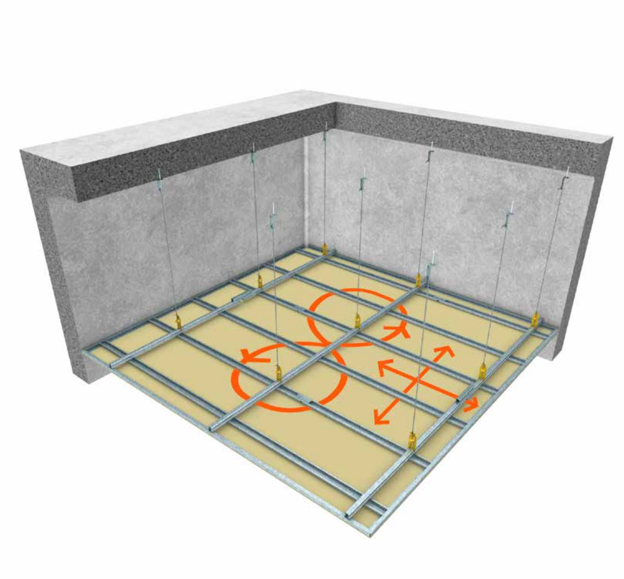
Rondo seismic designs for walls and ceilings, are tailored to suit each project's design requirements considering architectural detailing, and offer several advantages for tall buildings:

- Complete wall and ceiling seismic designs based on most efficient design solution
- Designed to resist lateral forces during an earthquake
- Will limit the structural damage of the systems
- Accommodate differential movements resulting from inter-storey drift
- Reduce the potential for tiles and lining boards to dislodge and block evacuation paths
- Consideration of critical services, as required, for IL4 Buildings
- Protects the safety of building occupants

For more information, view our Blog *"Everything you need to know about Seismic Design"*



SEISMIC LOAD IN WALLS



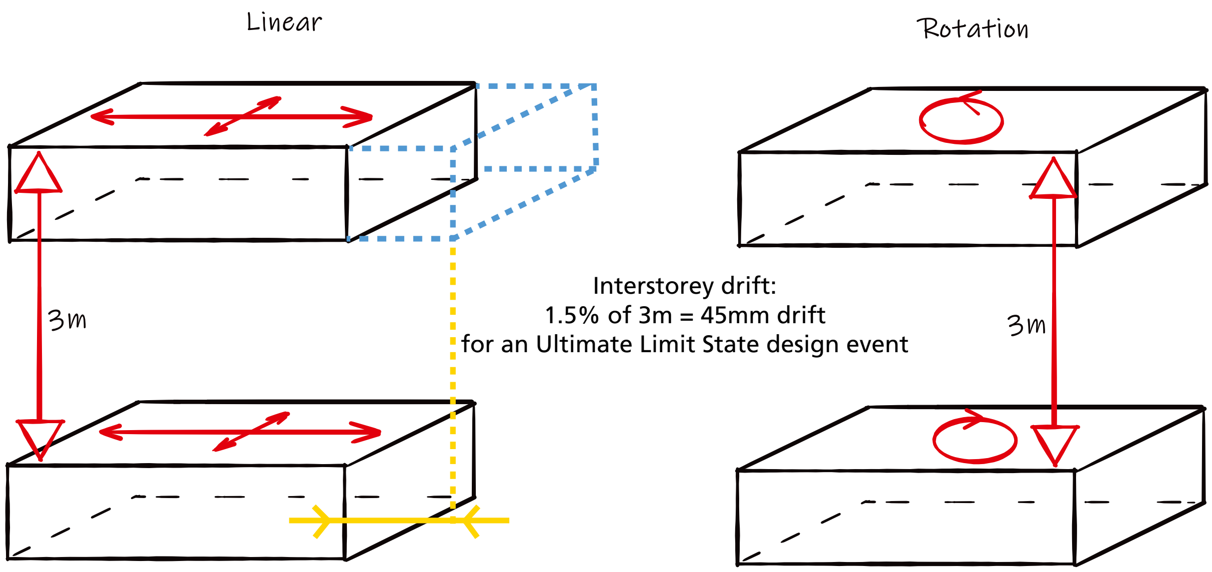
SEISMIC LOAD IN CEILINGS

1. DESIGN REQUIREMENTS (CONTINUED)

1.4 BUILDING MOVEMENT

All buildings will move due to wind and seismic actions however; the quantum and speed of movement experienced will depend not only on the event but also the building superstructure design. The building movement can differ between floors and the floors can move independently of each other, this is known as inter-storey drift.

Inter-storey drift is the relative movement between two consecutive floors and can be in any plane horizontal to the floor. It is proportional to the distance between the floors and the overall building stiffness, but is limited to 1.5% of the floor height under AS1170.4 for Australia, at an Ultimate Limit State (ULS) design seismic event. That means for every 1m of storey height the floors are permitted to drift up to 15mm in any direction. The building will move with the force of the earthquake and can have one floor moving in the opposite direction from the one below. This movement can take the form of a wave up the building and can also result in rotational movement of the superstructure due to the torsional effects arising from the structural form of the building.



INTER-STOREY DRIFT

For concrete superstructures, AS3600 limits the inter-storey drift to H/500 under a Serviceability Limit State design event and this equates to 2mm per 1m of storey height. This is significantly lower than the ULS limit and is typically taken as the no significant damage limit for the Rondo wall and ceiling systems, unless specified otherwise.

1.5 WHAT IS A TALL BUILDING?

There is no definition for a tall building, and this is somewhat subjective in real terms. However, throughout this document the term "tall building" is used everywhere so it is appropriate for us to define what we believe to be a tall building. Our definition is given within the context of the testing we conducted, and certainly is not the only definition.

The testing that has been completed has all been based on inter-storey drift, so it is appropriate that the definition for a tall building also reflect this. Our definition of a tall building is as follows:

Any building with a fundamental frequency less than 0.4Hz and/or;

Any building likely to experience inter-storey drift beyond H/500 at a Serviceability Limit State

2. BUILDING NOISE

2.1 INTRODUCTION

The wall and ceiling systems within the building are attached directly to the structure and therefore can experience the same movement as that of the building. More recently, this building movement has been found to create noise in the installed wall and ceiling framing systems and Rondo has been researching this phenomenon for the last two years, complimented by site investigations of actual apartments experiencing noise related issues.

Whilst the preceding pages have discussed the design requirements coming from the NCC, and the relevant design codes; building noise is not codified in the NCC nor any of its referenced standards and the following pages are provided, firstly as an overview of our test program to date, including all significant findings, but more importantly what we believe to be "best practice" to minimise potential noise issues in your next building project.

2.2 LET'S DEBUNK SOME MYTHS

In our experience, which is over 50 years as a business, noise issues in tall buildings have never really been an issue of significance. However, more recently, we have become aware of noise issues in some tall buildings and have heard, seen and read quite a few comments and publications around this phenomenon – most of which we do not agree with based on our extensive research into this phenomenon. Here a few myths we would like to debunk before proceeding:

a. **Only metal framed systems make noise?**

   Not true, we have visited a building which had a timber wall installed for comparative purposes only to find the same problem still existed.

b. **All building noise is coming from the steel framed systems?**

   Not true, only a relatively small proportion of the overall building noise, is emanating from the steel framed systems.

c. **I need a complicated solution to fix this problem?**

   Not true, as part of our research program we demolished and rebuilt a significant proportion of a problematic apartment using conventional products and have not had one complaint from the tenant since, which is more than 18 months - refer to page 14.

d. **All tall buildings experience noise issues?**

   Not true, we have been involved with the design and supply of tall building fitouts for decades now and have only had noise issues in a couple of tall buildings, all of which were apartment buildings.

   We have never had one complaint of a noise problem from a high-rise hotel or commercial building. The usage, construction and fitout of these buildings is significantly different to an apartment building which is why we believe they do not have a noise problem.

Is it possible for a Steel Stud Wall System to eliminate all building noise?

No. We have spent years researching and observing noise in tall buildings, and our findings conclude that specific installation details for the Rondo wall and ceiling systems will help reduce noise associated with these systems. No wall or ceiling system can eliminate all building noise. This is because tall buildings also generate noises related to the façade and installation of services.

Since our research project began in September 2017 at the Swinburne University, we have completed over 235 individual tests with configurations that considered both walls and ceilings. We were able to reproduce the same noises heard on site, and as a result, develop a good understanding of the primary causal effects of the noise.

From the laboratory, we were able to successfully rebuild an apartment using the techniques developed in the lab which allowed us to prove that real life results are possible.

3. TESTING

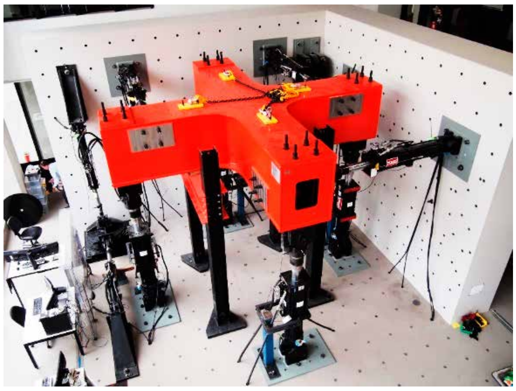
3.1 LABORATORY TESTING

Our program involved full-scale drywall and ceiling system tests, at various frequencies, using a six (6) axis hydraulic testing facility located at Swinburne University. Testing was primarily conducted at 0.2Hz which is approximately the first fundamental frequency (f_0) of a 230m tall building, with drift limits starting at H/500 and extending through to 2.5% of the wall height.

Testing included in-plane, out-of-plane and torsional modes, on test panels constructed in a controlled environment where variables were managed. We chose to test in this manner so the results were related to the building movement, and could be used for any building with known movement limits. To-date, we have completed over 235 individual tests.

The tests typically consisted of three wall panels 2.7m high with one side open to simulate a glass facade situation, with plasterboard wall and ceilings installed in various configurations as follows:

- **WALLS**
  - Conventional Deflection Head Track
  - QUIET TRACK Deflection Head Track
  - Conventional Nogging and FAST-FIX Nogging
- **CEILINGS**
  - Square Set Corner
  - Shadowline Corner
  - Disconnecting ceiling from wall channel
  - Disconnecting wall channel from studs
  - Floating ceiling



TESTING FACILITY

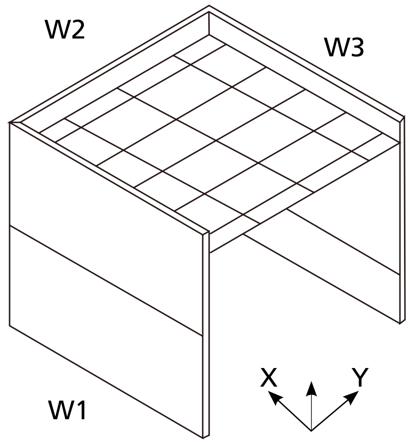
3.2 TESTING OVERVIEW

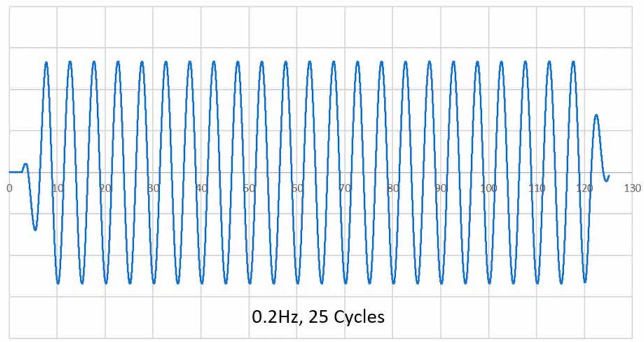
At the very start of this testing program it was determined that:

1. Testing had to relate to the expected building movement
2. Wall and ceiling construction required a benchmark position
3. Deliverables needed to be transferable to any building, globally

> "Rondo's overall concept to minimise the potential for noise is simple — if the walls remain stationary then they cannot make noise"

In order to understand the problem at hand it was necessary to investigate each element of the wall and ceiling system, to assess its' contribution to the issue. Accordingly, it was decided to construct the wall and ceiling systems as individual elements, and by testing each individual element we were then able to confidently isolate each source of noise. Having identified the source of the noise we were then able to develop and test installation details to mitigate the noise, using standard products, and eventually push the noise issue beyond the superstructure Serviceability Limit State.

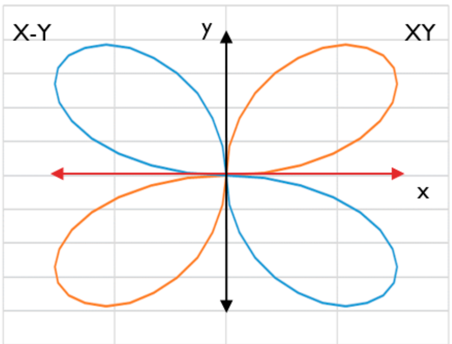




Predominantly, testing commenced in earnest using three wall panels (W1 – W3), with a suspended ceiling. All walls were 2.7m high, and the ceiling was approximately 2.4m above floor level.

A single test consisted of 25 complete cycles, at a frequency of 0.2Hz or a period of 5 seconds. This approximately corresponds to a concrete moment resisting framed building up to 200m tall, at an ultimate limit state. Whilst testing was conducted at other frequencies the issue is controlled by the drift level (displacement) rather than an acceleration issue.

A full test sequence consisted of checking both the X and Y axis orthogonal directions, as well as "clover leaf" testing to check the torsional displacements which can occur in high rise buildings. Testing in the orthogonal directions resulted in some walls experiencing in-plane actions, whilst simultaneously, the transverse walls experienced out-of-plane actions. The in-plane actions measure the slip performance of the deflection head track and the out-of-plane action measures the lateral performance of the deflection head track to accommodate the building movement. Typically, the clover leaf test is the worst-case scenario as all walls are subject to in-plane and out-of-plane actions simultaneously.



Drift level testing commenced at H/500, which equates to 5.4mm differential movement over the 2.7m wall height. This was selected as the minimum requirements as it is also the Serviceability Limit State deflection nominated in AS3600 for a concrete superstructure. Thereafter, the drift levels were incrementally increased typically down to H/240 however; some tests were conducted up to 1.5% and 2.5% drift (67.5mm for a 2.7m high wall) to assess the ultimate limit state drift defined in AS1170.4 and NZS1170.5 respectively. Beyond the H/500 drift limit, assessment was limited to damage and stability only.

Load cells and displacement transducers were positioned over the wall panels to assess the differential movement within the wall panels, as compared to the test rig. Coupled with noise monitoring this allowed the potential for noise to be determined. Additionally, after each test run the wall and ceiling panels were visibly checked for damage.

3. TESTING (CONTINUED)

3.3 NOISE OBSERVATIONS DURING LABORATORY TESTING (CONTINUED)

From our extensive testing, we were able to identify all sources of noise within the framing, and found the noise is not just coming from the head track. The following locations were found to be a source of noise during testing:

- Incorrect installation techniques
- Friction forces at head tracks
- Within the field of the walls
- Wall and ceiling junctions
- Wall to wall junctions

Incorrect installation techniques

During our test program we constructed and tested some walls and ceiling installations with construction defects commonly witnessed on site, such as screw fixings into the head track, to assess the noise impact of such works. It was found that screw fixing into the head track nearly always resulted in noise issues with the wall panels.

Frictional forces at head tracks

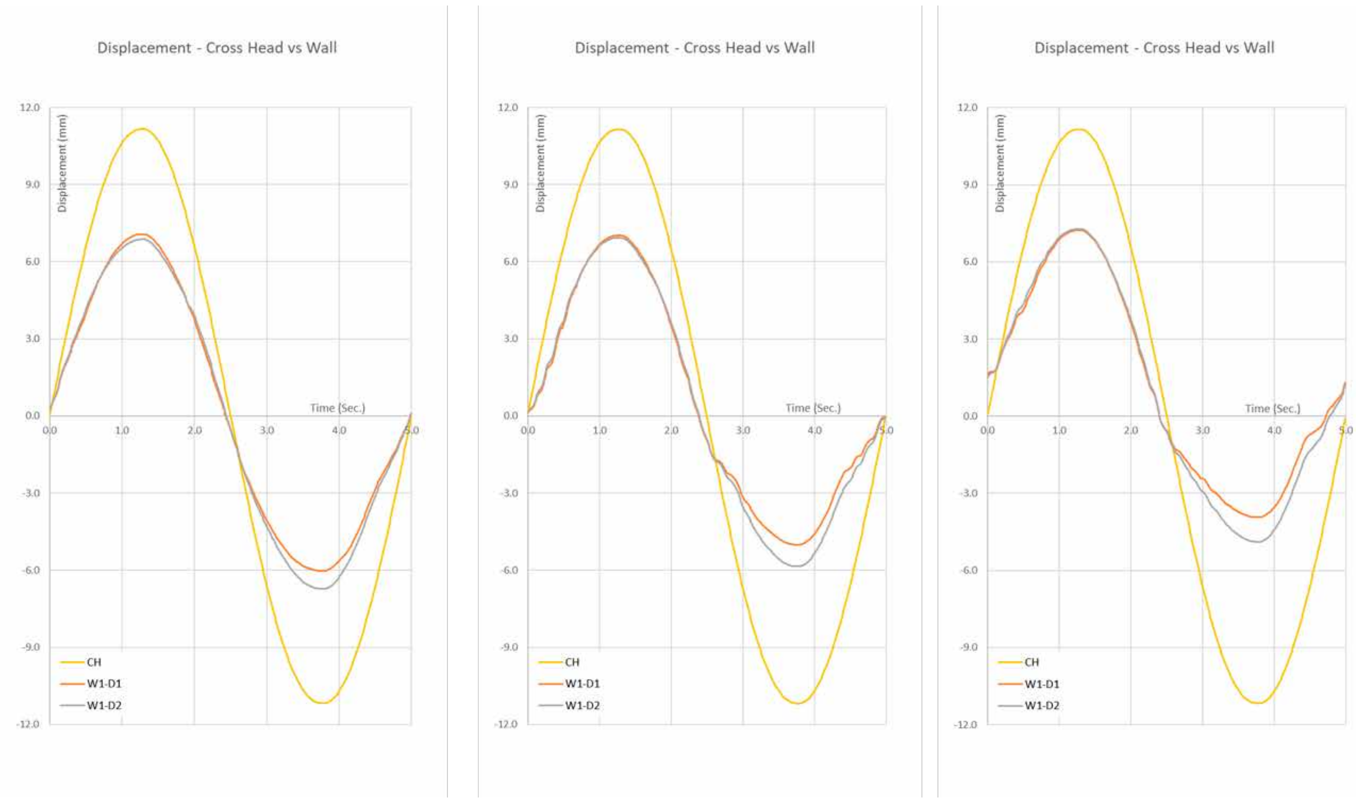
It was found very early in our testing program that the head track connection detailing was a significant element in the potential noise generation from the walls. "Creaking ship" noise was generated from conventionally constructed walls lined both sides, without a ceiling in place, and at a drift level of H/500.

Within the field of the wall

Noise was generated from within the field of the walls and we surmise this was due to the racking forces developed in the wall panel resulting from all, or a combination of (1) the frictional forces at the head track, (2) wall junction, with the out-of-plane wall pushing or pulling the in-plane wall panel and (3) the direct racking force through the ceiling / wall junction, particularly on square set ceilings.

Wall and ceiling junctions

Depending on the construction detail at the wall and ceiling junction, the ceiling can drive the wall panel during drift. For the more rigid wall and ceiling junction, square set, we run a series of tests to assess the reduction in the wall movement by disconnecting the ceiling in stages.



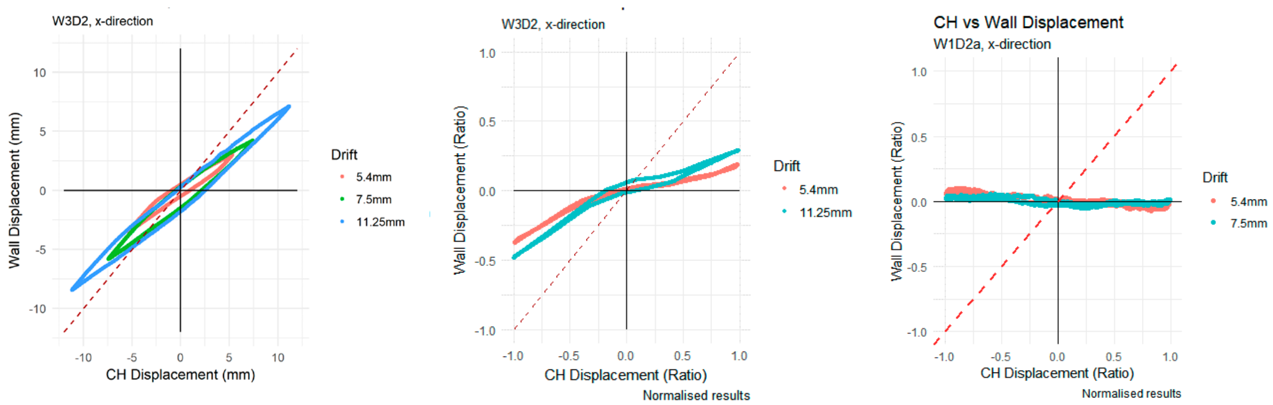
The graph on the previous page shows the comparative wall movement (orange and grey graphs) against the test rig (structure) movement (yellow graph), at an H/240 drift limit. The graphs, left to right respectively, depict (1) a conventional square set installation, (2) after removal of the screw fixing between the furring channel and perimeter channel and (3) after removal of the screw fixing between the furring channel and perimeter channel and screw fixing the perimeter channel to the plasterboard wall linings only.

It can be seen, when the test rig is moving in the positive direction, there is little change in the wall panel movement with approximately 7mm movement measured across all three wall panel tests. This is because the plasterboard ceiling is bearing against the end wall panel and pushing the wall panel, in addition to the racking force generated along the ceiling edge due to the perimeter channel and ceiling lining fixings into the wall panel.

Conversely, when the test rig is moving in the negative direction, the wall panel movement was reduced by approximately 16 – 33% when the ceiling was progressively disconnected from the wall panel. In this instance, the ceiling is pulling away from the end wall and is only reliant on the frictional forces generated at the ceiling to wall junction.

Wall to Wall junctions

Typical published details for "T" and "L" wall junctions detail a screw fixing between the abutting walls, apart from the plasterboard fixity at the wall corner. These simple connections, between the abutting walls, are sufficient to generate racking forces in the wall panels and determined through our testing which is depicted in the below graphs.



GRAPH OF WALL MOVEMENTS FOR ROUNDS 2, 3 AND 4 TESTING

These graphs show the wall movement relative to the testing rig. The red and green graphs are the wall movements at H/500 and H/360 drift lifts for Rounds 2, 3 and 4 of our testing programs. The graph has been normalised, and the axis may be taken as the percentage of relative movement of the wall panel.

Round 2 test, the wall and ceiling systems were constructed in accordance with normal published information, the mast was moving in the "X" direction, and wall panel W3 movement was being measured. In this direction the deflection head track should be sliding along the wall and taking up the building movement, however at the H/500 drift limit, the W3 wall panel was moving at approximately 60% of the movement of the mast, which equates to about 3.2mm for a 2.7m high wall. This movement increased to about 75% or 5.6mm at the H/360 drift limit. This means there is a potential for noise to be generated because the wall is moving with the structure.

Rounds 3 and 4, we tested various wall and ceiling configurations to minimise the wall movement. As shown in the Round 4 graph, the W3 wall panel exhibited little movement (horizontal line) as compared to the mast, even up to H/360 drift limits which is outside the code requirements. Based on our simple hypothesis; If the wall doesn't move it can't generate noise, disconnecting the wall panels is one means of reducing the noise potential.

3. TESTING (CONTINUED)

3.4 DAMAGE OBSERVATIONS DURING LABORATORY TESTING

Although not the primary focus of our testing program, it is essential to understand the impact of the building, wall and ceiling movement in terms of damage to the installed systems. This is of particular concern for Importance Level 4 buildings where post disaster functionality is a requirement.

Part of the problem around damage is perception and depending on a persons' understanding of what they are seeing can determine their perception of the damage. The seismic code AS1170.4 states SLS is deemed satisfied for IL1, 2 and 3 buildings, when the structure is designed in accordance with AS1170.4 and the relevant material standard. Additionally, Section 8 of AS1170.4 requires that Non-structural parts and components "accommodate the design inter-storey drift". What does all this mean in terms of acceptable performance?

The definition and specification of the non-structural elements serviceability limit states certainly requires further work, in Australia. In New Zealand, the earthquake code NZS1170.5 clearly nominates the SLS design criteria for all building Importance Levels together with the expected damage levels for the non-structural elements. The damage limits for the SLS states are summarised below:

SLS1 – the non-structural components do not require repair

SLS2 – the structure maintains operational continuity

This provides reasonable and clear expectations of performance for the non-structural elements.

The following photographs taken from the Rondo tests show typical damage of the wall and ceiling elements under various drift limits:

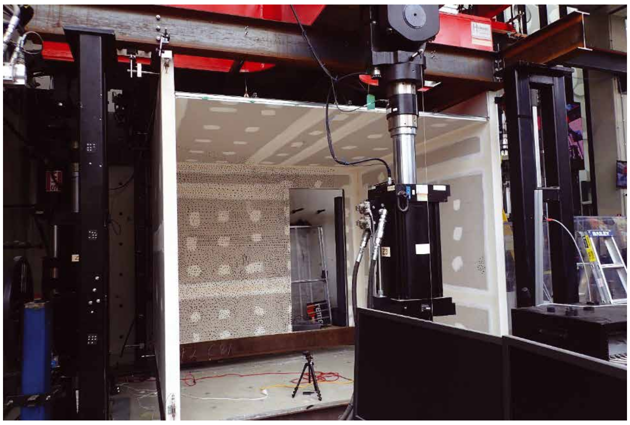


PHOTO 1 – ROUND 2 TESTING START

X	L/500 - X (trial)	No Visual Damage
X	L/500 - X	No Visual Damage
X	L/500 - Y	No Visual Damage
X	L/500 - ±X ±Y	No Visual Damage
X	L/500 - ±X ±Y	No Visual Damage
X	L/360 - X	No Visual Damage
	L/360 - Y	Crack at Base of W1 - W2 Junction (outside)

R2 L/500 (±5.40MM) DRIFT DAMAGE SUMMARY

There was no visible damage to the wall and ceiling systems after the completion of the four (4) L/500 drift tests, comprising X and Y directions in isolation and X ± Y in a clover leaf pattern. This installation was constructed in accordance with standard published information from Rondo and the plasterboard manufacturers, with square set joints between the walls and ceiling.



PHOTOS 3,4 & 5 – R2 L/360 (±5.40MM) EXTERNAL CORNER, NIB WALL END, DOOR OPENING BASE DAMAGE

There was visible damage to the wall systems after the completion of the four (4) L/360 drift tests, comprising X and Y directions in isolation and X ± Y in a clover leaf pattern. The no damage limit appears to lie somewhere between L/500 and L/360 drift for this type of construction.

Considering the New Zealand serviceability limits it appears SLS1 would be satisfied with an L/500 drift limit, and the next consideration would be the operational functionality limit (SLS2).


PHOTOS 6 & 7 – 1.5% DRIFT (40.5MM) INTERNAL CORNER, CEILING JUNCTION AND EXTERNAL CORNER

Between the L/360 (5.40mm) and 1.5% drift limits the damage to the wall and ceiling systems propagates and photos 6 and 7 show the extent of damage at the 1.5% drift limit. This level of damage and separation, whilst not resulting in loss of stability, would be quite disconcerting to any occupant of the building and would present significant issues for maintaining operational functionality for any services crossing these building elements.

Considering the New Zealand serviceability limits it appears SLS2 could be satisfied at approximately L/240 drift limits, noting that patch and paint repairs would be necessary however the expected damage would not require immediate repair and these could be scheduled with other works as appropriate.

The nominated construction details presented within this manual could potentially provide slightly better drift limits, but this currently requires further analysis and development.

4. IN-FIELD TESTING: APARTMENT REBUILD

Using our test findings, Rondo was requested to assist in the partial demolition and rebuild of the internal walls and ceilings of an apartment located in a skyscraper (ie; building height > 150m) in Melbourne CBD where the owner had been complaining of noise. The apartment is located about 20m below the mid height of the building. The building is classified as Importance Level 3 within the definitions provided in the NCC.

The installed ceilings in the Apartment were not Rondo products. Rebuild works commenced on site in February 2019.

4.1 SCOPE OF WORKS

The image below shows the typical floor plan of the apartment, and the hatched walls were all to be demolished, including the ceiling within the boundary of these walls, per the agreed scope of works. The green hatched walls are fire and acoustic rated inter-tenancy walls.

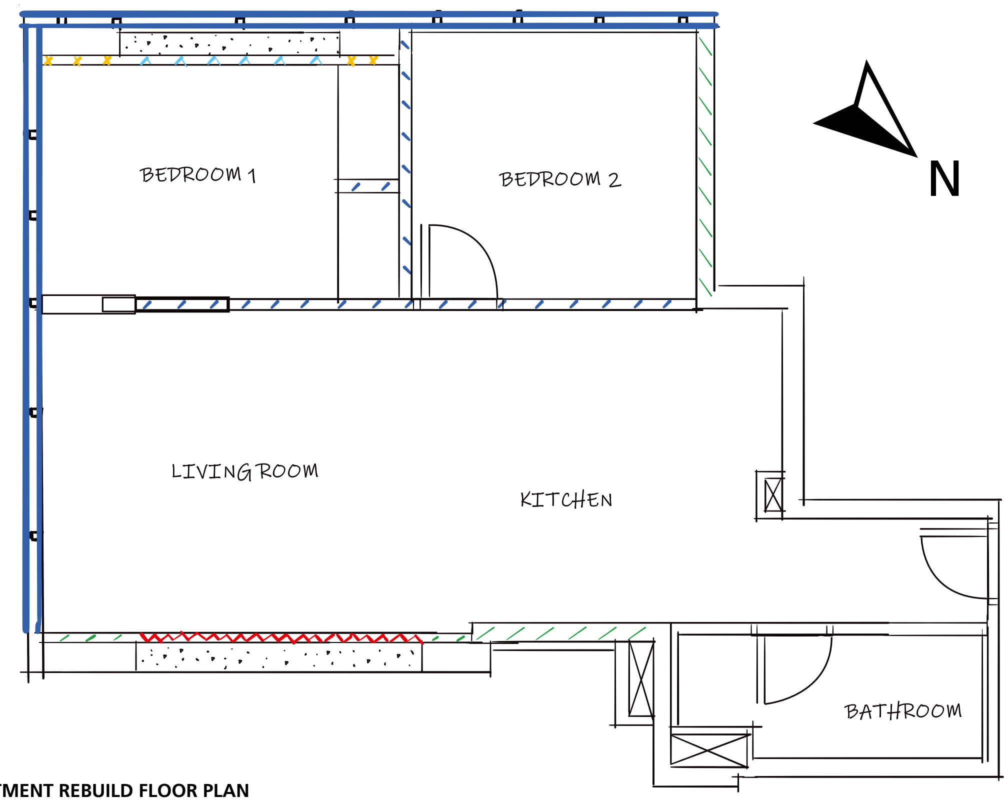
Upon receiving access to the Apartment one day before demolition, noise was heard and recorded in the apartment at several locations, including:

- Within Bedrooms 1 and 2
- Within the dividing wall between the bedrooms and Living / Kitchen area
- Within the Living room inter-tenancy wall
- Within the bathroom / hall wall

These elements were within the scope of works agreed with the builder, except for the bathroom wall, which was subsequently included but limited to a partial demolition / rebuild.

Additionally, noise was also heard and recorded in the common areas of the building near the lifts and a service shaft however; these areas were not within the agreed scope of works.

The nearest Bureau of Meteorology wind site to the project is located at Olympic Park in Melbourne, approximately 2.5km from the site. Peak wind gust on the day of commencement was 35km/h (9.72m/s). The wind speed during this noise event was significantly below what is considered a Serviceability Limit State (SLS) condition, as defined in AS/NZS1170.2 as 37m/s(133km/h).

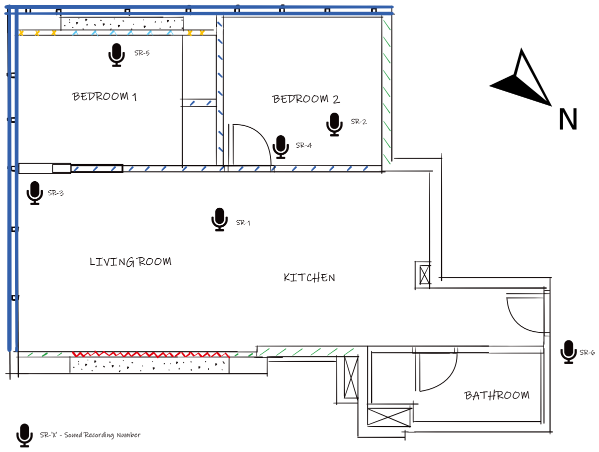


APARTMENT REBUILD FLOOR PLAN

4. IN-FIELD TESTING: APARTMENT REBUILD (CONTINUED)

4.2 NOISE OBSERVATIONS

The day before and during demolition, noise was heard around the locations marked on the adjacent floor plan.



APARTMENT REBUILD FLOOR PLAN

ID	Date	Time	Location	Wind#		Gust#		Description
				Direction	Speed (km/h)	Direction	Speed (km/h)	
SR-1	26 Feb 2019	06:11pm	Living Room	S	19.0	SSW	35.0	Room 2 before refurbishment
SR-2	26 Feb 2019	04:45pm	Bedroom 2	SSW	19.0	SSW	30.0	Living room wall T-junction before refurbishment
SR-3	6 Mar 2019	12:40pm	Living Room	SSW	15.0	WSW	43.0	Window frame during refurbishment
SR-4	29 Mar 2019	02:24pm	Bedroom 2	NW	22.0	NNW	44.0	Bedroom 2 after refurbishment
SR-5	29 Mar 2019	04:04pm	Bedroom 1	NNW	20.0	NNW	44.0	Bedroom1 refurbishment
SR-6	29 Mar 2019	04:03pm	Corridor	NNW	20.0	NNW	44.0	Noise in common area

- **SR-1: Living Room Wall**

  A creaking noise was coming from the Living Room wall, adjacent to the door of Bed 2. The wall linings were partially removed and found the wall stud was not installed at 90^0 to the plane of the wall, numerous cuts were made in the head track in the vicinity of the wall stud (some appearing unnecessary), and there were waves in the flange of the head track.

- **SR-2: Bedroom 2 at the junction with the Living Room Wall**

  A creaking noise and a loud crack were recorded coming from the Bed 2 wall, adjacent to the living room door. We found services bearing on the door jamb stud, cuts and penetrations in the wall linings stitched to battens (possibly as an attempt of repair), Head Track had been cut at service locations, and tape had been applied to Wall Studs and Head Track (possibly as a noise deadening).

- **SR-3: Living Room**

  A dull clunking noise was recorded, followed by a fast tapping noise coming from the façade glazed panel, adjacent to the Bedroom 1 door.

  At the time of recording, the ceiling linings and steel stud framing to Bed 1 had been removed. The wind could be heard whistling outside, and the fast tapping noise appeared to coincide with a wind gust.

4. IN-FIELD TESTING: APARTMENT REBUILD (CONTINUED)

4.2 NOISE OBSERVATIONS (CONTINUED)

- **SR-4: Bedroom 2**

  The noise recorded in Bed 2 was on a comparatively windy day. The average wind speed was approximately 20km/hr and gusting up to 44km/hr. The wall and ceiling linings were not fully installed, yet sound recordings were of a loud audible noise.

- **SR-5 & SR-6: Bedroom 1 and Corridor**

  SR5 and SR6 were recorded at the same time. Load creaking sounds coming from the walls was found to be wind whistling through the service duct in the corridor. Bed 1 had Rondo Steel Stud Framing installed as part of the re-work with no linings, and during this time, there was no audible noise coming from the reinstated works.

4.3 OUR FINDINGS

During demolition, the following issues were observed and identified by Rondo as possible causes of the noted noises within the apartment;

WALLS

1. Screw fixings installed into head track in some locations
2. Inadequate clearances between wall studs and services
3. Walls lined one side were not screw fixed into base track on the unlined side of wall
4. Nogging installation method not per Rondo recommendation
5. Temporary location screws in head track weren't removed prior to linings being installed
6. Header Track upturn too long and metal to metal contact with head track
7. Conventional Head Track (28mm flange) used in lieu of Deflection Head Track at column location
8. Insufficient stud engagement in Head Track
9. Wall studs cut without strengthening at cut location
10. Screw fixing into the bathroom jamb stud was removed and the stud moved such that the screw hole was no longer aligned, indicating the stud was under significant stress as a result
11. Linings screw fixed through glue daub locations

STEEL STUD FIXED INTO HEAD TRACK

4.3 OUR FINDINGS (CONTINUED)

CEILINGS

12. Top Cross Rail screw fixed to perimeter channel
13. Inadequate clearances provided to services
14. Top Cross Rail and Furring Channels installed with inadequate clearances to abutting walls
15. Furring Channel Interchange Clips legs bent outwards at some locations
16. Suspension rods installed with large radius bends
17. Ceiling Suspension Hangers installed using power actuated fasteners, with concrete bursting evident at many fixing locations
18. Screws fixed through Furring Channel at suspension clip locations

TCR SCREW FIXED TO PERIMETER CHANNEL AND CONTACT WITH LINING

SERVICES

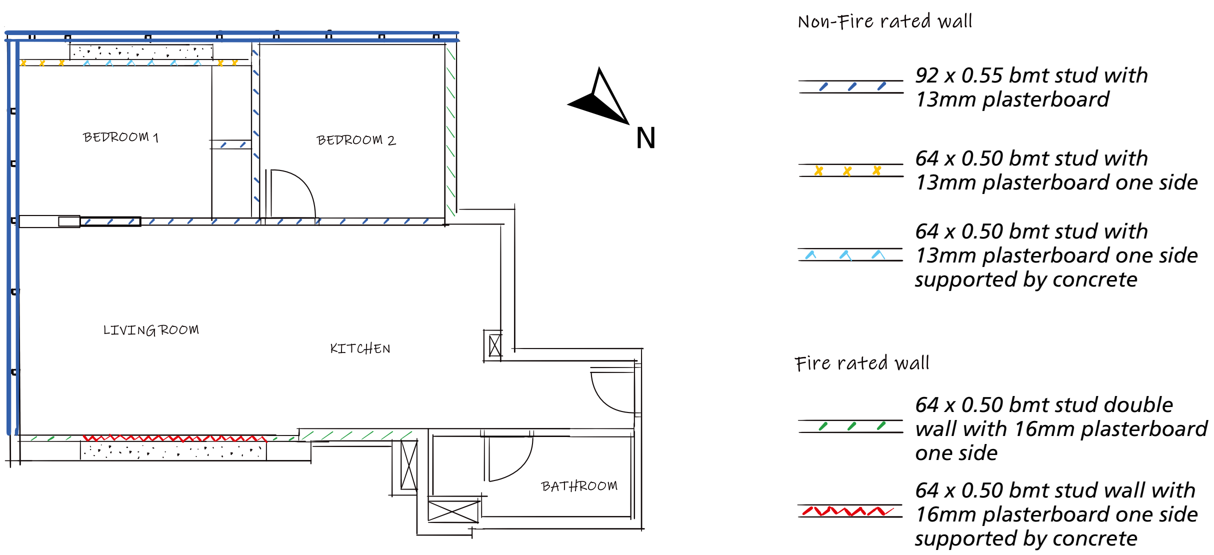
19. Services installed with inadequate clearances to stud framing
20. Services installed with inadequate clearances to ceiling framing members
21. Installed services had insufficient space within the ceiling plenum in the bathroom and were bearing against the hallway wall
22. Drainage conduit for AC unit was installed without grommets or provision to separate the pipe from the wall stud and was rubbing on the cut service hole edge
23. Head Tracks cut unnecessarily for electrical cables. Where the internal non-rated wall linings are terminated below the head tracks the electrical services can be passed down the wall cavity without needing to cut the head tracks
24. Services penetrations through acoustic wall not provided with acoustic treatment

MISSING GROMMET AND PIPE SCRAPING ON STUD WEB CAUSING NOISE

4. IN-FIELD TESTING: APARTMENT REBUILD (CONTINUED)

4.4 THE REBUILD AND OUR SOLUTION

Rondo prepared a comprehensive design for the apartment refurbishment, including a 100% site management plan to ensure construction aligned with our design intent.



■ **REBUILD SOLUTION**

ACOUSTIC & FIRE-RATED WALLS

Rondo supplied conventional Steel Stud Drywall Framing to be installed as the framing of the acoustic and fire-rated Inter-tenancy Walls. These walls were all lined one side with a single layer of 16mm plasterboard.

The fire-rated walls form a pressure seal, due to their construction methods and sealing requirements, and are therefore subjected to higher internal pressures in accordance with the wind code AS/NZS1170.2 requirements.

A nogging track was installed 100mm below the head track to prevent rotation of the wall stud and for structural adequacy in compliance with the NCC. It also provides lateral relief to the wall linings and allows the head track more freedom to move with the structure to which it is fixed, and further, limits the propensity to clamp the wall studs and induce movement into the wall panels.

The nogging installed at mid height is needed for structural adequacy in order to meet NCC compliance, whilst also preventing rotation of the wall stud which is a potential cause of noise within the wall under building movement.

NON-RATED WALLS

Rondo conventional Steel Stud and Track was used to construct the non-rated internal walls located between the bedrooms and living areas. The Rondo design satisfied the NCC Compliance requirements, but also had the wall linings terminated approximately 100mm short of the head track to reduce noise potential within the wall.

Testing had confirmed this simple construction detail reduced wall movement which subsequently minimises noise potential from the wall.

TRACK FIXINGS

All the head and base tracks were removed and reinstalled to ensure compliance and provide separation gaps between the tracks. Similarly, the wall studs at the "T" and "L" wall junctions were offset about 6mm to provide a separation gap and ensure no metal to metal connectivity at the wall junction.

The track setback provides allowance for the inter-storey drift of the structure whilst preventing metal to metal contact of the framing. Removal of the stud fixings at the corner provides a more flexible joint, and reduces the potential for racking forces to develop in the wall panels.

4.4 THE REBUILD AND OUR SOLUTION (CONTINUED)

DOOR OPENINGS

A common issue on site in relation to door openings, is that other trades move the stud framing to facilitate the installation of services. Contractors will sometimes screw fix jamb studs in place as a temporary means of stabilising the framing, however, if not removed prior to sheeting, it has consistently been found to be a source of noise.

Rondo designed a soldier which provides the necessary restraint to the jamb stud, whilst also allowing some lateral movement of the Head Track. The clearance between the soldier stud and jamb stud prevents metal-on-metal contact (potential noise) but also allows for in-plane inter-storey drift.

CEILING SYSTEMS

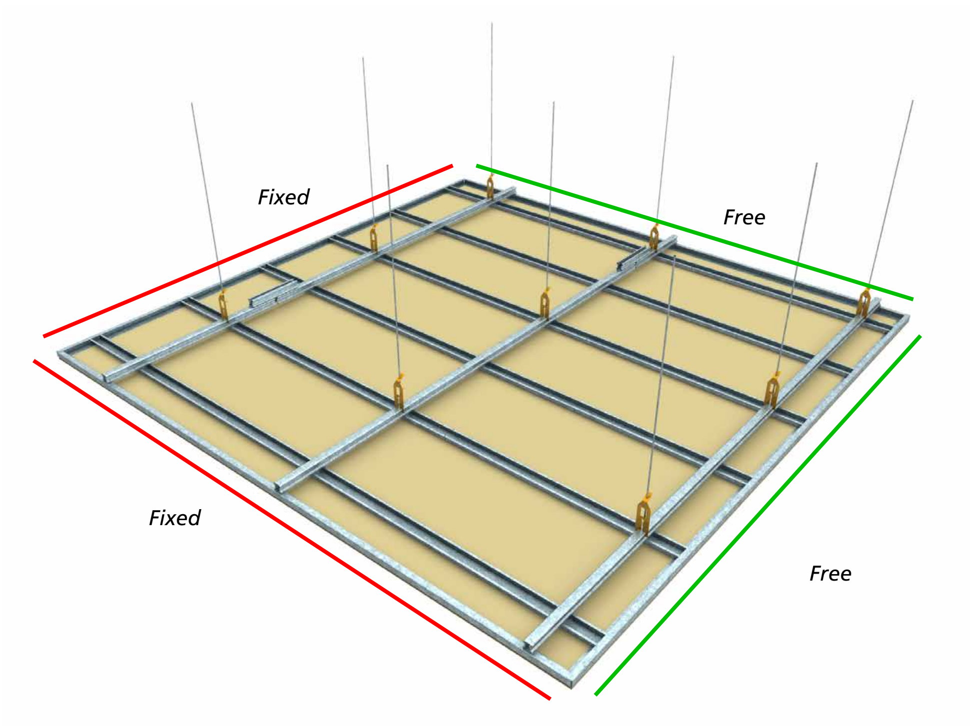
The apartment had standard, non-fire-rated concealed grid ceilings with one layer of 13mm plasterboard. All the exterior walls of the building were glass facade, and there was a pelmet at the facade junction. The ceiling plenum was used for return air, and the detailing for this provided venting to the ceilings.

Our testing has shown that there can be a significant level of racking developed in the wall panels as a result of the connectivity between the walls and ceiling, accordingly it was very important to introduce flexibility into the wall and ceiling junction. This is best achieved using a shadowline junction, however this was not acceptable in this instance because it was not a complete rebuild. Accordingly, the ceiling to wall junctions were rebuilt with a square set finish, to match the existing.

FIXED AND FREE END PERIMETER CEILINGS

With any ceiling system it is necessary to incorporate allowance for building and differential movement, whilst also restraining the ceiling under seismic actions. This is typically accorded using opposing "fixed" and "free" end conditions within the ceiling grid. The fixed end of the ceiling is typically rigidly connected at the perimeter, whereas the free end is floating at the perimeter.

Rondo designed the ceiling grid in the apartment with a fixed and free end perimeter solution. The exterior glass façade is considered as a free end in all cases due to the construction and movement of these systems, and this typically controls the fixed end of the ceiling in at least one direction.



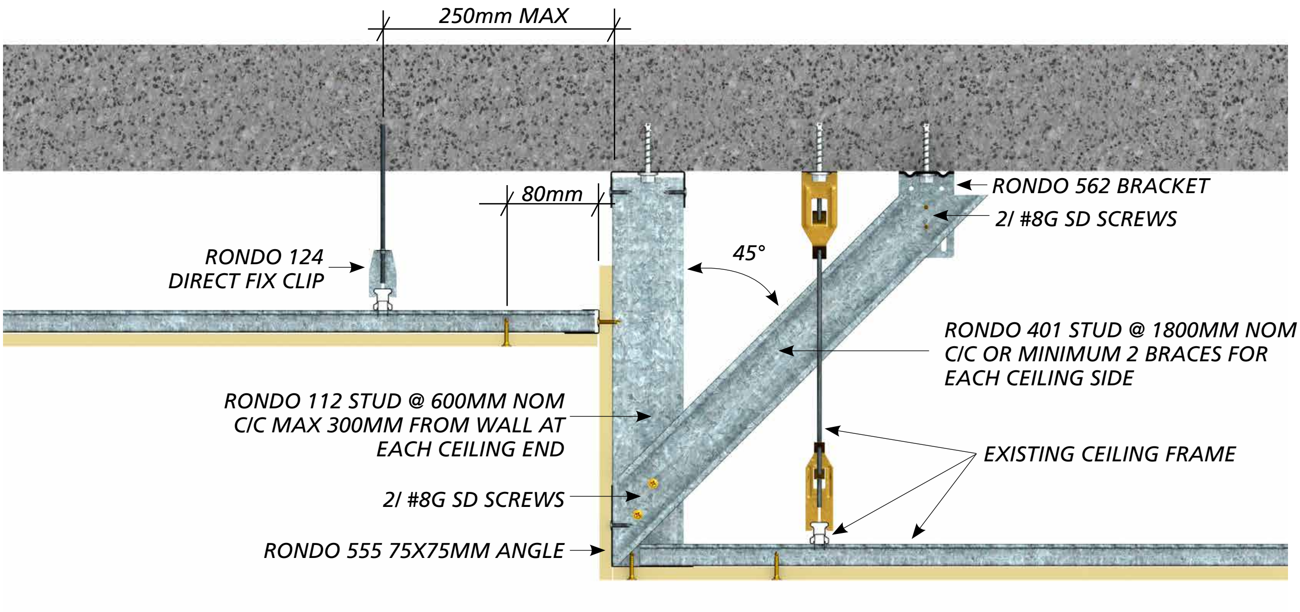
■ RONDO KEY-LOCK® CEILING: FREE/FIXED PERIMETER

4.4 THE REBUILD AND OUR SOLUTION (CONTINUED)

BULKHEADS

The ceilings contained several bulkheads and the ceiling termination at these points are as equally important as the perimeter connections to ensure the ceiling maintains adequate allowance for building movement. Bulkheads can be considered walls in terms of the ceiling grid design and can be designed as either fixed or free ends according to what is required.

In the apartment the bulkhead was designed for differential internal pressures as well as seismic loads where the ceiling is restrained by the bulkhead.



■ **BULKHEAD**

PELMET

The building had a glass façade, and the ceiling is terminated at this point with a pelmet. It was critical to ensure the pelmet is disconnected from the façade, to accommodate the expected differential movement at this location. The ceilings were typically demolished to the pelmet and the installed pelmets were retained after confirming they were disconnected from the facade.

CONCLUSION

Noise from the Apartment was observed at various locations and during wind gusts as low as 33km/hr. Since the works have been completed there have been many wind events well in excess of this wind speed. To date, our design team who worked on this rebuild are not aware of any complaints by the owner, and believe the reinstated works are performing satisfactorily.

This project is validation of Rondo's extensive testing and research into the noisy stud phenomenon and has proven laboratory testing results are directly transferable to the real world where there is a proper design in place and a quality management plan to oversee the construction.

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS

Our solution focuses on the following criteria:

1. Understanding the building and the expected building movement
2. Providing a "soft" connection between the walls and ceiling and structure
3. Limiting movement in the walls to reduce potential for noise
4. Providing a solution which is consistent with current practices

We believe the Rondo recommended solutions presented hereafter offers the benefit of simplicity, whilst simultaneously reducing the potential for noise annoyance.

Please refer to Design Data and General Notes on page 33 for important details that need to be considered.

5.1 WALL DETAILS

Rondo offer two alternative wall track solutions to limit noise potential in tall buildings. A conventional Wall Track or the patented QUIET-TRACK, which is a conventional steel track laminated on the inside that removes metal on metal contact.

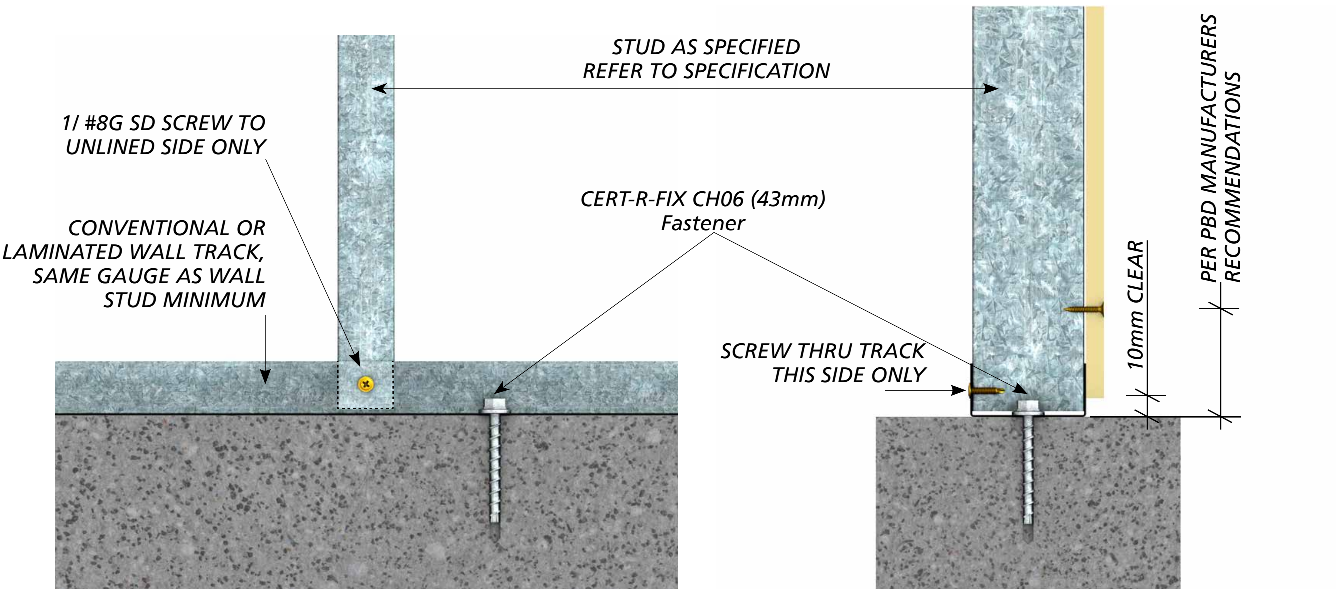
Rondo supplies QUIET-TRACK pre-laminated and therefore installation takes no additional time to install when compared to traditional wall framing.

Testing did not provide a clear advantage between the two wall tracks, and it should be noted a satisfactory result can be achieved with both. However, the QUIET-TRACK appearance is different and can be useful as a visual aid to reinforce the installation details to installers on site.

The following details show our Conventional Wall System and alternative Wall System using QUIET-TRACK System to provide flexibility in choice.

RONDO QUIET-TRACK

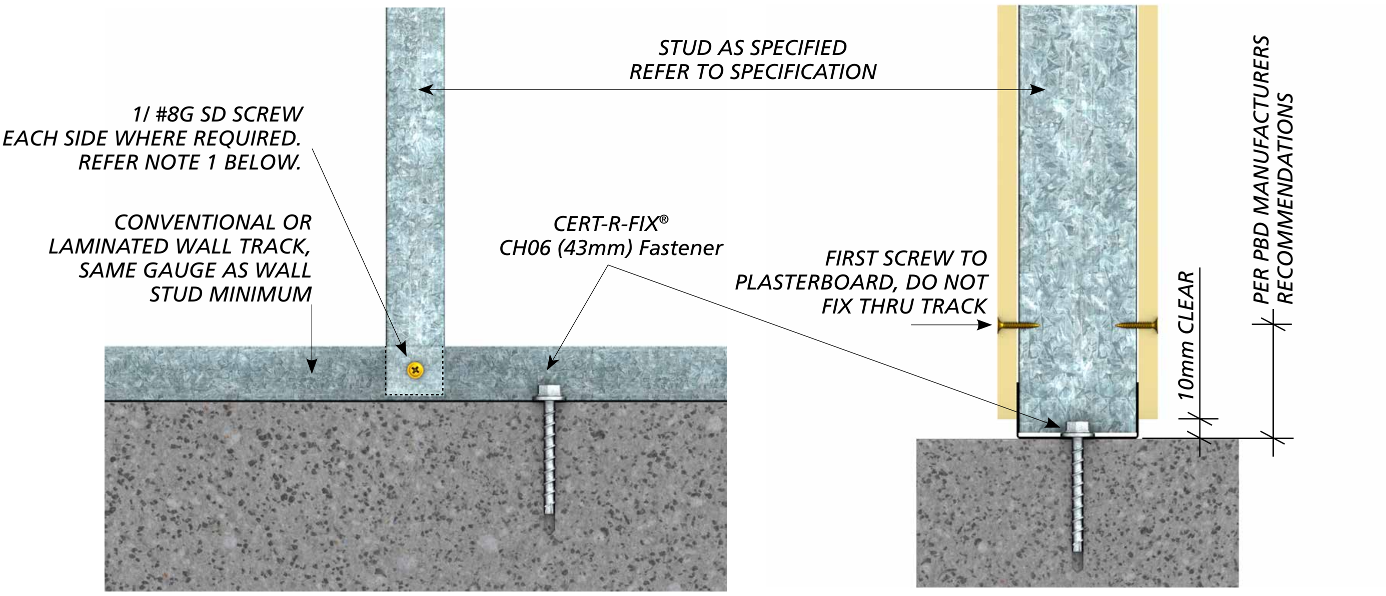
5.1.1 BASE TRACK DETAILS – PLASTERBOARD LINED ON ONE SIDE ONLY



BASE TRACK INSTALLATION FOR WALLS - LINED ONE SIDE: USING CONVENTIONAL WALL TRACK OR QUIET-TRACK

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

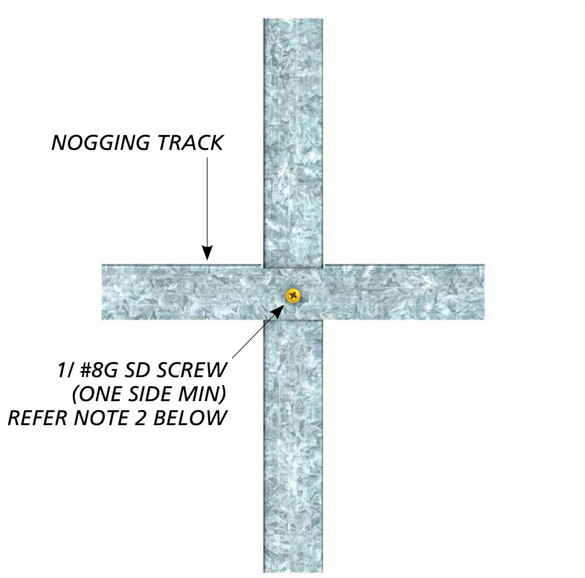
5.1.2 BASE TRACK DETAILS – PLASTERBOARD LINED ON BOTH SIDES



BASE TRACK INSTALLATION FOR WALLS LINED BOTH SIDES: USING CONVENTIONAL WALL TRACK OR QUIET-TRACK

5.1.3 NOGGING CONNECTION DETAIL

To understand how Noggings are required to achieve NCC Compliance and how they reduce wall movement and subsequent noise, refer to page 23.



NOGGING CONNECTION

NOTES:
1. Screw fixing studs to bottom tracks is not required, providing;
a. Wall is lined both sides, and
b. Stud is not at a "free" end, such as a nib wall or the like.
2. Unless noted otherwise, noggings are to be installed at the mid height of the wall.

Why do you need noggings for compliance?

Noggings are required for various reasons, but most importantly, noggings provide the means for compliance to the National Construction Code (NCC).

1. **NOGGINGS HELP ACHIEVE COMPLIANCE WITH THE NCC FIRE-RATED WALLS REQUIREMENTS:**

   The NCC addresses fire-resistance requirements of lightweight construction in Specification C1.8 Clause 3.4 (b) which states that fire-rated internal or external walls are to be subjected to a static uniformly distributed load test of 0.25kPa. Rondo includes Noggings, as required, in designs of fire-rated walls lined one side to ensure that they have the structural adequacy to meet the BCA Specification C1.8 requirements and comply with the fire-tested system.

2. **NOGGINGS ASSIST IN COMPLIANCE TO NCC STRUCTURAL REQUIREMENTS:**

   The NCC addresses structural adequacy requirements of lightweight construction in Section B. Within this part of the NCC, the minimum design actions to be considered are specified, and include amongst others wind and seismic actions. Rondo includes noggings, as required, in their lightweight construction designs to ensure that they have the structural adequacy to meet the NCC Section B compliance requirements.

3. **NOGGINGS PREVENT ROTATION OF THE WALL STUD WHICH IS A POTENTIAL CAUSE OF NOISE WITHIN THE WALL UNDER STRUCTURAL MOVEMENT:**

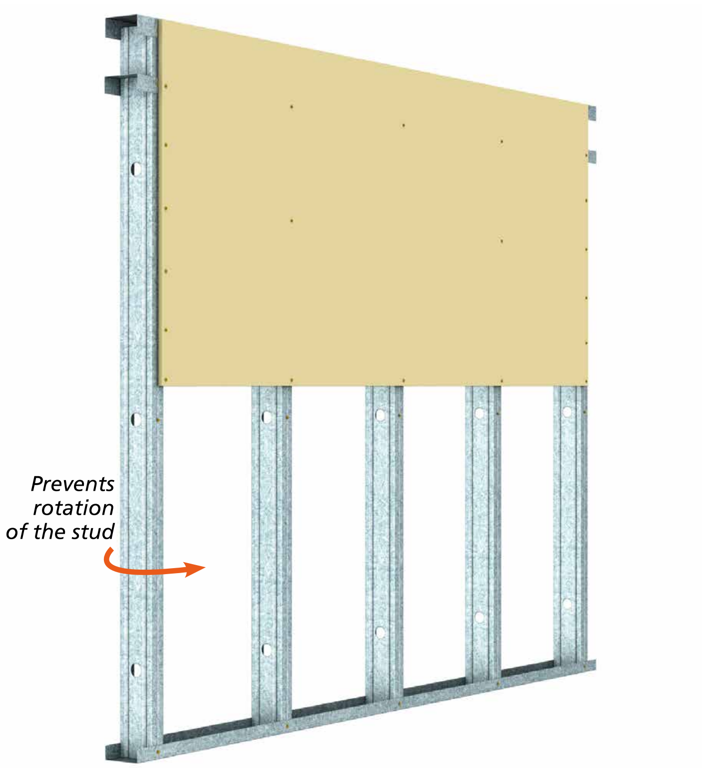
   Without the nogging, there is a greater chance of the wall studs rotating and therefore, increased risk of noise occurring in the wall due to structural movement

4. **NOGGINGS PROVIDE LATERAL RELIEF TO THE WALL LININGS, ALLOWING THE HEAD TRACK MORE FREEDOM TO MOVE WITH THE STRUCTURE IT IS FIXED TO, AND LIMITS THE PROPENSITY TO CLAMP THE WALL STUDS AND INDUCE MOVEMENT INTO THE WALL PANELS:**

   This is an integral part of the overall Rondo design methodology to minimise potential noise issues and does not compromise the performance of the wall.

For more information regarding the importance of Noggings, view our Blog “Do you know why you need Noggings?”

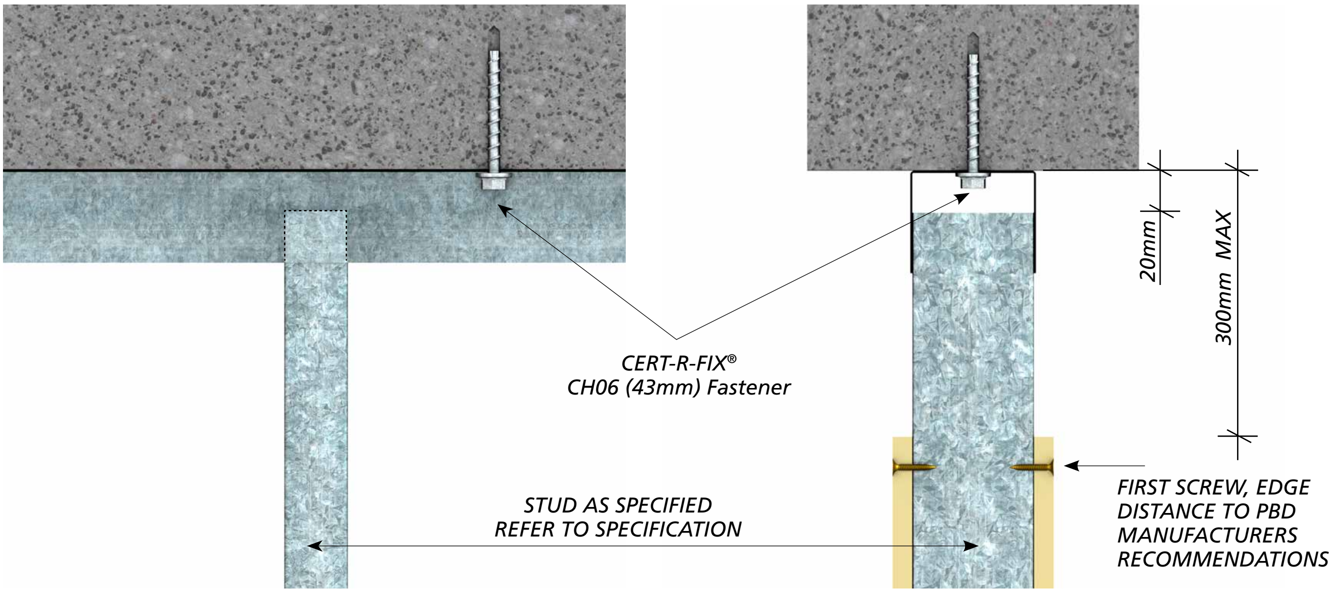
RONDO NOGGINGS



RONDO WALL SYSTEM WITH NOGGINGS

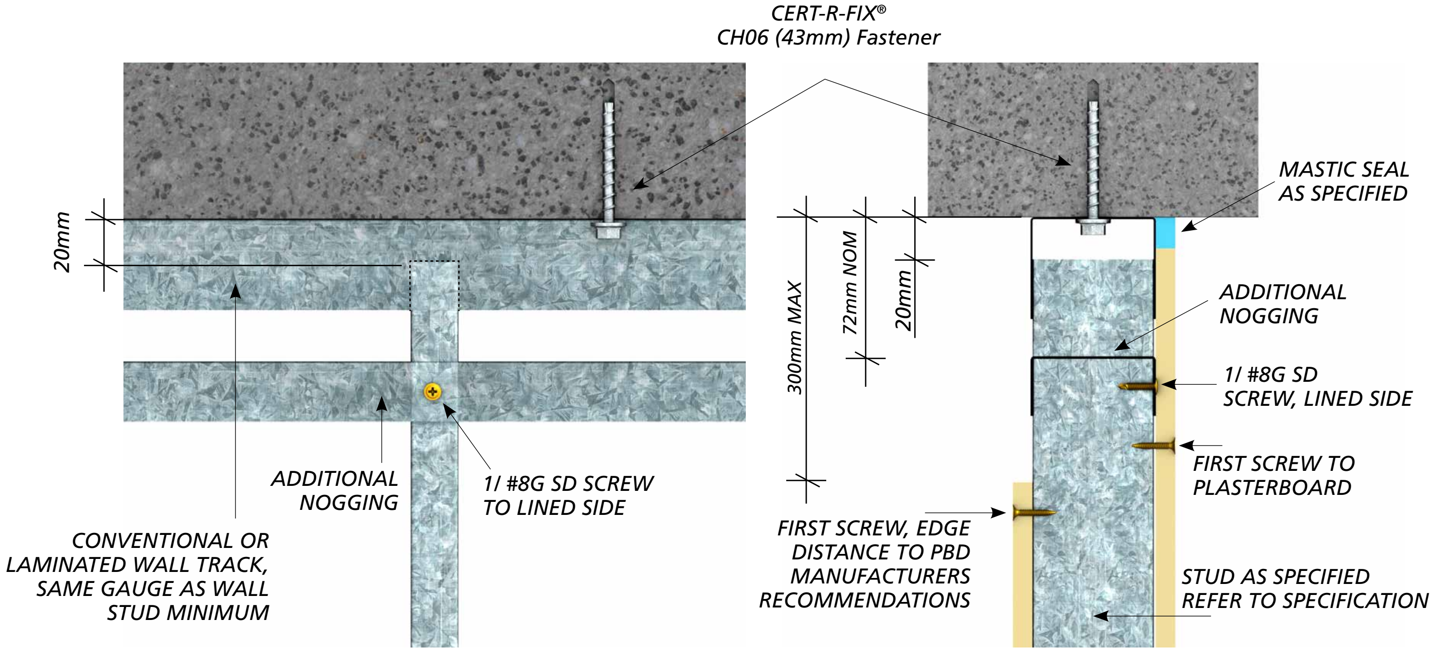
5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

5.1.4 HEAD TRACK CONNECTION NON-FIRE RATED WALLS



HEAD CONNECTION TRACK NON-FIRE RATED WALL - LINED BOTH SIDES: USING CONVENTIONAL DEFLECTION HEAD TRACK OR QUIET-TRACK DEFLECTION HEAD TRACK

5.1.5 HEAD TRACK CONNECTION ACOUSTIC RATED WALLS

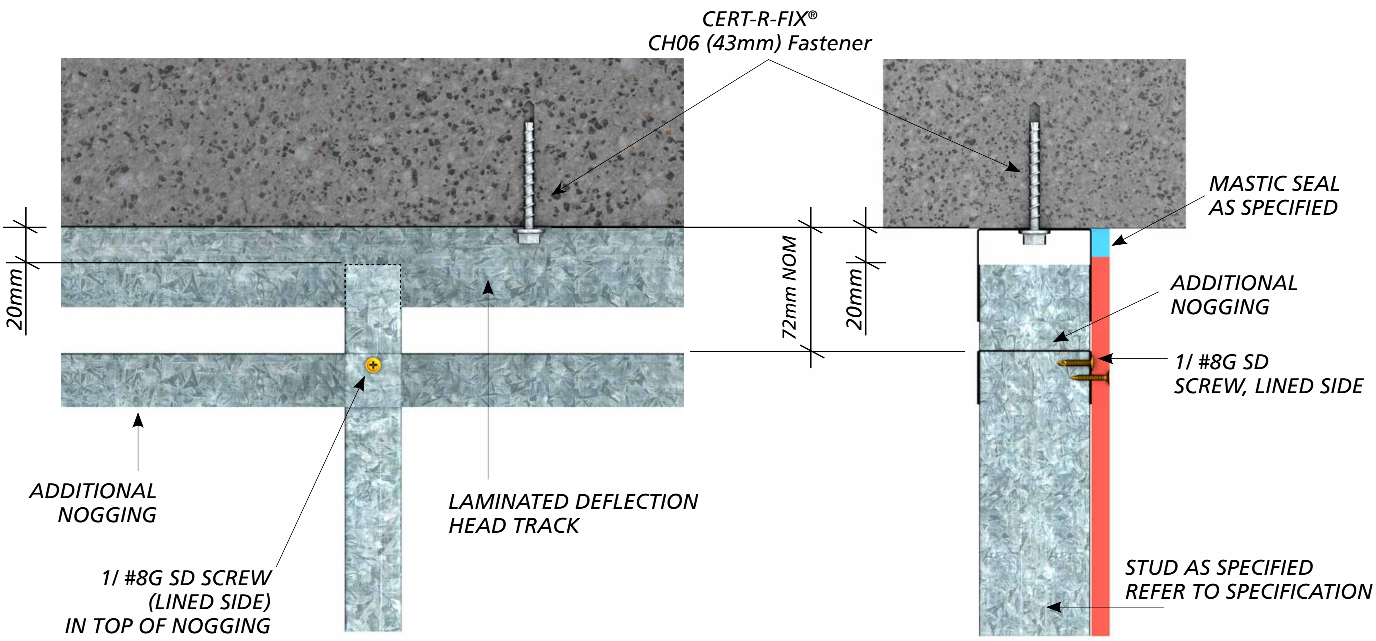


HEAD CONNECTION TRACK ACOUSTIC RATED WALL LINED BOTH SIDES: USING CONVENTIONAL DEFLECTION HEAD TRACK OR QUIET-TRACK DEFLECTION HEAD TRACK

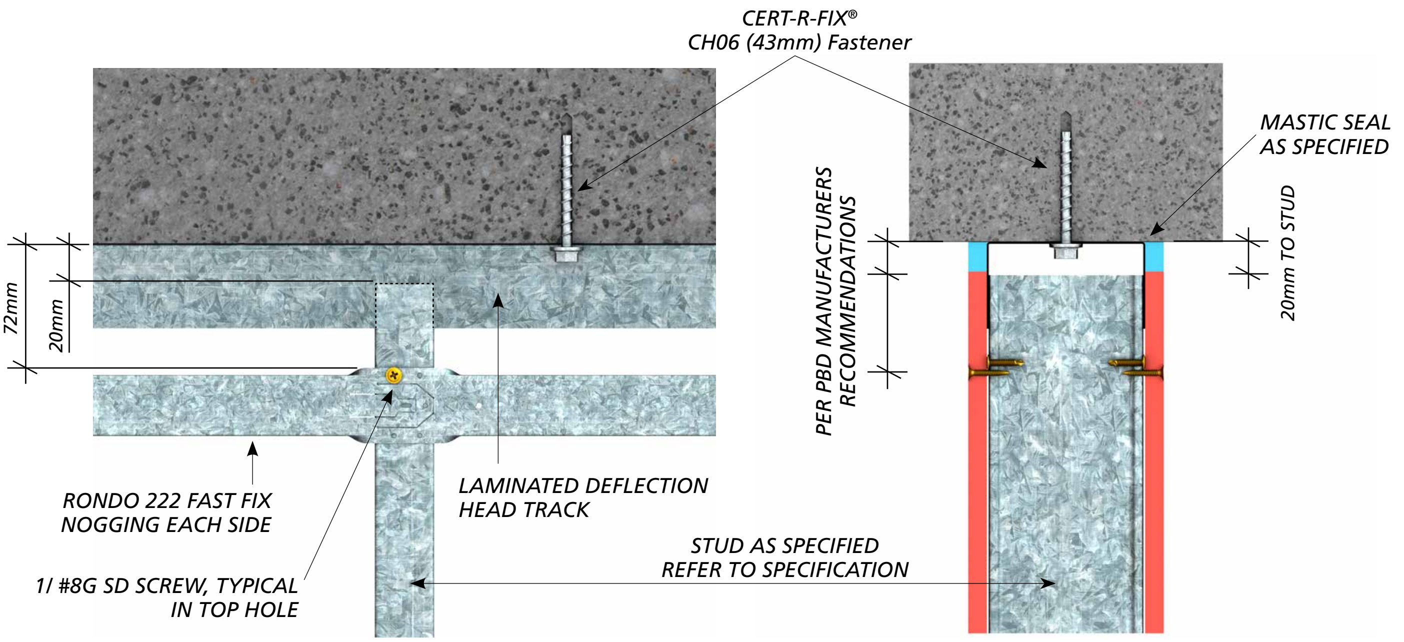
NOTES:

1. No screw fixings, temporary or otherwise, are permitted into the Head Track.

5.1.6 HEAD TRACK CONNECTION FIRE-RATED WALLS



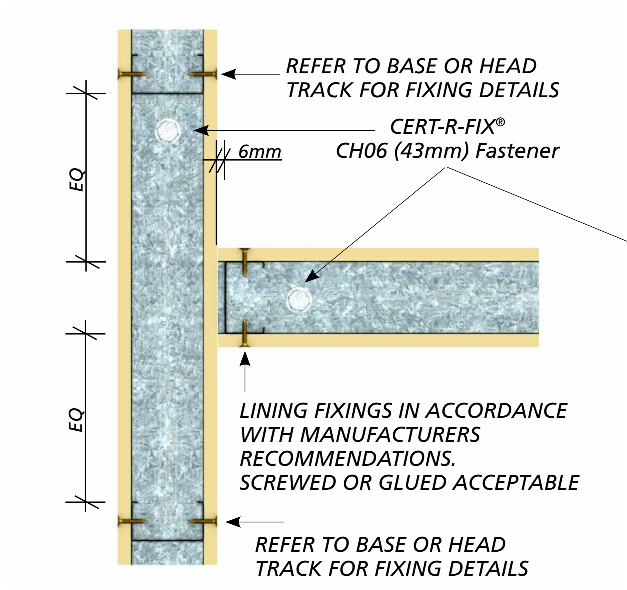
HEAD CONNECTION TRACK FIRE-RATED WALL - LINED ONE SIDE: USING CONVENTIONAL WALL TRACK OR QUIET-TRACK



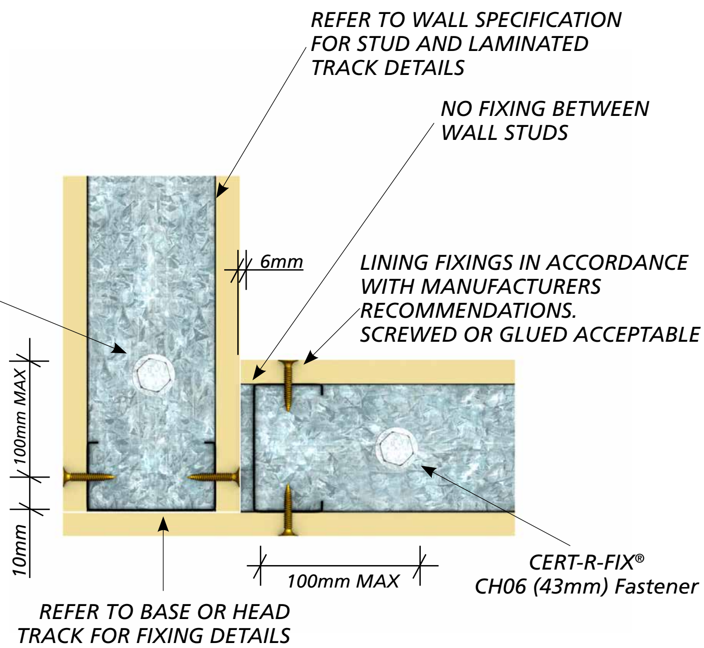
HEAD CONNECTION TRACK FIRE-RATED WALL: USING CONVENTIONAL DEFLECTION HEAD TRACK OR QUIET-TRACK DEFLECTION HEAD TRACK

NOTES:
1.No screw fixings, temporary or otherwise, are permitted into the Head Track.

5.2 T & L WALL JUNCTION DETAILS



■ T-JUNCTION TRACK AND LINING: NON-FIRE RATED CONSTRUCTION



■ L-JUNCTION TRACK AND LINING: NON-FIRE RATED CONSTRUCTION

NOTES:
1. For fire-rated construction all wall junctions are to be framed in accordance with board manufacturers details

5.3 DOOR OPENINGS

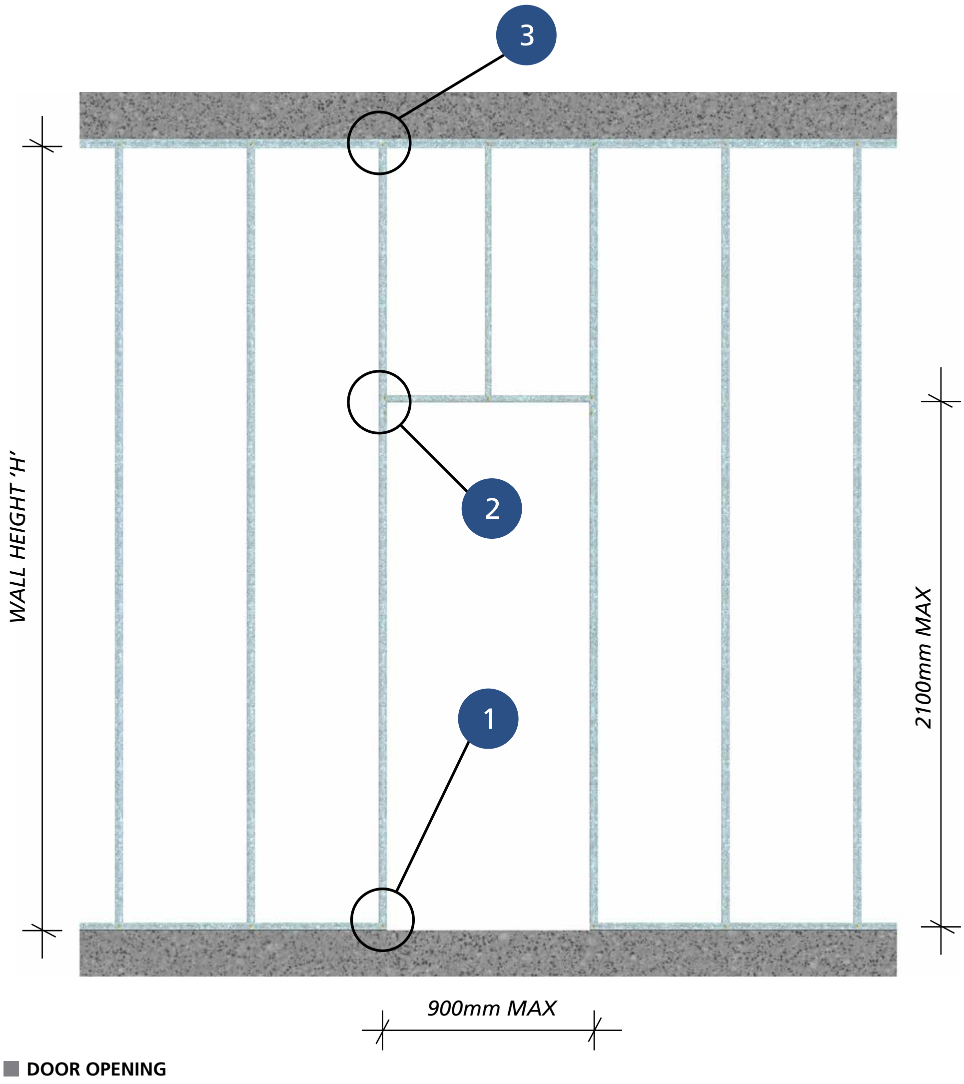


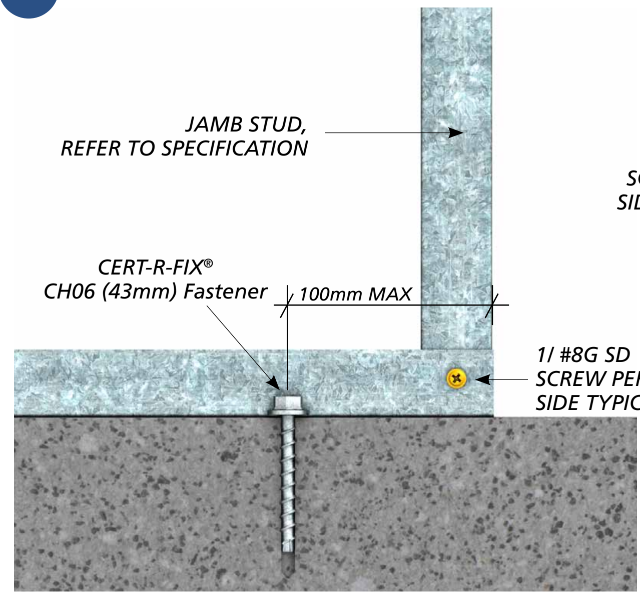
TABLE 1 - MAXIMUM DOOR WEIGHTS		
JAMB STUD	**WALL HEIGHT 'H'**	**MAX. DOOR WEIGHT (kg)**
JAMB STUD SPECIFICATION TO BE DETERMINED	2700	-
	2800	-
	2900	-
	3000[3]	-

NOTE:
Door openings and similar penetrations through the walls requires specific engineering design based on the actual site requirements. The details herein show typical base track, header and deflection head construction details to minimise noise potential from the completed wall.

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

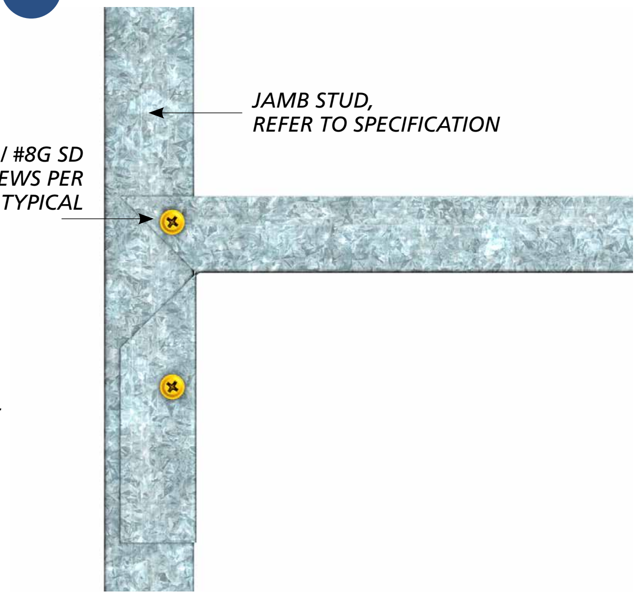
5.3 DOOR OPENINGS (CONTINUED)

1



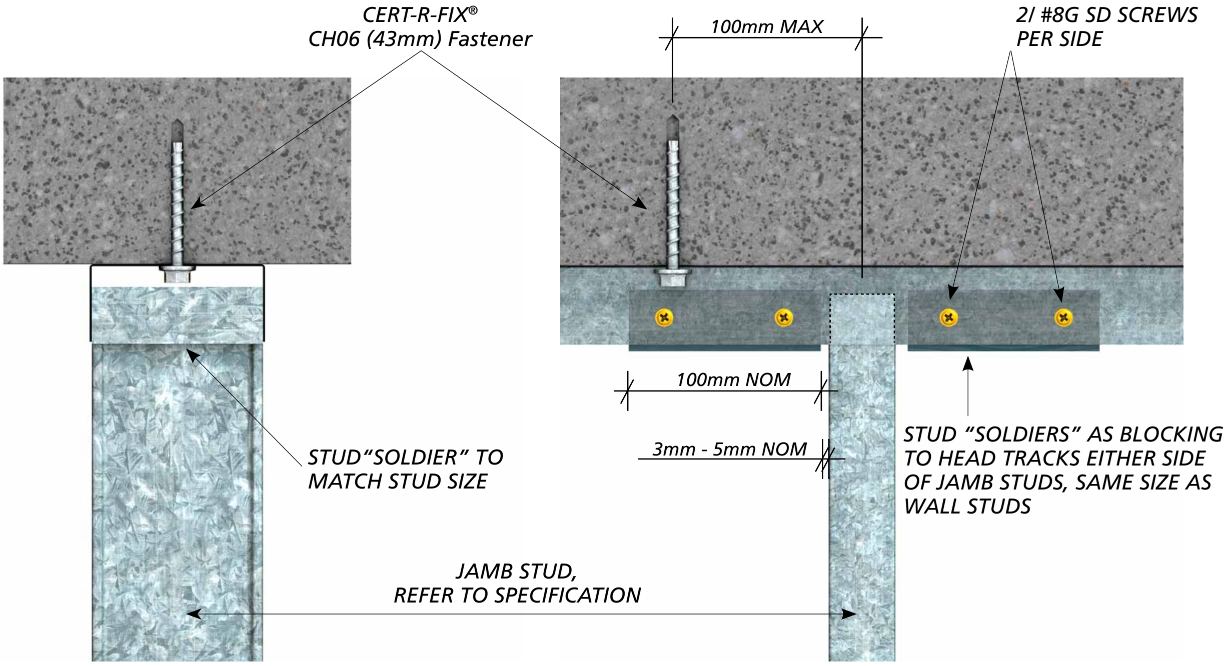
TYPICAL JAMB BASE CONNECTION

2



TYPICAL HEADER

3



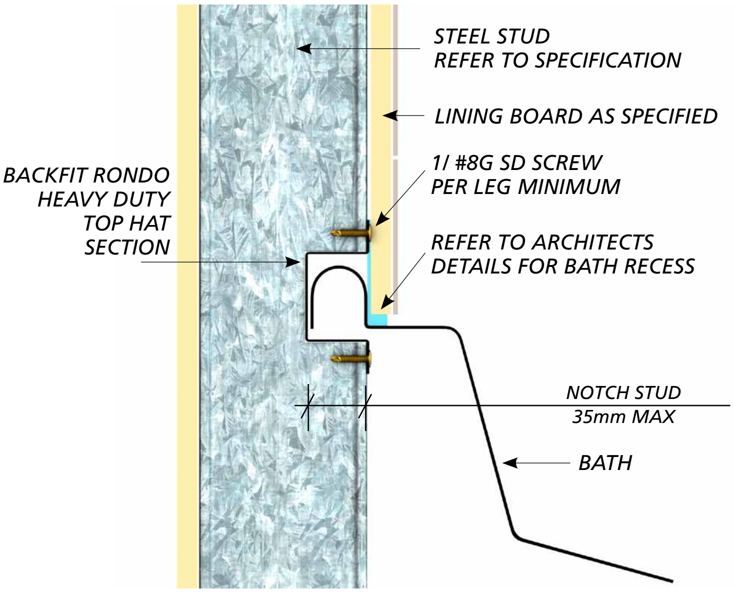
TYPICAL JAMB HEAD CONNECTION

TYPICAL JAMB HEAD CONNECTION

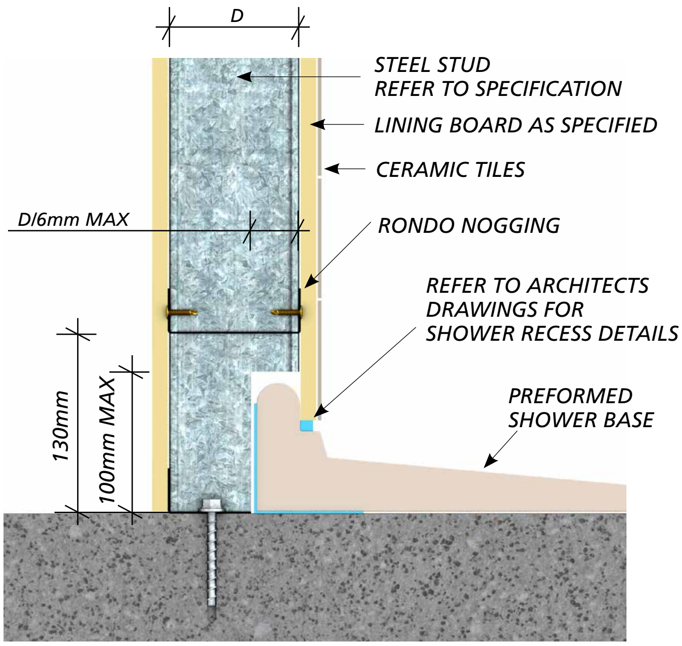
NOTES:
1. Steel stud soldiers may be left installed

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

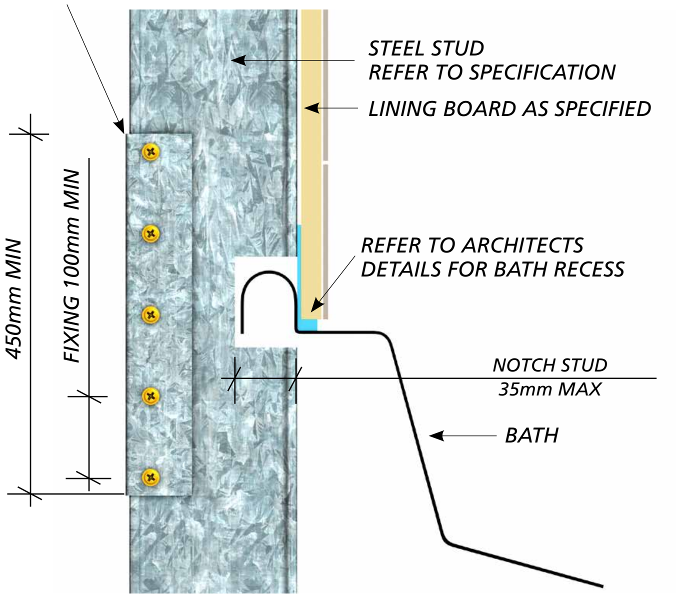
5.4 NOTCHING



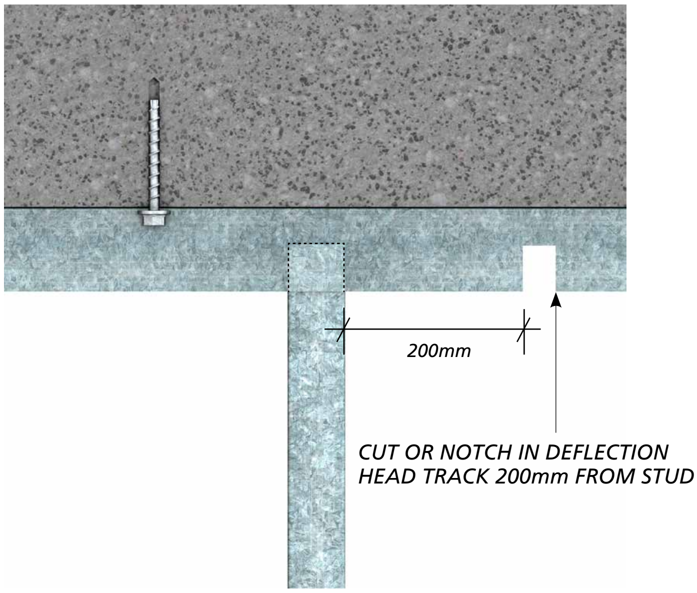
■ WET AREA NOTCHING WITH TOP HAT



■ WET AREA SHOWER NOTCHING



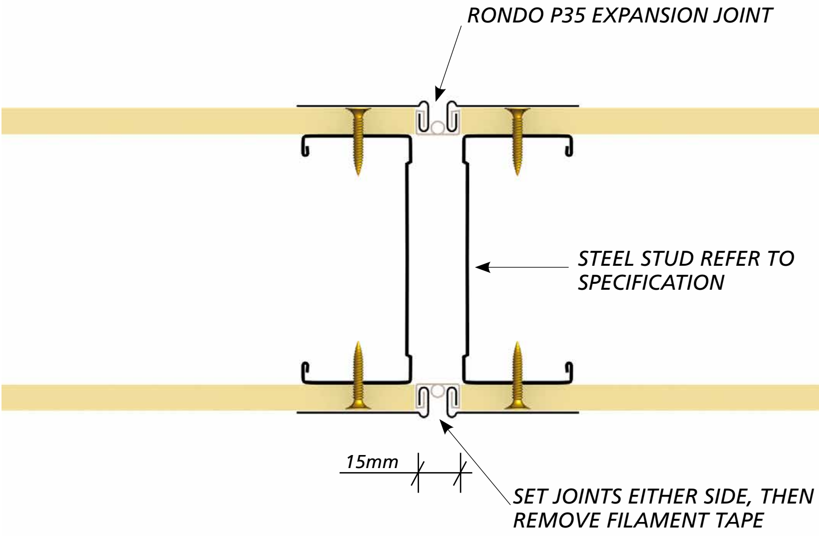
■ WET AREA NOTCHING WITH ANGLE



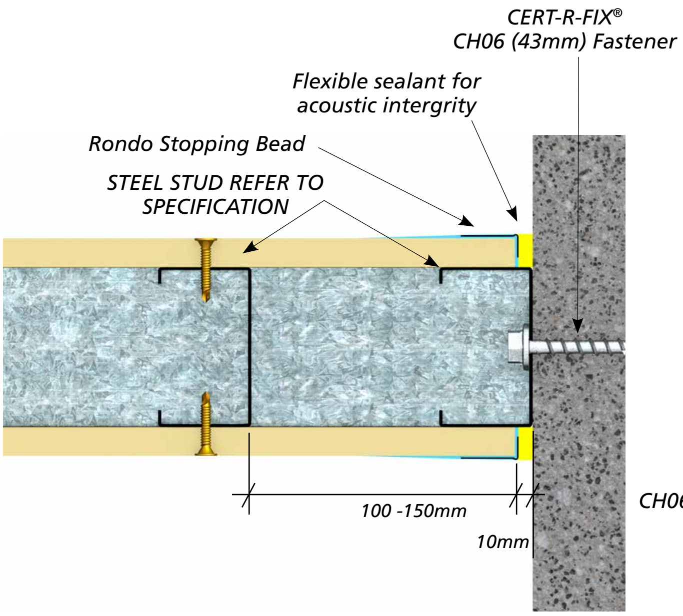
■ HEAD TRACK NOTCH

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

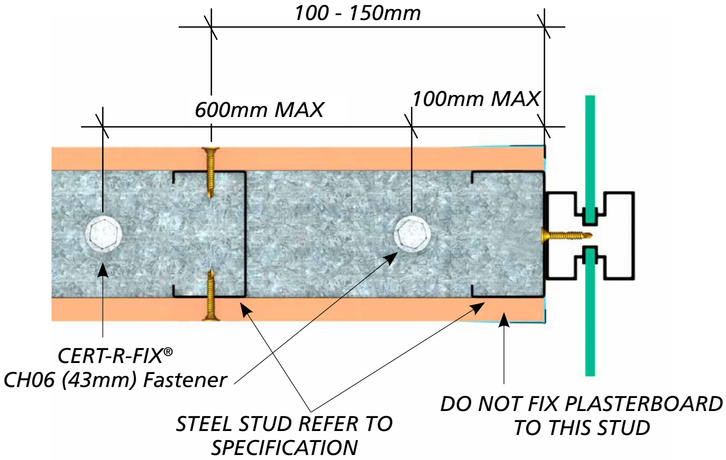
5.5 CONTROL JOINTS



VERTICAL CONTROL JOINT



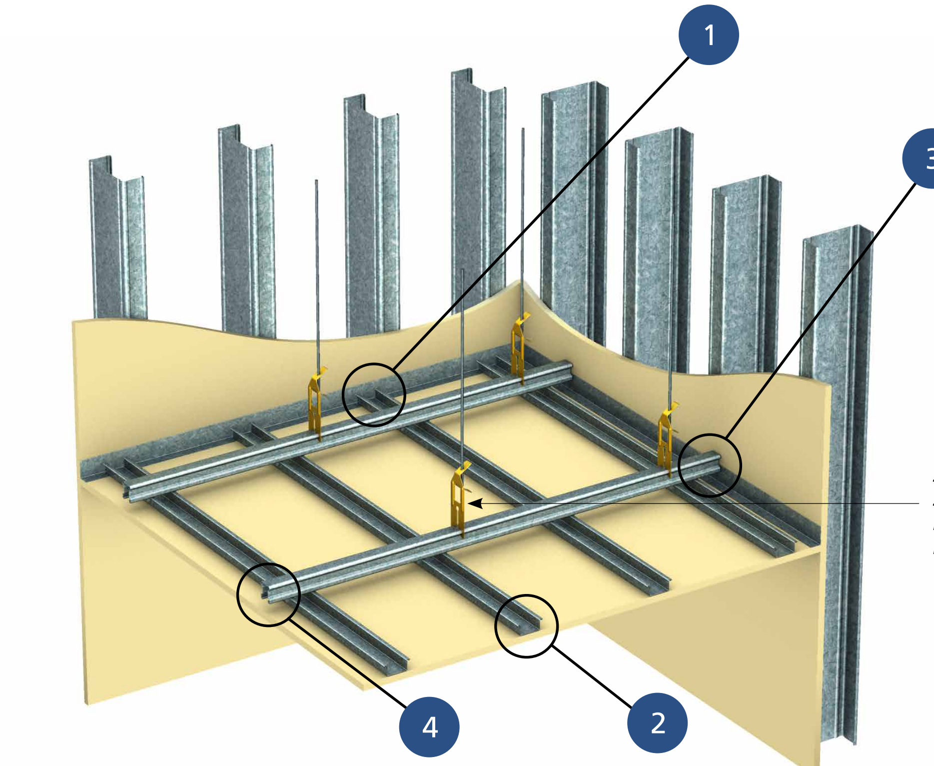
STRUCTURAL COLUMN CONTROL JOINT



WINDOW MULLION CONTROL JOINT

NOTE:
Any wall abutting a window mullion needs to be parallel to the window mullion at the junction to ensure the movement allowance is accommodated in the same plane as the expected movement of the mullion.

5.6 CEILING DETAILS



STANDARD RONDO KEY-LOCK® SUSPENSION: RONDO 121 SUSPENSION ROD TO RONDO 2534 SUSPENSION CLIP TO RONDO 127 TOP CROSS RAIL.

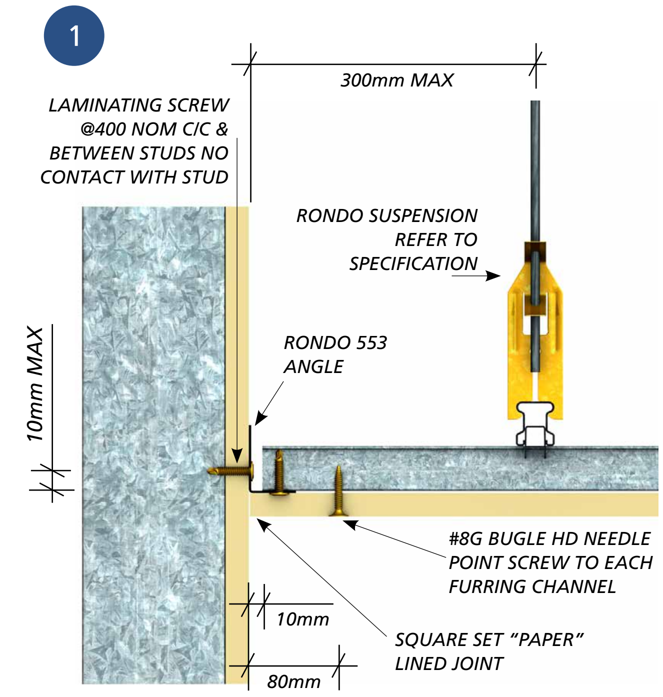
RONDO KEY-LOCK® - NON-BRACED

SUPPORT DIMENSIONS							
MAXIMUM LINING WEIGHT	FURRING CHANNEL (FC) DIRECTION			TOP CROSS RAIL (TCR) DIRECTION			WALL TRACK
	RONDO PART NO.	MAX SPAN (mm)	MAX SPACING (mm	RONDO PART NO.	MAX SPAN (mm)	MAX SPACING (mm)	RONDO PART NO.
TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC

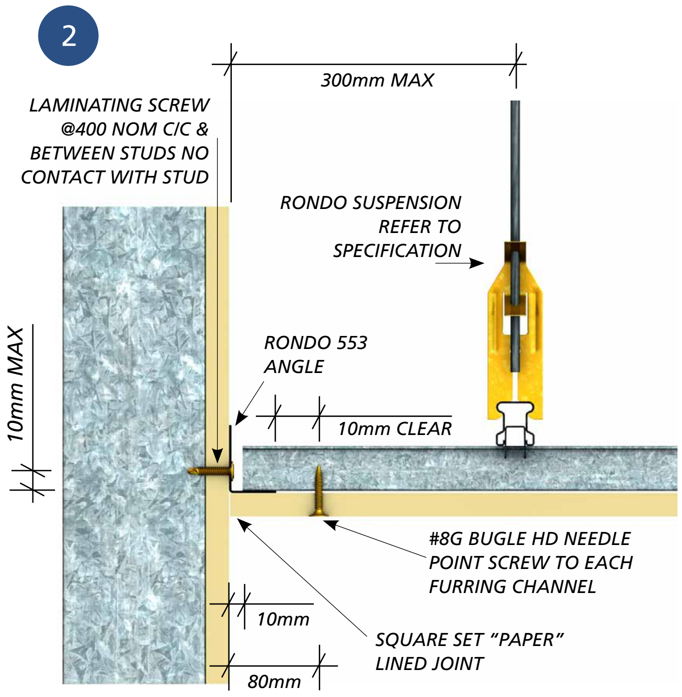
NOTE:
The ceiling systems require a specific engineering design solution to be provided in accordance with the project. The details presented here are for noise minimisation.

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

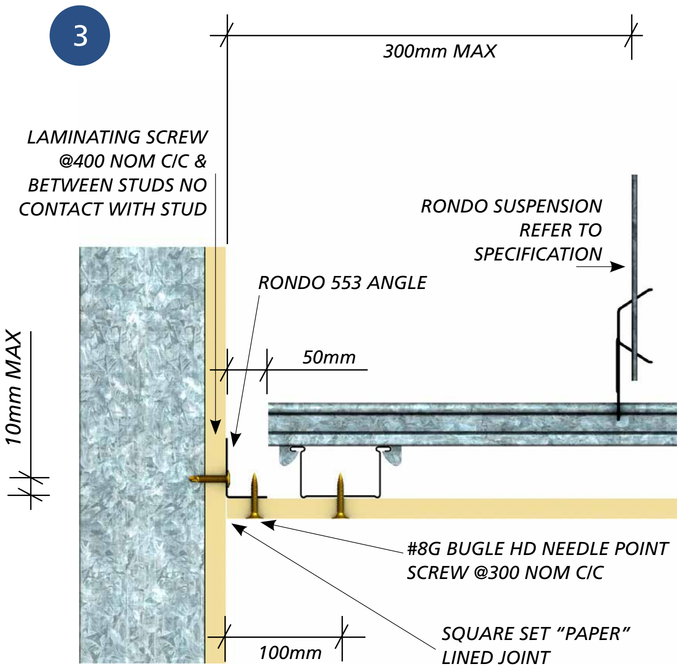
5.6 CEILING DETAILS (CONTINUED)



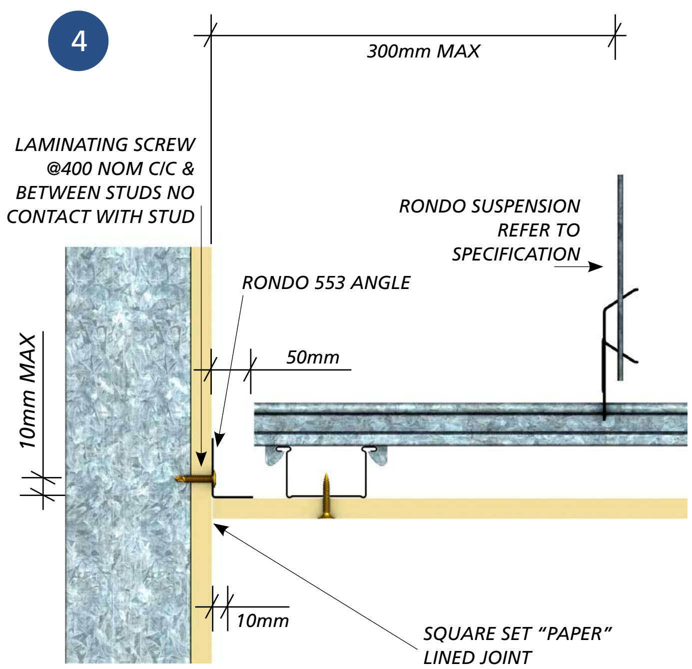
FURRING CHANNEL PERIMETER EDGE (FIXED)



FURRING CHANNEL PERIMETER EDGE (FREE)



TOP CROSS RAIL PERIMETER EDGE (FIXED)



TOP CROSS RAIL PERIMETER EDGE (FREE)

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

DESIGN DATA

1. The Rondo framing herein has been checked for compliance with the design data nominated within the corresponding standards, specified below

DEAD & IMPOSED LOADS TO AS/NZS 1170.1

WIND LOADING TO AS/NZS 1170.2

BUILDING IMPORTANCE LEVEL	3
ANNUAL PROBABILITY OF EXCEEDANCE (ULS)	V1000
ANNUAL PROBABILITY OF EXCEEDANCE (SLS)	V20
REGION	A
TERRAIN CATEGORY	TC3

NOTE:
The design data is based on the actual site requirements. The details herein show typical details that would be provided for a Rondo design.

SEISMIC LOADING TO AS/NZS 1170.4

BUILDING IMPORTANCE LEVEL	3
ANNUAL PROBABILITY OF EXCEEDANCE (ULS)	1:1000
ANNUAL PROBABILITY OF EXCEEDANCE (SLS1)	-
SITE SOIL CLASSIFICATION	Be
SITE HAZARD FACTOR (Z)	0.08

2. Loading other than that nominated above has not been considered & is therefore outside the scope of this design.
3. Joist live loading has not been applied. where the ceiling plenum depth exceeds 600mm refer back to Rondo for clarification.

INTER-STOREY DRIFT

1. The details herein have been developed for an inter-storey serviceability drift of up to $H_s/500$, where H_s is the storey height of the building
2. The project engineer shall confirm the expected inter-storey serviceability drift is within this limit, prior to works commencing on site
3. These details are based on extensive testing undertaken by Rondo at Swinburne smart structures laboratory. The details herein are consistent with test results current at the time of publishing, however, due to the uncertainty between testing and construction Rondo cannot preclude the possibility of noise.

5. OUR RECOMMENDED SOLUTIONS FOR TALL BUILDINGS (CONTINUED)

GENERAL NOTES

1. This drawing shall be read in conjunction with the Rondo specification for the project, & all architectural & other consultants' drawings & specifications, as maybe issued during the course of the project.
2. Any discrepancies shall be referred to Rondo for clarification prior to proceeding with the works.
3. Refer to Rondo where nominated wall height 'h' is exceeded as standard details and fastener requirements may change.
4. All sections as manufactured by Rondo Building Services Pty Ltd. Substitution with alternative components is not permitted.
5. Design assumes all sections have been installed in accordance with the details contained herein.
6. The design only considers the structural adequacy of the Rondo stud framing system. The supporting structure has not been checked & therefore remains the responsibility of the project / structural engineer.
7. Scaling from the drawing is not permitted & all dimensions & lengths specified are to be checked & confirmed on site prior to commencing work.
8. All stud walls are non-load bearing unless noted otherwise.
9. Splicing of the studs is not permitted, unless noted otherwise.
10. The framing design has been checked in accordance with AS/NZS 4600.
11. Fire & acoustic performance of the framing system has not been considered & shall be nominated by a suitably qualified consultant.

PROTECTIVE COATING

1. Unless noted otherwise, the framing specified has a coating designation of Z275, in accordance with AS/NZS 1397. That is, zinc coating of mass 275g/m^2.
2. The specified framing is not recommended for external wall framing applications,unless noted otherwise.

DEFLECTION HEADS

1. Where nominated, the deflection head details to concrete have been designed to accommodate up to & including 15mm of downward structural movement, with a construction tolerance of 5mm.
2. Where incremental slab deflection > 15mm is required, refer to Rondo for specific details & requirements.
3. The subcontractor shall verify the adequacy of this allowance prior to commencing works on site.

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First Printed MARCH 2021.