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Rethinking Apartment Building Construction - Consider Timber



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Introduction

Timber's sustainability credentials are attracting world-wide interest and advances in timber engineering have made timber an increasingly cost-competitive proposition.

Encouraging the construction industry to adopt innovative approaches needs information and evidence. Attention to technical design, construction costs and site processes is critical to show the value proposition of timber construction to customers and optimise its use.

This Guide¹ aims to help those involved in the decision chain (such as cost managers, estimators, design professionals, building developers and project managers) gain a better understanding of the value that timber construction systems offer apartment building projects.

The Guide is revision and addition to a previous guide that developed a model apartment building and corresponding timber solutions in Cross Laminated Timber and compared it with conventional concrete construction. The guide has now been updated to include a lightweight timber framed design as well as pricing to mid-2017 rates.

The revision also included feedback from users of the guide and accordingly took the opportunity to address omissions in the first edition; being the absence of concrete toppings to the floor of the timber solution and the lack of stairs to all solutions. As the original timber solution was designed prior to the development of the timber based Deemed-to-Satisfy (DTS) solution within the National Construction Code (NCC), the timber solutions were updated or designed so that all designs fully complies with the DTS solution within the NCC.

Other changes included modification to the façade so that the same rain screen solution was used for all building types, noting that there are differences to the external wall's structural and fire solution throughout each design and finally the CLT solution was redesigned so that it is now based on an Australian manufactured and sized product.

The intent of the base building's design was intended to be neutral to all three solution so that not one solution was favoured. This meant that the functional performance, constructability and cost effectiveness and compliance under the National Construction Code (NCC) remained evenly treated. Ultimately the guide provides a basis to provide explanation to the decision making that was required to develop the timber solutions.

¹ WoodSolutions Guide No 27 Rethinking Apartment Building Construction - Consider Timber

2

What Drives Decisions When Choosing Apartment Construction Systems?

A key objective of the research project was to understand the decision drivers along the customer/supply chain for the selection of apartment construction systems. Key areas of investigation included:

- Gathering information about customer needs and how construction affects things like the spatial requirements and liveability issues, especially when designing for high-end apartment living.
- Benchmarking against existing apartment construction systems, especially conventional post-tensioned concrete slab construction. This was found to be the main method used for apartment construction and was consequently used as the basis for comparison to timber.
- Understanding the nature of the overall delivery supply chain and related work flows, especially construction scheduling, productivity and prefabrication issues.
- Optimising the regulatory framework where it affects the viability of timber solutions, including fire and acoustic issues.
- Elements that have a significant difference in cost between the construction solutions. Cost neutral items or insignificant cost differences have been ignored. This resulted in the cost comparison focusing mainly on the superstructure costs.

Project Development

The research project was developed by a series of expert/stakeholder meetings, interviews, concept development sessions, design charrettes, cost planning studies, construction programming studies and design detailing studies aimed at developing the model apartment building and a cost-effective timber solution for it.

A team of experts worked together to provide input to the development process. Core collaborators included:

- **The Timber Development Association:** A market development association for the timber industry and the project leader for this work, on behalf of the timber industry.
- **The University of Technology Sydney:** A technology-driven university with an integrated understanding of the building industry and specific expertise in timber construction. The university co-developed the research method and mediated the strategic direction of the timber solutions in terms of detailed design, cost and site productivity issues.
- **studio505:** An architectural firm with a strong understanding of design and the effects of material and system selection. They prepared and led the design of the model apartment building with case specific input into the related timber solution.
- **Zimmermann Design Studio:** An Architectural firm that led the design of the timber framed apartment building and provided input into the related timber solution. The original concept design of the building is based on a design undertaken by studio505 the firm from which Zimmermann Design Studio emerged from.
- **MiTek:** A supply and support company for the timber framed Frame and Truss fabrication sector. They provided specialised services in structural design of timber frames, bracing and tie-down.
- **Taylor Thompson Whitting Consulting Engineers:** An engineering firm with specialised services in structural, civil and facade engineering that provided the structural concrete design for the concrete solution.
- **BCIS:** A global subsidiary of the Royal Institute of Chartered Surveyors who specialise in gathering building cost data used for reporting on cost trends for a variety building forms. BCIS provided quantity surveying, cost estimating and cost planning input for the 2014 version of the timber solution and the corresponding concrete solution.
- **MBM:** A national independent construction consultancy specialising in quantity surveying. They provided quantity surveying, cost estimating and cost planning input for the 2017 version of the timber framed solution and the corresponding concrete solution. They have in recent times developed real experience in timber construction and costings.
- **Timber Imagineering and Tim Gibney and Associates:** Heavy timber Fabrication Company and structural timber engineering services. They provided specialised design of lateral resisting frames as well as analysis of the CLT core.

Two timber solutions were chosen as the main element used in the timber solutions, being Cross Laminated Timber (CLT)² (Figure 1) and Lightweight Timber Framing (LTF) (Figure 2). Cross Laminated Timber was used in the lift and stair core in both design. Based on this, a preferred timber design solution was derived and tested on a cross-section of building owners, developers, designers and contractors to provide critical feedback. This design was then compared against a typical post-tension concrete design using band beams and columns (as detailed in Appendix A).

² For more information on Cross Laminated Timber refer to WoodSolutions Guide No 16; Massive Timber Construction Systems - Cross-laminated Timber (CLT)



Figure 1: Cross-Laminated Timber construction.

Architect: Waugh Thistleton, Engineer: Techniker, Contractor: Telford Homes,
CLT Supply and Installation: KLH UK, Photography: KLH UK



Figure 2: Timber Framed Apartment Building “The Green” by Frasers Property

4

The Model Apartment Building – the Basis for Comparison and Solution Development

The model apartment building was created to provide a basis for defining and presenting a timber-based solution, as well as a corresponding concrete solution. It provides a prototypical situation for modelling spatial, loading, fire and noise resistance conditions, enabling a neutral base for creating both the timber and competing concrete solutions.

The model building aimed to meet high-end consumer needs, including large and open room layouts. An emphasis was placed on characterising a building that could apply to many suburban/urban apartment situations across Australia.

The model apartment building is shown Figure 3. The building is divided into three distinct parts: car parking in the basement, retail space on the ground floor and seven stories of apartments. This mix of spaces mimics real world situations and creates a mix of different building classifications under the National Construction Code.

Figures 4 to 8 provide an overarching understanding of the model building, including the multiple faceted style façade, which creates an interesting yet complex aesthetic for the building. The basic spatial characteristics of the model are provided in Table 1.

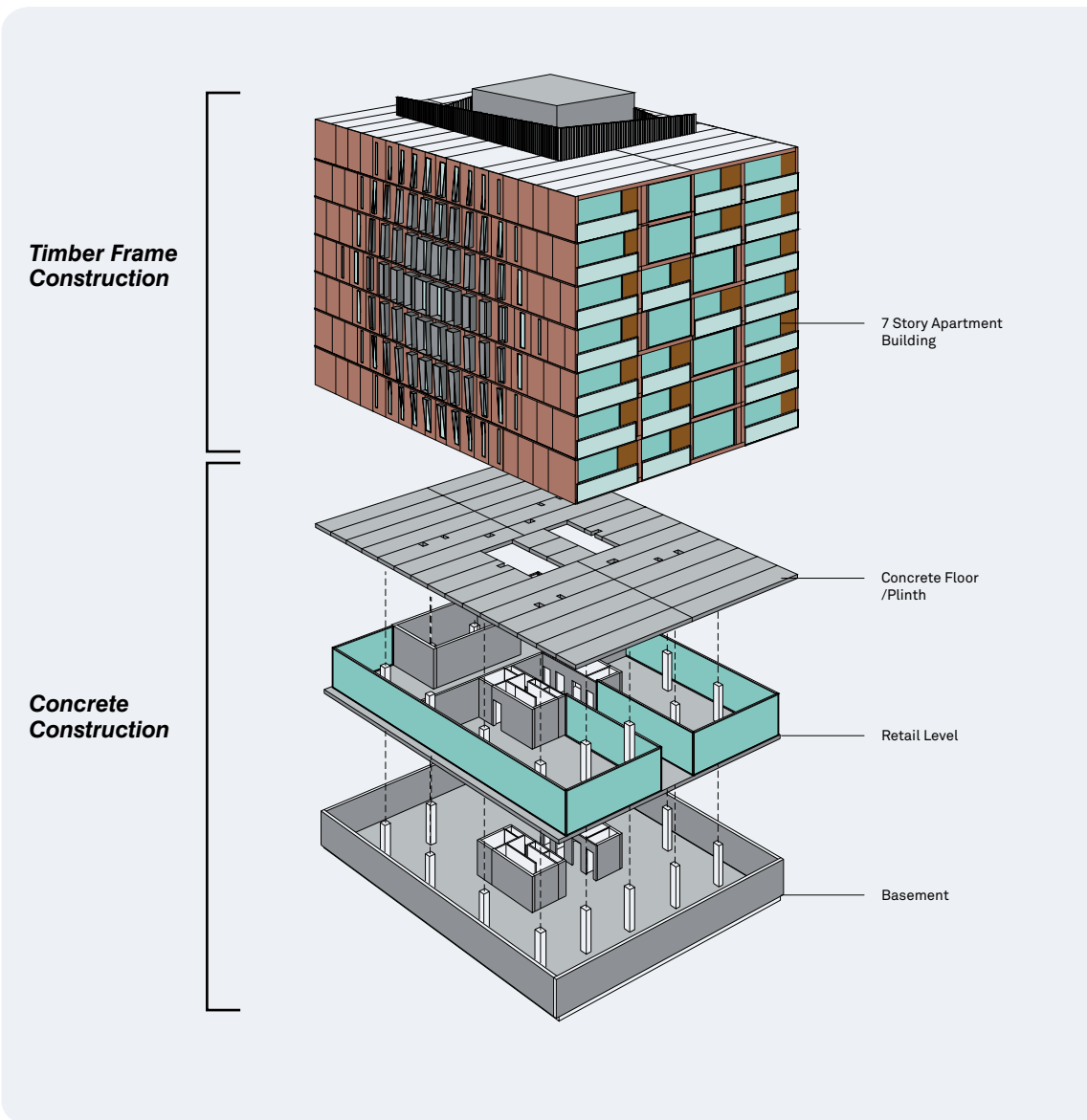


Figure 3: The building broken into three distinct zones.
Design and image: Zimmermann Design Studio and studio505:

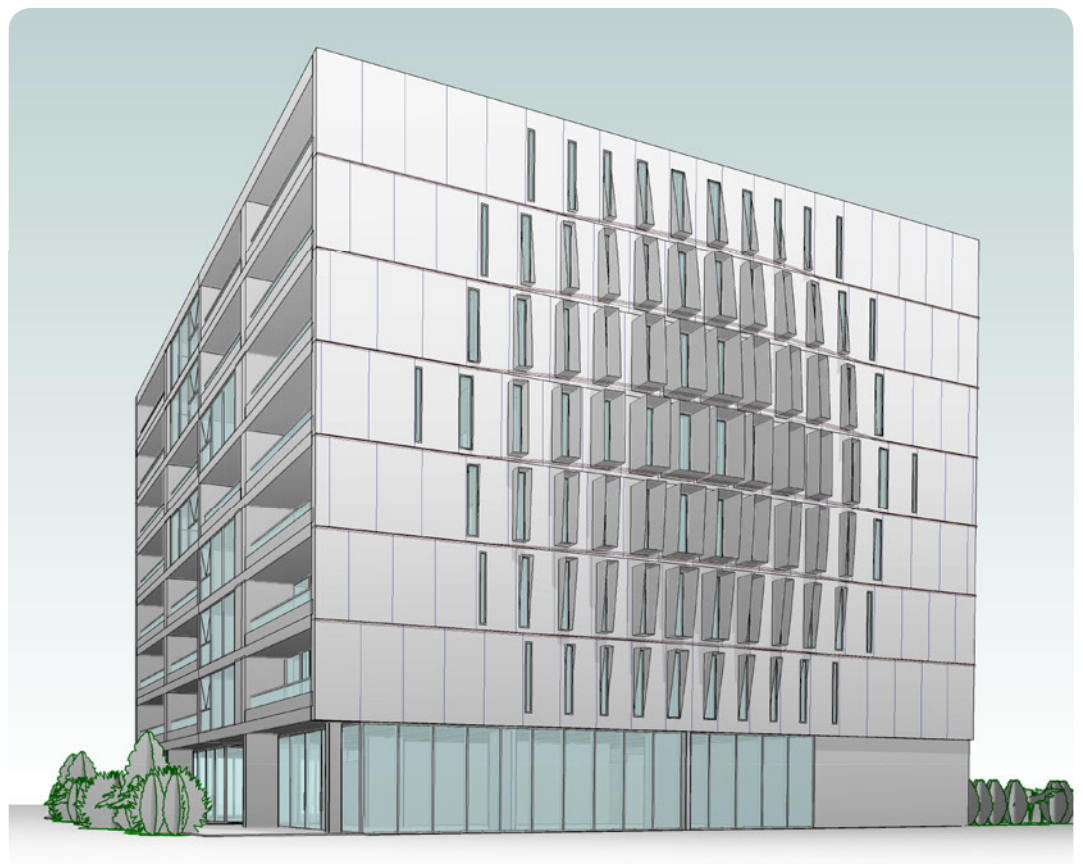


Figure 4: 3D exterior views. Design and images: Zimmermann Design Studio and studio505:

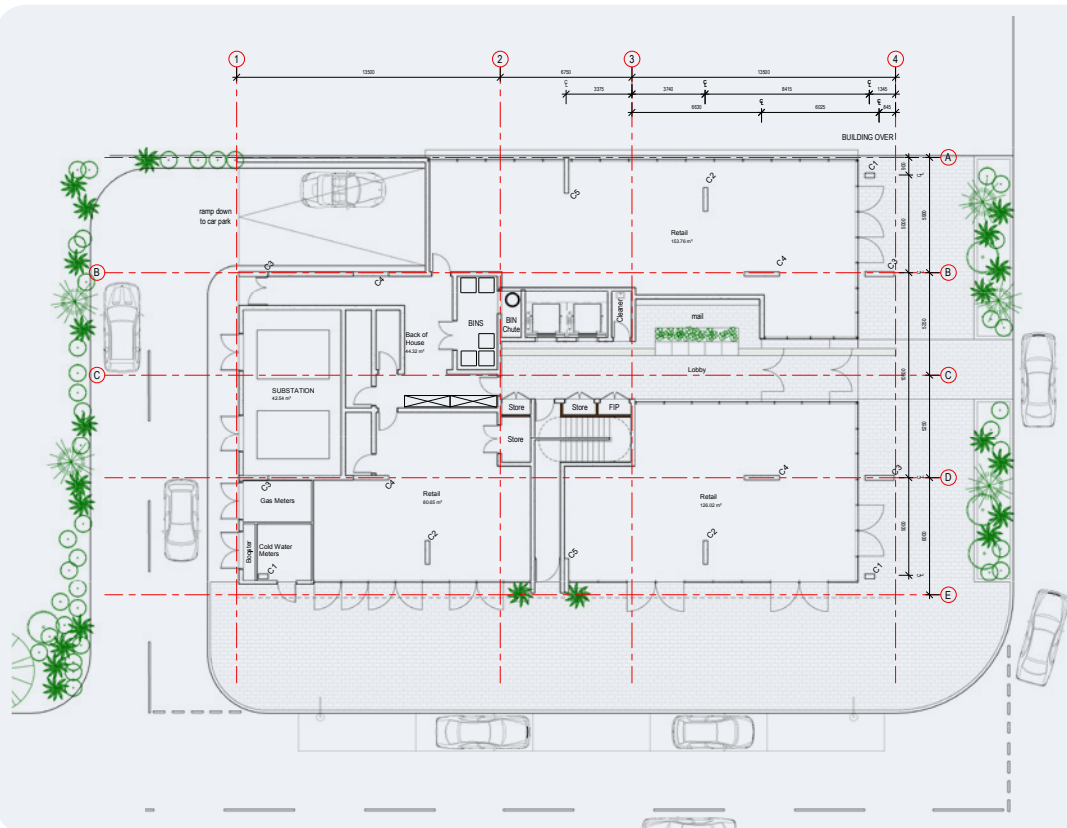


Figure 5: Plan view of retail level (ground floor).

Design and images: Zimmermann Design Studio and studio505:



Figure 5: Typical floor plan for apartment levels.

Design and images: Zimmermann Design Studio and studio505:



Figure 7: Section view - short section.

Design and images: Zimmermann Design Studio and studio505:



Figure 8: Section view - long section.

Design and images: Zimmermann Design Studio and studio505:

Table 1: Key spatial characteristics of the model apartment building.

Item	What was used in the model	Relevance and Reasons
Height	• An 8-storey design height above ground level, including 7 apartment levels and 1 retail level. • Timber Framed - A 26.9 m overall building height, with an NCC effective height of 23.7 m. - A 3.2 m floor to floor height for the apartment levels and 4.0 m for the retail level. • CLT and Concrete - A 26.2 m overall building height with an NCC effective height of 23.1 m. - A 3.1 m floor to floor height for the apartment levels and 4.0 m for the retail level.	• The apartment levels provide a 2.7 m habitable height plus room for the structure and services. Lower ceiling heights may also be possible in accordance with the NCC. • The retail level provides for a maximum depth of 650 mm (concrete) 500 mm (CLT and timber framed) thick transfer slab above, i.e. as used to transition loads from the timber to concrete parts of the building.
Area	• A floor plate area of 770 m². The apartment levels include 42 apartments (94–96 m² each). • The retail level assumes three shops varying in area from 77–150 m². It also includes a foyer area, an entrance to basement car parking, utility meter rooms, an electrical substation and a waste area.	• Feedback and analysis indicates that many suburban mid-rise apartment buildings fit the scenario provided.
Key set out criteria	• Length 34.0 m x Width 22.5m (edge to edge of floor plates). • An 8.2 x 8.2 m column grid used on the retail level (Level 1) and the basement level below.	• The width of the building accommodates the size and set-out of the large, high-end apartments. • The grid layout accommodates car parking in the basement.
Building ownership and fire compartment-alisation	• The building is considered to be strata titled including the retail area on the ground floor.	• Strata title creates the need for each title to be defined as a separate Sole Occupancy Unit under the NCC which creates fire and noise performance requirements.
Setbacks	• External wall distances are (at minimum) less than 1.5 m from the property boundary.	• The location of the building relative to other buildings or properties affects façade fire resistance requirements.

Note: Effective height refers to the distance from the floor level above the ground to floor level of the upper most habitable space but excluding the top most storey where used for items such water tanks, lifts, etc).

4.1 North and South Façade

The building's north and south façades is multifaceted with varying sized windows occurring on each level, (Figure 9). The façade is divided into four zones and they are repeated four times (Figure 10).

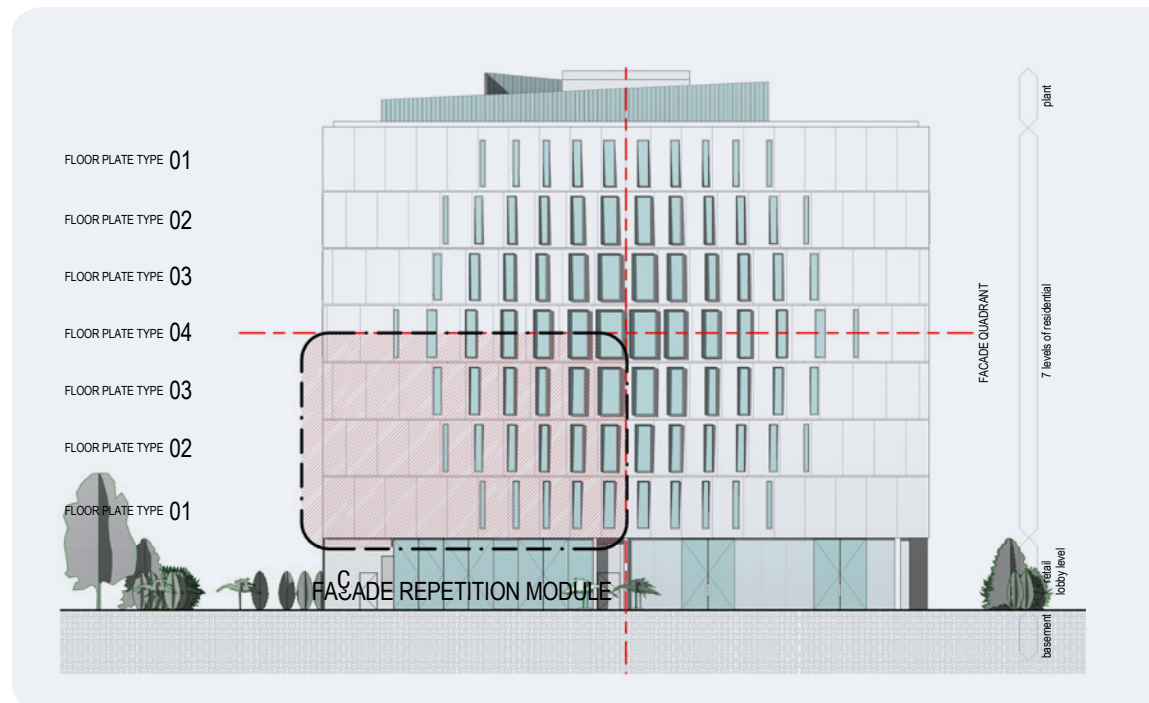
The intricate façade design is a consequence of the design team wanting the building to have more interesting architecture, while adding a degree of difficulty to the project's design. The façade's irregular window size means that opening do not line up on top of each other (Figure 11). This façade design drove the need to fully protect the buildings with sprinklers, as it removed the need for spandrel projection or panels.

The solution for this façade was provided by clipping on non-loadbearing pre-fabricated rain screen.



Figure 9: North and south façade.

Design and images: Zimmermann Design Studio and studio505:



10: Façade repetition. *Design and images: Zimmermann Design Studio and studio505:*

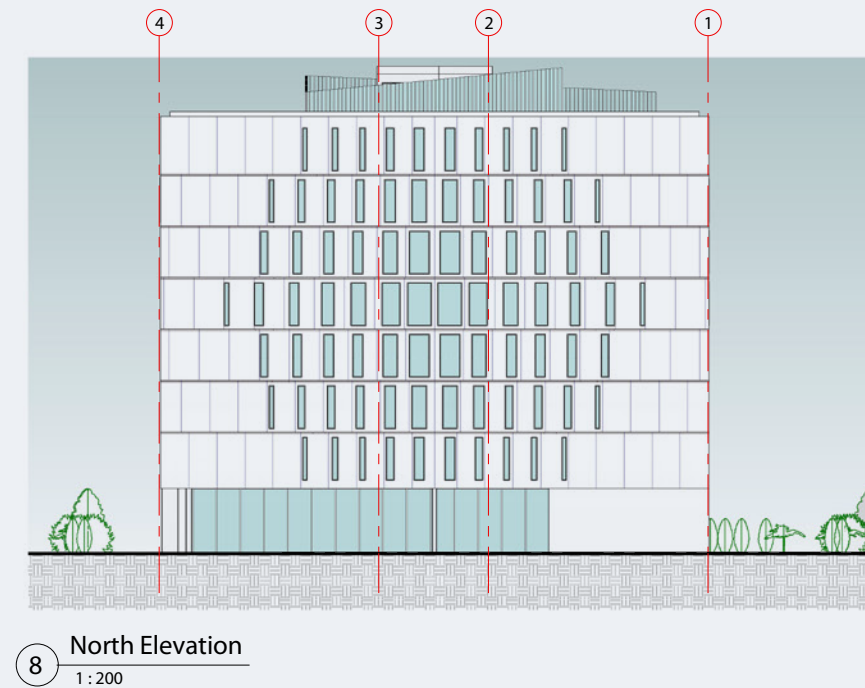


Figure 11: Difference in external wall location on various floor levels
 Design and images: Zimmermann Design Studio and studio505:

4.2 Core Differences between the Timber and Concrete Solutions

The main difference between the timber solutions and competing concrete solution concerns the wall and floor structure throughout the apartment levels of the building (i.e. the seven levels above the ground floor retail level).

Parameters pertaining to fire, acoustic and building services requirements (which affect both the timber and concrete solutions) are provided under dedicated headings below.

Other aspects are essentially the same and provide relative neutrality when comparing the two competing solutions. Consequently, discussion of the solution below Level 1 (retail level and basement car parking) has been excluded from this Guide.

4.3 Structural Themes

Parameters applied to the model:

- Deemed-to-Satisfy applied, imposed and wind loadings were taken from AS 1170 series of Standards.
- Load paths are managed in the apartment levels via cellular timber construction which converts to a concrete slab and column (grid) structure for the retail and basement levels below. The transition between the two is managed by a 500 mm deep concrete transfer slab for the timber solution. The concrete solution uses a concrete column and flat plate solution with infill non-loadbearing walls to separate SOU's. The columns in the apartment zone do not line up with column layout in the retail and basement zone requiring a concrete slab transfer solution.
- Weathered shale soil conditions have been applied in the structural design.

Reasons:

- While in technical terms, timber can be constructed below ground level, concrete construction is less likely to attract concerns about moisture penetration and termite activity. To allay such concerns, the timber solution uses a stainless steel mesh barrier at all hidden entry points between the concrete levels and the timber levels above.
- Concrete construction is used for the retail and basement levels because:
 - These levels pertain to Class 7b (car parking) and Class 6 (retail) under the NCC, and subsequently have higher fire resistance requirements than the main Class 2 apartment levels of the building. It was found more cost effective to use concrete construction on these lower levels.
 - The transfer slab was found to be the most cost-effective means of transferring loads, especially at the change between the apartment and retail zone.
- Weathered shale is a moderate foundation condition common in many parts of Australia and is relatively neutral for both timber and concrete solutions.

Additional points of interest:

- The lightweight nature of timber is particularly advantageous in poor foundation conditions. Though not dealt with specifically in this study, its lightweight nature contributes to reduced piling or smaller footing sizes.

4.4 Building Acoustics

Parameters applied to the model were designed to achieve above NCC's Deemed-to-Satisfy requirements including:

Floors:

- $R_w + C_{tr}$ (airborne) between 50 and 55
- $L_{n,w}$ (impact) between 40 (carpet) and 55 (hard surfaces).

Walls:

- Walls between neighbouring units: $R_w + C_{tr}$ (airborne) of 50 to 55 and is discontinuous construction i.e. separate wall leaves.
- Walls to plant room, lift shafts, stair shafts and corridors: between R_w 50 - 55. These walls must also be discontinuous construction.
- Service shafts; $R_w + C_{tr}$ (airborne) of 40.
- Doors to apartments: R_w 30.

Reasons:

- Since the apartments aim to meet high-end consumer standards, the nominated acoustic requirements have been selected to surpass minimum NCC's Deemed-to-Satisfy requirements..

4.5 Fire Resistance

Parameters applied to the model:

- The NCC defines the model building as being mixed use including Class 7a – car parking; Class 6 – retail; and Class 2 – residential. It involves a rise of 8 storeys which subsequently requires Type A fire resistant construction. For the apartment levels, this determines the Fire Resistance Levels required of individual building elements further dealt with below. Here, Deemed-to-Satisfy (DtS) provisions were applied to all of the concrete solution as well as the timber solution and the Fire Resistance Levels (FRLs) are identical for the concrete and timber solutions. The timber solution utilised the recent NCC Code change³ that allowed fire-protected timber construction to an effective height of 25 m.
- A sprinkler system was applied to the building at each floor level as well as the under-roof area for both the timber and concrete solutions to reduce spread of fire requirements that would otherwise limit design options for the external face of the building (as discussed in Section 4.1).

Reasons:

- A Deemed-to-Satisfy solution was applied to each solution to remove the need to develop a Performance Solution. It is recognised that a Performance Solution to elements of the building design for both solution may provide extra saving. This has been ignored in this comparison.
- The use of a sprinkler system removed the need for fire protection of openings in the exterior façade, therefore avoiding usage of spandrel panels and similar facade treatments. (NCC provision C2.6 removes the need for spandrel panels or horizontal projections where complying sprinklers are installed.) While this choice benefited the timber solution and was less necessary for the concrete solution, feedback from architects suggests that this potential economy associated with concrete (and similar) spandrel panels is rarely used because of the unwanted design limitations it places on the appearance of the building.

4.5.1 External Walls

Parameters applied to the model:

- The NCC (Table 3 Specification C1.1. Clause 3) Deemed-to-Satisfy Fire Resistance Level (FRL) has been applied to external wall elements for the concrete and timber solution. As the external walls are considered to be less than 1.5 m away from adjoining property
 - Loadbearing walls 90/90/90, and
 - Non-loadbearing walls - /90/90.
- The north and south façade's rain screen was pre-fabricated from non-combustible materials and span between each floor of the building. There is no difference in the rain screens construction technique between the timber and concrete solution.

³The 2016 NCC added a new DTS solution for timber buildings up to an effective height of 25 m.

4.5.1.1 Vertical separation of openings in external walls

Parameters applied to the model:

- There are no spandrel or horizontal projections relied on in the solution.

Reasons:

- The use of spandrel or horizontal projections interfered with the facade appearance (Section 4.1) and are not necessary when complying sprinklers are installed (NCC Provision C2.6).

4.5.2 Internal Walls

Parameters applied to the model:

- The NCC (Table 3 Specification C1.1. Clause 3) Deemed-to-Satisfy Fire Resistance Level (FRL) has been applied to fire-resisting lift and stair shaft walls; walls bounding public corridors and lobbies; walls between or bounding apartments; and walls relating to service shafts. The FRLs used are:
 - fire-resisting lift and stair shafts – loadbearing walls: 90/90/90 and non-loadbearing walls: -/90/90
 - walls bounding public corridors and lobbies – loadbearing: 90/90/90 and non-loadbearing: -/60/60
 - between or bounding apartments – loadbearing walls: 90/90/90 and non-loadbearing walls: -/60/60
 - service shafts – loadbearing walls: 90/90/90 and non-loadbearing walls: -/90/90

4.5.3 Floor Structure

Parameters applied to the model:

- The NCC (Table 3 Specification C1.1. Clause 3) Deemed-to-Satisfy Fire Resistance Level (FRL) has been applied to floor structure. The FRL used is 90/90/90.

4.5.4 Roof Structure:

Parameters applied to the model:

- A non-combustible roof covering is used.
- There is no fire resistance requirement for roof elements.
- Fire-rated walls extend to the underside of the non-combustible roof coverings.

Reasons:

- NCC (Spec C1.1 Clause 3.5) provides a concession for roofs in Class 2 buildings, requiring no fire resistance as long as a complying sprinkler systems and a non-combustible roof covering is used.

The Timber Solution

In response to the model building (including fire, acoustic, building services and structural loading requirements), this section presents a timber solution that aims to optimise cost, time and constructability requirements. It focuses on the seven levels constituting the Class 2 apartment section of the building (levels 1 to 8) and uses a number of themes:

- Two timber design solutions, one using Cross Laminated Timber and the other using lightweight timber framing for loadbearing walls, fire-rated walls, partition walls for non-loadbearing and/or non-fire resistant internal walls, floor and roof elements.
- Use of Cross-Laminated Timber for lift shaft and stair shaft as well as the stairs in both solutions.
- Level 1 floor and below is in concrete (Figure 12 provides details of concrete transfer slab).

Construction solutions are provided below in Section 5.1 for lightweight timber frame and Section 5.2 for Cross Laminated Timber.

In contrast, the concrete solution uses a more commonly used post tensioned flat plate design, which is detailed in Appendix A for comparative purposes.

Many other aspects of the overall construction are common to both the timber and concrete solutions and have subsequently been excluded from the ongoing discussion. This includes the:

- Basement construction
- Retail level construction
- Façade rain screen (structural component of external walls are included in the comparison)

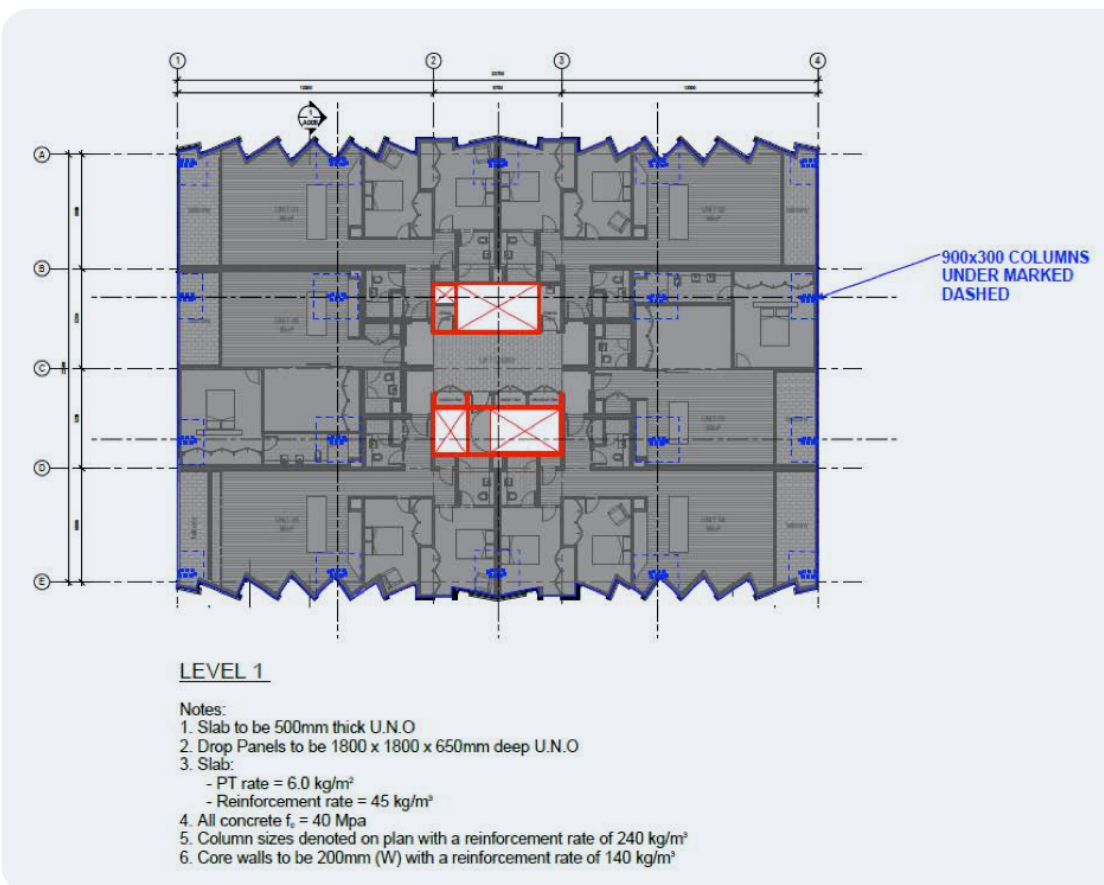


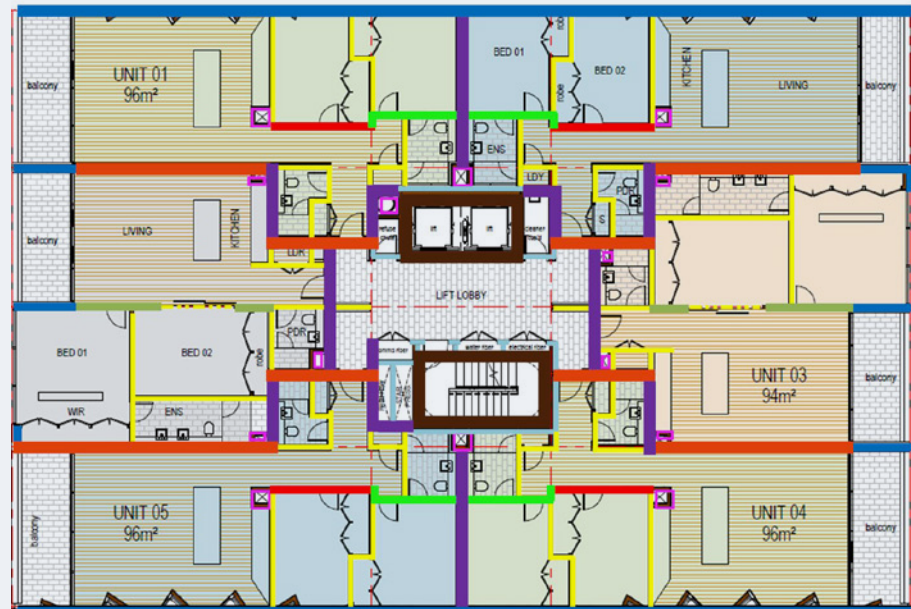
Figure 12: Details of the concrete transfer slab at Level 1 for the timber solution

5.1 Lightweight Timber Frame Solution

5.1.1 External and Internal Walls

What was used in the lightweight timber solution:

- Lightweight timber framing has been used for all external and internal walls (excluding stair and lift shafts) that are loadbearing and/or require fire resistance levels (see Figure 13 for details). Specific element sizes vary according to application and the location in the building i.e. lower levels because of higher loads use either larger or higher strength studs. Refer to Table 2 for the location of each wall type and Tables 3, 4 and 5 for the corresponding sizing of the studs.



Wall Location	Wall Number & Colour Code	Description
External	1	Single stud load-bearing fire-rated wall
Apartment bounding Walls	2	Double stud load-bearing fire and acoustic rated wall
	3	Double stud non load-bearing fire and acoustic rated wall
	4	Single stud load-bearing fire-rated wall – FLW 5.3 m
Internal Apartment Walls	5	Single stud load-bearing fire-rated wall – FLW 4.4 m
	6	Single stud load-bearing fire-rated wall – FLW 3.4 m
	7	Single stud non load-bearing fire-rated wall
	8	Single stud non load-bearing wall
Shafts	9	Lift and stair shaft
	10	Service shaft

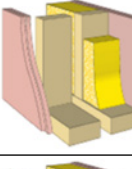
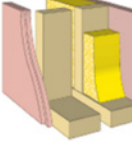
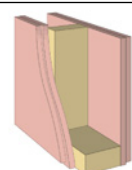
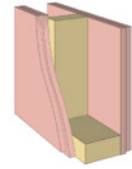
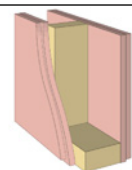
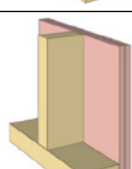
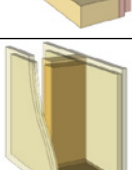
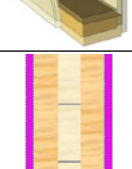
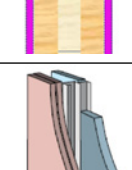
Figure 13: Typical Floor Plan showing timber framed wall types

Zimmermann Design Studio, studio505 and TDA:

NOTE: FLW means “Floor Load Width” a common term used to indicate the width of the floor bearing onto a wall.

³ Further information on Timber char capacity can be found in WoodSolutions Guide No 3: Timber-framed Construction for Commercial Buildings Class 5, 6, 9a & 9b - Design & construction guide for BCA compliant fire-rated construction

Table 2: Wall Systems Description

	Diagram of Wall System	Structural System	Linings & Insulation	Acoustic Rating Rw + Ctr	Fire Rating
1		Refer to Table 3 for stud and plate sizes	Inside: 2 x 13 mm fire grade plasterboard Outside: 2 x 13 mm fire grade plasterboard + Aluminium composite panel on battens. 75 mm mineral wool in between battens	N/A	90/90/90
2		Refer to Table 4 for stud and plate sizes	2 x 13 mm fire grade plasterboard both sides of wall with 75 mm glasswool in the cavity	52#	90/90/90
3		Studs and Plates: MGP10 70 x 45 @ 600 crs	2 x 13 mm fire grade plasterboard both sides of wall with 75 mm glasswool in the cavity	N/A	90/90/90
4		Refer to Table 5 and FLW 5.3 m for stud and plate sizes	2 x 13 mm fire grade plasterboard both sides of wall	N/A	90/90/90
5		Refer to Table 5 and FLW 4.4 m for stud and plate sizes	2 x 13 mm fire grade plasterboard both sides of wall	N/A	90/90/90
6		Refer to Table 5 and FLW 3.4 m for stud and plate sizes	2 x 13 mm fire grade plasterboard both sides of wall	N/A	90/90/90
7		Studs and Plates: MGP10 70 x 45 @ 600 crs	2 x 13 mm fire grade plasterboard both sides of wall with 75 mm glasswool in the cavity	N/A	90/90/90
8		Studs and Plates: MGP10 70 x 35 @ 600 crs	10 mm standard grade plasterboard or 6 mm fibre cement (if in wet area)	N/A	N/A
9		125 mm 5 layer CLT	1 x 16 mm fire grade plasterboard each side of CLT	52* (Note: in combination with Wall 7)	90/90/90
10		102 mm metal frame	25 mm plasterboard shaft liner 2 x 13 mm fire grade plasterboard	40#	90/90/90

Acoustic estimates from CSR Red Book

*Acoustic estimate from FWPA CLT Acoustic Research Program

Table 3: External Wall Stud and Plate Sizes

	External Walls
	Level 7
Plates	MGP10 90 x 35
Studs	MGP10 90 x 35 @ 600 crs
	Level 6
Plates	MGP10 90 x 35
Studs	LVL 90 x 35 @ 600 crs
	Level 5
Plates	MGP10 90 x 35
Studs	LVL 90 x 35 @ 600 crs
	Level 4
Plates	LVL 130 x 35
Studs	LVL 130 x 35 @ 600 crs
	Level 3
Plates	LVL 130 x 35
Studs	LVL 130 x 35 @ 600 crs
	Level 2
Plates	LVL 130 x 35
Studs	LVL 130 x 35 @ 600 crs
	Level 1
Plates	LVL 130 x 35
Studs	LVL 130 x 35 @ 600 crs

Table 4: Apartment bounding wall stud and plate sizes

	Double Stud Walls Load Bearing
	Level 7
Plates	MGP10 90 x 35
Studs	MGP10 90 x 35 @ 600 crs
	Level 6
Plates	MGP10 90 x 35
Studs	LVL 90 x 35 @ 600 crs
	Level 5
Plates	MGP10 90 x 35
Studs	LVL 90 x 45 @ 600 crs
	Level 4
Plates	MGP10 90 x 35
Studs	LVL 2 x 90 x 35 @ 600 crs
	Level 3
Plates	MGP10 90 x 35
Studs	LVL 2 x 90 x 35 @ 600 crs
	Level 2
Plates	MGP10 90 x 35
Studs	LVL 2 x 90 x 45 @ 600 crs
	Level 1
Plates	MGP10 90 x 35
Studs	LVL 3 x 90 x 45 @ 600 crs

Table 5: Internal apartment single stud and plate sizes

	Single Stud FLW = 5.3 m	Single Stud FLW = 4.4 m	Single Stud FLW = 3.4 m
	Level 7		
Plates	MGP10 90 x 35	MGP10 90 x 35	MGP10 70 x 35
Studs	MGP10 90 x 45 @ 450 crs	MGP10 90 x 45 @ 600 crs	MGP10 70 x 45 @ 450 crs
	Level 6		
Plates	MGP10 120 x 45	MGP10 120 x 35	MGP10 90 x 35
Studs	MGP10 120 x 45 @ 450 crs	MGP10 120 x 45 @ 600	MGP12 90 x 45 @ 450 crs
	Level 5		
Plates	MGP10 140 x 35	LVL 130 x 35	MGP10 120 x 35
Studs	MGP12 140 x 35 @ 450 crs	LVL 130 x 35 @ 600 crs	MGP12 120 x 35 @ 450 crs
	Level 4		
Plates	LVL 130 x 35	LVL 130 x 35	MGP10 120 x 35
Studs	LVL 130 x 35 @ 450 crs	LVL 130 x 35 @ 600 crs	MGP12 120 x 45 @ 450 crs
	Level 3		
Plates	Ribbon Nogging ¹	Ribbon Nogging ¹	LVL 130 x 35
Studs	LVL 130 x 35 @ 450 crs	LVL 130 x 35 @ 600 crs	LVL 130 X 35 @ 450 crs
	Level 2		
Plates	Ribbon Nogging ¹	Ribbon Nogging ¹	LVL 130 x 35
Studs	LVL 130 x 35 @ 450 crs	LVL 130 x 35 @ 600 crs	LVL 130 X 35 @ 450 crs
	Level 1		
Plates	Ribbon Nogging ¹	Ribbon Nogging ¹	LVL 130 x 35
Studs	LVL 130 x 35 @ 450 crs	LVL 130 x 35 @ 600 crs	LVL 130 X 35 @ 450 crs

NOTES: ¹Ribbon Nogging are plates on edge housed into studs. Refer below for more explanation.

Reasons:

Avoidance of Compression Perpendicular to Grain Issues

Timber's compressive strength perpendicular to grain is much less than it is parallel to grain and if left without consideration could cause axial shortening issues within the building leading to misalignment of plumbing, flashing and cladding. Two techniques have been used within this design to minimise these effects and they are discussed below.

Balloon Framing

Traditional framing techniques used in house construction, termed platform construction, have a portion of timber framing perpendicular to grain to the load path, i.e. floor framing, beams and wall plates, refer Figure 14.

To minimise perpendicular to grain crushing an old construction system termed “balloon framing” is used. Balloon framing is where the studs are more than one storey high and the floor system is hung off the side of the stud. This design uses a modern version of this termed “semi-balloon framing”. This is where the studs are floor to floor in height and have the floor framing supported off the side of the studs, refer Figure 15.

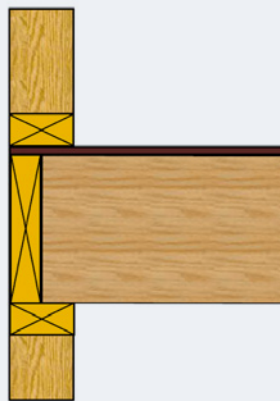


Figure 14: Platform Framing System

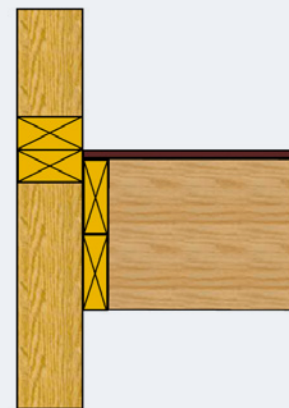


Figure 15: Semi Balloon Framing

Ribbon Nogging

Although Semi-Balloon framing remove most of the horizontal timber out of the design, timber wall plates are still contained within the wall frame and load path. The lower storeys of this design where dominated by the bearing strength of the wall plates, so much so the stud sizes were being determined by this issue.

To avoid using studs sizes greater than need the studs were aligned on top of each other and the wall plates where placed on edge and rebated into the studs, refer Figure 16. This configuration allowed the stud ends to bear directly onto each other.

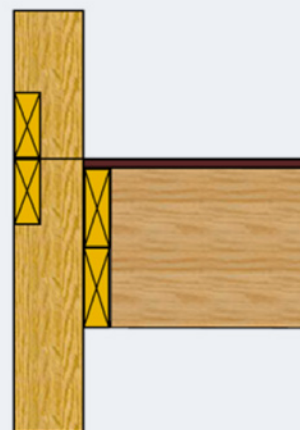


Figure 16: Ribbon nogging replacing wall plates

5.1.2 Stair and lift shaft

The system use 125 mm thick 5 ply Cross laminated timber.

Fire protection to the CLT varies depending on whether a stud wall abuts it or that it is in the inside of the shaft. Stud wall's fire protection is as for other walls utilising two layers of 13 mm fire grade plasterboard. Where there is no frame wall abutting the shaft, 16 mm fire grade plasterboard is direct fixed to the CLT.

Reasons:

- Where required for acoustic reasons, CLT wall panels have additional stud construction to improve sound performance (Table 2).

5.1.3 Floor and Roof Structure

What was used in the timber solution:

Lightweight timber framed floor cassettes where used, refer Figure 17. They have an overall depth of 382 mm including floor sheets. Timber framing consists of parallel chord trusses at 450 centres. Top and bottom chords are made from 90 x 45 MGP 12 and webs from pressed metal, refer Figure 17. Cassettes vary in length and width depending on the layout. Generally the floor cassettes length is the span between supporting walls and 2.7 m wide, being a common floor sheet size and width of truck used to deliver the cassettes.



Figure 17: Section through timber floor cassette.

The cassettes sit onto a timber ledger. One half of the ledger is screwed to the side of the wall studs and the other to the end of the cassette, refer Figure 18. This joining method makes the installation easier and quicker as well as providing an element that can be used as a cavity barrier.

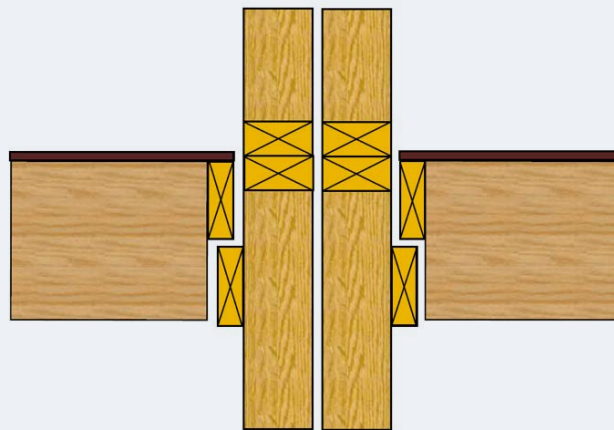


Figure 18: Illustration of ledger support for timber floor cassette.

Reasons:

- The timber framed floor cassettes are used to speed up installation of the floor framing.
- Floor trusses are used to allow plumbing services to transverse through the floor.
- Due to the walls running from floor to floor, the floor cassettes must span between wall frames.
- Timber ledgers on wall studs and cassettes also act as cavity barrier, a NCC requirement.

Fire Resistance

- Fire resisting to the underside of the floor is provided by two layers of 16 mm fire resisting plasterboard fixed to a resilient mounted furring channel. This configuration provides an FRL 90/90/90 and meets the NCC's requirement for Clause A 1.1 for Fire-Protected Timber.
- Fire resistance is not required for the roof as the walls about the underside of the non-combustible roof coverings.

Acoustic

Sound attenuation is provided by a number of elements in the floor system, refer Figure 19. These include;

- 40 mm thick cement based screed
- 10 mm rubber mat between cement based screed and structural flooring
- Furring channels hung on resilient mounts attached to the underside of the floor cassettes framing
- 75 mm glasswool insulation at 14 kg/m³

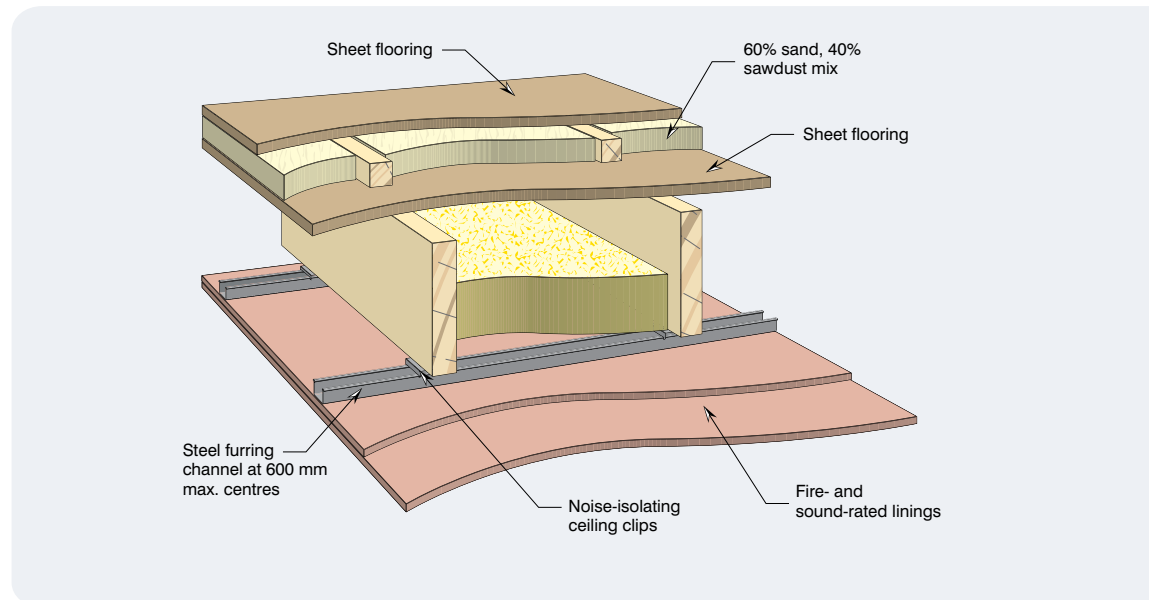


Figure 19: Section through acoustic floor framing

The acoustic performance

- $R_w + C_{tr}$: 51
- L_n : 40 to 55 (depends on floor coverings used)

Beams are required in two internal openings:

- Two 240 x 90 LVL13 beams under the floor in opening in wall in Units 3 and 6.

5.1.4 Lateral Resistance

Lateral resistance and over turning of the building is dealt in a number of solutions. Firstly the CLT used for the lift and stair shaft is assumed to provide one third of the lateral resistance. Additional lateral resistance is provided by the use of varying number of shear walls on each level of the building. The lowest storeys requires more shear walls than the top storey.

Three shear walls are used;

- Galvanised metal cross bracing, AS1684.2 Table 8.18 (d)
- Double skin plywood walls with tie-down rods, AS1684.2 Table 8.18 (i)
- Laminated Veneer Lumber (LVL) moment frames

A typical shear wall layout is found in Figure 20.



Figure 20: Level 1 Shear Wall Layout

Design and images: Zimmermann Design Studio, studio505 and TDA:

Reason:

- The CLT core of the building has large lateral resistance capacity.
- Metal cross bracing are used as they don't increase the wall thickness.
- Double skin plywood wall with tie-down rods are very efficient shear walls. They do increase the wall thickness but this effect can be reduced by utilising internal apartment walls. Internal apartment walls with cupboards attached hide the additional wall thickness.
- LVL moment frames are used on the east and west façade as they frame around the openings without interfering with the window or door opening.

5.2 Cross Laminated Timber Solution

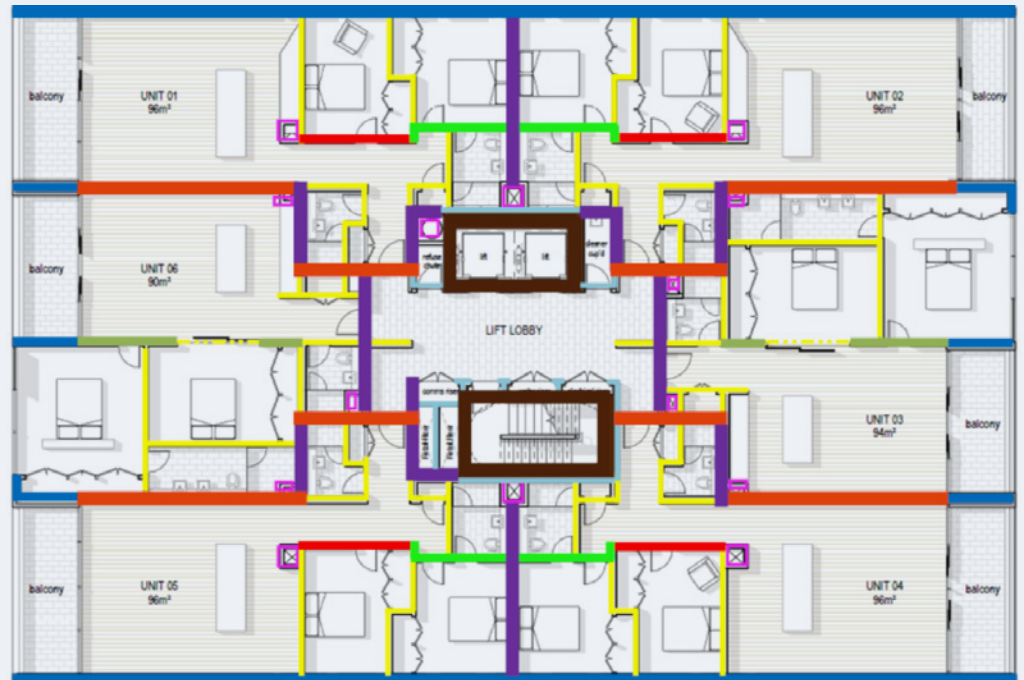
5.2.1 External and Internal Walls

What was used in the timber solution:

Cross laminated timber has been used for all external and internal walls (including stair and lift shafts) that are loadbearing and/or require fire resistance levels (refer to Figure 21 for details).

Partition walls within apartments that are not fire resisting are lightweight timber stud walls. CLT element sizes vary according to application, refer to Table 6 which includes:

- Fire protection to the CLT was used in all cases.
- Where required for acoustic reasons, CLT wall panels have additional stud construction to improve sound performance, refer Table 6.
- The stair and lift shaft are twin wall CLT systems, separated by a 20 mm cavity.
- Service shafts are constructed from metal stud with 13 mm plasterboard and 25 mm shaft wall system.
- Non-loadbearing and/or non-fire resisting partition walls within apartments are constructed from 70 x 35 mm timber framed studs at 600 mm centres walls with plasterboard or fibre cement linings.



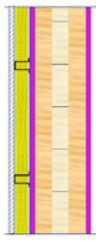
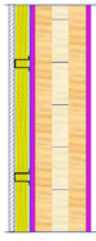
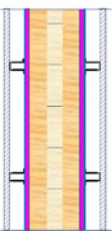
Wall Location	Colour Code	Description
External – North & South	1	Fire protected CLT with rain screen supporting FLW 3.0 m
External – East & West	2	Fire protected CLT with rain screen supporting FLW 5.3 m
External Wall Balcony	3	Fire protected CLT with rain screen supporting FLW 5.6 m
External Wall Balcony both side	4	Fire protected CLT with rain screen both sides supporting FLW 5.6 m
Apartment bounding Walls - Load bearing	5	Fire protected CLT with stud wall to one side supporting FLW 5.6
Apartment bounding wall – non-load-bearing	6	Fire protected CLT with stud wall to one side
Internal Apartment Walls - Load bearing	7	Fire protected CLT supporting FLW 5.25 m
Internal Apartment Walls	8	Fire protected CLT supporting FLW 4.4 m
Internal Apartment Walls	9	Fire protected CLT supporting FLW 3.9 m
Internal Apartment Walls/ Lift and Stair shaft	10	Fire protected CLT supporting FLW 1.5 m
Interior Lift and Stair shaft	11	Fire protected CLT with plasterboard on outside
Partition walls	12	Timber framed walls
Service shaft	13	Steel studs and shaft liner

NOTE: FLW means "Floor Load Width" a common term used to indicate the width of the floor bearing onto a wall.

Figure 21: Typical Floor Plan showing timber framed wall types

Design and images: Zimmermann Design Studio, studio505 and TDA:

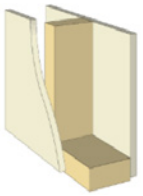
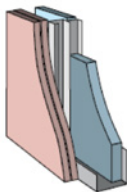
Table 2: Wall Systems Description

Colour Code	Wall Location	Illustration	Level	Description	Coverings	Acoustic Rating Rw + Ctr	Fire Rating
1	External – North & South FLW 3.0 m		8	XLAM CL3 85	Interior: 16 mm Fire grade PBD. Exterior: 16 mm fire grade plasterboard, vapour permeable membrane, battens and fibre cement panels	N/A	90/90/90
			7	XLAM CL3 105			
			6	XLAM CL3 105			
			5	XLAM CL3 105			
			4	XLAM CL3 105			
			3	XLAM CL3 105			
			2	XLAM CL3 115			
2	External – East & West FLW 5.3 m		8	XLAM CL3 85	Interior: 16 mm Fire grade PBD. Exterior: 16 mm fire grade plasterboard, vapour permeable membrane, battens and fibre cement panels	N/A	90/90/90
			7	XLAM CL3 105			
			6	XLAM CL3 105			
			5	XLAM CL3 105			
			4	XLAM CL3 125			
			3	XLAM CL3 135			
			2	XLAM CL3 135			
3	External East & West FLW 5.6 m		8	XLAM CL3 85	Interior: 16 mm Fire grade PBD Exterior: 16 mm fire grade plasterboard, vapour permeable membrane, battens and fibre cement panels	N/A	90/90/90
			7	XLAM CL3 105			
			6	XLAM CL3 105			
			5	XLAM CL3 105			
			4	XLAM CL3 125			
			3	XLAM CL3 145			
			2	XLAM CL3 150			
4	External wall between balconies		8	XLAM CL3 85	Exterior both sides: 16 mm fire grade plasterboard, vapour permeable membrane, battens and fibre cement panels	N/A	90/90/90
			7	XLAM CL3 105			
			6	XLAM CL3 105			
			5	XLAM CL3 105			
			4	XLAM CL3 125			
			3	XLAM CL3 145			
			2	XLAM CL3 150			
5	Apartment bounding Walls -Load bearing FLW 5.6		8	XLAM CL3 85	Exterior both sides: 16 mm fire grade plasterboard, vapour permeable membrane, battens and fibre cement panels	50*	90/90/90
			7	XLAM CL3 105			
			6	XLAM CL3 105			
			5	XLAM CL3 105			
			4	XLAM CL3 125			
			3	XLAM CL3 145			
			2	XLAM CL3 150			
6	Apartment bounding wall – non-load-bearing		8	XLAM CL3 85	16 mm Fire grade plasterboard direct fixed both sides of CLT. 20 mm gap, 70 mm timber frame with 13 mm standard grade plasterboard on stud wall face with 75 glasswool insulation between frames	50*	90/90/90
			7	XLAM CL3 85			
			6	XLAM CL3 85			
			5	XLAM CL3 85			
			4	XLAM CL3 85			
			3	XLAM CL3 85			
			2	XLAM CL3 85			

Acoustic estimates from CSR Red Book

*Acoustic estimate from FWPA CLT Acoustic Research Program

Table 2: Wall Systems Description (Continued)

Colour Code	Wall Location	Illustration	Level	Description	Coverings	Acoustic Rating Rw + Ctr	Fire Rating
7	Internal Apartment Walls - Load bearing FLW 5.3 m		8	XLAM CL3 85	16 mm fire grade plasterboard direct fixed both sides of CLT.	N/A	90/90/90
			7	XLAM CL3 105			
			6	XLAM CL3 105			
			5	XLAM CL3 125			
			4	XLAM CL3 135			
			3	XLAM CL5 150			
			2	XLAM CL5 150			
8	Internal loadbearing apartment walls FLW 4.4 m		8	XLAM CL3 85	16 mm fire grade plasterboard direct fixed both sides of CLT.	N/A	90/90/90
			7	XLAM CL3 105			
			6	XLAM CL3 105			
			5	XLAM CL3 105			
			4	XLAM CL3 115			
			3	XLAM CL3 125			
			2	XLAM CL3 135			
9	Internal loadbearing apartment walls FLW 3.9 m		8	XLAM CL3 85	16 mm Fire grade PBD direct fixed both sides of CLT.	N/A	90/90/90
			7	XLAM CL3 85			
			6	XLAM CL3 105			
			5	XLAM CL3 105			
			4	XLAM CL3 115			
			3	XLAM CL3 125			
			2	XLAM CL3 125			
10	Internal loadbearing apartment walls/lift and stair shaft FLW 1.5 m		8	XLAM CL3 85	16 mm Fire grade PBD direct fixed one sides of CLT.	52* When combined with wall 11. Resilient strip placed between CLT to maintain 20 mm gap and discontinuous construction	90/90/90
			7	XLAM CL3 85			
			6	XLAM CL3 85			
			5	XLAM CL3 85			
			4	XLAM CL3 105			
			3	XLAM CL3 105			
			2	XLAM CL3 105			
11	Interior Lift and Stair shaft		All Levels	XLAM CL3 105	16 mm Fire grade PBD direct fixed one sides of CLT when twinned with wall abutting apartment and other service shafts, otherwise 16 mm fire grade pbd both sides	52* When combined with wall 10. Resilient strip placed between CLT to maintain 20 mm gap and discontinuous construction	90/90/90
12	Partition walls		All Levels	Studs and Plates: MGP10 70 x 35 @ 600 crs	10 mm standard grade plasterboard or 6 mm fibre cement (if in wet area)	N/A	N/A
13	Service shaft		All Levels	Steel stud and	25 mm plasterboard shaft liner	N/A	N/A

* Acoustic estimate from FWPA's CLT Acoustic Research Program

Acoustic estimates from CSR Red Book

5.2.2 Floor Structure

What was used in the timber solution:

- 225 mm thick 5-ply longitudinal-faced CLT panel spanning over three supports with a maximum span of 6 m (Figure 23 and Table 7).
- Beams under CLT panels reinforce areas over openings:
 - Two 240 x 90 LVL13 beams under the floor in opening in wall in Units 3 and 6.

Reasons:

- The CLT panel thickness provides the best spanning capacity and vibration control relative to the other timber options available.
- The layout and CLT panel arrangement minimises waste material and transportation costs.

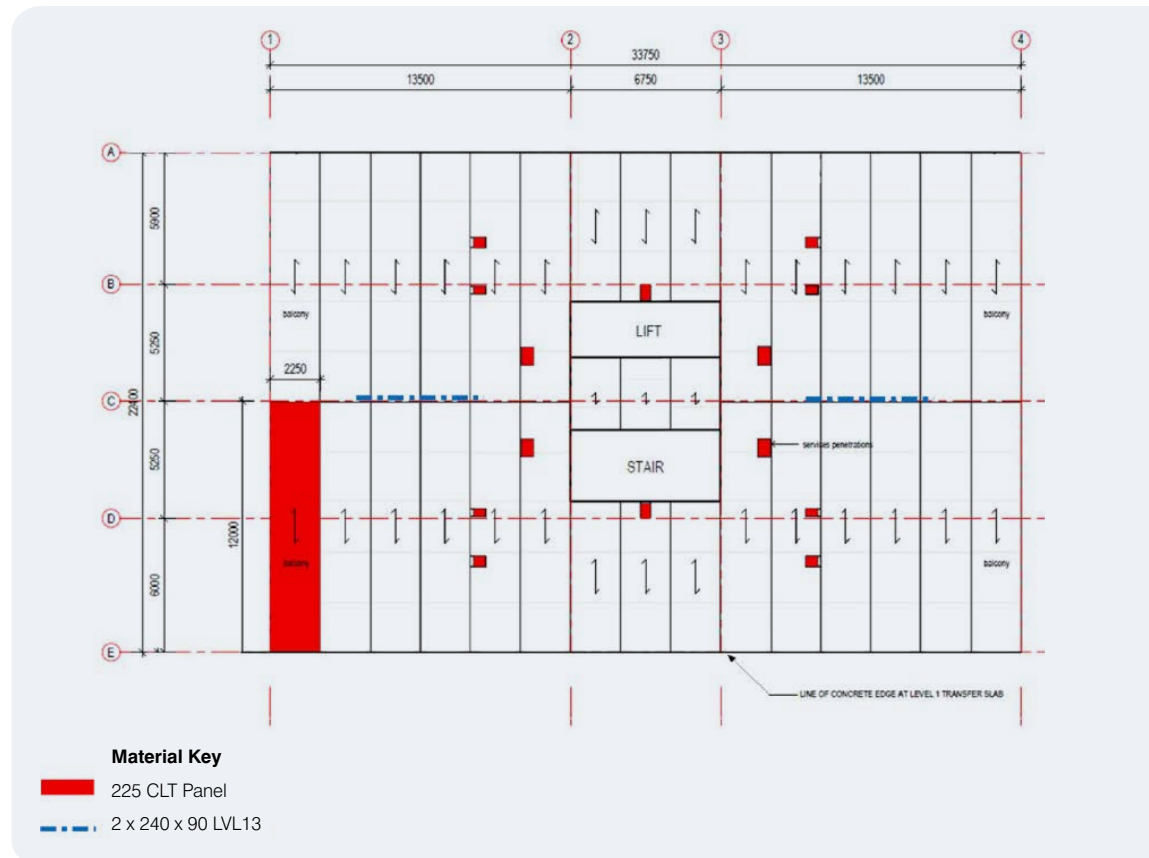


Figure 23: Floor and Roof System Plan Design and image: Studio 505

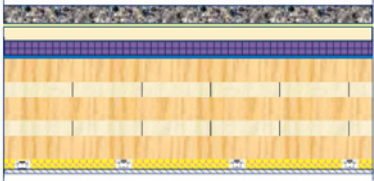
Type	Diagram of Floor System	Description	Acoustic		Fire rating
			Rw + Ctr	Ln,w (Ci)	
Floor		Layer 1 – 40 mm cement screed Layer 2 – 10 mm recycled rubber mat Layer 3 – XLAM CL5 225 Layer 4 – 16 mm fire grade plasterboard Layer 5 – 50 mm insulation (14 kg/m³) Layer 6 – Adjustable clips Layer 7 – Furring Channel Layer 8 – 13 mm Standard grade plasterboard	51	55	90/90/90
Roof		Layer 1 - Gravel Layer 2 – 40 mm styrofoam Layer 3 – Geotext separation fabric Layer 4 - Drainage cell Layer 5 – Water proof membrane Layer 6 – XLAM CL5 150 Layer 7 – 50 mm insulation (14 kg/m³) Layer 8 – Adjustable clips Layer 9 – Furring Channel Layer 10 – 10 mm Standard grade plasterboard	N/A	N/A	N/A

Figure 23: Floor and Roof System Plan Design and image: Studio 505

Note: Acoustic results based on Auckland Uni CLT Acoustic test (based on 140 mm thick CLT)

5.2.3 Floor Structure

What was used in the timber solution:

- 150 mm thick 5-ply longitudinal-faced CLT panel spanning over three supports with a maximum span of 6 m (Figure 23 and Table 7).
- Beams under CLT panels reinforce areas over openings:
 - Two 240 x 90 LVL13 beams under the floor in opening in wall in Units 3 and 6.

Reasons:

- Thinner CLT can be used for the roof in comparison to the floor as the roof has no fire rating and no screed applied.
- Falls for drainage can be formed by sloping the top of level 7 walls, removing the need to apply a screed.

5.2.4 Lateral Resistance

- Lateral resistance and over turning of the building is dealt in the use of CLT. CLT is used for all bounding walls to SOUs, lift and stair shaft and provide the lateral resistance requirements of the building.

Reasons:

- CLT in combination with brackets and screws is an excellent median to transfer lateral loads.

6

The Workflow and Speed Onsite of the Timber Solution

What was assumed in terms of planning construction of the model:

- A crew of six site workers were used for the installation of the timber solution (excluding crane driver, dogman, traffic control, site management staff etc.).
- All connection of timber framing and CLT elements used nails, brackets and/or screw fixings.
- The construction program associated with the installation of the core structural elements above the Level 1 transfer slab until completion of the façade only, was considered.
- The installation time for the façade's rain screen, MEP, interior coverings, and so on, was assumed to be similar for both solutions.
- The Cost Plan used a 6 week construction saving for both the timber frame and CLT erection.

Reasons:

- Each solution is identical until the Level 1 transfer slab commences and the model has assumed that they take the same length of time until this point.
- Above the concrete transfer level, the time taken to install the superstructure to roof level for the concrete solution was estimated to take 6 weeks longer than both timber solutions.
- Construction time beyond the installation of the superstructure was assumed to be identical.
- Refer to Section 7.7 for other potential cost savings

Cost Plan Results - Comparing the Timber and Concrete Solutions

Using the model apartment building described in Section 4, the timber solutions described in Section 5 and the corresponding concrete solution described in Appendix A, a cost estimate and cost planning comparison was undertaken to help determine the potential benefits of the timber solutions. The cost comparison was only undertaken for the parts of the building that were considered to have different costs. The elements of the building that are identical in costs for each model, such as the façade, and mechanical, electrical and plumbing items, were excluded from the cost plan.

To create stable costing conditions, it was assumed that the building would be constructed in suburban Sydney.

7.1 Process Taken to Obtain Comparison Design and Quotes

From the parameters of the model apartment building discussed in Section 5, three designs were developed: one in the conventional material (concrete in this case) and this was compared to a lightweight timber framing and CLT.

The cost plan was developed by the MBM (see Appendix B for full cost plan results) an independent firm that is developing a data base of successful timber buildings. MBM independently measured quantities off supplied drawings and obtained quotes from the market where needed or utilised current data within their database to develop a price for this model.

An all-inclusive price for the optimisation of design, shop detailing, fabrication, freight and supply considerations (off-site storage, etc), fixtures and fittings and just-in-time delivery to site was made and used in the study.

7.2 Cost Plan Results

The basic differences in the cost plans for each model are shown in Table 6. MBM's detailed results can be found in Appendix B.

Element	Timber Framed	Cross Laminated Timber	Concrete
Columns	34,935.00	34,935.00	365,644.00
Upper Floors	1,567,887.00	2,539,961.00	1,810,398.00
Staircase	81,200.00	81,200.00	66,150.00
Roof	256,260.00	233,100.00	356,617.00
External Walls (excludes rain screen)	335,511.00	518,082.00	416,165.00
Internal Walls	1,417,544.00	1,286,436.00	1,224,522.00
Wall Finishes	Included	Included	Included
Ceiling Finishes	667,390.00	Included	459,085.00
Preliminaries	-287,000.00	-287,000.00	-
Total	4,073,727.00	4,406,714.00	4,698,581.00

Table 6: Cost Plan Results.

In analysing the differences between the plans, it can be seen that the timber building provides a saving of

- Timber Framed: \$624,854.00 or 13% cheaper than the concrete solution and \$332,987 or 7.5% cheaper than Cross Laminated Timber solution
- Cross Laminated Timber: \$291,867.00 or 6% cheaper than the concrete solution

Significant savings under the timber solution are found in:

- the concrete transfer slab at Level 1
- the loadbearing structure including some walls, floors, columns and roof
- the preliminary costs for the project (including crane, site sheds, supervision, scaffolding, and traffic control costs)

Additional costs under the timber solution (relative to the concrete solution) are in:

- the fire protection of the timber elements
- the termite protection of the timber elements

Each is discussed in more detail below.

7.3 Savings in the Concrete Transfer Slab

As the timber solution is lighter in weight (20% of the mass of concrete) than the concrete solution, a thinner and cheaper concrete transfer slab is possible.

- Timber \$364,350.00
- Concrete \$537,441.00
- Difference -\$173,091 (32% cheaper)

7.4 Preliminary Cost Savings

The timber solution includes an estimated saving in preliminaries of approximately \$280,000, based on a construction program saving six weeks over the concrete solution. MBM calculate that the traditional 12 month construction program and found it could be reduced to 10 ½ months. Based on a total project prelims cost of \$2.5m the approximate cost per week is \$52,000.00 per week. This equates to a potential saving of \$287,000 when additional costs such as termite protection is removed.

7.5 Additional Costs

There were a number of additional cost considered for the timber framed solution and they were

- Extra costs for the additional linings required for fire protection of timber load bearing walls and floors.
- The timber and CLT solutions sit atop a concrete basement (car park) and concrete retail level. As an additional precaution, the timber and CLT structure has termite protection by way of stainless mesh steel protection to all hidden entry points from the ground to the concrete structure. This protection was estimated to add \$25,000 to the timber and CLT solution.

7.6 Other Potential Cost Saving for the Timber Solution

The following items include areas where cost saving potential exists in the timber solution, but for this cost exercise they have not been included.

- **Smarter Scaffold Erection Potential:** The timber structure only requires the use of scaffolding for the installation of the façade panels. The installation of cladding to the timber frame panels, before erecting, could remove the need for scaffold and be replaced with hand rails already attached to floor cassettes. Joints in the cladding could be completed by the use of mobile elevated platform.
- **Earlier start time on internal works:** Additional time savings are possible due to the earlier start time for internal work, as achieved by the earlier completion for the main structure (as discussed previously). Activities such as services rough-ins and internal wet area construction could all begin earlier compared to the concrete solution.
- **Easier substrate for linings and finishes:** The time to carry out fit-out activities is generally less than for concrete structures. For instance, cordless screw guns and nailing can be used, which is light, quick and easy to use. Concrete structures require drilling into concrete, which is slow, noisy and dirty, and requires anchor or friction-style fixings.
- **Footing Costs:** The timber solution is calculated to be 50% lighter than the concrete solution which potentially provides lighter and cheaper footings.
- **Crane size and type:** Crane savings discussed previously focus on the reduced hire period required for the timber solution, but there is also potential to use a lighter, remotely controlled crane (i.e. operated from the floor deck under construction). For instance, the timber solution's maximum panel weight is only 2,500 kg.
- **Truck Deliveries:** Deliveries for the timber solution are significantly reduced, saving supervision, handling at the road level and traffic management. Just-in-time delivery of timber can avoid panel storage on site.

Conclusion

A model eight-storey, high-end 42-apartment building was designed and costed using two timber solutions and a conventional concrete-framed solution for a theoretical location in suburban Sydney. The site was assumed to have no significant cost implications concerning site access, ground conditions or neighbouring properties.

The timber solutions investigated were cross laminated timber and lightweight timber frame. This review was previous carried out in 2014 for cross laminated timber only. Since this time the CLT apartment has been redesigned to meet all aspects of the new NCC's Deemed-to-Satisfy fire protected timber requirements. Furthermore the design was change to sizes and spans that suit Australian produced CLT as well as including missing items from the first study being cement screed to floors and stairs. In addition a lightweight timber framed design was also considered.

The study found the superstructure costs for the timber framed solution to be \$624,854.00, more cost effective, which equates to a 13% saving compared to the concrete solution. The Cross Laminated Timber solution was also found to be \$291,867 or 6% cheaper. The main structural component costs were found to be lower in the timber model, but the fire protection requirements to some of these elements and the cost of termite protection offset some of this advantage.

Savings also existed in the preliminary costs for the project, an area not fully recognised when comparing costs.

This Guide recommends that timber apartment building be considered as a viable alternative to traditional post tensioned concrete frame construction, particularly where:

- a lightweight structure provides structural benefits (including in poor foundations)
- prefabricated construction offers advantages
- the timber solution can be optimised for a given design
- the need for a short construction program is apparent
- there is a genuine intent to reduce preliminary costs

Importantly, the level of cost comparison with concrete must go beyond a basic comparison of material costs and should instead weigh up a holistic spectrum of cost-sensitive issues affecting the construction process.

A

Appendix A: Comparison Design: The Concrete Solution

A1 Floor and Roof

Generally, a 200 mm flat plate concrete slab reinforced using conventional steel reinforcement and post tensioning cables, refer to Figures A1 and A2 on reinforced concrete columns.

Table A1 details the acoustic performance.

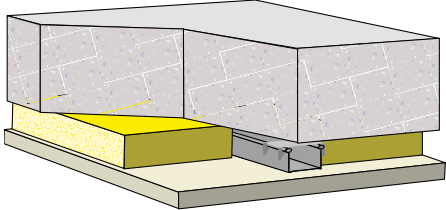
Type	Diagram of Floor System	Description	Acoustic		Fire rating
			Rw + Ctr	Ln,w (Ci)	
Floor		200 mm concrete slab, with furring channel at 600 crs, supporting 10 mm plasterboard. 50 mm polyester insulation is placed between furring channel	53 ⁹	35 to 40 with carpet and underlay	90/90/90

Table A1: Acoustic and fire performance of concrete floor.

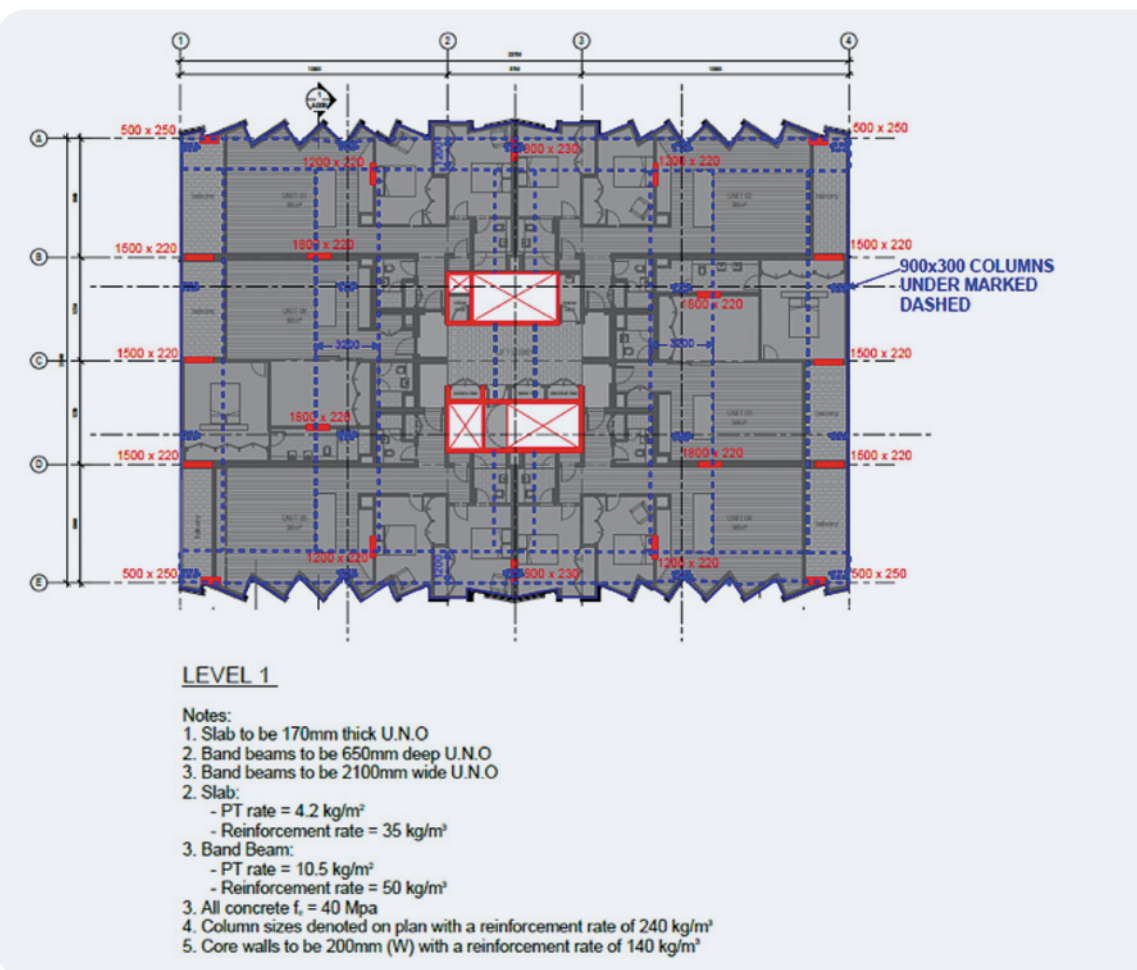
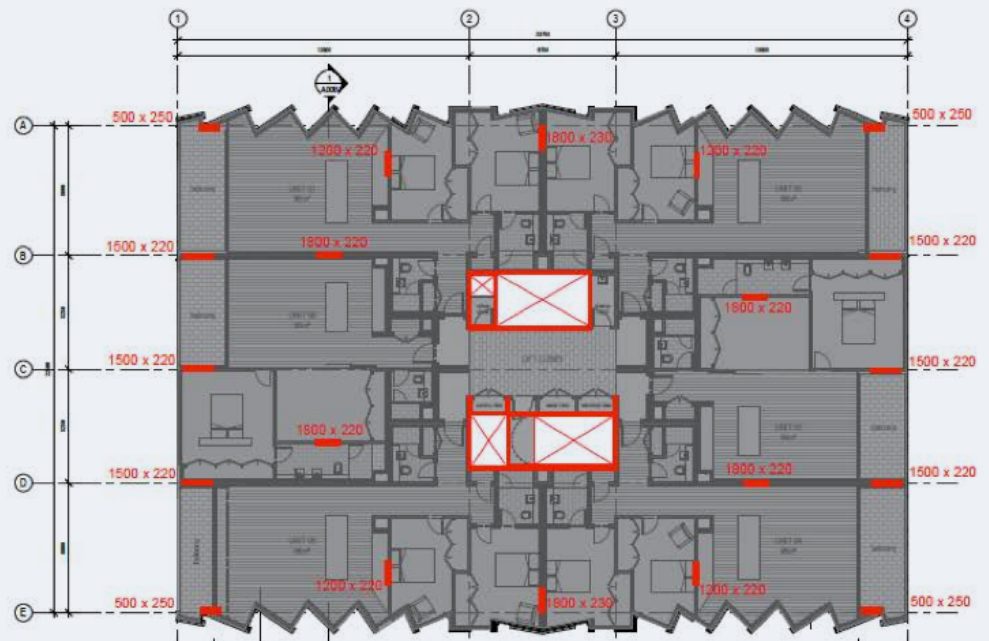


Figure A1: Level 1 concrete slab. Design and image: TTW

⁹ Boral Plasterboard System CFA10U



LEVEL 7

Notes:

1. Slab to be 200mm thick U.N.O
2. Slab:
 - PT rate = 4.2 kg/m²
 - Reinforcement rate = 35 kg/m³
3. All concrete $f_c = 40$ Mpa
4. Column sizes denoted on plan with a reinforcement rate of 240 kg/m³
5. Core walls to be 200mm (W) with a reinforcement rate of 140 kg/m³

Figure A2: Level 2 to 7 and roof concrete slab. Design and image: TTW

A2 Wall Systems

What was used in the timber solution:

- An aerated concrete wall system with metal studs, refer to Table A2.

Wall Type	Diagram of Wall System	Description		Acoustic Rw + Ctr	Fire rating
		Structural	Linings & Insulation		
Internal		75 mm aerated lightweight concrete panel, with 64 mm steel stud with 20 mm air gap between aerated concrete and steel stud	13 mm fire-resisting plasterboard linings both side of wall (moisture-resistant used in wet areas). 75 mm glass wool in air gap	53 ¹⁰	90/90/90

Table A2: Acoustic and fire performance of concrete solution walls.

¹⁰ High Rise Multi-Residential Intertency and Service Walls Design and Installation Guide, Hebel, 2014



APPENDIX B

ESTIMATE REPORT



Costs for Timber Framed, CLT and Concrete Construction in Low Rise Residential

For Timber Development Association

MBM1545-0002 – 5 October 2017

Prepared by – Kelvin Perrie



QUANTITY SURVEYING | BUILDING CONSULTANCY |
TAX & ASSET SERVICES | PPP ADVISORY | INFRASTRUCTURE |
FACILITIES MANAGEMENT ADVISORY | EXPERT WITNESS





1. Executive Summary

MBM have been engaged by TDA to update the cost estimates previously prepared for the TDA for Timber Framed (LVL), CLT and concrete construction for a residential apartment building.

We have updated the costs based on recent market feedback as well as supplier information where relevant. The result of these updates is an increase across all 3 methodologies, although the bottom line is lower than the previously issued estimates due to the exclusion of the facade as this is deemed to be typical across all construction methodologies. The cost increases in the remaining trades are due in large to an overall increase in cost across the construction market with a greater impact on the concrete constructed option.

These cost estimates only consider the components of the building that were deemed to have different costs. The elements of the building that were considered common for each model, such as the façade, the basement and the services costs are excluded from the estimates.

Whilst we appreciate that this approach is not 100% accurate, it was acknowledged by all involved in this report (design and costing) that for the purposes of this exercise - and given the early level of design documentation available - the potential cost differences were negligible enough to the extent that they had no material effect on the results. Hence their exclusion.

To create stable costing conditions, it was assumed that the building would be constructed in suburban Sydney.

Please refer to Appendix A and Appendix B for detailed cost estimates.

1.1 Estimate Summaries

The below table summarises the **current** cost estimate for the timber framed option and the concrete constructed option:

Description	TIMBER FRAMED	CROSS LAMINATED TIMBER (CLT)	CONCRETE
Columns	\$ 34,935.00	\$ 34,935.00	\$ 365,644.00
Upper Floors	\$ 1,567,887.00	\$ 2,539,961.00	\$ 1,810,398.00
Staircases	\$ 81,200.00	\$ 81,200.00	\$ 66,150.00
Roof	\$ 256,260.00	\$ 233,100.00	\$ 356,617.00
External Walls	\$ 335,511.00	\$ 518,082.00	\$ 416,165.00
Internal Walls	\$ 1,417,544.00	\$ 1,286,436.00	\$ 1,224,522.00
Wall Finishes	Included	Included	Included
Ceiling Finishes	\$ 667,390.00	Included	\$ 459,085.00
Preliminaries Adjustment	-\$ 287,000.00	-\$ 287,000.00	\$ -
Total Estimate Cost	\$ 4,073,727.00	\$ 4,406,714.00	\$ 4,698,581.00



The below table summarises the *previous* cost estimate (by others) for the timber framed option and the concrete constructed option:

Description	TIMBER FRAMED	CROSS LAMINATED TIMBER (CLT)	CONCRETE
Columns	\$ 33,150.00	\$ 33,150.00	\$ 337,373.00
Upper Floors	\$ 1,405,872.00	\$ 1,470,378.00	\$ 1,517,633.00
Staircases	Excluded	Excluded	Excluded
Roof	\$ 256,260.00	\$ 290,138.00	\$ 329,603.00
External Walls	\$ 1,047,822.00	\$ 1,086,240.00	\$ 1,135,070.00
Internal Walls	\$ 1,432,204.00	\$ 690,438.00	\$ 1,193,057.00
Wall Finishes	Included	\$ 866,068.00	Included
Ceiling Finishes	\$ 597,955.00	\$ 597,955.00	\$ 459,085.00
Preliminaries Adjustment	-\$ 287,000.00	-\$ 287,000.00	\$ -
Total Cost	\$ 4,486,263.00	\$ 4,747,367.00	\$ 4,971,821.00

The most notable increase to both estimates is the inclusion of the Staircases. “Airstair” is a timber product which has been included at advised rates with the preliminaries adjusted accordingly to account for the reduced programme using the “Airstair” when compared with concrete fire stair construction.

The concrete construction estimate has risen largely due to increases seen recently in the construction market, particularly regarding formwork.

1.2 Estimate Analysis

In analysing the differences between the three cost estimates, it can be seen that the Timber Framed and CLT methodologies provide a saving of \$624,854 and \$291,867 or 15% and 6% respectively when compared to the Concrete estimate.

Significant savings under the timber solutions (the same principles apply to both) are found in:

- the concrete transfer slab at Level 1
- the loadbearing structure including walls, floors, columns and roof
- the preliminary costs for the project (including crane, site sheds, supervision, scaffolding, and traffic control costs)

Despite the savings it is acknowledged that the timber solution does carry some negative price adjustments (relative to the concrete solution) in:

- the fire protection of the CLT elements
- the termite protection of the timber elements



2 Added Cost Benefits

2.1 Australian Sourced Timber

Australia's first cross laminated timber manufacturing plant will be built this year with many more to follow to meet the increasing demand of timber construction. These facilities will ensure builders will be able to choose and utilise CLT products that have been designed and sustainably produced in Australia from Australian Timber. Locally sourced CLT will have vast cost benefits in terms of reducing time and transport costs and furthermore, encourage the support of local manufacturers and labour forces which will subsequently benefit the Australian economy. Developing Australian sourced CLT will boost Australia's competitiveness internationally in terms innovative design and manufacturing. This will also be incredibly beneficial in recognising and improving the green performance of Australian construction, with these systems rewarding the use of locally produced materials in building designs.

2.2 Life Cycle Cost Analysis

The reduced life cycle costs of CLT are evident from studies that have been carried out overseas (i.e. for projects completed outside of Australia.) Data on Australian projects is sparse at this stage but nonetheless supporting the same message from international studies. CLT outperforms concrete systems in terms of thermal insulation, internal moisture management, acoustic insulation, air tightness and fire resistance. Due to the performance capabilities of CLT, the energy efficiency of the building increases, with the embodied energy within ensuring reduced operational costs. The durability and robust nature of CLT also ensures that there are fewer maintenance and operation requirements throughout the life cycle of the building. CLT can additionally be recycled ensuring zero waste in the production process and therefore minimal disposal costs. Exemplifying the overall reduced life cycle costs.

MBM are currently in the process of compiling local studies on life cycle cost and these will be presented in next years' report.

2.3 Marketing and Sales Information

Demand for CLT has increased year on year over the last 5 – 7 years. This increase shows no signs of slowing down. The increase is not only due to the cost and time savings which timber offers but more interestingly the demand is a result of the public (and industry) shift towards a more sustainable and environmentally conscious market that acknowledge the environmental, economic and social benefits within timber design and construction.

This growth is paramount in Australia, with the demand for affordable and innovative designs evident and witnessed via the rapid occupancy and sales of recently developed CLT projects.

CLT satisfies not only the sophisticated, innovative and practical needs of homebuyers but also the ideology of contemporary marketing and sales teams.



2.4 Conclusion

The LVL and CLT options were found to be more cost effective - not only in MBM's opinion but also by the begrudging agreement of contractors.

The current savings achieved with the use of timber are arguably at a higher point than can typically be expected given the significant increase in concrete construction across the construction industry, even so, it is MBM's opinion that as the industry accepts the timber methodology as a viable alternative to concrete and steel, this saving is likely to increase.

Put simply, the benefits of timber in terms of simplicity of design engineering, the speed of construction and the potential workmanship quality, translate to tangible cost savings as well as a host of other - more social, environmental and societal - gains.

The facts are unarguable. Timber is a viable and necessary alternative to concrete construction.



3 Appendices

3.1 Appendix A: Timber Framed (LVL) Estimate

[illegible]

03. Timber Framing - Cost Plan Rev 2 - 171011



SUMMARY		\$
Timber Framing		4,073,727
PROJECT TOTAL (Excl GST)		4,073,727

Notes:

MBM

Client: Timber Development Association

Project Code: 0001

Printing Date: 11/10/2017

Report Name: 03. Timber Framing - Cost Plan Rev 2 - 171011

DETAILED SUMMARY



Client: Timber Development Association
Project: Timber Framed Construction

Details: 03. Timber Framing - Cost Plan Rev 2 - 171011
MBM0001
Date - 11/10/2017

Code	Description	Starting Page	% of Cost	Cost/m2	Total
1	Timber Framing				
1.1	Columns	Page 4	0.86		34,935
1.2	Upper Floors	Page 4	38.49		1,567,887
1.3	Staircases	Page 4	1.99		81,200
1.4	Roof	Page 4	6.29		256,260
1.5	External Walls	Page 4	8.24		335,511
1.6	Internal Walls	Page 5	34.80		1,417,544
1.7	Wall Finishes				Included
1.8	Ceiling Finishes	Page 7	16.38		667,390
1.9	Preliminaries Adjustment	Page 7	-7.05		-287,000
					4,073,727

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 11/10/2017
Report Name: 03. Timber Framing - Cost Plan Rev 2 - 171011

REPORT DETAILS



Client: Timber Development Association
Project: Timber Framed Construction

Details: 03. Timber Framing - Cost Plan Rev 2 - 171011
MBM0001
Date - 11/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1	Timber Framing				
1.1	Columns				
1.1.1	900 x 300 RC columns incl. 40MPa concrete, formwork, reinforcement at 240kg/m3 and post-tensioning at 6kg/m2; 18no.	51	m	685.00	34,935
					34,935
1.2	Upper Floors				
1.2.1	RC suspended slab, 500 thick incl. 40MPa concrete, formwork, reinforcement at 45kg/m3 and post-tensioning at 6kg/m2; 18no.	772	m2	435.00	335,820
1.2.2	RC drop slab to underside of transfer slab, 1800 x 1800 x 650 thick, incl. 40MPa concrete, formwork, reinforcement at 45kg/m3	18	no.	1,585.00	28,530
1.2.3	Truss Cassettes				
1.2.4	Total floor area - 6 Levels	4,629	m2	180.00	833,220
1.2.5	40mm unreinforced topping slab incl. 10mm resilient matting to all floor areas - 6 levels	4,629	m2	80.00	370,317
					1,567,887
1.3	Staircases				
1.3.1	Stairs 'AirStair' - supply cost - 1 x 7 levels	7	level	6,500.00	45,500
1.3.2	Installation	21	m/rise	1,250.00	26,250
1.3.3	Extra over above for fixings and handrails	21	m/rise	450.00	9,450
					81,200
1.4	Roof				
1.4.1	Truss Cassettes				
1.4.2	As per lower levels	772	m2	145.00	111,940
1.4.3	50mm thick cement and sand mortar bedding laid to falls and finished to receive waterproofing	772	m2	55.00	42,460
1.4.4	Approved roof waterproofing membrane applied to concrete roof slab above screed	772	m2	50.00	38,600
1.4.5	Drainage cell laid above the waterproofing	772	m2	25.00	19,300
1.4.6	Dow Wrapshield HP geotextile separation fabric laid above drainage cell below insulation	772	m2	5.00	3,860
1.4.7	40mm thick R2.0, Dow Styrofoam RTM-X closed cell insulation laid above drainage cell	772	m2	45.00	34,740
1.4.8	Dow Wrapshield HP geotextile separation fabric laid above insulation below concrete paving	772	m2	5.00	3,860
1.4.9	Allow for dressing around drainage outlet including forming cut out in drainage cell, Insulation system, making good and the like; 200mm dia	1	item	1,500.00	1,500
					256,260
1.5	External Walls				
1.5.1	Level 1				
1.5.2	With insulation, internal lining and associated items, 130mm thick stud	80	Lm	630.00	50,507
1.5.3	Level 2				
1.5.4	With insulation, internal lining and associated items, 130mm thick stud	80	Lm	630.00	50,507
1.5.5	Level 3				
1.5.6	With insulation, internal lining and associated items, 130mm thick stud	80	Lm	630.00	50,507
1.5.7	Level 4				
1.5.8	With insulation, internal lining and associated items, 130mm thick stud	80	Lm	630.00	50,507

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Client: Timber Development Association
Project Code: 0001
Printing Date: 11/10/2017
Report Name: 03. Timber Framing - Cost Plan Rev 2 - 171011

REPORT DETAILS



Client: Timber Development Association
Project: Timber Framed Construction

Details: 03. Timber Framing - Cost Plan Rev 2 - 171011
MBM0001
Date - 11/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1.5	External Walls				
1.5.9	Level 5				
1.5.10	With insulation, internal lining and associated items, 90mm thick stud	80	Lm	555.00	44,494
1.5.11	Level 6				
1.5.12	With insulation, internal lining and associated items, 90mm thick stud	80	Lm	555.00	44,494
1.5.13	Level 7				
1.5.14	With insulation, internal lining and associated items, 90mm thick stud	80	Lm	555.00	44,494
					335,511
1.6	Internal Walls				
1.6.1	<u>Wall thicknesses reduce as the loading reduces at higher levels</u>		Note		
1.6.2	CLT				
1.6.3	CL5, 125mm	644	m2	265.00	170,660
1.6.4	Bracing				
1.6.5	<i>Bracing is generally included in wall rates</i>	NOTE			
1.6.6	Allowance for moment framing - generally above openings - 400mm high, LVL	183	Lm	90.00	16,470
1.6.7	Level 1				
1.6.8	Single stud, load-bearing, fire rated, LVL 130 x 35 @ 450cts	9	Lm	610.00	5,765
1.6.9	Double stud, load-bearing, fire rated, 3 x 90mm x 45mm studs @ 600 cts	49	Lm	1,010.00	49,046
1.6.10	Single stud, non-load-bearing, fire rated wall, 70mm x 45mm @ 600 cts	25	Lm	590.00	14,768
1.6.11	Single stud, load-bearing, fire rated, LVL 130mm x 35mm @ 450 cts	15	Lm	640.00	9,914
1.6.12	Single stud, load-bearing, fire rated, LVL 130mm x 35mm @ 600 cts	15	Lm	610.00	9,242
1.6.13	Double stud, non-load-bearing wall, 2 x 70mm x 45mm @ 600 cts	41	Lm	770.00	31,778
1.6.14	Service shaft, fire rated, 102mm metal frame	32	Lm	600.00	19,410
1.6.15	Single stud, non-load-bearing (assumed non-fire rated), 70mm x 35mm @ 600 cts	120	Lm	395.00	47,384
1.6.16	Level 2				
1.6.17	Single stud, load-bearing, fire rated, LVL 130 x 35 @ 450cts	9	Lm	610.00	5,765
1.6.18	Double stud, load-bearing, fire rated, 2 x 90mm x 45mm studs @ 600 cts	49	Lm	830.00	40,305
1.6.19	Single stud, non-load-bearing, fire rated wall, 70mm x 45mm @ 600 cts	25	Lm	590.00	14,768
1.6.20	Single stud, load-bearing, fire rated, LVL 130mm x 35mm @ 450 cts	15	Lm	640.00	9,914
1.6.21	Single stud, load-bearing, fire rated, LVL 130mm x 35mm @ 600 cts	15	Lm	610.00	9,242
1.6.22	Double stud, non-load-bearing wall, 2 x 70mm x 45mm @ 600 cts	41	Lm	770.00	31,778
1.6.23	Service shaft, fire rated, 102mm metal frame	32	Lm	600.00	19,410
1.6.24	Single stud, non-load-bearing (assumed non-fire rated), 70mm x 35mm @ 600 cts	120	Lm	395.00	47,384
1.6.25	Level 3				
1.6.26	Single stud, load-bearing, fire rated, LVL 130 x 35 @ 450cts	9	Lm	610.00	5,765
1.6.27	Double stud, load-bearing, fire rated, 2 x 90mm x 45mm studs @ 600 cts	49	Lm	830.00	40,305
1.6.28	Single stud, non-load-bearing, fire rated wall, 70mm x 45mm @ 600 cts	25	Lm	590.00	14,768
1.6.29	Single stud, load-bearing, fire rated, 130mm x 35mm @ 450 cts	15	Lm	640.00	9,914
1.6.30	Single stud, load-bearing, fire rated, 130mm x 35mm @ 600 cts	15	Lm	610.00	9,242

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 11/10/2017
Report Name: 03. Timber Framing - Cost Plan Rev 2 - 171011

REPORT DETAILS



Client: Timber Development Association
Project: Timber Framed Construction

Details: 03. Timber Framing - Cost Plan Rev 2 - 171011
MBM0001
Date - 11/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1.6	Internal Walls				
1.6.31	Double stud, non-load-bearing wall, 2 x 70mm x 45mm @ 600 cts	41	Lm	770.00	31,778
1.6.32	Service shaft, fire rated, 102mm metal frame	32	Lm	600.00	19,410
1.6.33	Single stud, non-load-bearing (assumed non-fire rated), 70mm x 35mm @ 600 cts	120	Lm	395.00	47,384
1.6.34	Level 4				
1.6.35	Single stud, load-bearing, fire rated, LVL 120 x 35 @ 450cts	9	Lm	570.00	5,387
1.6.36	Double stud, load-bearing, fire rated, 2 x 90mm x 45mm studs @ 600 cts	49	Lm	830.00	40,305
1.6.37	Single stud, non-load-bearing, fire rated wall, 70mm x 45mm @ 600 cts	25	Lm	590.00	14,768
1.6.38	Single stud, load-bearing, fire rated, LVL 120mm x 45mm @ 450 cts	15	Lm	570.00	8,829
1.6.39	Single stud, load-bearing, fire rated, LVL 130mm x 35mm @ 600 cts	15	Lm	610.00	9,242
1.6.40	Double stud, non-load-bearing wall, 2 x 70mm x 45mm @ 600 cts	41	Lm	770.00	31,778
1.6.41	Service shaft, fire rated, 102mm metal frame	32	Lm	600.00	19,410
1.6.42	Single stud, non-load-bearing (assumed non-fire rated), 70mm x 35mm @ 600 cts	120	Lm	395.00	47,384
1.6.43	Level 5				
1.6.44	Single stud, load-bearing, fire rated, LVL 120 x 35 @ 450cts	9	Lm	568.00	5,368
1.6.45	Double stud, load-bearing, fire rated, 90mm x 45mm studs @ 600 cts	49	Lm	690.00	33,506
1.6.46	Single stud, non-load-bearing, fire rated wall, 70mm x 45mm @ 600 cts	25	Lm	590.00	14,768
1.6.47	Single stud, load-bearing, fire rated, LVL 120mm x 35mm @ 450 cts	15	Lm	568.00	8,798
1.6.48	Single stud, load-bearing, fire rated, LVL 130mm x 35mm @ 600 cts	15	Lm	610.00	9,242
1.6.49	Double stud, non-load-bearing wall, 2 x 70mm x 45mm @ 600 cts	41	Lm	770.00	31,778
1.6.50	Service shaft, fire rated, 102mm metal frame	32	Lm	600.00	19,410
1.6.51	Single stud, non-load-bearing (assumed non-fire rated), 70mm x 35mm @ 600 cts	120	Lm	395.00	47,384
1.6.52	Level 6				
1.6.53	Single stud, load-bearing, fire rated, LVL 90 x 45 @ 450cts	9	Lm	560.00	5,292
1.6.54	Double stud, load-bearing, fire rated, 90mm x 45mm studs @ 600 cts	49	Lm	690.00	33,506
1.6.55	Single stud, non-load-bearing, fire rated wall, 70mm x 45mm @ 600 cts	25	Lm	590.00	14,768
1.6.56	Single stud, load-bearing, fire rated, 90mm x 45mm @ 450 cts	15	Lm	560.00	8,674
1.6.57	Single stud, load-bearing, fire rated, 120mm x 45mm @ 600 cts	15	Lm	595.00	9,014
1.6.58	Double stud, non-load-bearing wall, 2 x 70mm x 45mm @ 600 cts	41	Lm	770.00	31,778
1.6.59	Service shaft, fire rated, 102mm metal frame	32	Lm	600.00	19,410
1.6.60	Single stud, non-load-bearing (assumed non-fire rated), 70mm x 35mm @ 600 cts	120	Lm	395.00	47,384
1.6.61	Level 7				
1.6.62	Single stud, load-bearing, fire rated, LVL 70 x 35 @ 450cts	9	Lm	540.00	5,103
1.6.63	Double stud, load-bearing, fire rated, 90mm x 45mm studs @ 600 cts	49	Lm	690.00	33,506
1.6.64	Single stud, non-load-bearing, fire rated wall, 70mm x 45mm @ 600 cts	25	Lm	590.00	14,768
1.6.65	Single stud, load-bearing, fire rated, 70mm x 45mm @ 450 cts	15	Lm	540.00	8,365
1.6.66	Single stud, load-bearing, fire rated, 90mm x 45mm @ 600 cts	15	Lm	560.00	8,484
1.6.67	Double stud, non-load-bearing wall, 2 x 70mm x 45mm @ 600 cts	41	Lm	770.00	31,778
1.6.68	Service shaft, fire rated, 102mm metal frame	32	Lm	600.00	19,410

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 11/10/2017
Report Name: 03. Timber Framing - Cost Plan Rev 2 - 171011

REPORT DETAILS



Client: Timber Development Association
Project: Timber Framed Construction

Details: 03. Timber Framing - Cost Plan Rev 2 - 171011
MBM0001
Date - 11/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1.6	Internal Walls				
1.6.69	Single stud, non-load-bearing (assumed non-fire rated), 70mm x 35mm @ 600 cts	120	Lm	395.00	47,384
					1,417,544
1.8	Ceiling Finishes				
1.8.1	Standard suspended ceiling grid, 15mm drop; 10mm PB to and including top hat channels; 50mm insulation to underside of roof only	772	m2	85.00	65,620
1.8.2	2x16mm FRPB on resilient mount ceiling and furring channel incl. 75mm (14kg/m3) insulation to other levels	4,629	m2	130.00	601,770
					667,390
1.9	Preliminaries Adjustment				
1.9.1	Provision of time related preliminaries based on the duration of structure construction time.		NOTE		0
1.9.2	Preliminaries based on reduced construction duration of:	6	weeks	-52,000.00	-312,000
1.9.3	Termite Protection Allowance	1	item	25,000.00	25,000
					-287,000

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 11/10/2017
Report Name: 03. Timber Framing - Cost Plan Rev 2 - 171011

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MBM has used its reasonable endeavour so that the data contained in this report reflects the most accurate and timely information available and is based on information that was current as of the date of this report.

The preparation of this report has relied on information provided by the Addressee and by third parties. MBM has not verified this information and we assume no responsibility and make no representations with respect to adequacy, accuracy or completeness of such information.

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Client: Timber Development Association
Project Code: 0001
Printing Date: 11/10/2017
Report Name: 03. Timber Framing - Cost Plan Rev 2 - 171011



3.2 Appendix B: CLT Estimate

[illegible]

SUMMARY		\$
CLT		4,406,714
PROJECT TOTAL (Excl GST)		4,406,714

Notes:

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Cross Laminated Timber

DETAILED SUMMARY



Client: Timber Development Association
Project: Cross Laminated Timber

Details: 01. CLT - Cost Plan Rev 2 - 170915
MBM0001
Date - 5/10/2017

Code	Description	Starting Page	% of Cost	Cost/m2	Total
1	CLT				
1.1	Columns	Page 4	0.79		34,935
1.2	Upper Floors	Page 4	57.64		2,539,961
1.3	Staircases	Page 4	1.84		81,200
1.4	Roof	Page 4	5.29		233,100
1.5	External Walls	Page 4	11.76		518,082
1.6	Internal Walls	Page 5	29.19		1,286,436
1.7	Wall Finishes				Included
1.8	Ceiling Finishes				Included
1.9	Preliminaries Adjustment	Page 5	-6.51		-287,000
					4,406,714

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Cross Laminated Timber

REPORT DETAILS



Client: Timber Development Association
Project: Cross Laminated Timber

Details: 01. CLT - Cost Plan Rev 2 - 170915
MBM0001
Date - 5/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1	CLT				
1.1	Columns				
1.1.1	900 x 300 RC columns incl. 40MPa concrete, formwork, reinforcement at 240kg/m3 and post-tensioning at 6kg/m2; 18no.	51	m	685.00	34,935
					34,935
1.2	Upper Floors				
1.2.1	RC suspended slab, 500 thick incl. 40MPa concrete, formwork, reinforcement at 45kg/m3 and post-tensioning at 6kg/m2; 18no.	772	m2	435.00	335,820
1.2.2	RC drop slab to underside of transfer slab, 1800 x 1800 x 650 thick, incl. 40MPa concrete, formwork, reinforcement at 45kg/m3	18	no.	1,585.00	28,530
1.2.3	CLT floor - 40mm cement, 10mm recycled rubber mat, 225mm thick CLT, 16mm FRPB, adjustable clips and furring channel with 50mm glasswool insulation and 13mm FRPB	4,629	m2	470.00	2,175,611
					2,539,961
1.3	Staircases				
1.3.1	Stairs 'AirStair' - supply cost - 1 x 7 levels	7	level	6,500.00	45,500
1.3.2	Installation	21	m/rise	1,250.00	26,250
1.3.3	Extra over above for fixings and handrails	21	m/rise	450.00	9,450
					81,200
1.4	Roof				
1.4.1	CLT				
1.4.2	As per lower levels	772	m2	115.00	88,780
1.4.3	CLT roof - 150 mm thick with adjustable clips and furring channel and 10mm plasterboard ceiling	772	m2	55.00	42,460
1.4.4	Approved roof waterproofing membrane applied to CLT roof slab	772	m2	50.00	38,600
1.4.5	Drainage cell laid above the waterproofing	772	m2	25.00	19,300
1.4.6	Dow Wrapshield HP geotextile separation fabric laid above drainage cell below insulation	772	m2	5.00	3,860
1.4.7	40mm thick R2.0, Dow Styrofoam RTM-X closed cell insulation laid above drainage cell	772	m2	45.00	34,740
1.4.8	Dow Wrapshield HP geotextile separation fabric laid above insulation	772	m2	5.00	3,860
1.4.9	Allow for dressing around drainage outlet including forming cut out in drainage cell, Insulation system, making good and the like; 200mm dia	1	item	1,500.00	1,500
					233,100
1.5	External Walls				
1.5.1	<i>The below rates include for the CLT supplied and fixed, internal and external fire resistant linings, waterproofing and other minor associated items</i>		Note		
1.5.2	External - East & West FLW 5.25 - CL5 135mm	14	m2	360.00	5,040
1.5.3	External - East & West FLW 5.25 - CL3 135mm	14	m2	321.00	4,494
1.5.4	External - East & West FLW 5.25 - CL3 125mm	14	m2	311.00	4,354
1.5.5	External - East & West FLW 5.25 - CL3 105mm	42	m2	336.00	14,112
1.5.6	External - East & West FLW 5.25 - CL3 85mm	14	m2	260.00	3,640
1.5.7	External - North & South FLW 3.0m - CL3 125mm	207	m2	311.00	64,378
1.5.8	External - North & South FLW 3.0m - CL3 105mm	1,237	m2	295.00	364,909
1.5.9	External Wall Balcony FLW 5.625m - CL5 135mm	27	m2	360.00	9,720

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Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Cross Laminated Timber

REPORT DETAILS



Client: Timber Development Association
Project: Cross Laminated Timber

Details: 01. CLT - Cost Plan Rev 2 - 170915
MBM0001
Date - 5/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1.5	External Walls				
1.5.10	External Wall Balcony FLW 5.625m - CL5 145mm	27	m2	352.00	9,504
1.5.11	External Wall Balcony FLW 5.625m - CL3 125mm	27	m2	311.00	8,397
1.5.12	External Wall Balcony FLW 5.625m - CL3 105mm	79	m2	285.00	22,515
1.5.13	External Wall Balcony FLW 5.625m - CL3 85mm	27	m2	260.00	7,020
					518,082
1.6	Internal Walls				
1.6.1	Wall height is 2844mm as advised		Note		
1.6.2	Internal Apartment bounding Walls - Load Bearing FLW 5.625m - CL3 150mm	105	m2	410.00	43,050
1.6.3	Internal Apartment bounding Walls - Load Bearing FLW 5.625m - CL3 145mm	105	m2	402.00	42,210
1.6.4	Internal Apartment bounding Walls - Load Bearing FLW 5.625m - CL3 125mm	105	m2	361.00	37,905
1.6.5	Internal Apartment bounding Walls - Load Bearing FLW 5.625m - CL3 105mm	313	m2	335.00	104,853
1.6.6	Internal Apartment bounding Walls - Load Bearing FLW 5.625m - CL3 85mm	105	m2	310.00	32,550
1.6.7	Internal Apartment bounding Walls - non-load bearing - CL3 85mm	660	m2	310.00	204,600
1.6.8	Internal Apartment Walls - Load Bearing FLW 5.25m - CL3 150mm	27	m2	255.00	6,885
1.6.9	Internal Apartment Walls - Load Bearing FLW 5.25m - CL3 150mm	27	m2	216.00	5,832
1.6.10	Internal Apartment Walls - Load Bearing FLW 5.25m - CL3 135mm	27	m2	206.00	5,562
1.6.11	Internal Apartment Walls - Load Bearing FLW 5.25m - CL3 125mm	27	m2	191.00	5,157
1.6.12	Internal Apartment Walls - Load Bearing FLW 5.25m - CL3 105mm	54	m2	181.00	9,774
1.6.13	Internal Apartment Walls - Load Bearing FLW 5.25m - CL3 85mm	27	m2	155.00	4,185
1.6.14	Internal Apartment Walls FLW 4.4m - CL3 135mm	45	m2	255.00	11,475
1.6.15	Internal Apartment Walls FLW 4.4m - CL3 125mm	45	m2	216.00	9,720
1.6.16	Internal Apartment Walls FLW 4.4m - CL3 115mm	45	m2	191.00	8,595
1.6.17	Internal Apartment Walls FLW 4.4m - CL3 105mm	135	m2	181.00	24,434
1.6.18	Internal Apartment Walls FLW 4.4m - CL3 85mm	45	m2	155.00	6,975
1.6.19	Internal Apartment Walls FLW 3.9m - CL3 125mm	77	m2	216.00	16,632
1.6.20	Internal Apartment Walls FLW 3.9m - CL3 125mm	77	m2	206.00	15,862
1.6.21	Internal Apartment Walls FLW 3.9m - CL3 115mm	77	m2	191.00	14,707
1.6.22	Internal Apartment Walls FLW 3.9m - CL3 105mm	154	m2	181.00	27,873
1.6.23	Internal Apartment Walls FLW 3.9m - CL3 85mm	154	m2	155.00	23,870
1.6.24	Internal Apartment Walls / Lift Shaft and Stair Shaft FLW 1.5m - CL3 105mm	242	m2	163.00	39,447
1.6.25	Internal Apartment Walls / Lift Shaft and Stair Shaft FLW 1.5m - CL3 85mm	322	m2	138.00	44,436
1.6.26	Interior Lift and Stair Shaft - CL3 105mm	698	m2	206.00	143,791
1.6.27	Internal Partition Walls	2,313	m2	125.00	289,125
1.6.28	Service Shaft	578	m2	185.00	106,930
					1,286,436
1.9	Preliminaries Adjustment				
1.9.1	Provision of time related preliminaries based on the duration of structure construction time.		NOTE		

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Cross Laminated Timber

REPORT DETAILS



Client: Timber Development Association
Project: Cross Laminated Timber

Details: 01. CLT - Cost Plan Rev 2 - 170915
MBM0001
Date - 5/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1.9	Preliminaries Adjustment				
1.9.2	Preliminaries based on reduced construction duration of:	6	weeks	-52,000.00	-312,000
1.9.3	Termite Protection Allowance	1	item	25,000.00	25,000
					-287,000

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Cross Laminated Timber

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Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Cross Laminated Timber



3.3 Appendix C: Concrete Construction Estimate

[illegible]

02. Concrete Construction - Rev 2 - 170915



SUMMARY	\$
Concrete (Conventional)	4,698,582
PROJECT TOTAL (Excl GST)	4,698,582

Notes:

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Concrete Construction

DETAILED SUMMARY



Client: Timber Development Association
Project: Concrete Construction

Details: 02. Concrete Construction - Rev 2 - 170915
MBM0001
Date - 5/10/2017

Code	Description	Starting Page	% of Cost	Cost/m2	Total
1	Concrete (Conventional)				
1.1	Columns	Page 4	7.78		365,644
1.2	Upper Floors	Page 4	38.53		1,810,398
1.3	Staircases	Page 4	1.41		66,150
1.4	Roof	Page 4	7.59		356,617
1.5	External Walls	Page 4	8.86		416,165
1.6	Internal Walls	Page 5	26.06		1,224,522
1.7	Wall Finishes				Included
1.8	Ceiling Finishes	Page 5	9.77		459,085
					4,698,582

MBM

Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Concrete Construction

REPORT DETAILS



Client: Timber Development Association
Project: Concrete Construction

Details: 02. Concrete Construction - Rev 2 - 170915
MBM0001
Date - 5/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1	Concrete (Conventional)				
1.1	Columns				
1.1.1	RC columns 500 x 250 incl. 40MPa concrete, formwork, reinforcement at 240kg/m3; 28no.	82	m	410.00	33,620
1.1.2	RC columns 1500 x 220 incl. 40MPa concrete, formwork, reinforcement at 240kg/m3; 42no.	123	m	870.00	107,009
1.1.3	RC columns 1200 x 220 incl. 40MPa concrete, formwork, reinforcement at 240kg/m3; 28no.	82	m	725.00	59,450
1.1.4	RC columns 1800 x 220 incl. 40MPa concrete, formwork, reinforcement at 240kg/m3; 28no.	82	m	1,015.00	83,230
1.1.5	RC columns 1800 x 230 incl. 40MPa concrete, formwork, reinforcement at 240kg/m3; 14no.	41	m	1,035.00	42,435
1.1.6	900 x 300 RC columns incl. 40MPa concrete, formwork, reinforcement at 240kg/m3, post-tensioning at 6kg/m2; 18no.	57	m	700.00	39,900
					365,644
1.2	Upper Floors				
1.2.1	RC suspended transfer slab 170 thick, incl. 40MPa concrete, formwork, reinforcement at 40kg/m3, post-tensioning at 4.2kg/m2	772	m2	270.00	208,441
1.2.2	RC attached beams to transfer slab (measured above), 2100 x 650, incl. 40MPa concrete, formwork, reinforcement at 40kg/m3	280	m	1,175.00	329,000
1.2.3	RC suspended slab 200 thick, incl. 40MPa concrete, formwork, reinforcement at 35kg/m3, post-tensioning at 4.2kg/m2	4,629	m2	275.00	1,272,957
					1,810,398
1.3	Staircases				
1.3.1	Concrete fire stairs inclusive of handrails and associated works	21	m/rise	3,150.00	66,150
					66,150
1.4	Roof				
1.4.1	RC suspended transfer slab 200 thick, incl. 40MPa concrete, formwork, reinforcement at 35kg/m3, post-tensioning at 4.2kg/m2	772	m2	275.00	212,297
1.4.2	50mm thick cement and sand mortar bedding laid to falls and finished to receive waterproofing	772	m2	55.00	42,460
1.4.3	Approved roof waterproofing membrane applied to concrete roof slab above screed	772	m2	50.00	38,600
1.4.4	Drainage cell laid above the waterproofing	772	m2	25.00	19,300
1.4.5	Dow Wrapshield HP geotextile separation fabric laid above drainage cell below insulation	772	m2	5.00	3,860
1.4.6	40mm thick R2.0, Dow Styrofoam RTM-X closed cell insulation laid above drainage cell	772	m2	45.00	34,740
1.4.7	Dow Wrapshield HP geotextile separation fabric laid above insulation below concrete paving	772	m2	5.00	3,860
1.4.8	Allow for dressing around drainage outlet including forming cut out in drainage cell, Insulation system, making good and the like; 200mm dia	1	item	1,500.00	1,500
					356,617
1.5	External Walls				
1.5.1	75mm Hebel external wall panel, Wall Type 1, 1290 x 3069	28	no.	635.00	17,780
1.5.2	75mm Hebel external wall panel, Wall Type 1, 2590 x 3069	42	no.	1,270.00	53,340
1.5.3	75mm Hebel external wall panel, Wall Type 1, 2230 x 3069	42	no.	1,095.00	45,990
1.5.4	75mm Hebel external wall panel, Wall Type 1, 2120 x 3069	28	no.	1,040.00	29,120
1.5.5	75mm Hebel external wall panel, Wall Type 1, 1650 x 3069	28	no.	810.00	22,680

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Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Concrete Construction

REPORT DETAILS



Client: Timber Development Association
Project: Concrete Construction

Details: 02. Concrete Construction - Rev 2 - 170915
MBM0001
Date - 5/10/2017

Code	Description	Quantity	Unit	Rate	Amount
1.5	External Walls				
1.5.6	75mm Hebel external wall panel, Wall Type 1, 4590 x 3069	28	no.	2,255.00	63,140
1.5.7	75mm Hebel external wall panel, Wall Type 1, 2470 x 3069	28	no.	1,250.00	35,000
1.5.8	75mm Hebel external wall panel, Wall Type 1, 2350 x 3069	28	no.	1,155.00	32,340
1.5.9	75mm Hebel external wall panel, Wall Type 1, 2940 x 3069	28	no.	1,490.00	41,720
1.5.10	75mm Hebel external wall panel, Wall Type 1, 1290 x 3069	14	no.	1,445.00	20,230
1.5.11	RC walls, 200 thick, incl. 40MPa concrete, formwork and reinforcement at 140kg/m3	129	m2	425.00	54,825
1.5.12	Alucobond on and including timber framing to Hebel external wall panels (measured elsewhere), Wall Type 1 - EXCLUDED FROM ALL OPTIONS		Excluded		
					416,165
1.6	Internal Walls				
1.6.1	RC walls 200 thick, incl. 40MPa concrete, formwork and reinforcement at 140kg/m2	899	m2	425.00	382,075
1.6.2	Wall Type 2, incl. Hebel panel, stud frame with insulation and 13mm plasterboard to both sides	1,611	m2	214.00	344,754
1.6.3	General internal walls, incl. 64mm stud framing, with 13m plasterboard to both sides	2,799	m2	97.00	271,503
1.6.4	Internal walls to we areas, incl. 64mm stud framing, with 6mm FC sheet to one side and 13mm plasterboard to other side	305	m2	116.00	35,380
1.6.5	Wall Type 7, 102mm C-H metal stud framed wall, lined between studs with 25mm FR PB, 2/13mm FR PB to finish	607	m2	230.00	139,610
1.6.6	10mm plasterboard lining to inside face of external Hebel wall panels	2,048	m2	25.00	51,200
					1,224,522
1.8	Ceiling Finishes				
1.8.1	Suspended plasterboard ceiling throughout	5,401	m2	85.00	459,085
					459,085

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Client: Timber Development Association
Project Code: 0001
Printing Date: 5/10/2017
Report Name: Concrete Construction

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Project Code: 0001
Printing Date: 5/10/2017
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MBM has offices in Sydney, Melbourne, Brisbane, Perth, Canberra, Adelaide and the Gold Coast.

We operate as a single entity and are able to utilise specialised skills from any office to deliver a successful outcome for your project or development.

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