Preliminary Design for Mid-rise Timber Buildings

Alastair Woodard
Today’s Presentation

• The importance of **the concept / preliminary design phase**
• The importance of **working together as a team from the start**
• The importance of **knowing what you can (and can’t) do**
• The importance of **knowing who can help you**
• Some of the important **structural engineering considerations you might not at first be considering**
Project: Library at the Dock
By: Lendlease
Location: Docklands, Melb, VIC
Project :: 25 King
Architects :: Bates Smart
Builder :: Lendlease
Location :: Brisbane, Qld
Image :: Bates Smart

Gulam post & beam
CLT floor plates

WORLD’S TALLEST TIMBER OFFICE BUILDING
Project :: 25 King
Architects :: Bates Smart
Builder :: Lendlease
Location :: Brisbane, Qld
Image :: Bates Smart
Project :: 55 Southbank
Architects :: Bates Smart
Builder :: Atelier Constructions
Location :: Melbourne
Image :: Bates Smart

220 Room Vertical Hotel Extension
2 Level Steel & Concrete Transfer Deck
10 Level CLT Wall, Floor & Roof Structure
Project Scope & CLT Extent

- **CLT Wall**
- **Floor & Roof Structure**
- **Transfer Structure**
- **Existing Structure**

**Project:** 55 Southbank
**Architects:** Bates Smart
**Builder:** Atelier Constructions
**Location:** Melbourne
**Image:** Bates Smart

- 220 Room Vertical Hotel Extension
- 2 Level Steel & Concrete Transfer Deck
- 10 Level CLT Wall, Floor & Roof Structure
First CLT panels being lifted

Project :: 55 Southbank
Architects :: Bates Smart
Builder :: Atelier Constructions
Location :: Melbourne
Image :: Bates Smart
What do all these timber projects have in common?

A very **timber committed** and knowledgeable **project team**
What do all these timber projects have in common?

A structural engineer prepared to design in timber
**Phase 1: Preliminary Design**

- Step 1: Performance considerations and overall building layout
- Step 2: Preliminary structural design – including Early Supplier Involvement (ESI)

**Phase 2: Detailed Design**

- Step 3: Vertical load – Roof and floor design
- Step 4: Vertical load – Wall design
- Step 5: Vertical movement design
- Step 6: Lateral load – Stability design
- Step 7: Check robustness
- Step 8: Other engineering details for consideration
- Step 9: Engineering drawings and documentation for certification

**Phase 3: Fabrication & Assembly**

- Step 10: Engineered timber systems fabrication (shop drawing review)
- Step 11: On-site construction assembly supervision - certification
Technical Design Guides

WS Design Guide 50 –

Due for release mid-2019

Contents

Preface
Acknowledgements
Design Process and Guide Layout
1. Mid-rise Timber Building Design Methodology
2. Design Loads and Criteria
3. Roof Design
4. Floor Design
5. Wall Design
6. Vertical Movement Design
7. Lateral Load Resistance Design
8. Robustness Design
Glossary

Appendix 1: Worked Example for a Timber Framed Apartment Building
Appendix 2: Worked Example for a CLT Mass Timber Panel Apartment Building
Phase 1: Preliminary Design

Step 1: Performance considerations and overall building layout

Step 2: Preliminary structural design

– including Early Supplier Involvement (ESI)
Mid-rise Timber Building Design & Construction Chain

Approving Authorities

Commissioning

Mid-rise Timber Building Design & Construction Chain

Concept

Design

Detailed Design

Tender & Fabrication

On-site Assembly

A wide range of building professionals involved

Concept

Costs Plan

Tender

Fabrication

Construction

Commissioning

Project Manager
Fabricator or Supplier

Project Manager
Architect
Site Engineer
Installer
Preliminary Design Phase – **Work Together**

**ECI Time Advantage**

**Traditional Lump Sum Tender Model**

<table>
<thead>
<tr>
<th>0</th>
<th>Wk4</th>
<th>Wk8</th>
<th>Wk12</th>
<th>Wk16</th>
<th>Wk20</th>
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**ECI Model**

<table>
<thead>
<tr>
<th>ECI Phase:</th>
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<td>Competitive Bid:</td>
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<tr>
<td>Recommendation:</td>
<td>1 week</td>
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</table>

**Time Saving**

8 - 14 weeks

Wood Solutions Seminar – October 2018
Preliminary Design Phase – **Knowledge**

Know what you can (and can’t) do

- NCC Provisions
- Timber system options
The National Construction Code (NCC) is the regulatory framework for determining the minimum design and construction requirements for buildings in Australia.

**NCC Volume One**

*Building Code of Australia 2019*

for Class 2 to Class 9 Buildings is the document relevant to mid-rise timber buildings

(hereon referred to simply as the NCC)
Two pathways are available under the NCC to demonstrate performance.

**Figure A0.2**

**NCC COMPLIANCE STRUCTURE**

- Compliance Level
- Performance Requirements
- Performance Solution and/or Deemed-to-Satisfy Solution

**Note:**
1. The term *Performance Solution* was formerly known as *Alternative Solution*.
2. The terms *Performance Solution* and *Deemed-to-Satisfy Solution* were formerly used under the term *Building Solution*. 
The 2016 NCC allowed under the Deemed-to-Satisfy (DTS) provisions the use of fire-protected timber construction systems in

- ✓ Class 2 (apartments)
- ✓ Class 3 (e.g. hotels)
- ✓ Class 5 (offices) buildings up to 25 metres in effective height (hereon in termed ‘mid-rise construction’).

The 2019 NCC has expanded DTS provisions to all building classes.
C1.13 Fire-protected timber: Concession

**Fire-protected timber** in a Class 2, 3 or 5 building may be used wherever an element is *required* to be *non-combustible*, provided—

(a) the building is—
   (i) a separate building; or
   (ii) a part of a building—
      (A) which only occupies part of a *storey*, and is separated from the remaining part by a *fire wall*; or
      (B) which is located above or below a part not containing *fire-protected timber* and the floor between the adjoining parts is provided with an *FRL* not less than that prescribed for a *fire wall* for the lower *storey*; and

(b) the building has an *effective height* of not more than 25 m; and
(c) the building has a sprinkler system throughout complying with *Specification E1.5*; and
(d) any insulation installed in the cavity of the timber building element *required* to have an *FRL* is *non-combustible*; and
(e) cavity barriers are provided in accordance with *Specification C1.13*. 
C1.13 Fire-protected timber: Concession

Fire-protected timber may be used wherever an element is required to be non-combustible, provided—

(a) the building is—
   (i) a separate building; or
   (ii) a part of a building—
      (A) which only occupies part of a storey, and is separated from the remaining part by a fire wall; or
      (B) which is located above or below a part not containing fire-protected timber and the floor between the adjoining parts is provided with an FRL not less than that prescribed for a fire wall for the lower storey, and

(b) the building has an effective height of not more than 25 m; and

(c) the building has a sprinkler system (other than a FPAA101D or FPAA101H system) throughout complying with Specification E1.5; and

(d) any insulation installed in the cavity of the timber building element required to have an FRL is non-combustible; and

(e) cavity barriers are provided in accordance with Specification C1.13.
Summary – NCC DTS Provisions

- The NCC DTS provisions cover both
  - traditional ‘lightweight timber framing’ and
  - new ‘massive timber systems’ such as CLT, GLT, LVL, NLT

consist of the use of appropriate layers of fire resistant plasterboard – to provide ‘fire-protected timber’ – the use of compliant automatic sprinkler systems, and cavity barriers.
Summary of General Fire Design Principles

Firstly, the use of automatic fire sprinklers to suppress a fire before the timber structure is threatened.

Secondly, the use of fire-grade plasterboard to effectively ‘fire-protect’ the timber elements in the low probability event that the sprinklers fail.

Thirdly, the use of cavity barriers to prevent fire or smoke spread through the cavities if the fire-grade plasterboard is breached.

Fourthly, the use of non-combustible insulation to minimise fire spread in cavities if the fire-grade plasterboard is breached.
Timber Construction Options for Mid-rise Timber Buildings

Design of Mid-Rise Timber Buildings
Timber Construction - **Lots of Options**
Lightweight Timber Construction Options

Roof Systems
- Open Frames
- Partially Enclosed
- Fully Closed

Wall Systems

Floor Cassette Systems

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Massive Timber Construction Options

- Glulam (GLT)
- Cross Laminated Timber (CLT)
- Laminated Veneer Lumber (LVL)
- Nail Laminated Timber (NLT)
Massive Timber – Previous NCC 2016 Definition

GENERAL PROVISIONS

Low-rise platform lift means a power-operated device for raising or lowering people with limited mobility on a platform, that is controlled automatically or by the application of constant pressure to a control.

Luminance contrast means the light reflected from one surface or component, compared to the light reflected from another surface or component.

Massive timber means an element not less than 75 mm thick as measured in each direction formed from chemically bonded laminated timber and includes:

(a) Cross laminated timber (CLT).
(b) Laminated veneer lumber (LVL).
(c) Glued laminated timber (Glulam).

Mezzanine means an intermediate floor within a room.
**Massive Timber – NCC 2019 Definition**

**Schedule 3 Definitions**

**Luminance contrast** means the light reflected from one surface or component, compared to the light reflected from another surface or component.

**Massive timber** means an element not less than 75 mm thick as measured in each direction formed from solid and laminated timber.

**Medium Hazard** means any condition, device or practice which, in connection with a water supply, has the potential to injure or endanger health.

Timber Construction Options

- 12-14 Storeys
- NCC Timber construction up to 25m under DTS
- 6-7 Storeys
Optimised Timber Construction Class 2 or 3

Concrete core

Mass timber core

As load increases – use more studs

Multi-Res Apartments 1-6 Storeys

Lightweight Timber
Optimised Timber Construction Class 2 or 3

As load increases – use more studs

Multi-Res Apartments 1-6 Storeys
Lightweight Timber

Multi-Res Apartments 6 – 8 Storeys
Lightweight Timber + Massive Timber

Above 6 storeys use Massive Timber in lower storeys (LVL, CLT)
Optimised Timber Construction Class 2 or 3

Project: Aveo Norwest
 Builders: Strongbuild
 Location: Baulkham Hills, NSW

Multi-Res Apartments 6 – 12+ Storeys
 Massive Timber (CLT)
Optimised Timber Construction – Class 5 Offices

**Heavy Timber**

**Post & Beam**
(Glulam, LVL)

**Portal Frames**
(Glulam, LVL, Box-beams)
Vertical Extensions Using Timber Construction

Vertical Extensions using timber construction above an existing concrete structure

55 Southbank Boulevard, Melbourne
CLT 10 storey addition

*Image: Bates Smart*
Design of Mid-Rise Timber Buildings

Considerations Impacting on the Structural Engineering Approach
Preliminary Design
NCC Performance Considerations

1. Structural performance
   - NCC Part B1 Structural Provisions
2. Fire performance
   - NCC Section C of the NCC
3. Acoustic performance
   - NCC multiple requirements
4. Robustness
5. Weatherproofing
6. Building services
7. Energy efficiency
Phase 1: Preliminary Design
NCC Performance Considerations

1. Structural performance
2. Fire performance
3. Acoustic performance

Structural
• Approach
• Design

Structural
• Loading
• Layout
**Massive Timber** (*Lower level of protection to timber*)

- Minimum 75mm thickness of massive timber element, with required FRL, with no concealed spaces between plasterboard coverings and timber
  - e.g. Glulam - GLT, CLT, LVL, NLT

- Fire protective covering required:
  - Element with appropriate layers of fire protective covering, generally 1 layer of **16mm fire-grade plasterboard** for walls and ceilings
**General Timber** *(High level of protection to timber)*

- FRL lightweight timber-framed construction
  - e.g. 90, 120, 140 x 45mm

- Fire-grade plasterboard linings required (typical 90 min. solution):
  - 2 x **13mm** fire-grade plasterboard for walls, and
  - 2 x **16mm** fire-grade plasterboard for ceilings
NCC Acoustics

**Acoustic Requirements**
- Mass (floor build-ups, wall lining)
- Suspended ceilings (resilient mounts)
- Separation
- Isolation (decoupling)
- Avoid sound bridges (flanking)

- **Impact & Airborne**
  
- **Minimise Flanking**
Wall Design Considerations – Fire & **Acoustics**

**Discontinuous walls**

**Staggered stud walls**

**Single stud walls + resilient mounts**

ACOUSTIC REQUIREMENTS WILL INFLUENCE WALL LAYOUT CONFIGURATIONS
### Table 3: Walls – Deemed-to-Satisfy Sound Insulation Requirements in Class 2 and 3 Buildings

<table>
<thead>
<tr>
<th>Wall Situation</th>
<th>Wall Rating</th>
<th>Entry Door Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Space</td>
<td>SOU – generally all spaces except those noted below</td>
<td>Separates</td>
</tr>
<tr>
<td>A bathroom, sanitary compartment, laundry or kitchen</td>
<td>Separates</td>
<td>Separates</td>
</tr>
<tr>
<td>A bathroom, sanitary compartment, laundry or kitchen</td>
<td>Separates</td>
<td>Separates</td>
</tr>
<tr>
<td>Plant and lift shaft</td>
<td>Separates</td>
<td>Separates</td>
</tr>
<tr>
<td>Stairway, public corridor, public lobby or the like or part of a different BCA building classification</td>
<td>Separates</td>
<td>Separates</td>
</tr>
</tbody>
</table>
Acoustic Wall Configurations

Discontinuous wall

Staggered stud wall
Mass Air Mass Resonance

Small cavities in systems can dramatically affect the acoustic performance of a system even though the same amount of material and overall width are the same.
Floor Design Considerations – **Fire & Acoustics**

**Floor Depth**
- 300 – 450 mm
- 60 - 70 mm

**Acoustic Overlay**
- Fire rated plaster
- Suspended non-fire rated ceiling

**Acoustic Insulation**
- >10dB improvement

**Impacts on**
- Structural loading
- Floor depth

**Isolating the Ceiling Lining from the Joists**
- Provides the main benefit

**Resilient Mounts**

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woodsolutions.com.au
Floor Design Considerations – Fire & Acoustics

- Structural loading
- Floor depth

Mass acoustic overlay on mat

Flooring material

FOR PRELIMINARY DESIGN ASSUME AT LEAST 40kg/m² OF ADDED OVERLAY MASS

Impacts on

40 – 100 mm

300 – 450 mm

60 - 70 mm
Floor Design Considerations – Fire & Acoustics

- Structural loading
- Floor depth

Impacts on

FOR PRELIMINARY DESIGN ASSUME AT LEAST 40kg/m² OF ADDED OVERLAY MASS

Sprinklers or downlights

Mass acoustic overlay on mat

Suspended non-fire rated ceiling
**Table 4.7 Overlay topping options to achieve a 40 kg/m² system mass target**

<table>
<thead>
<tr>
<th>Product</th>
<th>Density (kg/m³)</th>
<th>Unit Thickness</th>
<th>Unit Mass (kg/m²)</th>
<th># of Layers in System</th>
<th>System Mass (kg/m²)</th>
<th>System Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Screed Mix (w/ particle board for lightweight)</td>
<td>2000</td>
<td>40</td>
<td>80</td>
<td>1</td>
<td>80.0</td>
<td>40</td>
</tr>
<tr>
<td>Sand (dry) installed between battens w/ particle board top</td>
<td>1600</td>
<td>25</td>
<td>40</td>
<td>1</td>
<td>40.0</td>
<td>25</td>
</tr>
<tr>
<td>Promat System Panel</td>
<td>1100</td>
<td>18</td>
<td>19.8</td>
<td>2</td>
<td>39.6</td>
<td>36</td>
</tr>
<tr>
<td>JH Compressed Fibre Cement (CFC) Structural Flooring</td>
<td>1920</td>
<td>15</td>
<td>28.8</td>
<td>2</td>
<td>57.6</td>
<td>30</td>
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<tr>
<td>Particleboard</td>
<td>746</td>
<td>19</td>
<td>14.2</td>
<td>3</td>
<td>42.5</td>
<td>57</td>
</tr>
<tr>
<td>Knauff Brio Board</td>
<td>1100</td>
<td>18</td>
<td>19.8</td>
<td>2</td>
<td>39.6</td>
<td>36</td>
</tr>
<tr>
<td>Supaboard</td>
<td>1200</td>
<td>18</td>
<td>21.6</td>
<td>2</td>
<td>43.2</td>
<td>36</td>
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<tr>
<td>BGC Durafloor</td>
<td>1300</td>
<td>19</td>
<td>24.7</td>
<td>2</td>
<td>49.4</td>
<td>38</td>
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<tr>
<td>CSR Cemintel C</td>
<td>1625</td>
<td>18</td>
<td>29.3</td>
<td>2</td>
<td>58.6</td>
<td>36</td>
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<tr>
<td>Fiberock</td>
<td>950</td>
<td>16</td>
<td>15.2</td>
<td>3</td>
<td>45.6</td>
<td>48</td>
</tr>
</tbody>
</table>

For preliminary design assume at least 40 kg/m² of added overlay mass.
Floor/Wall Design Considerations - Acoustics

In-fill floor strip required to provide diaphragm action in floor plate

Acoustic mat upturned at wall

Concrete screed or high-density flooring

Acoustic insulation e.g. R2.0 non-combustible 90 Gold Batts

2/16mm fire rated plasterboard or equivalent with resilient mounts

45mm mineral wool cavity barrier or similar

Optional – additional non fire-rated ceiling allowing sprinklers and wiring to be installed without penetrating fire-protection layer

Impacts on

• Layout
• Floor diaphragm action
Design of Mid-Rise Timber Buildings

Structural Engineering Resources
### CLT floor Span

<table>
<thead>
<tr>
<th>Element</th>
<th>Size</th>
<th>Load</th>
<th>Indicative Span (m)</th>
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<tbody>
<tr>
<td>Domestic</td>
<td>100</td>
<td>Domestic Multi Res Office Heavy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>Domestic Multi Res Office Heavy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>Domestic Multi Res Office Heavy</td>
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<td></td>
<td>175</td>
<td>Domestic Multi Res Office Heavy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>Domestic Multi Res Office Heavy</td>
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<tr>
<td></td>
<td>225</td>
<td>Domestic Multi Res Office Heavy</td>
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<tr>
<td></td>
<td>250</td>
<td>Domestic Multi Res Office Heavy</td>
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</tr>
<tr>
<td></td>
<td>275</td>
<td>Domestic Multi Res Office Heavy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>Domestic Multi Res Office Heavy</td>
<td></td>
</tr>
</tbody>
</table>

*CLT: Cross-Laminated Timber

**Notes:**
- Domestic - SDL=0.5, Q=1.5
- Multi Res - SDL=1, Q=2
- Office - SDL=1.5, Q=3
- Heavy - SDL=2, Q=5

**Comparative Span Tables for Quick Preliminary Sizing**
Manufacturer Technical Literature

Designing with XLam Cross Laminated Timber

Continuous Span

\[ Q = 2.0\text{ kPa} \]

<table>
<thead>
<tr>
<th>SDL</th>
<th>0.0 kPa</th>
<th>0.5 kPa</th>
<th>1.0 kPa</th>
<th>2.0 kPa</th>
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</thead>
<tbody>
<tr>
<td>CL5/100</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>CL5/130</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>CL5/145</td>
<td>4.2</td>
<td>4.2</td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td>CL5/150</td>
<td>4.4</td>
<td>4.4</td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>CL5/165</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
</tr>
<tr>
<td>CL5/175</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
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<tr>
<td>CL5/185</td>
<td>5.2</td>
<td>5.2</td>
<td>5.2</td>
<td>5.2</td>
</tr>
<tr>
<td>CL5/205</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
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<tr>
<td>CL5/225</td>
<td>5.7</td>
<td>5.7</td>
<td>5.7</td>
<td>5.7</td>
</tr>
</tbody>
</table>

\( Q \) = Live load
SDL = Super imposed dead load
Think Timber Early

Consider timber early and engage with the manufacturer / supplier

Preliiminary design phase:
- Concept
  - Client
  - Architect
  - Approving Authorities

Preliminary Design:
- Architect
- Structural Engineer
- Fabricator or Supplier
- Project Manager

Preliminary Costing:
- Architect
- Cost Planner
- Fabricator or Supplier
- Project Manager

Detailed Design:
- Architect
- Structural Engineer
- Fabricator or Supplier
- Project Manager
- Specialist Consultants: Acoustic, Hydraulic, Fire, Facade, etc.

Detailed design phase:
- Costs Plan
  - Architect
  - Cost Planner
  - Fabricator or Supplier
  - Project Manager

Tender:
- Project Manager
- Fabricator or Supplier

Supply & construction:
- Fabrication
  - Project Manager
  - Fabricator or Supplier

- Construction
  - Project Manager
  - Architect
  - Site Engineer
  - Installer
Supply – Timber Framed Systems

Frame & Truss Manufacturing Sector

Specialised Suppliers

- Pryda
- MiTek
- Multinail
Supply – Heavy Timber Systems

Glulam Manufacturers and Suppliers
Supply – Massive Timber Panel Systems – CLT & LVL

CLT Manufacturer/Suppliers

LVL Manufacturer/Suppliers
WoodSolutions Mid-rise Team
a FREE service to assist you

WoodSolutions Mid-Rise Advisory Program
Conclusion

• The concept / preliminary design phase is key to timber being either IN or OUT
• Work together as a TEAM from the start
• Remember structural engineering considerations will be impacted on by others
• Know what you CAN DO
• Know who can HELP you and use them
WS Design Guide 50 – Engineering Design Assistance

WS Design Guide 50 – Mid-rise Timber Building Structural Engineering Design Guide

Due for release mid-2019