Phoenix Apartments – Structural Design

Kevin Berry

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Your Partner in Engineering
Kevin Berry Project Experience

Kevin Berry, Director
BE (Hons), MIEAust + CPEng

2017 – Current
Director, TTW

2015 – 2017
Technical Director, TTW

2011 – 2014
Associate Director, TTW

2010 – 2011
Senior Structural Engineer, TTW

2006 – 2010
Senior Engineer, BuroHappold Ltd, UK

2004 – 2006
Graduate Engineer, Holmes Consulting Group, NZ
Over 50 Years of Timber Experience

Kevin Berry
Director

Barry Young
Director

Atreyu De Lacy
Associate Director

Jane Armstrong
Associate

Alex Zecevic
Associate

Sameed Khan
Structural Engineer

Brooke Simmons
Structural Engineer

TTW

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Phoenix Apartments
Presentation Overview

Overview
- Project Team
- Project Information
- Structural Overview
- Design Considerations
- Detailed Design
- Site Phase
- Lessons Learned
Key Project Team

Kevin Berry
Director

Rajneel Ram
Senior Structural Engineer

Sameed Khan
Structural Engineer
Project Information

Overview
- Project located at Cudgegong Road in Rouse Hill
- Project is split into 2 buildings:
  - Building A – 5 Stories
  - Building B – 6 Stories
- Timber structure erected by Strongbuild
- CLT sourced from Binderholz in Germany
- LVL sourced from Wesbeam and Dindas
- Project is currently being completed by Westbourne Construction

Project Location

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Structural Overview

**Design Concept**

- Slab on Ground Basement Carpark
- Post-Tensioned Concrete podium
- Hybrid CLT floor and prefabricated LVL stud wall timber superstructure
- CLT lift and stair cores above podium level

**ETABS Modelling**
Structural Overview

- Concrete Podium Slab
- Concrete Basement
- Caparks with Dincel Retaining Walls
- CLT Lift/Stair Cores
- CLT Floor panels
- LVL Stud Wall
- Concrete PT Podium Slab

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Structural Overview

Cross Laminated Timber Floors

- CLT floor acts as a diaphragm between load bearing elements
- Vibration performance needs to be checked to ensure acceptable occupant comfort in service
- Steel beams used to carry floors over large openings in walls

Erection of floor panels on site
Structural Overview

Prefabricated Timber Walls

- LVL stud walls clad with plywood/OSB panels for bracing
- Plasterboard used to protect timber in fire limit state
- Engineered timber allowed for more stories to be constructed than traditional MGP10 as well as crushing of top and bottom plates in walls which usually governs stud spacing
- Walls are prefabricated to expedite on site erection
- Stud clusters used to carry concentrated loads at ends of beams
Wall Stability

- Timber shear walls are used to resist lateral loading.
- Lateral forces generate overturning loads in the wall which are resolved in a compression/tension couple at the ends of the wall using studs and tie down rods.
**Structural Overview**

**Wall Stability**

- Tie down forces in walls are achieved using proprietary steel tie down system by Simpson Strong Tie
- Rods run up the length of the building and are anchored into concrete slab at the base
- Oriented Strand Board (OSB) provide bracing for upper walls with lower bracing requirements
- Plywood used for bracing of lower level walls with higher bracing load requirements
Structural Overview

Connections

▪ Screw connections to tie together timber elements

▪ Proprietary brackets used to carry shear and tension loads for CLT panels and connecting stud walls to concrete
Design Considerations

Imposed Loading

- Weight of cementitious screed required for acoustic purposes needed to be considered in superimposed loading
- Apartment loads in line with those for self-contained occupancy units
- Additional consideration required for use of pod bathrooms where heavy lifting slabs may be used

Typical Floor Loading Plan
Design Considerations

Lateral Loading

▪ Wind Loading
  ▪ Design stud walls to carry ultimate wind loading
  ▪ Check stud walls for lateral deflection under service wind

▪ Seismic Loading
  ▪ Ensuring sufficient ductility in the system during a seismic event
  ▪ Allow for overstrength to ensure ductile failure mechanism
  ▪ Review of load path hierarchy

Typical Shear Diagram and Deflection Shape for Timber Wall
Design Considerations

**Durability**

- Termite barriers to prevent infestation and damage to timber structure
- Insect treatment of timber elements
- Ensure elements are protected from the elements by cladding and plasterboard

*Studs treated for potential insect infestation*
Design Considerations

Procurement of Materials

- CLT supplied by Binderholz required long lead times as items were shipped from Europe
- CLT elements required early finalisation to allow for shipment from Europe
- Local availability of LVL meant LVL design could be developed for longer

CLT Shipment from European Factory
Design Considerations

Transportation

- CLT panel lengths limited to 11.8m to allow for transport in shipping containers
- Use of standard BBS125 panels to allow for easy transport of panels
- Panels were processed in Strongbuild factory before being sent to site by truck
Design Considerations

Buildability

▪ Use of 3 standard CLT panels to allow for buildability and simplify detailing 100, 160 and 180 thick

▪ Extensive use of standard connections using screws, brackets and nails to simplify on site connections

▪ Strengthening of CLT floor with LVL blocking to prevent crushing
Design Considerations

Manufacturing Requirements

- Panelised walls
- Jointing details to ensure simple erection on site
- Prefabricated panels allow for protection of wall panels from the elements during construction
- Consideration required for manufacturing tolerances

Review of Stud Wall Shop Drawings
Design Considerations

Inspection Regime
- Most elements prefabricated in factory
- Factory based inspections for prefabricated elements
- Periodic site inspections to ensure items are properly installed on site

Factory Inspection of prefabricated elements
Design Considerations

Fire Engineering Requirements

- Consideration for charring to AS1720.4 where required
- Plasterboard used primarily to protect timber stud walls
- Combination of plasterboard and charring to ensure performance of CLT panels in a fire limit state
- Depth of charring depths on CLT elements confirmed using fire tests on CLT specimens
Design Considerations

Axial Shortening

- Amount of axial shortening calculated to determine required gaps in façade
- Gaps to be left at top and bottom of walls as well to prevent OSB/plywood becoming vertically loaded when building shortens
- Avoid placing vertical loading bearing steel and timber elements directly next to each other due to incompatible axial stiffness
- Groups timber studs used to carry steel beams in lieu of steel columns to ensure even axial shortening compared to stud walls
Detailed Design

**CLT Floors**
- Eurocode 5 used for design of CLT elements including strength and serviceability checks
- Gamma method to check deflections to consider rolling shear effects of transverse CLT layers
- Floor panels covered in non-structural screed to improve both vibration and acoustic performance
- Vibration checked using EC5 principles as well as FEM to determine response factors

Footfall Analysis of CLT Floorplate
Detailed Design

Timber Stud Walls

- Strength of timber stud walls determined using AS1720.1
- Crushing of LVL bottom plates often governs strength design in stud wall
- Staples used to connect sheathing to LVL studs to speed up production
- Preliminary checks on staples done against EC5
- Confirmation of staple performance by full scale wall tests at University of New South Wales

Install of Sheeting using staples
Detailed Design

Wall Capacity Testing

- **Stage 1**
  - Testing of small scale specimens to determine staple capacity and slip performance
  - Results were used to predict performance in full scale tests and verify capacities calculated as per Eurocode 5

- **Stage 2**
  - Full scale wall tests to verify vertical load carrying capacity of wall
  - Full scale wall testing to very lateral load carrying capacity of stud wall using staples to connect sheathing
  - Verify ductility performance of wall system to validate design assumptions

Full Scale Wall Testing
Wall Capacity Testing

- Testing Process:
  - Stud walls were subject to a lateral pushover test with loading as per BSEN26891
  - Peak lateral load carrying capacity of the shear wall is then used to determine load cycle for cycling testing
  - Cyclic testing is completed to ISO 21581 using a force controlled procedure that slowly loads and unload the wall
  - The same load is applied for 3 cycles before the load is increased for another 3 cycles
  - Load is gradually increased until failure occurs

Accelerated loading protocol as per ISO 21581
**Detailed Design**

**Design of Lateral System**

- Lateral load in walls checked using both hand calculated tributary area based distribution and stiffness based distribution in ETABS
- CLT diaphragm may be analysed using same principles as traditional plywood diaphragm
- Discontinuities in CLT panels mean without proper detailing of panel joins and chord splices, CLT diaphragm cannot transmit loads into adjacent panels and so spans locally to walls

![Image: FP Innovations]
Detailed Design

Design of Lateral System

- Modelling of diaphragm shows CLT core walls and timber shear walls have similar stiffness
- Similar stiffness means CLT tends to span locally between walls instead of to cores
- CLT elements span between lateral load resisting walls means axial chord forces do not need to be transferred to adjacent CLT panels
- This design approach of panels spanning locally to walls greatly simplifies diaphragm connections
Detailed Design

Design of Lateral System

- Longitudinal Spline connections in non-load bearing direction are designed for shear flow when diaphragm experiences bending. However this only occurs if CLT panels act monolithically. If panels are designed to span locally, these connections are no longer critical as shown on the next slide.

- Screw connections are used to transfer shear loads into walls as well as transmit loads from walls over to walls under.

Wall to Floor Connection to Transmit Shear into wall below.

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Design of Lateral System

- CLT panels acting as a diaphragm behave as a mix of composite and non-composite behaviour.
- The level of composite action between the CLT panels is affected by the stiffness of the screw connections in the longitudinal splines between the panels.
- When more screws are used to connect CLT panels, the joints become stiffer, attract more load and allow for greater composite action but affects critical connections.

Panel In Plane Stresses changing with Longitudinal Spline Joint Stiffness
**Detailed Design**

**Design of Lateral System**

- Stress levels are very sensitive to level of composite action.
- Greater composite action affects which connections become critical.
- Small levels of non-composite action result in large bending stresses within individual panels.
- Proper analysis is needed to verify these forces can be appropriately transferred to adjacent panels if transverse splines are used.
- Vital to follow through on a design philosophy to ensure all load is accounted for depending on design approach.

Change in panel bending stresses with change in composite action.
Detailed Design

Design of Lateral System

▪ Longitudinal Spline
  ▪ Composite Action Critical

▪ Transverse Spline
  ▪ Non-Composite Action Critical
Site Phase

Temporary Props to Support Wall Panels
Site Phase

Phoenix Apartments

Rouse Hill Town Centre
2.0km (approx.)

Rouse Hill Anglican College
120m (approx.)

Rouse Hill Train Station
2.0km (approx.)
Site Progress
Lessons Learnt

- Designing for manufacturing needs early integration of design approach including consideration of manufacturing tolerances.
- Placement of sheathing in panelised line is critical due to edge distance requirements.
- Utilising more material to improve detailing practicality is ultimately a better design approach.
- Design philosophy for dealing with lateral loading needs to be consistent across all elements and connections.
- Crushing of floor panels and bottom plates must be checked as it often critical.
- Effects of differential axial shortening should be minimised by not directly placing vertical elements of different materials directly next to one another.
About Us

This year TTW celebrates 60 years of designing buildings throughout Asia Pacific. As leading consulting engineers, we partner with architects, builders and project managers to tackle the most complex projects and engineer their vision.

A privately-owned Australian company, our strong reputation exists due to our proven ability to produce innovative, economical and elegant designs in the public and private sector. We offer the benefits of scale with respective disciplines successfully delivering significant projects through structural, civil, traffic and façade engineering services.

Focusing foremost on the client’s goal, our design approach is customised for every project. Our solutions are enhanced by our dedicated and integrated teams' approach and the use of advanced engineering techniques for modern materials.

ONE TTW is our ethos, which encapsulates all the experienced, smart and creative people that make us who we are. We value; integrity, teamwork, innovation, communication, sustainability and our community.

Structural Our structural team is the largest in NSW and to date we have 140 structural engineers across our 4 locations. The team's ability to deliver award winning designs is under pinned by the hands-on service approach lead by our 6 Directors. Assigned to every project we take on, together our Directors combined structural design experience covers 160+ years. We ensure clients and project teams can always have direct access to our most senior engineers, on all projects.

Civil Our Civil engineers have 30+ years of established relationships and are dedicated to our client’s mission. The team provide successful solutions in master planning, roads, storm water drainage, urban landscape and land development.

Traffic Our traffic engineers have a 20+ year track record in providing engineering studies and investigations for hospitals, educational facilities, public institutions, shopping centres, residential developments, town centres, transport hubs, and industrial sites.

Facade Our Façade team excels at delivering award-winning, robust, light-weight façades that bring to life the public face of a building. The team employs advanced technology and works with high-performance materials to maximise environmental sustainability, increase longevity, and lower maintenance costs


6 directors 60 years 80% repeat clients
500+ awards 60 years 5 billion+ project rev
45+ technical staff 5 billion+ project rev

“Our work is only as good as the minds behind it.”
Dick Taylor, Founding Partner - TTW

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Thank you!