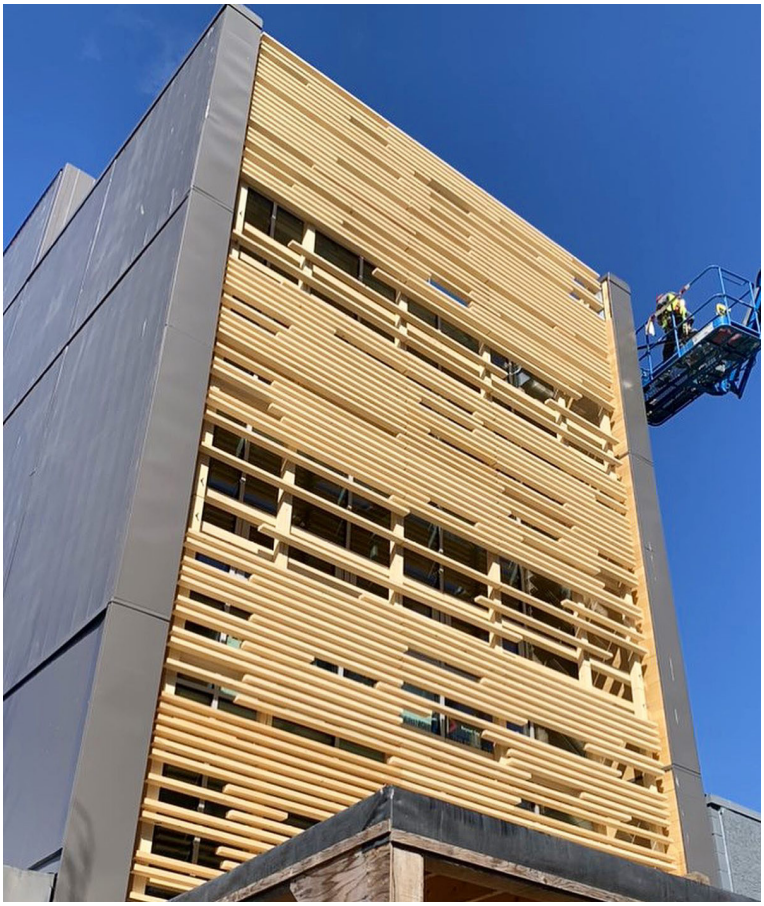
ON-SITE CONSTRUCTION AND PROJECT DELIVERY



Installation of oN5 facade. (Image: Scius)

oN5 is a four-storey office building located near the intersection of Ontario and E. 5th Avenue in Vancouver. Built on a narrow difficult-to-access mid-block site with only 7.54-metre wide street frontage, the commercial project overcomes significant constructability challenges by using a prefabricated all-timber structure. Cross-laminated timber (CLT) panels form the floors, walls and roof. The prefabricated loadbearing CLT walls are built to achieve Passive House envelope performance. The CLT floor panels use an innovative adhesive system to perform as a contiguous two-way slab and so forego the need for beams.

Preparation key to on-site success

oN5's project delivery method directly linked design and construction through a highly integrative planning process based on close collaboration between the architect, structural engineer and construction manager, design-assist from key experts, trades and suppliers, and the use of building information modelling (BIM)-based virtual design and construction (VDC) from conceptual design through to fabrication and on-site project delivery.

The VDC process allowed the team to create a streamlined "digital twin" of the oN5 building. Key project team members could visualise, simulate, rehearse and make decisions during design that led to successful construction. The VDC process also enabled the parallel sequencing of on-site and off-site programs of work and the "virtual builds" informed the trucking and craning schedules which had to coordinate with rush-hour traffic and street closures.

PROJECT TEAM

owner
1155776 BC Ltd
architect
Hemsworth Architecture Inc.
structural engineer
Equilibrium Engineering Inc.
timber specialty engineer
Timber Engineering Inc.
mechanical engineer
Rocky Point Engineering Ltd
construction manager
Naikoon Contracting Ltd
electrical engineer
MCL Engineering Ltd.
exterior envelope
Dubas Engineering Ltd.
fire suppression
TC Engineering Ltd.
code
Evolution Building Science Ltd.
geotechnical
GVH Consulting Ltd.
CLT fabricator
Katerra
seismic dampers
Tectonus
structural adhesive
Timbertec

BUILDING STATS

site area
280.375m²
site dimensions
32.185m long x 7.540m wide
gross floor area
840m²
height
17.3m
fsr
3
major occupancies
"D" Business and Personal Services; "F2" Industrial
applicable code
Vancouver Building Bylaw Article 3.2.2.59 (Group D); 3.2.2.77 (Group F)

ARCHITECT'S PERSPECTIVE

Hemsworth Architecture noted the architectural design process was substantially the same, but the inclusion of innovative technologies and VDC did require adjustment from typical architectural projects familiar to their architectural peers. Hemsworth Architecture, Equilibrium Consulting and Naikoon Contracting's highly collaborative approach was developed during their previous mass timber, passive house project, 1 Lonsdale, in North Vancouver.

Structural constraints and innovations

The Tectonus dampers and TS3-enhanced CLT slabs placed limitations to the architectural layout, including the location of the core and openings, and necessitated the complex scissor stair uncommon in building's of oN5's size. Hemsworth noted that the technical demonstration aspect demanded by the owner required a very flexible and dynamic approach that took more time upfront during design.

VDC and prefabrication—Trade-offs

The team's collaborative approach was critical for oN5's delivery to transition into the VDC process. This transition was closer to design-build and included challenges associated with coordination of a larger team pre-construction.

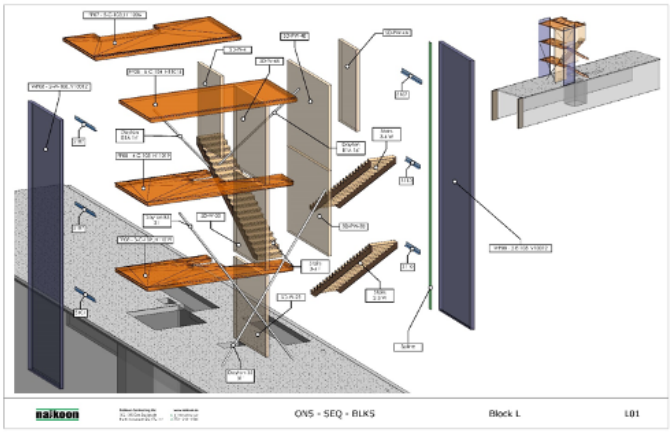
The VDC process was required for the parallel development of the CLT prefabrication and construction design that had to be substantially set for the start of construction. The prefabrication, structural and assembly constraints, along with the integration of new technology meant the architect's vision of an all CLT interior was not possible. While storeys two through four have exposed CLT, it was not possible on the ground floor.

The advantages of prefabrication come with trade-offs: architects need to learn and gain expertise in understanding when prefabrication's advantages are "net positive" given the trade-offs, for a project's goals and constraints.

Building detailing—Architect builder partnership

The integrated approach to construction had significant benefits for oN5's building envelope detailing. Hemsworth Architecture's expertise in high energy performance, together with Naikoon's expertise in construction method and means during design helped to meet performance requirements, and finishing, ensuring the design intent was executed successfully and cleanly. They were focused on solutions rather than guessing (and making mistakes) on what the other meant during the high pressure, time-sensitive site construction phase for oN5.

Site assembly plan: Block L — diagram and schedule.



(Diagram: Adapted from Naikoon assembly plan)

THE OWNER'S PERSPECTIVE

Robert Malczyk, who was also the timber specialty engineer on the project, felt the strongest factor of success was the seamless integration of the core project team, necessary for the amalgamation of expertise, experience and collaboration that was required upfront for oN5 to achieve its technical goals under real-world constraints.

Robert wanted to hire consultants and contractors who were committed to the success of the innovative project and could work as a team. It was important to be able to reach the key project and business decision-makers at any time the project demanded and have discussions and make commitments between staff at all levels between firms.

The size and scope of the project (budgeted for $5 million) fell between small and medium contractors: it was too small for large contractors to justify the overhead, but the project required commercial construction management and overhead not typically available from small firms (that mostly focussed on residential).

Seamless integration of project team

In the end, a team was selected that had worked together before—Hemsworth Architecture, Naikoon Contracting Ltd. and Equilibrium Consulting Inc. They understood the project and each other's work style and saw oN5 as the next step in developing their working relationship. As the design matured, expert consultants, trades and suppliers were brought on to advise oN5's design for off-site construction, rapid on-site assembly and energy performance.

The core team formalized the collaborative delivery of oN5 with a non-binding team charter, detailing expectations for collaboration and procedures that compliment traditional contracts. As testament to the level of trust between the owner and the construction manager, the CCDC 5B construction management project was left open for the entire project.

CORE CONTRACTS

The core team utilized standard contracts common in BC.

- **Equilibrium Consulting**
- **Hemsworth Architecture: RAIC Document 6**
- **Naikoon Contracting: CCDC-5B**

Core team—single organization

oN5's success required the tight overlapping scopes of work to be coordinated. The core team functioned like a single organization, with strong relationships and commitment to team success. For example, the architect utilized a scissor stair that opened more area for the office levels, but required intricate coordination between code, structure and constructability during design, for rapid, safe and efficient erection later.

Teams on high-pressure, innovative projects often risk burn-out that can erode relationships, collaboration, and commitment critical to success. The oN5 team was able to overcome disagreements through compromise, preserving team integrity and ensuring follow through to success. Robert said, "We argued a lot, but always found solutions we can all live with. We never doubted we would all work to make the project a success".

Innovative technologies & team

oN5 is best described as an integrated system of innovative technologies and practices, delivered by an innovatively integrated team. For example, Tectonus collaborated with the structural engineer to design the dampers to Canadian codes—while simultaneously working with Naikoon to ensure the dampers would be coordinated for their VDC methodology. The construction manager, structural engineer and wood fabricator's direct collaboration also allowed the integration of adjustability and constructability considerations for the CLT and structural steel that would be key to successful rapid on-site assembly and envelope detailing.

"Ultimately, the value of innovations is not measured in technical journals, magazine pictures or interesting stories, but by the commercial viability, long-term building performance, and desirability of the building in serving people's needs."

- Robert Malczyk, Timber Engineering

VDC FOR ON-SITE ASSEMBLY

Naikoon was responsible for the VDC model, but the process required the continued attention of consultants during weekly coordination meetings to ensure design intent was maintained and to help with the development of integrated solutions.

"Live" VDC model

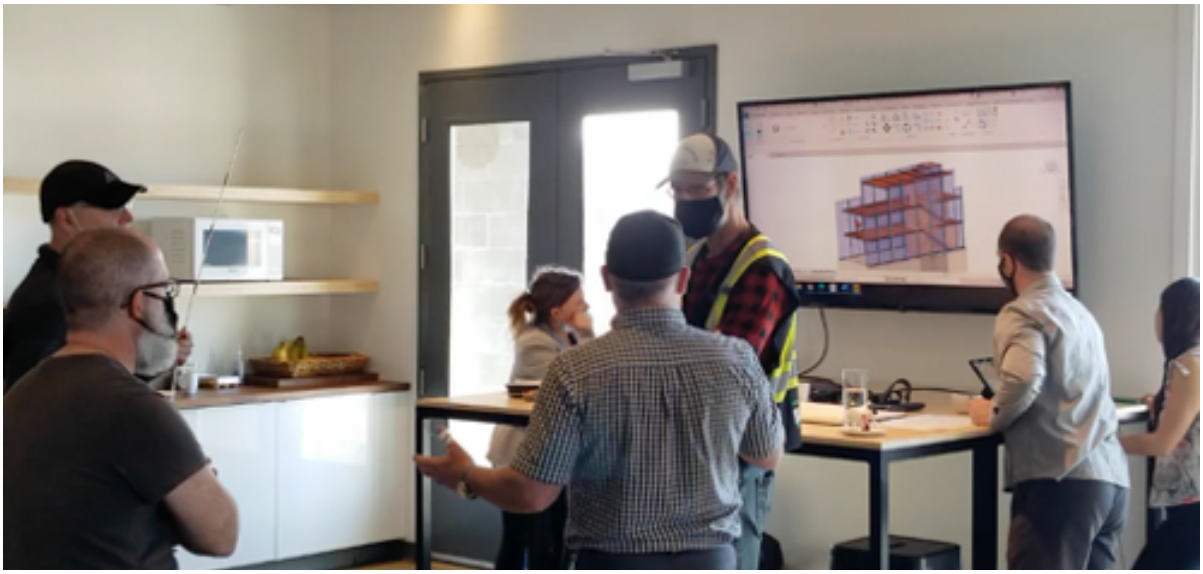
The BIM-VDC model used for the site assembly required practices, software tools and workflows that were "live": dynamic and agile enough to keep up with on-the-fly decisions during coordination meetings. This needed to be organic to support quick iteration and rapid assessment of cost, time, logistics, that could have significant impact on team decisions. For example, the detailed BIM-VDC model was utilized by the engineer to design temporary supports for the end of each day's site assembly. The step-by-step model provided an exact twin of any possible situation for the structural engineer's design, even if the assembly team was behind or ahead of schedule.

Trade collaboration

oN5's off-site construction and rapid site assembly required very close integration of key trades and suppliers into the VDC process during project design. For example, Naikoon worked closely with Eagle West Crane to plan out the transportation, lifting and logistics, for the long and narrow building that had restricted lines of sight at the north elevation. VDC controlled costs, and helped the team plan the safe flying of panels and the planning of temporary supports required to keep the structure stable and safe.

"The relationship between owner, architect, engineer and construction manager based on trust, balance and openness, allowed the team to focus on solving issues and developing innovative solutions—the fun stuff—and not who to blame when things go wrong."

– Brant Forrester, Naikoon Contracting



Pre-construction meeting with crane operator. (Photo: Scius)

ON-SITE CONSTRUCTION SEQUENCE

Naikoon's organic BIM-VDC capabilities—including Revit modelling, sequencing, time-lapse and animations, ensured the site assembly was planned and executed successfully.

Simultaneous construction

oN5's site cast concrete foundations and concrete masonry unit (CMU) first level walls were designed and built conventionally and completed on-time and on-budget a month before the CLT wall panels were due to be installed. The CLT panel preparations at Naikoon's lay-down yard was completed ahead of time, weeks before foundation completion.

Virtual twin

Naikoon built the virtual twin of oN5 in-house from the CLT fabrication model, with feedback from the architect and engineer during weekly progress meetings, as well as feedback from key on-site contractors: in-particular the crane company and the traffic contractor.

Sequence time-lapsed videos

Naikoon created a series of sequence time-lapse videos and animations from the VDC model as briefing tools for the rapid site assembly of CLT panels, and the envelope connections. The VDC model also produce the block assembly plan. Together, the site assembly team was fully briefed and ready with a complete understanding of what, when and how each panel was to be flown and assembled, down to 15-minute increments.

The videos/animations and block assembly plan were the most important daily work plan tool. Knowing the details ahead of time, enabled the crane operator to fly many of the panels into place blind. Naikoon's erection team was able to minimize down-time: staging shoring, steel connections, tools, etc. for the next panel, and connecting the envelope details between panels, as the next panel was being prepared.

Naikoon also used these as briefing tools to prepare replacement team members (site assembly happened during COVID-19), ensuring they were prepared and safe for the day.

"There definitely were constraints given the integration of technologies, the construction focused VDC process and a demanding owner, familiar with the building industry. The architect's design intent and professional obligations also had to be hard coded into the process to work, which could have been frustrating between the different stakeholders. Fortunately, the team's relationship, trust and focus on project success made oN5 not only successful, but a pleasant project. We look forward to this team's next ambitious project."

~Project Architect, Dean Shwedyk

BIM virtual design and construction model. (Image: Naikoon Revit Model)

ON-SITE ASSEMBLY: CLT CONNECTIONS

From top to bottom: CLT walls, floors and wood components followed the assembly plan; from delivery to trade tasks. Tasks in the assembly plan covered every aspect of assembly, from install, to shoring, to connections, and back-framing. (Images: Top, Scius; Bottom, Naikoon)

Daily start-up routine

At the start of each day, Naikoon's site manager would use the assembly plan to lay out the day's work, noting panel and wall locations and approximate shoring points and preparing the steel angles and equipment.

Typical CLT wall panels

Each structural wall panel was delivered sequentially by truck, per the assembly plan sequence.

Panel flying: Each panel was lifted via a custom lift system and flown into position, often precisely between wall or floor CLT panels and temporary shoring.

Panel alignment: The crew would make fine adjustments for plumb/level, and secure the panels using rolling ladders, ladders, and lifts to reach 2 or 3 levels up as needed.

Connections: The structural-envelope connections for each panel were completed as subsequent panels were flown and installed.

Typical panel installation sequence from back to front

Truck delivery of CLT panel.

CLT panel flying.

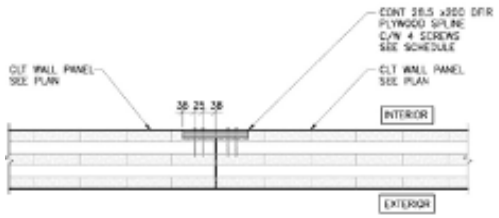
CLT panel alignment.

Structural connections.

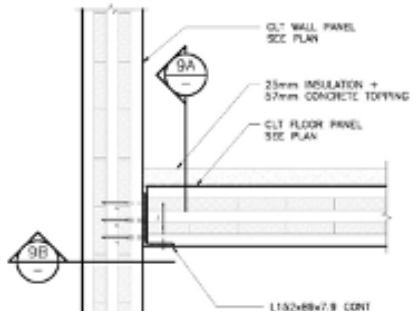
Temporary shoring.

Completing connections and keeping productive before the next delivery. (Timelapse: Multivista)

ON-SITE ASSEMBLY: CLT CONNECTIONS



Wall to wall connection details. (Drawing: Timber Engineering)



Floor to wall connection details. (Drawing: Timber Engineering)

The team tried several different methods to streamline the fastening of the large number of screws and bolts, particularly with the wall-to-wall plywood panels. In the end, marking the pattern on the plywood, and the steady hand of a tradesperson was the best method. Key CLT connections comprised:

Structural wall-to-wall

The butt-joint CLT wall connections were completed with a self-adhered membrane behind pre-cut 30-centimetres wide by 2.54-centimetres thick plywood structural spline with a tight pattern of screws. Note this plywood panel is a finished surface, flush with the finished, interior side of the CLT wall panels.

Structural wall-to-floor

The wall-to-floor panel connections with L-angle steel, flush-fit on the underside of each CLT floor panel, and part of the CLT wall surface. A tight screw pattern on both legs of the L-angle.

Structural wall-to-roof

The roof connection is like the structural wall-to-floor connection. However, with the roof panels, the vapour barrier membrane was installed off-site at the laydown yard, as temporary rain protection during and after installation, until the roof assembly was completed.

CLT wall panel to concrete suspended slab connection (note: pre-milled channel and "blind" fire wall assembly). (Image: Naikoon)

Interior air barrier taping behind plywood wall splines. (Image: Naikoon)

ON-SITE ASSEMBLY: CONNECTION TYPES

oN5 used different screws, spacing and patterns depending on the connections on the previous page. The VDC and sequencing sessions was key to ensuring the Naikoon team was aware of which was for what, minimizing the chances of difficult to detect errors.

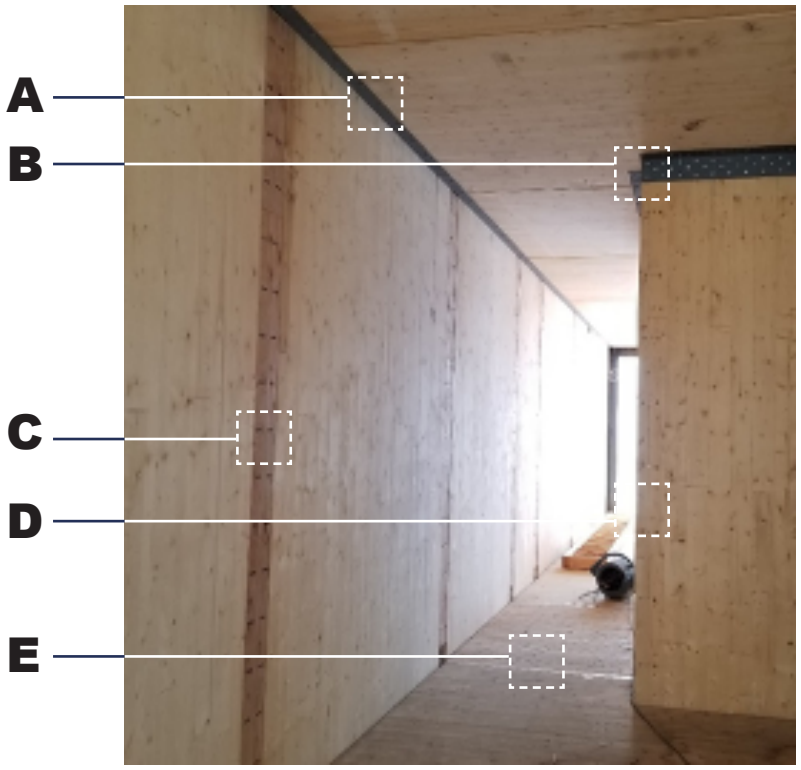
A. 2 types, Simpson strong-tie fasteners for each leg of L-angle steel, CLT floor ledger to CLT wall.

B. 1 type, Simpson strong-tie fastener for both legs of L-angle steel, CLT floor ledger to CLT core.

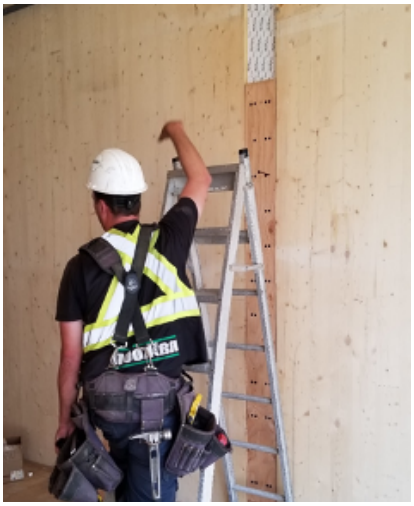
C. 1 type, Simpson strong-tie fastener for all plywood spline panels, widening spacing from 100 to 500 each level up, 2 to 4 floors.

D. 2 types, Simpson strong-tie fasteners; depending on the connection, the screws, spacing and pattern is different.

E. 1 type, full-thread, counter-sunk fasteners for TS3 floor butt-joint; different spacing depending on the distance from the building core.



(Photo: Scius)



Naikoon trade installing some of the numerous screw connections. (Photo: Scius)

ON-SITE ASSEMBLY: TECTONUS INSTALLATION

The most challenging assembly was the 7-ply CLT core panels, each of which weighed 4,080 kilograms. The alignment, connection and shoring were complicated by the fact the panels had bowed while resting on dunnage at the laydown yard and took more time than expected to install on-site. The north and east panels had the Tectonus and associated steel hardware pre-fitted to facilitate quick installation on-site:

Template layout and base preparation

Cast-in-place bolts and rods were fit precisely by creating templates of their corresponding steel hardware on the core panels at the laydown yard. The concrete base was also left uncast to provide a level of adjustment under the steel hardware, filled and grouted after the panels and Tectonus were successfully connected.

Tectonus installation

Each damper was aligned on to the embedded steel connections and braced in the exact position for the CLT panels to be dropped in place. A steel shoe was installed onto the panels prior to flying and installation.

Precise panel flying

The core panels each had to be precisely lowered onto the Tectonus and steel, requiring detailed coordination between the crane operator and the site manager.

Fine alignment and connection

With the panels hanging over the Tectonus and steel hardware, Naikoon made careful, fine adjustments, checking for alignment as the panel was lowered, connecting the Tectonus to the CLT panels with bolts.

Temporary shoring

The large panels were adjusted for plumb/level and shored like typical CLT panels.

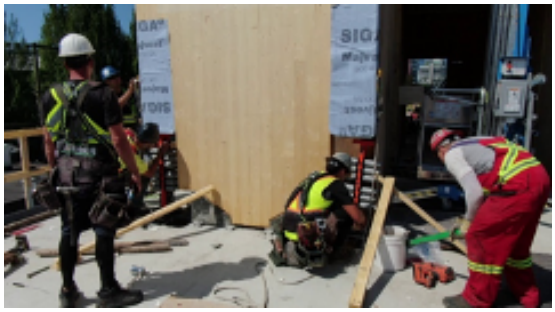
Core panel connections

Corner butt-joints required tight pattern screws.

Installing steel panel connections.

Precise flying of the CLT panels to its exact location.

Aligning the steel connections.



Connecting panel connections to embedded steel hardware.
(Photos: Naikoon)

ON-SITE ASSEMBLY: ADHESIVE SYSTEM

TS3 butt-joining bonding technology was used to achieve 7-metre wide biaxial CLT slab spans.

Developed in Switzerland by Timbertec, the TS3 butt-joint adhe sive system was developed to realize typical skeleton buildings consisting of only glued timber elements, without using fasteners like screws, nails or metal plates. Using TS3 meant that the floor slabs for oN5 could be designed to span seven metres without the need for beams—thereby saving costs and streamlining mechanical services layouts.

Using TS3, the slab system works as a flat slab carrying vertical loads biaxial and consists of timber slab elements like CLT glued together on site with a high performing butt-joint bonding technology.

For oN5, the TS3 primer was applied offsite. Once the slabs were installed, the two-part adhesive was injected into the seam via pre-drilled holds that forced the adhesive in from the bottom of the joint up, thereby ensuring a uniform and complete cover to the slab edge.

Assembly, toe-screw connection

The floor CLT panel butt-joint had a tight pattern of opposing toe-screws to hold the panels during assembly.

Preparation

Naikoon prepared each joint with a series of angled drilled, channels to allow the glue to flow between and contact the joint surfaces. A layer of air-barrier tape sealed the joint.

Adhesive application

TS3 binary-tube applicator forced the glue into the channels. Channel spacing ensured complete adhesive coverage along the joint.

The adhesive application was not as difficult as expected but did take several days for all CLT floor levels. Training by Timbertec was accomplished via webcam and photos.

The TS3 adhesive was injected into the slab edge seam through pre-drilled holes.

The slabs were propped until the TS3 has cured.

Without glulam beams, the building service runs could be streamlined. (Photos: Naikoon)

FINAL CLT INSTALLATION

The site assembly process went as scheduled. The first panel left North Vancouver on July 19, 2021, and the last panel was installed on site in Vancouver on August 10, 2021—a total of 15 working days from start to finish.

8:20am (start of day 14)

10:20am

11:05am

11:50am

12:50pm

5:00pm (end of day 15)

KEY TAKE-AWAYS

Construction management tracking and planning

VDC and the development of the block plan acted as a data-driven metric for site assembly progress. This allowed carefully planned activities, contingencies, and shift resources to make up time as site assembly progressed and kept both the owner and consultant updated on progress in real-time during rapid site assembly.

Construction flexibility

oN5 demonstrated focused, front-end planning yielded a lean and efficient construction sequence and schedule, which allowed for greater capacity to react to unexpected situations. For example, the difficult fitting of the bolt connections for the Tectonus dampers, and rain (activating the moisture management contingency plan) all had minimal effect on the overall site assembly schedule.

Project team tasking

In addition to construction, the schedule provided a level of predictability for consultant field reviews. This was critical, as the pace of construction was very quick, requiring consultants to be sequenced as tasks during construction, to ensure they did not affect site assembly.

Owner awareness

The block assembly schedule provided a level of certainty for the building owner. While the owner, as principal of Timber Engineer, was very familiar with innovative wood projects, the reassurance provided by the detailed, easy to follow assembly plan was a significant boost in confidence in the ability of Naikoon to erect the building per their ambitious schedule.

Naikoon Contracting - site assembly team. (Photo: Naikoon)

Budget (exc. land costs)
$4,300,000

Square feet cost
$475

Budget variation
None (on budget)

Construction time
15 months

Mass timber assembly
15 working days

Schedule variation
None (on budget)

Air tightness
0.60 ACH @ 50 Pa

This is the fourth in a series of bulletins regarding oN5. Other bulletins include: introduction; high performance low carbon construction; off-site construction experience; and regulatory perspectives. All bulletins can be found at www.naturallywood.com/project/on5-building.

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