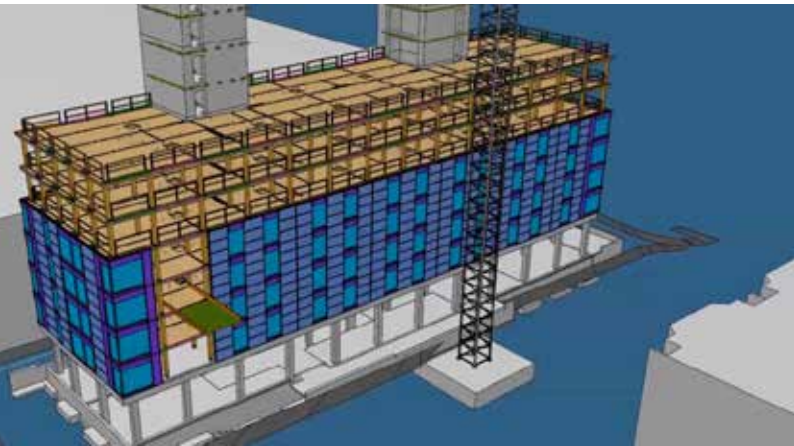


INNOVATION IN HYBRID MASS TIMBER CONSTRUCTION

TALLWOOD HOUSE

BROCK COMMONS TALLWOOD HOUSE
CONSTRUCTION MODELLING





INTRODUCTION

The University of British Columbia is at the forefront of the contemporary movement to revitalize mass timber construction and demonstrate potential applications for engineered wood products. The innovative wood buildings erected to date on the Vancouver campus have been primarily institutional and operational, such as the Forest Sciences Centre, Campus Energy Centre, and Wesbrook Community Centre. The newest building, and the first residential one, to be added to the portfolio is the University's tall wood building: the 54-m-high (18-storey) Brock Commons Tallwood House.

Brock Commons, which was completed in May 2017, is the first North American use of mass timber products in a residential high-rise. It is one of the University's five planned, mixed-use, student residence complexes which are designed to provide affordable housing for students while acting as academic and recreational hubs for the campus community. While the overall design of the residences is similar, Brock Commons Tallwood House is unique in the use of a hybrid mass timber structure. The foundation, ground floor, second-floor slab, and stair/elevator cores are concrete, while the superstructure is composed of prefabricated cross-laminated timber (CLT) panel floor assemblies supported on glue-laminated timber (GLT) and parallel strand lumber (PSL) columns with steel connections. The building envelope is comprised of prefabricated, steel-stud frame panels with a wood-fibre laminate cladding, and a traditional SBS (styrene-butadiene-styrene) roof assembly on metal decking.

FACTS

- HEIGHT IS 54 M (18 STOREYS)
- SITE AREA IS 2,315 M²
- GROSS AREAS IS 15,120 M²
- FOOTPRINT IS ABOUT 15x56 M, TOTALLING 840 M²
- TYPICAL FLOOR-TO-FLOOR HEIGHT IS 2.81 M FOR THE MASS TIMBER STRUCTURE ON THE UPPER FLOORS, AND 5 M ON THE GROUND FLOOR

FRONT COVER
CadMakers Inc.

BACK COVER
KK Law

VDC is a subset of BIM in that it primarily focuses on the 3D geometric representation of a facility to support analysis for design and construction of a facility, but does not necessarily contain product information such as product data and specifications.

The project team used an integrative design approach that included the construction manager, as well as select trades, working collaboratively with the design consultants on design development, regulatory approvals, and extensive preconstruction planning. Key University stakeholders were also actively involved throughout the project. A unique feature of Brock Commons' design and construction processes was the intensive use of virtual design and construction (VDC) tools and methods. VDC modelling is supported through building information modelling (BIM), which is a data-based project-delivery process centered on the collaborative, multi-disciplinary development of an integrated digital model of the building, and its components and systems. The model serves as a tool to support design decisions, coordination, and construction planning, and it can later be used to manage the building's operation and maintenance, as well as renovations and end-of-life decommissioning. While BIM tools are gaining in popularity around the globe, adoption and implementation are still limited in Canada.



DIGITAL MODELLING

VIRTUAL DESIGN AND CONSTRUCTION MODEL

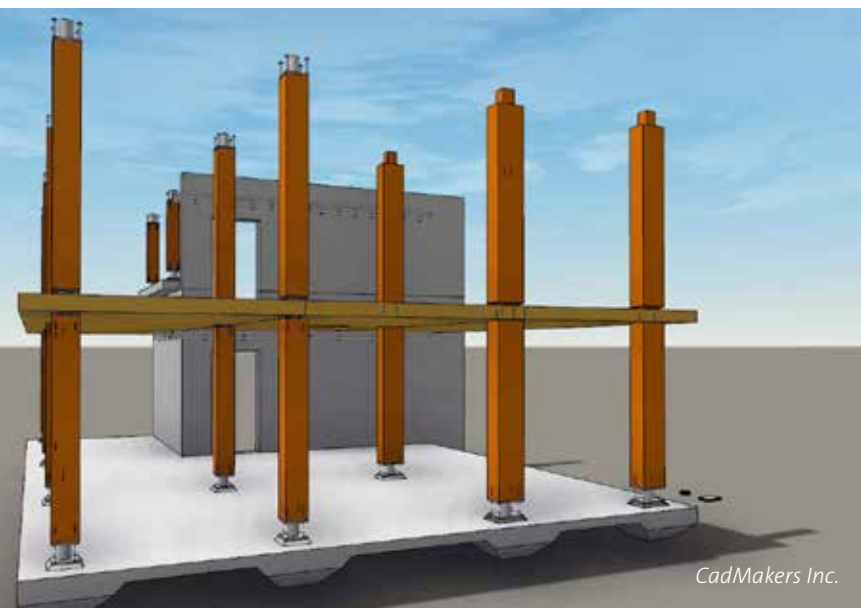
As part of Brock Commons' design and preconstruction phase, a virtual design and construction (VDC) model of the building was created. This VDC model was a comprehensive 3D model composed of all the building elements, from the structure to interior finishes to the mechanical and electrical systems.

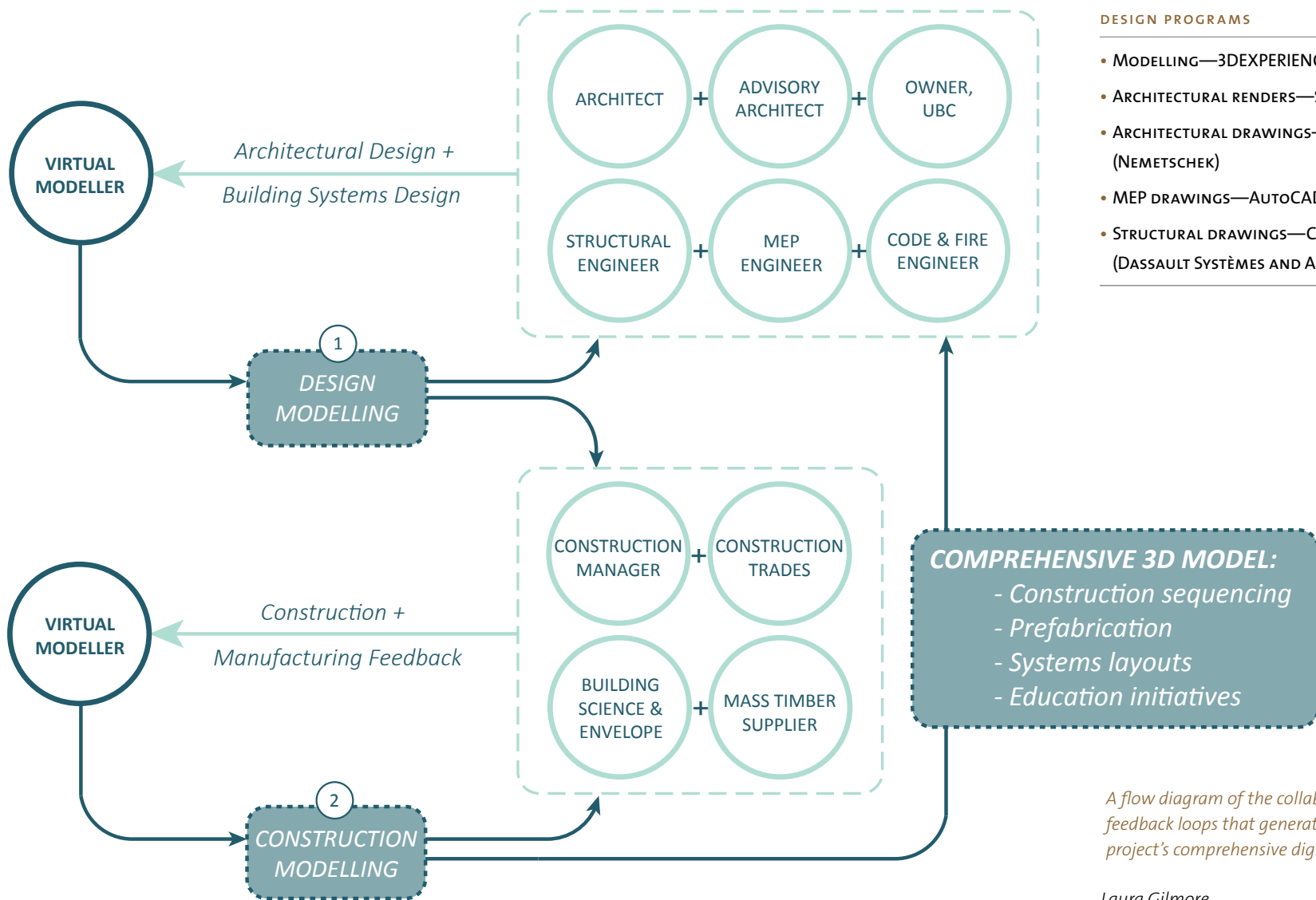
CadMakers Inc., the dedicated VDC consultant, worked from the consultants' 2D drawings and 3D models concurrently with the development of the stamped construction documents. Every detail, including excavation, was included, along with precise geometries, so that any construction process could be animated and any element or set of components could be exported in various formats.

During the design phase, the VDC model's primary function was to assist in design development and decision making. The modellers worked in close collaboration with the design team, promptly incorporating design iterations and updates and notifying the team of any issues and conflicts that needed to be addressed, in order to ensure the model was

always accurate and detailed in its representation of the project. The VDC model also functioned as a tool for communicating with the construction trades prior to tender. It helped in describing the scope of work relative to the project as a whole and in demonstrating that the design, while innovative, was not complex or highly risky.

During preconstruction, the VDC model was used to create a full-size, proof-of-concept mock-up of part of two floors of the building. The mock-up helped to validate the VDC model, as well as the design decisions, with the help of feedback from the trades. It also provided an opportunity to study constructability and installation feasibility, test communication procedures for prefabrication, select installation equipment, and identify options for efficiencies. These experiences and knowledge informed the construction planning, including sequencing and prefabrication assembly packages. The VDC model was also the basis for the fabrication model that was used directly by the CNC machines for the CLT panel stress tests.





DESIGN PROGRAMS

- MODELLING—3DEXPERIENCE (DASSAULT SYSTÈMES)
- ARCHITECTURAL RENDERS—SKETCHUP (TRIMBLE)
- ARCHITECTURAL DRAWINGS—VECTORWORKS (NEMETSCHKE)
- MEP DRAWINGS—AUTOCAD (AUTODESK)
- STRUCTURAL DRAWINGS—CATIA AND AUTOCAD (DASSAULT SYSTÈMES AND AUTODESK)

COMPREHENSIVE 3D MODEL:
 - Construction sequencing
 - Prefabrication
 - Systems layouts
 - Education initiatives

A flow diagram of the collaborative feedback loops that generated the project's comprehensive digital model.

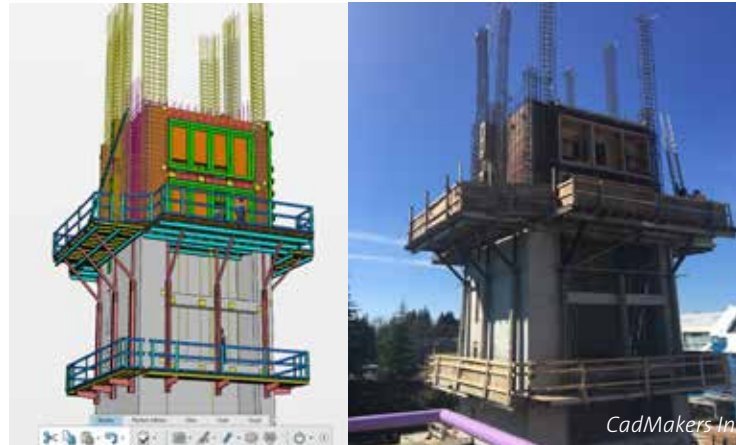
Laura Gilmore

USE OF VDC MODEL IN CONSTRUCTION PLANNING

As the project owner, the University at the outset directly hired the VDC modelling firm to be a part of the project team, and the firm's modellers functioned as facilitators throughout design development and construction. The VDC modellers represented the owner's interest, rather than a specific discipline, and were empowered to contact the consultants and trades directly to request and coordinate details of the building elements and assembly. The communication between team members and the VDC modellers was constant and included formal reports which tracked design changes, as well as phone calls, emails, and coordination meetings. This approach enabled them to keep the model updated and address challenges and improvements throughout construction.

The VDC modellers worked closely with the construction manager, Urban One Builders, and the rest of the team, on the construction planning for Brock Commons. The schedule for the project was very aggressive, which, along with the small size of the site, placed importance on the coordination of the production, storage, delivery, and installation of all the building components. The planning was a highly collaborative process; it included input and feedback from all the specialized trades and personnel regarding the constructability and safety of building assemblies and the sequencing of specific activities.

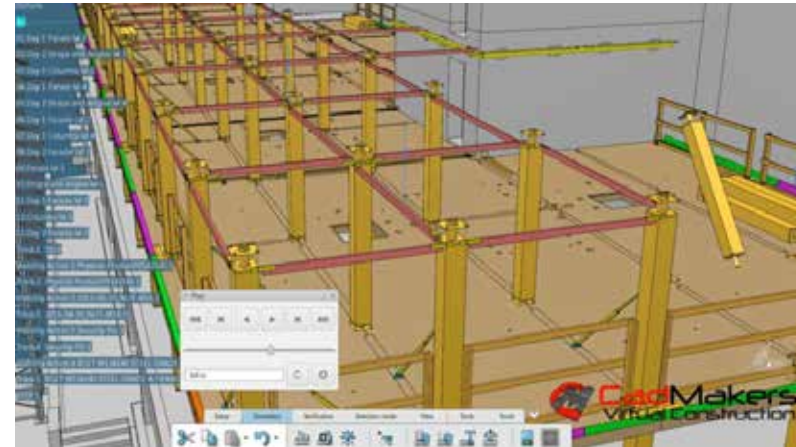
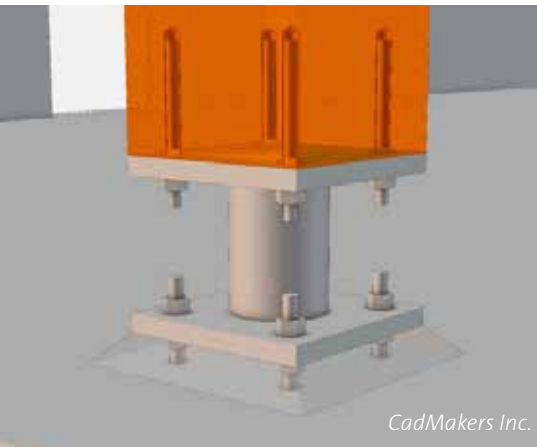
As a key tool within the planning process, the VDC model was used to develop animated simulations that illustrated the sequences of installation and assembly outlined in the construction schedule. Also known as time-based construction modelling, these animations were highly detailed and based on 1-hour increments. Animation was essentially a virtual construction process for the building, which allowed the construction manager and the trades to work through the installation procedures in 3D and confirm their feasibility prior to actual construction.



Modelled and actual construction.

Some assumptions about the time required to complete tasks, for example regarding crane speeds, had to be made prior to the beginning of construction, and these were included in the original schedule. However, over the course of construction, the modellers recalibrated the simulations to reflect the actual durations of activities as they became known, thus improving the planning and scheduling of the remainder of the work.

The model was also employed in financial planning through the development of rapid budget prototyping. Individual budgets were developed by the construction manager and the VDC modellers, with input from the design-assist trades, for each design decision point, using materials quantities from the model, and estimates of labour productivity and work-step durations. Due to the extensive detail available in the model it was possible to create accurate materials quantity estimates in real time. These budgets allowed different options to be analyzed and helped control the project's finances.



PREFABRICATION

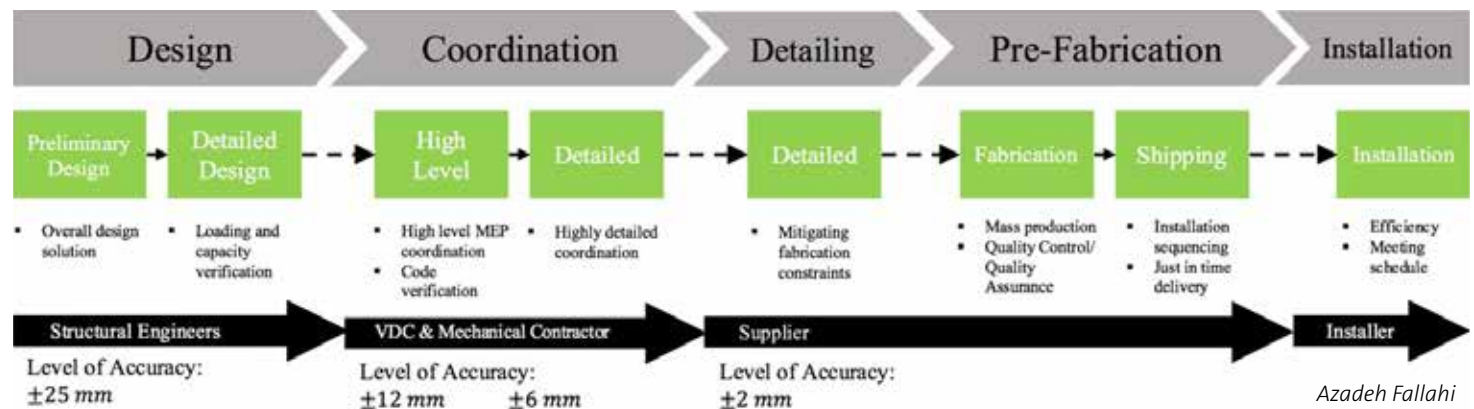
USE OF VDC IN PREFABRICATION AND SYSTEM DESIGN

Prefabrication of structural and envelope components was a key strategy in meeting the project's timelines and budgets. The Brock Commons project used this type of construction approach—i.e., “kit-of-parts” prefabrication—to an extent not usually seen in high-rise residential building construction.

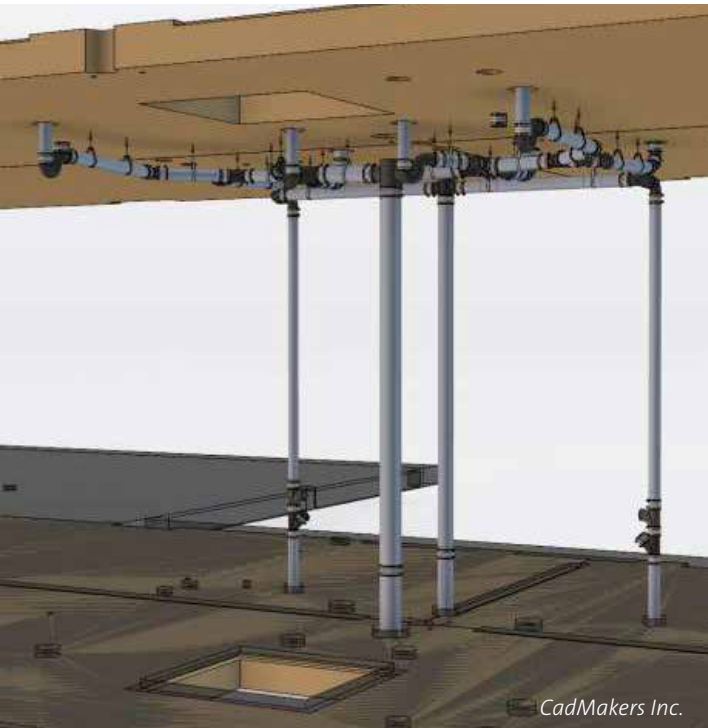
For the mass timber structure, models of the specific components were generated from the VDC model and validated by the structural engineer and transferred directly to the mass timber supplier, Structurlam Products LP. This included the wood elements—CLT panels, and PSL and GLT columns—as well as the steel connections and drag straps. The steel fabricator was subcontracted to the wood fabricator in order to streamline the process and achieve the tight tolerances. The supplier then modified the model to ensure the tight tolerances were achieved—while accommodating the mechanics of fabrication, such as saw thickness and drill-bit diameter—and then used the resulting fabrication model to operate the CNC machine to cut the pieces to size and drill the penetration holes. The tolerances for the mass timber components were ± 2 mm, a requirement that would have been challenging to meet without the use of the VDC model.

The mechanical, electrical, and plumbing (MEP) systems on this project were included in the VDC model. Typically, engineers design these systems and their specifications but leave the spatial layouts to the construction trades to decide at the site in conjunction with the construction manager or general contractor. For Brock Commons, the VDC modellers worked with the engineers and the trades to fully design and model the layout of the MEP systems within the building.

This level of detail was required for the prefabrication of the CLT panels so the cutouts for each system penetration could be made during fabrication rather than on site. It also enabled the construction manager and trades to develop an accurate bill of materials and detail the sizes and dimensions of the system components to facilitate procurement, off-site preparation, and on-site assembly and installation. For example, the detailed modelling of the mechanical room enabled the cutting and welding of pieces to be done off site, thus reducing the on-site construction time from the typical 3 to 4 months to less than 1 month.



Azadeh Fallahi



CadMakers Inc.



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Detailed modelling of the building systems, in coordination with the mass timber structural elements.



CONSTRUCTION

EFFECTS OF THE MODEL ON THE CONSTRUCTION PROCESS

The detailed planning and sequencing, along with the prefabrication of major elements, enabled the project team to meet an aggressive schedule: the concrete foundation, ground floor, and second-floor transfer slabs were completed in 3.5 months; the concrete stair and elevator cores were completed in 3.5 months; and the mass timber structure, the steel roof, and the majority of the envelope were completed in about 3 months. Also, detailed planning, made possible by the VDC model, allowed construction processes to be standardized and streamlined.

Interdisciplinary cooperation among the project team during construction was critical. The VDC model was an important tool in facilitating communication between team members by giving everyone a common frame of reference. Construction planning, using the modelling of construction sequences, was a collaborative effort that helped to secure buy-in from the construction trades. The on-time performance required by the aggressive schedule was a challenge for some of the trades that were accustomed to more flexible timelines for on-site work. The trades' input not only helped ensure a realistic work plan and schedule, but also helped give them a sense of ownership in the project.



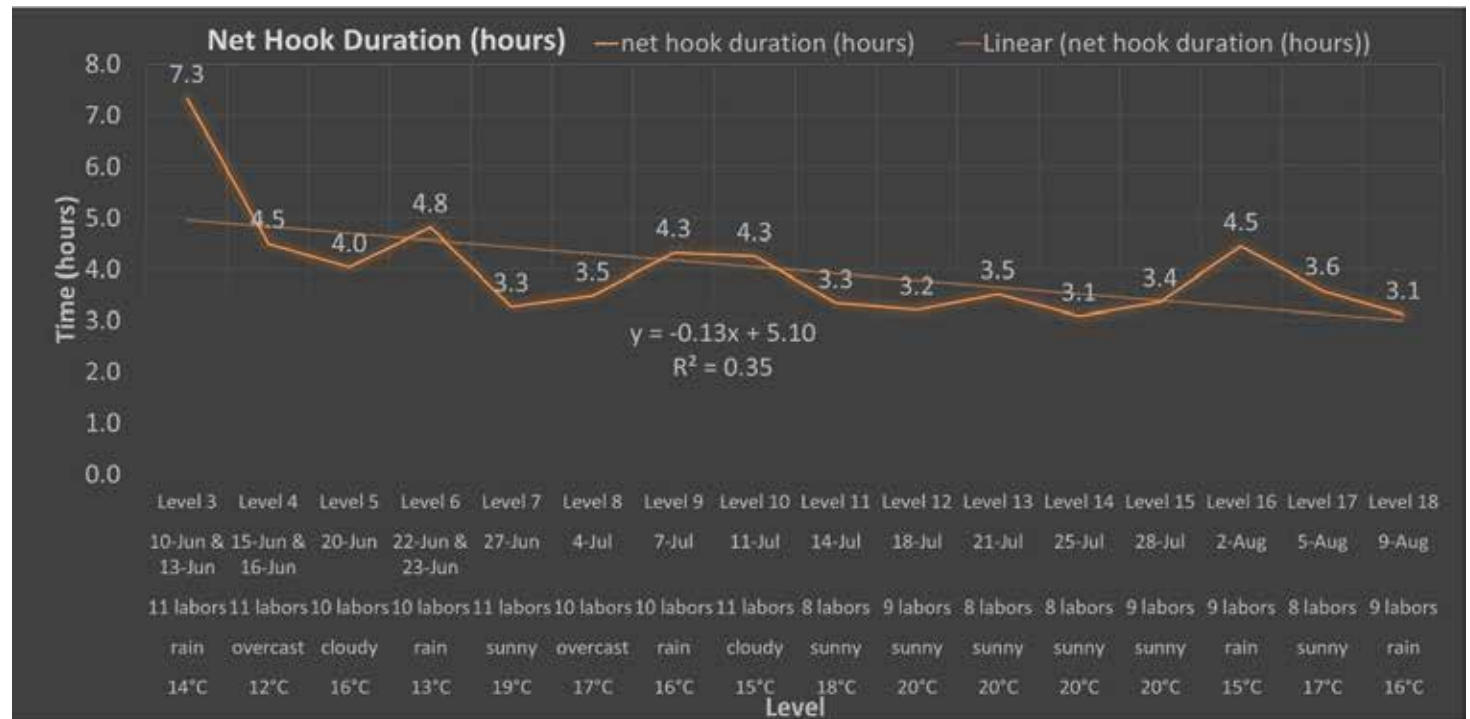
Azadeh Fallahi

The total construction duration of the 17 floors of mass timber structure was less than 10 weeks, and the total duration of installation of 16 floors of envelope panels (excluding the ground-floor curtain wall) was less than 9 weeks.

As part of the sequencing, the prefabricated components were sorted and loaded onto trucks to minimize on-site handling. Thus when a truck reached the construction site, the components could be craned out in the required order and directly installed on the building or positioned in staging areas on each floor. The model helped the construction team visualize the work, establish the loading and installation order for the components, and facilitate the coordination between the different crews on site.

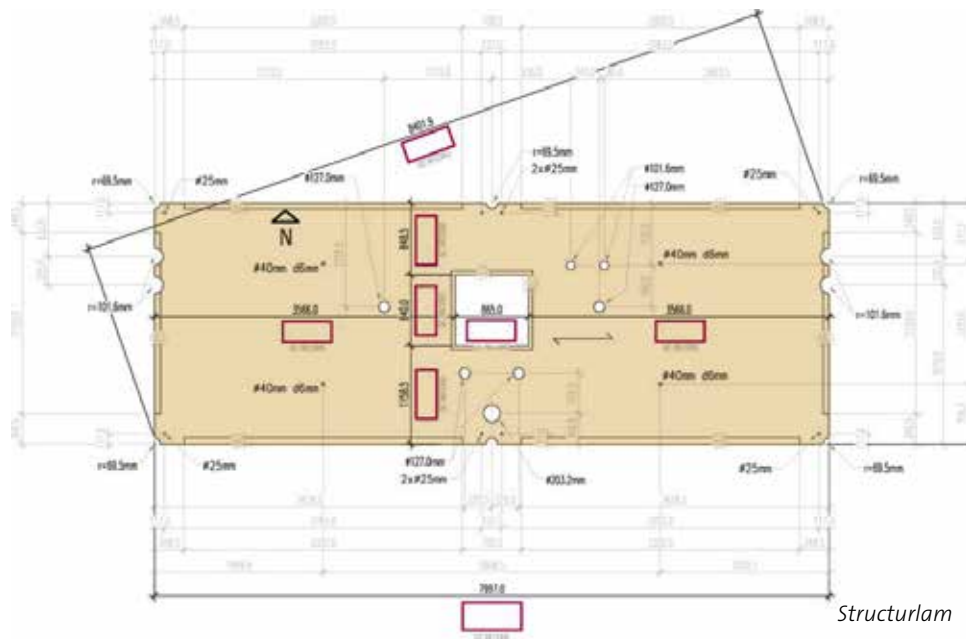
The repetition of the structural and envelope design on each floor and the use of a standardized installation sequence also contributed to the trades' learning efficiencies as the project progressed. For example, based on a productivity analysis of hook time, the first floor of CLT panels (floor 3) took 7.3 crane hours to install, while the last floor (floor 18) took 3.1 crane hours. And, the first floor of residential envelope cladding (floor 2) took 12.7 crane hours to install, while floor 15 took only 4.4 crane hours.

Analysis of on-site productivity by measuring hook time—the duration of one cycle of the crane used to deliver materials to the floors. During the mass timber construction there was a total of 464 crane cycles, or 29 cycles per floor. Variation typically corresponded to changes in weather conditions, the number of workers and their level of familiarity with the process, and, in two cases, instances of rework. By Mohamded Kasbar.



Prefabrication and just-in-time delivery decreased the extent of on-site assembly time, which was somewhat complex because of the limited size of the construction site. These processes also improved the quality and precision of the components, productivity of fabrication, and overall safety for the trades because the detailed work and critical tasks could be completed in the controlled environment of the factory rather than on site by workers at significant heights in variable conditions. Prefabrication also reduced waste, both on and off site, because the specific sizes and dimensions of components were determined in advance by means of the VDC model and the components were made or cut to the tight specific specifications, with limited trial and error being necessary.

The model was sent to the fabricator in an STP file format. STP is a simple geometric file that can be utilized by different software programs. The VDC modeller used CATIA, and the fabrication process used Cadwork Wood.



LESSONS LEARNED

The VDC model facilitated planning and communication throughout multiple aspects of the design and preconstruction phase and the construction phase because it provided a comprehensive, accurate, and highly detailed representation of the building.

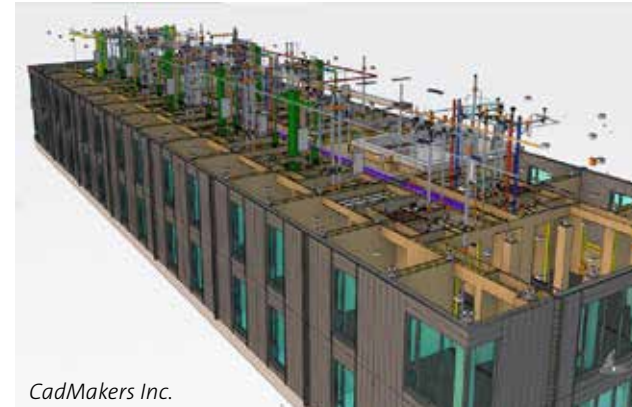
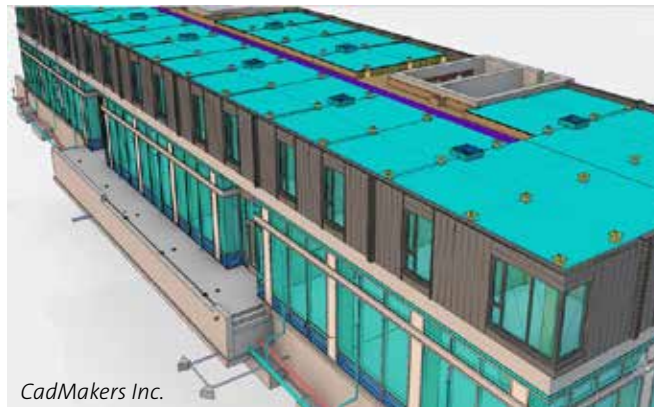
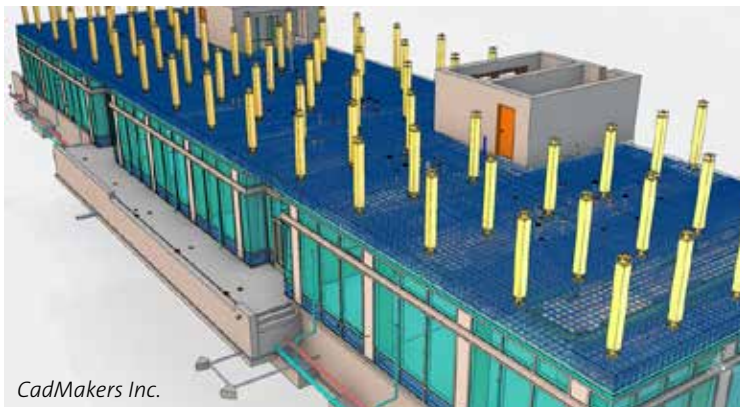
The owner empowered the VDC modellers to collect information from the entire project team, and act as facilitators through the entire project.

- The VDC modellers worked directly with the consultants and trades to understand the building design, the constructability and safety issues, and the installation processes, and to identify areas of potential clashes or improvements.
- The model was kept up to date throughout the construction phase by incorporating design changes in the drawings, site instructions, requests for information responses, approved shop drawings, and as-built deviations.

The use of the VDC model helped minimize issues related to communications among the construction crews—e.g., crew positioning and activities, types of required equipment, and understanding the various roles within the larger process—which allowed the construction manager to focus on other matters, such as identifying opportunities to improve construction efficiency.

Use of the single primary model as the basis for prefabrication design and coordination was key to making the rapid assembly process possible.

- The MEP contractors created a detailed design layout for the building systems with the VDC modellers prior to the fabrication. This design helped inform the locations and sizes of the cuts in the CLT panels during prefabrication, thus ensuring all the components would fit together correctly.
- The VDC model was transferred directly to the mass timber fabricator to use in the prefabrication of the CLT panels and GLT/PSL columns—with all the specific dimensions, cuts, and penetrations included in the file—thereby minimizing on-site work and rework.
- The construction manager utilized the VDC model to create the installation sequencing and procedures, including the grouping and shipping of elements to the construction site, in order to optimize the use of the crane and the crews.



CASE STUDY

This case study was prepared by the University of British Columbia's Centre for Interactive Research on Sustainability. The contributors are:

Angelique Pilon, PMP, MArch
 Zahra Teshnizi, MASA, CPHD
 Laura Gilmore, BEDS
 Diana Lopez Behar, BEng
 Salah Koleilet, URPL
 Joseph Rimland, BSc
 Tim Herron, BEd

Information in this case study is based on the findings and documentation of the research team:

Erik A. Poirier, PhD
 Azadeh Fallahi, BSc
 Mohamed Kasbar, BSc
 Sheryl Staub-French, PhD
 Thomas Froese, PhD

PROJECT CREDITS

OWNER
 University of British Columbia,
 Student Housing and Hospitality Services

OWNER'S REPRESENTATIVE
 University of British Columbia,
 Infrastructure Development

PROJECT MANAGER
 UBC Properties Trust

ARCHITECT OF RECORD
 Acton Ostry Architects Inc.

TALL WOOD ADVISOR
 Architekten Hermann Kaufmann ZT GmbH

STRUCTURAL ENGINEER
 Fast + Epp

MECHANICAL, ELECTRICAL, FIRE PROTECTION ENGINEER / LEED CONSULTANT
 Stantec

BUILDING CODE & FIRE ENGINEERING
 GHL Consultants Ltd.

BUILDING ENVELOPE & BUILDING SCIENCES
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BUILDING ENERGY MODELLING
 EnerSys Analytics Inc.

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 CadMakers Inc.

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DESIGN-ASSIST TRADES
 Structurlam Products LP
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CONCRETE TRADE
 Whitewater Concrete Ltd.

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OTHER CASE STUDY RESOURCES (WWW.NATURALLYWOOD.COM)

Brock Commons Tallwood House: Design & Preconstruction Overview

Brock Commons Tallwood House: Code Compliance

Brock Commons Tallwood House: Design Modelling

Brock Commons Tallwood House: Construction Overview

Brock Commons Tallwood House: Performance Overview





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