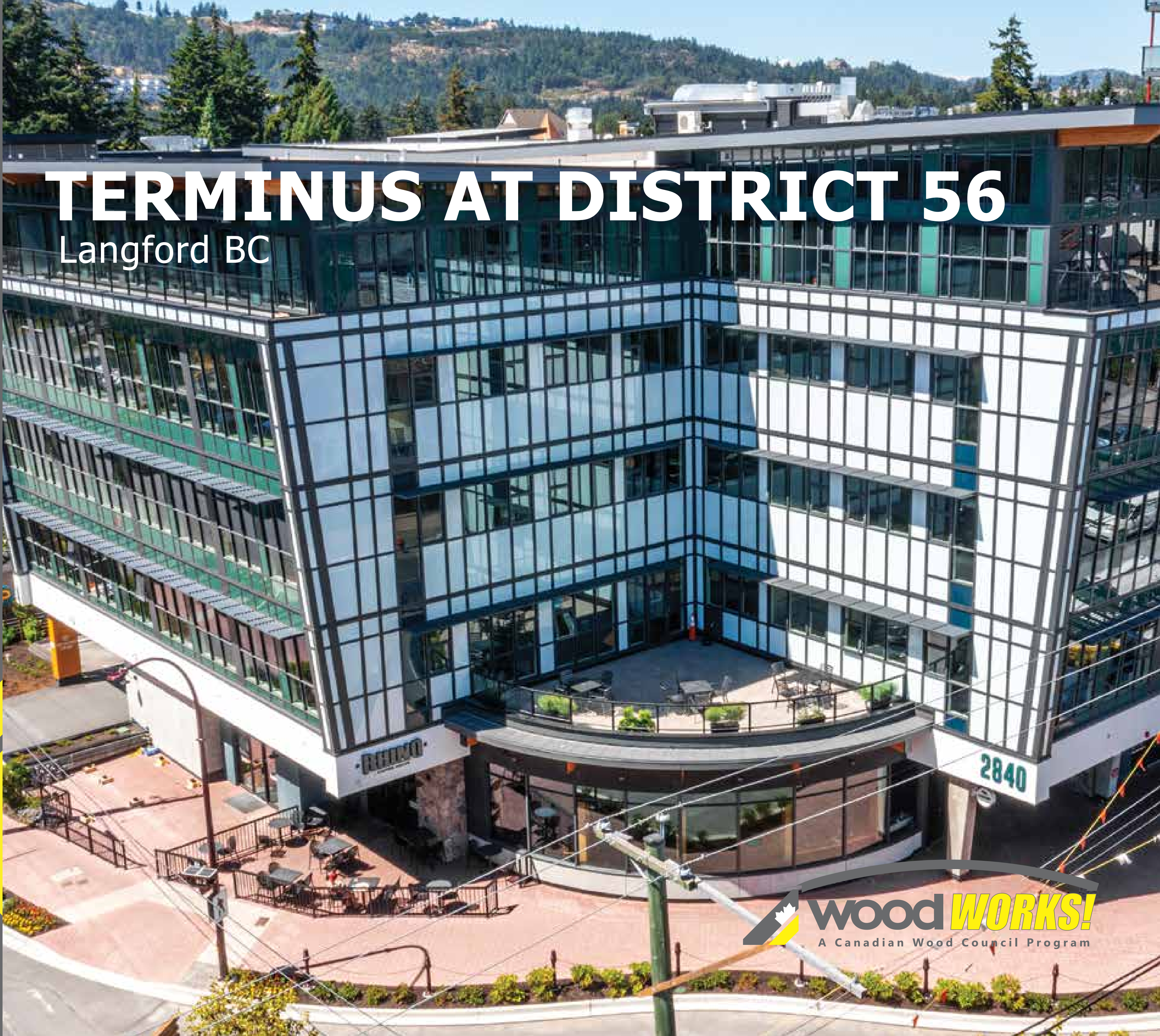
TERMINUS AT DISTRICT 56

Langford BC



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Completed in 2021, and located in the most earthquake prone region in Canada, this five-storey commercial building in Langford BC, is notable for its innovative and elegant exposed mass timber structure; creating an interior environment of the highest quality while setting a North American precedent for seismic design (Figures 1.1 and 1.2).

Figure 1.1: (Cover) Aerial view of the completed Terminus at District 56 project. (Credit Skyscope; courtesy DBS)
Figure 1.2: The interior of the building is notable for its exposed wood surfaces and steel bracing elements. (Credit Dasha Armstrong; courtesy DBS)
Figure 1.3: Location map of Langford BC. (Credit Wikipedia)
Figure 1.4: View of Langford from the west hills in 2012 (Credit Wikipedia)
Figure 1.5: Downtown Langford in 2021. (Credit Skyscope; courtesy DBS)

Figure 1.5

Figure 1.3

Figure 1.4

1.0 Background

Located on the southern tip of Vancouver Island, Langford is the third largest municipality in British Columbia's Capital Regional District. It is rapidly transitioning from a suburban community to a major urban centre and, according to the latest national census data, Langford is one of the fastest growing communities in the country (Figures 1.3, 1.4 and 1.5).

The benefits of growth have been numerous; with the increased tax revenues from new development reinvested into beautification initiatives, public amenities and new facilities. New development has also brought new jobs, services, affordable housing, and greater housing diversity. Despite the tangible benefits of development, climate protection and sustainability remain at the forefront of the city's Official Community Plan.

Figure 1.2

At the urban scale, increased density and the juxtaposition of commercial, residential and other uses, reduces the environmental impacts of transportation; while higher performance standards for new construction lower the greenhouse gas emissions from the operation of the buildings themselves. In addition, the City of Langford has taken a progressive position on reducing the embodied carbon of buildings, encouraging the use of mass timber to help address this increasingly important component in the overall greenhouse gas emissions equation.

Due to the amount of development in Langford, utilizing new building technologies is a profound opportunity for our community to be a leader in sustainability.
- City of Langford Official Community Plan

The City of Langford has emerged as a leading advocate for mass timber construction, with Terminus at District 56 being one of several projects to benefit from the building departments proactive approach and openness to innovation. Together with the other phases of the District 56 development, it provides a template for future development and densification of the downtown core.

2.0 The Genesis of District 56

Terminus is the first project to be completed in the multi-phase District 56 development, that will ultimately occupy half a city block in the centre of Langford. Phase 2, completed in 2022, is the 12-storey Tallwood 1 mixed-use residential and commercial building, the first to be completed under the new Encapsulated Mass Timber Construction (EMTC) provisions of the BC Building Code (Figure 2.1). The District 56 development fits with the City's vision as articulated by mayor Stew Young: "We want to tighten up our downtown core; it's all about livability and walkability."

Figure 2.1

Figure 2.2

District 56 is the brainchild of Design Build Services (DBS) a local, family owned business that has operated as both a developer and design-build consultant in British Columbia for 12 years. For DBS President and Director of Development Mathew McKay, engagement with mass timber began with a series of mid-rise apartment buildings in Victoria, that he worked on with architect Jack James, in which CLT floors were combined with light wood frame walls to speed up construction and reduce costs.

Figure 2.1: Rendering of Tallwood 1. (Courtesy DBS)
Figure 2.2: Interior view of Elkford Community Centre. (Courtesy Naturally Wood)

The inspiration to further explore the potential of mass timber came from a combination of web research and site visits. Important precedents included the Community Conference Centre in Elkford BC (Figure 2.2) ; and the eight-storey mixed-use Carbon 12 building in Portland, OR (Figure 2.3). From a developer's perspective, it was the simplicity, economy and speed of mass timber construction that captured McKay's imagination; along with the visual warmth of exposed wood as an interior finish.

Figure 2.3

Figure 2.4

For the Terminus project, DBS retained Jack James as the architect of record, while DBS itself (under McKay's leadership) was the developer, project manager and general contractor. From the outset, the intention was that Terminus would house the head office of DBS and act as a 'calling card' for the company and its values (Figure 2.4).

Figure 2.3: The Carbon 12 building in Portland OR. (Credit Wikipedia)
Figure 2.4: DBS wanted to create a building that would embody its own values of quality and sustainability. (Credit Dasha Armstrong; courtesy DBS)

3.0 The Terminus at District 56 Project

The case for mass timber is most often presented as an environmental one; that for the uninitiated comes with the daunting, and potentially costly, prospect of a complete reorganization of the building design and delivery process.

As a vertically integrated company; DBS was uniquely positioned to track the cost implications of incorporating mass timber (specifically CLT) through the design build process. On his previous midrise projects McKay had realized there were savings to be made; particularly if CLT was chosen from the outset and could be detailed and fabricated in the factory. A brief return to light wood frame floor systems had resulted in schedule delays and additional costs, further encouraging the move to mass timber.

As McKay observes: 'At the heart of the matter is the widespread and persistent scarcity of skilled labour. CLT can reduce costs of floors which would otherwise require a very large number of parts: joists, plywood, connections etc., and many more hours of labour. In addition, light wood frame floors typically result in considerably more construction waste. "

The 44,000 square feet (4090 square metres) Terminus building is five storeys in height; the top four being constructed of mass timber with glulam columns and beams, CLT floors and elevator shafts.

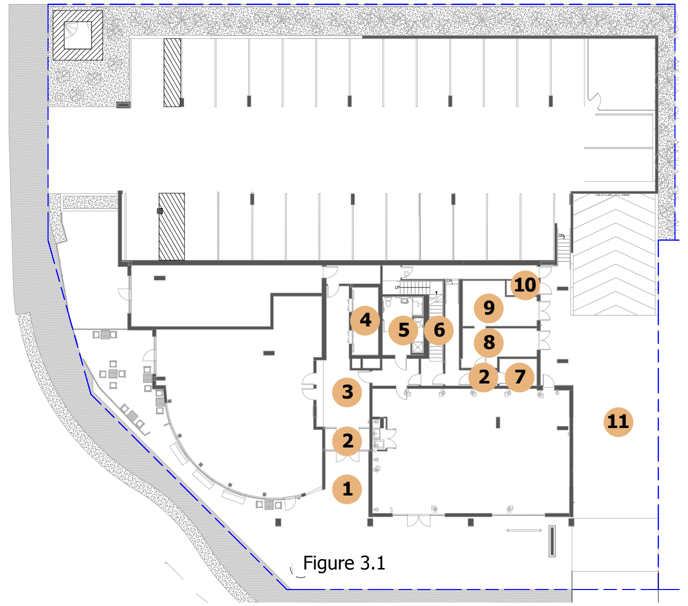


Figure 3.1

Main floor plan

1. Principal entry
2. Vestibule
3. Exit lobby
4. Elevator
5. Showers
6. Exit stairs
7. Janitor
8. Refuse
9. Recycling
10. Storage
11. Loading zone

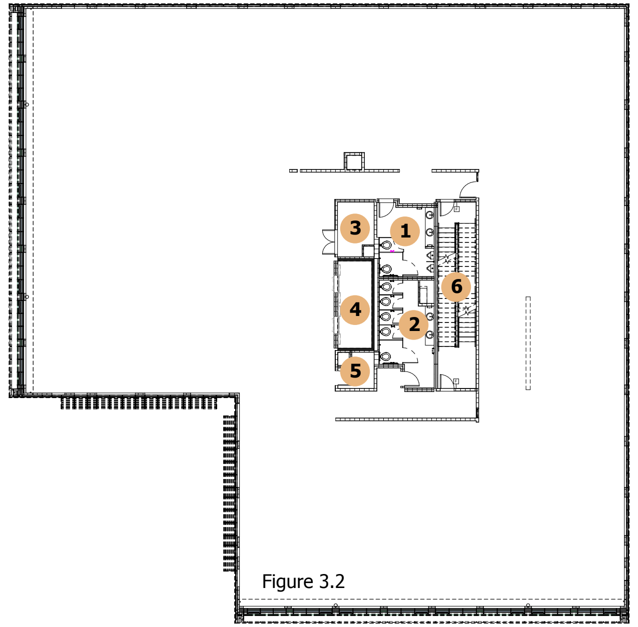


Figure 3.2

Floor plan

1. Men's washroom
2. Women's washroom
3. Mechanical
4. Elevator
5. Electrical
6. Exit stairs

Figure 3.1: Site Plan of Terminus at District 56. (Credit Jack James Architect, courtesy DBS)
Figure 3.2: Typical floor Plan of Terminus at District 56. (Credit Jack James Architect; courtesy DBS)
Figure 3.3: Building Section of Terminus at District 56. (Credit Jack James Architect, courtesy DBS)
Figure 3.4: Interior view of Terminus, showing glulam post and beam structure, CLT floors and exposed steel bracing elements. (Credit DBS)

The ground floor and below grade parking garage are of poured in place concrete construction. A six storey building would have been permissible under the BC building code, but could not be accommodated within the maximum height of the prescribed zoning envelope (Figures 3.1, 3.2, 3.3 and 3.4).

The visit to Carbon 12 in Oregon, together with a subsequent visit to the Katerra plant in Spokane, WA; influenced McKay's design approach for the Terminus project. Having not been impressed by what he considered inadequate sound isolation between the floors of Carbon 12; McKay chose to add an acoustic mat and a lightweight concrete topping to the CLT floors in his building.

Figure 3.3

Building section

1. Electrical
2. Telecommunication
3. Recycling
4. Men's washroom
5. Mechanical room
6. Pump room
7. Vestibule

Figure 3.4

Similarly, the complexity of routing mechanical ducts between and around the beams in the Katerra building, had resulted in an industrial look McKay considered incompatible with the Class A office space he wanted to create. Instead, he chose to install a 175mm raised floor system (Figures 3.5 and 3.6). The floor void serves as a supply air plenum for the displacement ventilation system. A series of heating and cooling loops under the raised floor serve units located at 20-feet (6.1-metre) intervals around the perimeter of the building. These units can be in either heating or cooling mode; enabling individual temperature control for each suite. Stale air returns through high level grilles to the central core where it is exhausted through energy recovery ventilators (ERVs).

The optimal structural grids for mass timber construction are not the same as those typically used for concrete or steel structures. While designers of mass timber office buildings often opt for a 20-feet x 30-feet (approximately 6-metre x 9-metre) grid; McKay worked closely with Aspect structural engineers and fabricator Structurlam Mass Timber to find the solution that would optimize the use of material, without compromising the layout of the office spaces.

The final choice was a post and beam glulam frame, laid out on a 20-feet x 20-feet (6.1 x 6.1 metres) grid; that enabled full length, 5-ply CLT floor panels to span efficiently across two bays of the building (Figure3.7). The L-shaped plan, with its two wings meeting at the elevator and stair core; was designed to be an exact multiple of the 8-feet x 40-feet (2.4 x 12.2- metres) panels that are the maximum standard size produced by Structurlam (Figure 3.8). This arrangement simplified connection details (Figure 3.9) and eliminated the need for secondary beams (except at the seismic braces as noted below – Figure3.10) so the glulam beams span in only one direction.

This layout allows for the subdivision of the office space into units that range in area from 700-square feet (65-square metres) to 13,240-square feet (1,230-square metres) offering commercial tenants flexibility and choice. The relatively shallow depth of the glulam beams ensures generous ceiling heights and daylight penetration deep in to the building (Figure 3.11).

The building enclosure uses the Starline 9000 series double-glazed window wall system with insulated spandrel panels (Figure3.12). The maximum height for the system is four floors; so the window wall on the top floor is independently supported on steel beams that run between the glulam columns. The opaque sections of the window wall are backed with an uninsulated steel stud furring wall with a drywall finish that conceals electrical runs.

The reflective roof finish reduces the heat island effect (Figure 3.13), and connection to the City of Langford's geothermal district energy system further reduces overall energy demand.


Figure 3.5


Figure 3.6


Figure 3.7

Figure 3.5 and 3.6: Installing a raised floor helped conceal building services, with the void acting as a plenum for air distribution. (Credit DBS)
Figure 3.7: The optimal structural system was based on a 6.1m x 6.1m grid, with beams in one direction only and the CLT panels spanning across two bays. (Credit Aspect Structural Engineers)
Figure 3.8: 3.8 CLT to glulam beam connection at panel junction. (Credit Aspect Structural Engineers)
Figure 3.9: CLT to glulam beam connection mid-panel. (Credit Aspect Structural Engineers)

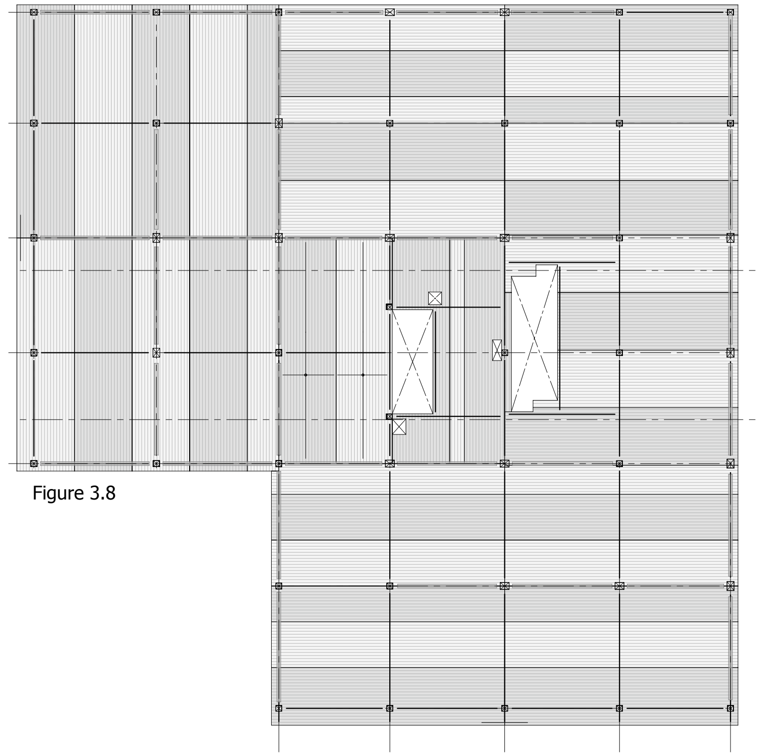


Figure 3.8

Level 4 plan

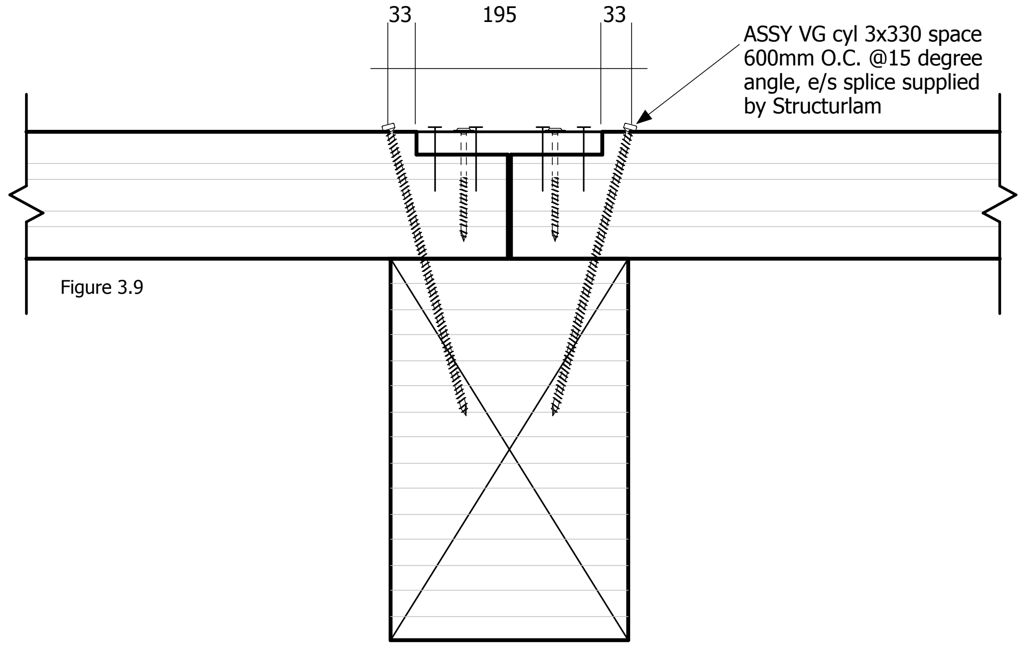


Figure 3.9

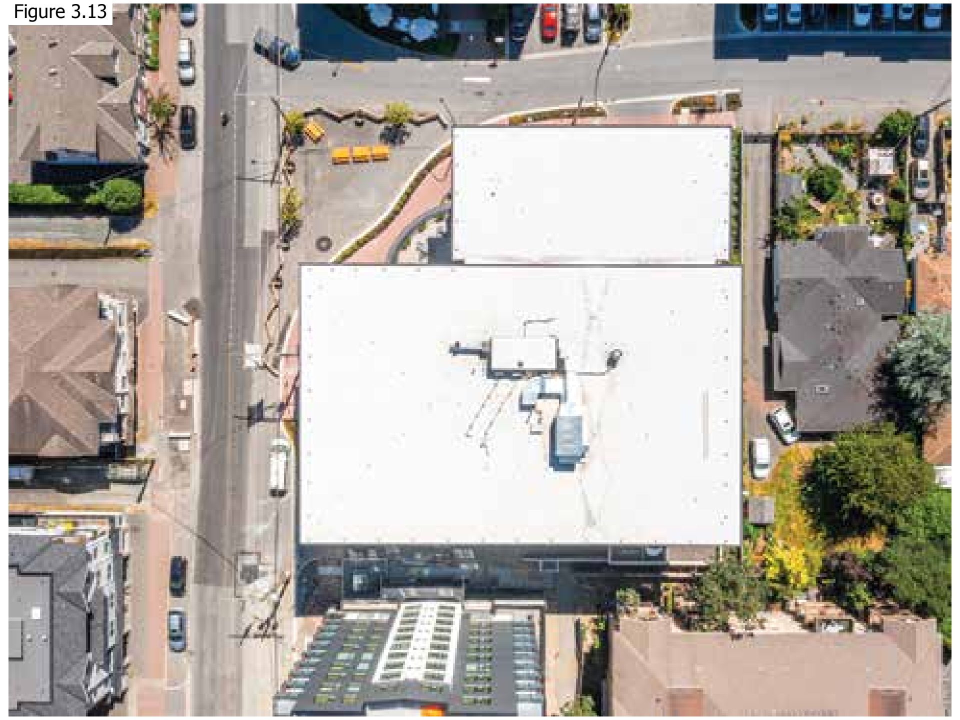
CLT floor panel to beam connection at splice

Figure 3.10

Figure 3.11

Figure 3.12

Figure 3.13



4.0 Site Context

The Pacific Coast is the most earthquake-prone region of Canada. In the offshore region to the west of Vancouver Island, more than 100 earthquakes of magnitude 5 or greater (large enough to cause damage had they been closer to land) have occurred during the past 70 years.

Part of the Pacific Ring of Fire, the concentration of earthquakes along the west coast is related to the presence of active faults, or breaks in the earth's crust. The surface of the earth is always changing, as the earth's crust is made up of "plates" that are constantly moving relative to one another at speeds of about 0.75 to 4-inches (2 to 10 centimetres) per year. The plates can move relative to one another in three different ways: A - slide past one another, B – move apart, and C – collide (Figure 4.1).

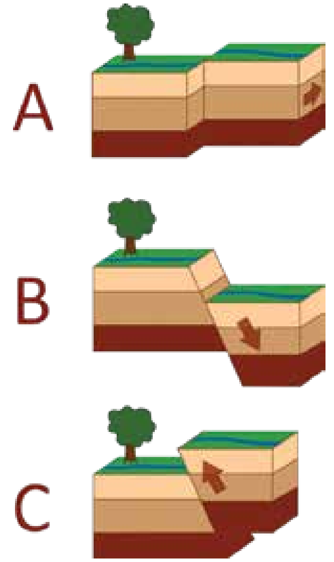
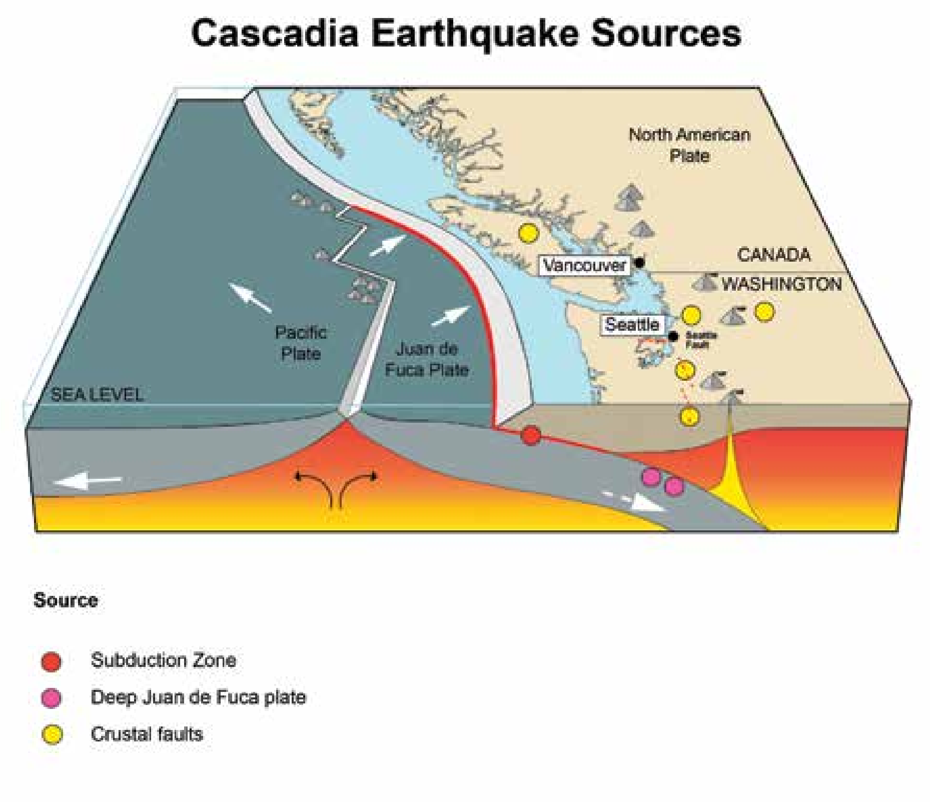


Figure 4.1



The west coast of Canada is one of the few areas in the world where all these types of plate movements take place, resulting in significant earthquake activity. In the region around southern Vancouver Island, the relatively small oceanic Juan de Fuca plate is sliding incrementally beneath the much larger North American continental plate (Figure 4.2). The movement of the Juan de Fuca plate is not constant, with friction forces creating a succession of minor tremors, before slippage occurs, resulting in a more substantial earthquake. Seismic activity can impose both horizontal and vertical forces on a building.

Figure 3.10: In the lateral direction, beams were only required where buckling restraint braces occur. (Credit Aspect Structural engineers)
Figure 3.11: The relatively shallow beams allow daylight to penetrate deep into the building. Credit Dasha Armstrong; courtesy DBS)
Figure 3.12: Close up of exterior window wall system. (Credit DBS)
Figure 3.13: Drone view of low albedo roof. (Credit Skyscope; courtesy DBS)
Figure 4.1: Three types of tectonic plate movement contributing to seismic events. (Credit Wikipedia)
Figure 4.2: Tectonic plates in the Cascadia region. (Credit Wikipedia)

5.0 Structural Design

The Terminus building was designed before and during the COVID-19 pandemic that affected supply chains from 2019 to 2021. The general uncertainty in the marketplace contributed to a short interruption in the project, when a couple of tenants pulled out while the concrete substructure was being poured.

As noted above, the four-storey glulam and CLT structure is laid out on a rigorously consistent 20-feet x 20-feet (6.1m x 6.1-metre) grid; with only two places where custom details were required. These were on level five, where the flat roof steps down and lateral forces must be effectively transferred between the upper and lower diaphragms; and around the CLT stair and elevator shaft, which had to be isolated structurally from the rest of the building, so lateral forces from the floor diaphragms would not be transferred to the vertical elements that were not designed to be part of the lateral resisting system.

Motivated by a desire to provide future tenants with a beautiful and robust building, and to establish themselves as leaders and innovators in the mass timber industry, DBS conveyed a willingness early in the project to explore various state-of-the-art options for the building's lateral force resisting system.

The simplicity throughout the rest of the building gave Aspect Structural Engineers the time to investigate lateral system options that might not otherwise have been possible. The initial priorities guiding this investigation were cost and aesthetics. In consultation with the project team, these were expanded to include ductility, post-earthquake repairability, and the identification of successful precedents.

"The really unique feature with Terminus is that the lateral system is a hybrid lateral system. It's buckling restrained steel braces in a glulam frame. This is a relatively new approach. Typically, if you have buckling-restrained braces (BRB) or steel braces, you have the entire frame of steel, but for Terminus we kept the columns and the beams as wood, and we just introduced the BRB braces. Using more wood offers a warmth striking design and adds to the carbon savings of the project."

- Ilana Danzig, Associate Principal, Aspect Structural Engineers

Aspect explored the suitability and comparative costs of four possible systems; including;

- Glulam Brace Frames with Quaketek Proprietary Friction Dampers
- Glulam Brace Frames with Tectonus Proprietary Resilient Slip Friction Joints (RSFJ)
- Moderately Ductile Glulam Brace Frames
- Steel Buckling Restrained Braces (BRB) in a Timber Frame

Comparative advantages and disadvantages included the requirement for some systems to incorporate additional steel moment frames; whether or not the system was self-centring; and whether or not the system had already been codified in Canada.

After much consideration, the project team selected steel buckling restrained brace frames (BRBs) as the lateral system for Terminus, a low-cost and high-performing system appropriate to the high seismic loads, DBS' design preferences, and the project budget (Figure 5.1).

A BRB is a steel section that is restrained from buckling by a concrete sleeve and designed to yield in both tension and compression during an earthquake. Placing the BRB in a timber frame is a brand-new approach that allows the timber to be celebrated while achieving cost effective ductility. Within the braced bay, columns and beams are timber, and only the diagonal elements are steel. Although steel buckling restrained braces are not a novel technology on their own, research did not identify any precedents in North America, where bracing elements had been connected directly into glulam beams and columns, rather than into steel frames.

In addition to the technical challenges posed by this novel approach, the all-wood strategy required the agreement of the Authority Having Jurisdiction to consider the alternative solution; and coordination between the structural engineer, the mass timber fabricator and the specialist subcontractor who would fabricate the steel bracing elements.


Figure 5.1

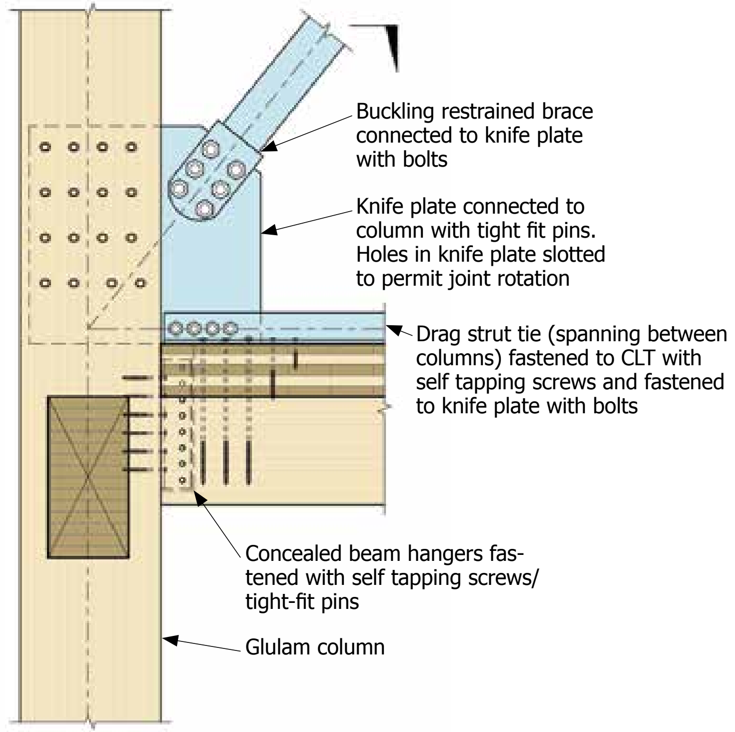


Figure 5.2

Typical brace frame column connection

Figure 5.1: Comparative analysis of different seismic resistance options resulted in the choice of steel buckling restraint braces (BRBs). Credit Skyscape; courtesy DBS)
Figure 5.2: Typical brace to column connection detail, with embedded knife plates and multiple tight fit pins.
(Credit Aspect Structural engineers)

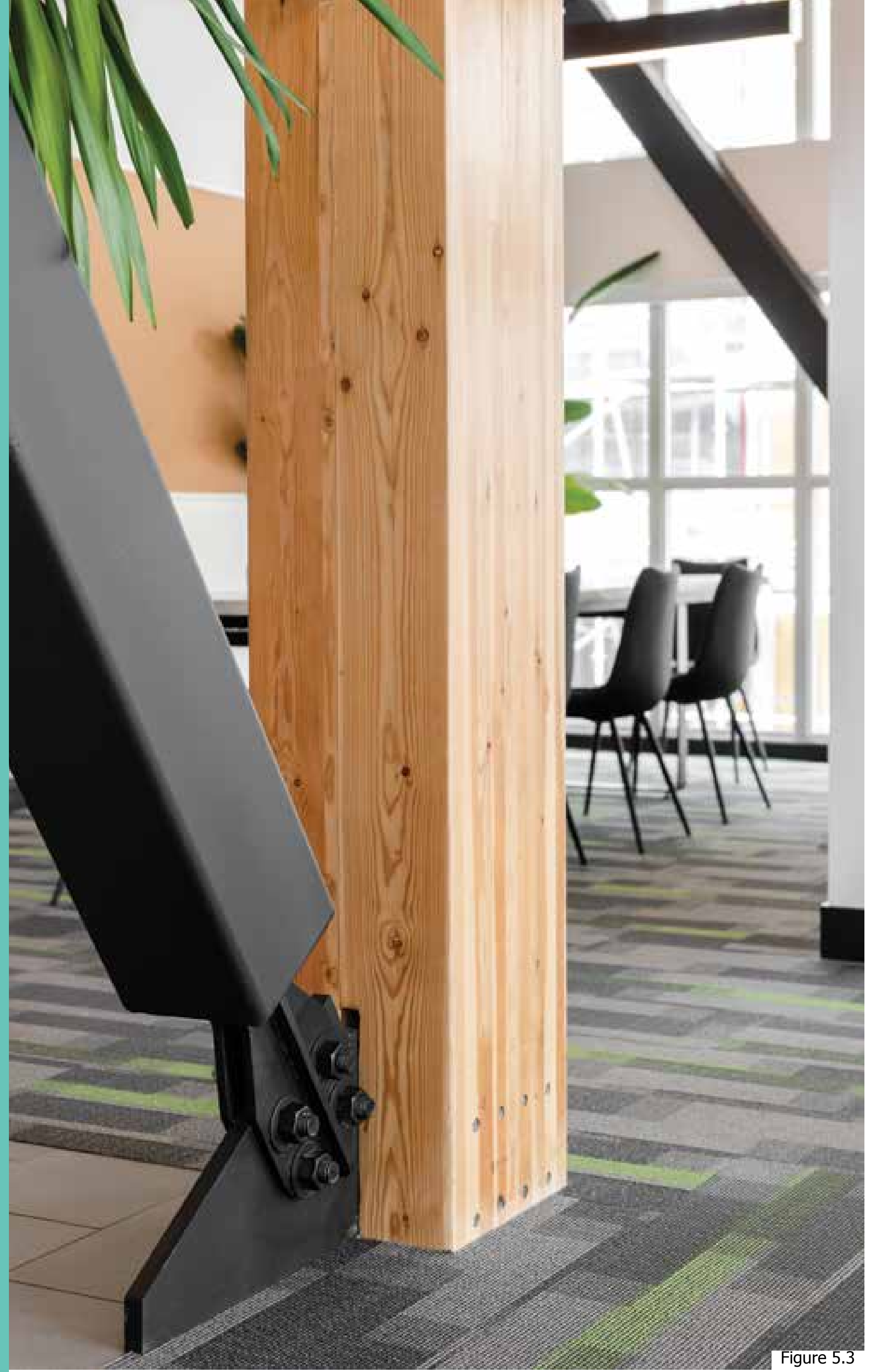


Figure 5.3

The primary structural challenge was to ensure that ductile failure would occur in the steel elements, rather than in the timber elements. To this end, the connections between steel brace and wood structure were designed with multiple embedded knife plates and tight fit pins, to spread the loads evenly throughout the full cross section of the mass timber elements (Figures 5.2, 5.3, 5.4 and 5.5).

Tight fit pins offered the best balance of strong and ductile connections. Researchers at the University of Canterbury in New Zealand, tested a glulam frame BRB mock-up comprising tight fit pin connections during an experimental study investigating the cyclic performance of this type of system. The study confirmed that, as designed, the action of the BRBs governed the performance of the system as a whole.

The typical brace to column connection features two 25mm thick steel knife plates fastened to the columns with multiple rows of 16mm diameter stainless steel tight fit pins. The knife plates project inwards from the columns to receive the end of the braces, which connect to the plates with four or six (depending on the size of the brace) 28mm diameter F3125 heavy hex head steel bolts.

Analysis determined that, If the connection were to be overloaded, the steel pins would bend, but the wood element would not fail. The limiting factor in the design calculations was not brittle failure of the wood, but ductile failure of the steel.

Given the significant seismic forces the system is designed to resist, the connections themselves are very large. However, the anchor plates have been designed to fit within (and therefore be concealed by) the raised floor system, making only the elegant brace connections (and the braces themselves) visible to building occupants.

Also hidden are the steel angles and drag straps that tie the braces to the columns and the floor diaphragms. Whether from above or below, all that is visible is the diagonal steel tubes connecting the beams and columns; and the uncluttered soffit of the CLT floor panels, or the tiled finish of the raised floor system.

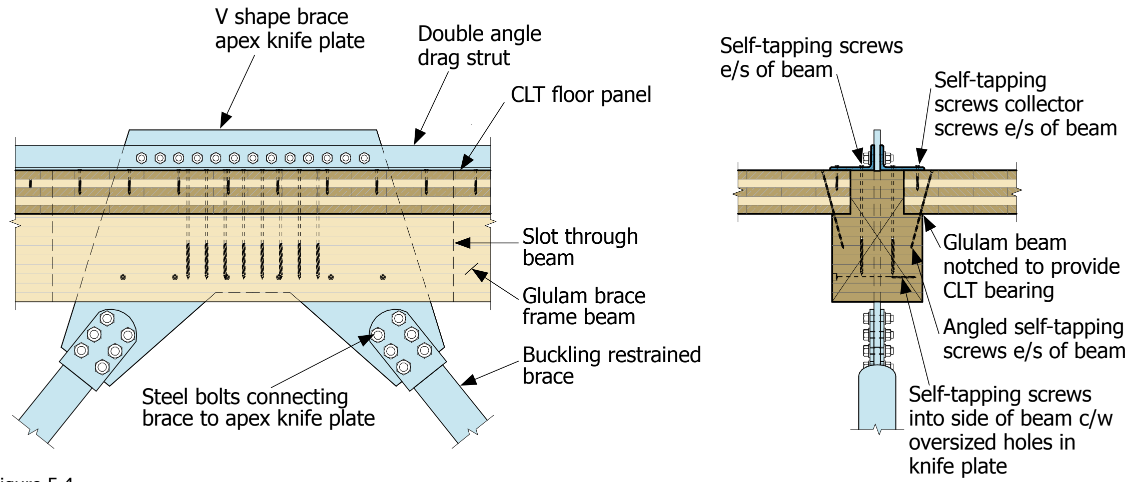


Figure 5.4

Typical brace frame apex detail

Figure 5.3: View of brace to column connection visible in finished building. (Credit DBS)
Figure 5.4: Typical brace to beam connection detail. (Credit Aspect Structural Engineers)
Figure 5.5: View of brace to beam connection visible in finished building. (Credit DBS)

Figure 5.5

6.0 Connection Design

The construction schedule for the project was very tight; meaning that the conventional sequence for resolving connection details (concept design followed by shop drawings) had to be compressed. With Structurlam fabricating and supplying all the mass timber elements, they established the geometry of the connections while Aspect did the detailed design and calculations.

With multiple knife plates and as many as 40 tight fit pins for each connection; the tolerances for fitting things together on site were considered too tight. To ensure smooth installation, it was decided that Structurlam would pre-install the column base connections in the factory, meaning that any tolerance issues between the connector and the complex milled CNC-sockets it fit into, could be dealt with in the factory under controlled conditions, ensuring site installation was straightforward (Figure 6.1).

Aspect and DBS laid out the braces in a chevron orientation, spanning between each floor from the concrete podium to the roof. ASPECT used the software RFEM by Dlubal to run a linear dynamic analysis to establish brace loads, and CoreBrace from Utah was selected as the BRB supplier. CoreBrace's buckling restrained brace design features a ductile steel plate core enclosed within an outer steel casing, a grout fill, and a proprietary debonding interface material.

The ends of the ductile steel plate core are connected to steel lug plates extending out beyond the ends of the outer casing, complete with a bolt hole pattern for connection to the timber superstructure (Figure 6.2).

The use of high strength, ductile BRB braces meant that the CLT stair and elevator shafts could not be incorporated into the lateral system for the building. Instead, it was necessary to isolate the CLT shafts from the surrounding building, so they could not be affected by the lateral movement of the main glulam frame under seismic loads.

Figure 6.1: Factory installation of the base connections ensured that field installation of the bRBs would be straightforward. (Credit Aspect Structural engineers)

Figure 6.1

Figure 6.2

The openings for the shafts are framed at each floor with glulam beams, but a gap is left on all sides, with the connections being achieved with slip joints. These joints increase in width from the lowest to the highest level; reflecting the fact that deflection at the top of the building is much greater than that experienced at the bottom. The BRB braces are arranged around the perimeter of the building, and it is only in brace locations that transverse beams are required.

The two other locations in the building where special detailing was required are the step in the roof on the top floor (where the floor to floor height increases from 15-feet to 18-feet) and between the first and second floors, where the structure transitions from concrete to mass timber.

Where the roof steps up, a transverse header beam is used to pick up the ends of the longitudinal beams and transfer the lateral forces to the glulam columns.

Above the first floor, a 900-millimetre thick concrete slab was required to transfer the gravity loads from the 20-feet x 20-feet glulam column grid above, to the larger grid of the concrete structure below. The choice to make this transfer between levels 1 and 2 (rather than between the parking garage and level 1) was made in part to give the ground floor retail units larger column-free space; and partly because a thick transfer slab at ground level would have impacted the clearance on the vehicle ramp to the underground parking level.

Figure 6.2: The brace includes an interior steel plate within a grout filled steel cylinder. (Credit DBS)

7.0 Conclusion

The success of Terminus at District 56 offers lessons in mass timber design and construction that have implications far beyond the City of Langford. Its story combines the conviction of a developer determined to create a state-of-the-art office environment to attract high-end tenants; a municipality that recognizes the contribution mass timber buildings can make to its climate change goals; structural engineers with the confidence and creativity to pursue innovative solutions in a challenging seismic context; and fabricators capable of manufacturing and coordinating the high-performance, precision components required to realize these goals.


Figure 7.3


Figure 7.4

As a branding exercise, Terminal at District 56 has been a runaway success for DBS; not only showcasing their own values and expertise in a new head office; but attracting blue chip tenants and Triple A rents in a previously unproven location (Figures 7.1, 7.2, 7.3 and 7.4).

Matthew McKay believes DBS is benefiting from two trends, the ‘flight to quality’ as businesses move out of older buildings where the cost of maintenance and operations is increasing; and the growing realization (as witnessed first in major high-tech companies) that a beautiful work environment helps attract and retain the best employees. As such, Terminus at District 56 has set a new benchmark in mass timber construction for others in Canada to emulate.


Figure 7.2

8.0 Project Team

Owner/Developer
DBS Design- Build Services

Architect of Record
Jack Jones Architect

Structural Engineer
ASPECT Structural Engineers

Project Manager and General Contractor
DBS Design-Build Services

Mass Timber Fabricator
Structurlam Mass timber Corporation

BRB Fabricator
CoreBrace

Figure 7.1, 7.2, 7.3 and 7.4 the DBS office has been a successful branding exercise for the company; promoting the high quality interiors that can be achieved in a mass timber building; and attracting ‘blue chip’ tenants to the project. (Credit Dasha Armstrong; courtesy DBS)

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