3 over 3

1856 East Georgia St

Fast + Epp

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7. Structural Overview – 1856 East Georgia St, Fast + Epp

7.1. Site Constraints

1856 East Georgia St is an existing site with limited accessibility. The existing building is surrounded by trees, with a street to the north, existing buildings close to the property line on the east and west, and a laneway to the south.

Figure 1 – Location within Vancouver

This building is fairly regularly shaped, although the building edge is articulated with the perimeter walls stepping in and out. There is also a partial basement in this building, which provides an additional design and construction challenge. The roof of this building is generally flat with some roof build up at the edges. There are also patios extending from some of the units.

An ideal building format for this study would be regularly shaped, have no patios, have no basement, and have a flat roof.

7.2. Structural Design Concept

The design concept for Building 5 is 3 new stories of mass timber floors and walls built over the existing lightwood framing building, supported by an exoskeleton steel diagrid that transfers forces into the ground through a concrete foundation system. The lateral system is a steel diagrid that encompasses the entire building, old and new.

The gravity and lateral systems of the new and existing will be separate. The two buildings will be able to act independently from each other. The intent of this method of design is to impart no new structural demand on the existing building, either gravity or lateral. If an upgrade of the existing building is required by the Authority Having Jurisdiction (AHJ), there is an opportunity to use the new structure to support the existing.

The intent of this study is to leave the tenants in place during construction. This means minimizing the effect on the living conditions during construction, and minimizing the time of construction.

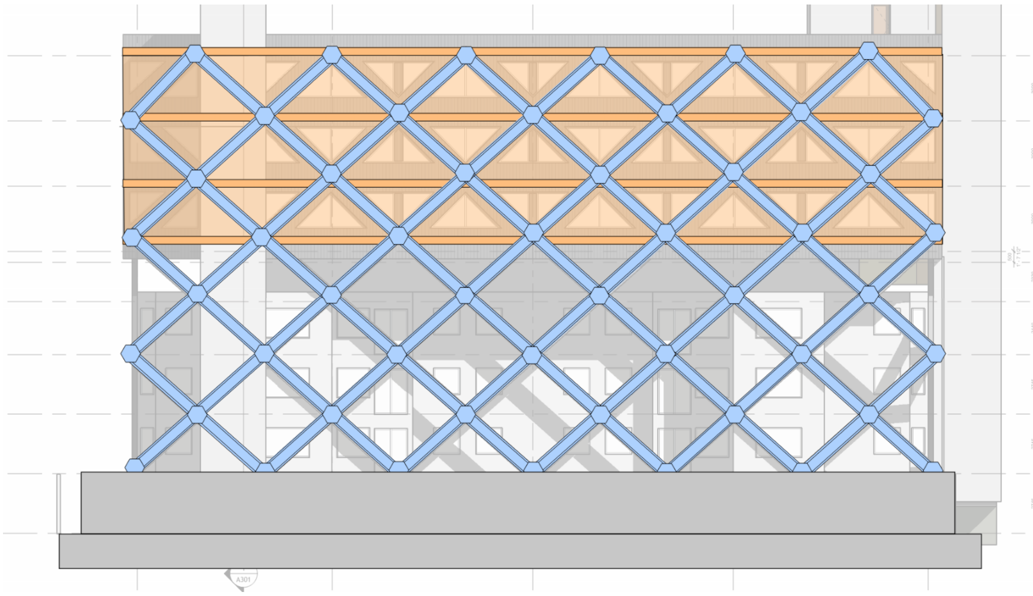


Figure 2 – 1856 East Georgia St. Elevation

7.2.1. Design Criteria

The new structure has been designed to the Vancouver Building by-law 2019. Major changes are not expected to occur when the new building by law comes into effect. The seismic loading used in this feasibility study is from NBCC 2020.

The standards the structure has been designed to are as follows:

- CSA O86 – Engineering Design in Wood
- CSA A23.3 – Design of Concrete Structures
- CSA S16 – Design of Steel Structures.

The assumed soil conditions are as follows:

Serviceability Limit State Bearing Resistance	300 kPa
Ultimate Limit State Bearing Resistance	450 kPa
Site Class	C

7.2.2. Deflection

The deflection limits the new structure has been designed for is as follows:

- Seismic drift limit of h/40

- Live load deflection of L/360
- Total deflection of L/240

7.2.3. Design Loads

See Appendix.

7.2.4. Structural Materials

The main structural materials being proposed for this study are mass timber CLT panels, steel, and reinforced concrete.

See Appendix.

7.2.4.1. Why These Materials

Mass timber is being proposed as the main construction material for the upper 3 floors and roof for the following reasons:

Efficiency

Mass timber panels can be shipped to the construction site preassembled. This approach facilitates a rapid construction timeline, which is essential for a project like this where the lower building is ideally occupied during construction.

Sustainability

Mass timber has a significantly lower embodied carbon footprint compared to traditional building materials like steel and concrete. Timber is a renewable resource that can be replenished over time, and mass timber typically results in less waste during construction.

Locality

This project makes use of locally sourced materials by utilizing a British Columbian CLT supplier. This choice supports local regional industries and reduces transportation emissions associated with the CLT.

Stability

Mass timber is well suited for large spans as it can provide lateral stability as well as being the main gravity system.

Weight

Mass timber is a lightweight construction material that will minimize the impact of the structure on the existing foundations, and reduce the extend of new foundations required.

Steel is being proposed as the material for the diagrid exoskeleton for the following reasons:

Durability

Steel is a strong, durable material that can withstand weathering and environmental factors that occur when a structure is exposed. As the diagrid will be exposed to external conditions, steel's ability to maintain structural integrity over time ensures long-lasting performance in the external application.

Efficiency

Steel has a high strength to weight ratio, and using steel for the external lateral and gravity system allows the use of smaller member sizes that will have less of an impact on the existing windows, patios, etc. without compromising the structural performance.

Flexibility

Steel can be fabricated into a wide range of shapes and forms, which allows for design versatility. Steel can also be more easily modified during construction than other typical building materials. If requirements evolve on site, steel can be modified with relative ease.

7.2.4.2. Building Enclosure

This study assumes that the exterior steel diagrid will be either galvanized or painted with epoxy paint to protect the structure from the elements.

The interior mass timber will be weather protected by the building's exterior cladding. Please refer to the related sections in the architectural report.

7.2.5. Foundation Concept

The foundation concept consists of concrete grade beams that surround the existing building, aligning with the new diagrid structure. The most efficient structural layout is to have the grade beams centered on the diagrid, and the existing foundations will need to be underpinned in most locations to allow for this work.

To minimize the thickness and length of the grade beams, soil anchors are being utilized at the exterior corners of the building.

The foundations were designed based on a typical soil condition in Vancouver, with a Serviceability Limit States bearing pressure of 300 kPa. This pressure will vary from site to site, and in some cases specific sites will have a lower or higher Serviceability Limit State pressure than what has been assumed in this feasibility study. The final value would have to be determined by the site-specific geotechnical investigations. This would affect final sizing of the foundation system elements.

7.2.6. Gravity Framing Concept

New upper structure

The main gravity system for the new portion of the building is 5 ply CLT floor and roof panels spanning between 5 ply CLT walls. These CLT walls are continuous vertically over all three levels and act as deep beams clear spanning across the building width. They are supported on each side of the building by the steel diagrid. All other walls are non-structural partitions, which allows for flexibility with unit layouts. A midspan opening can be provided in each CLT wall to allow for a hallway throughout the length of the building.

New stairwells and an elevator shaft are being provided on the exterior of the building. These elevators and stairs only service the upper portion and allow for the new portion of the building to be separate from the existing. Conventional light wood framing is used for the stairwell construction.

Parkade level

The existing parkade floor plate is wider than the existing building above it along two sides. Where the steel diagrid lands on the existing suspended slab, new concrete transfer beams and columns will transfer the gravity loads into the foundation system. A combination of new concrete shear walls and existing concrete shear walls will transfer the lateral load into the foundation system. New additional concrete walls and columns will eliminate some of the existing parking stalls. If even more parking stalls is possible to eliminate, it could lead to more structural efficiency by removing new concrete transfer beams.

7.2.7. Lateral Stability Concept

The vertical lateral system along all four sides for the new portion of the building is a steel diagrid exoskeleton, design to transfer lateral load from new building into the foundation system. Diaphragm action at each new floor and roof is provided by the CLT floor and roof panels. The steel exoskeleton is designed with an RdRo equal to 1. The CLT walls are gravity only, they are not intended to be shear walls.

Using a diagrid provides interesting architectural opportunities with its appearance. Building 5 is housing operated by BC Indigenous Housing Society, and an opportunity with this design would be incorporating the cedar weave pattern into the diagrid design.

On the parkade level, the diagrid will land on concrete shear walls that transfer to the foundation system.

As mentioned earlier in the report, the soil has been assumed to be Site Class C. In case where actual site class is different, seismic loads might affect the currently proposed lateral load resisting system.

The design intent is for the new and the existing building portions to act independently from each other. If a seismic upgrade is required by the Authority Having Jurisdiction (AHJ), there is an opportunity to use the new structure to support the existing.

7.3. Constructability

7.3.1. Building Form Providing Maximum Number of Units

This structural form incorporates long span CLT and minimal vertical elements like walls and columns, allowing for flexibility and maximum use of the interior space. The CLT panel layout also eliminates the needs for drop beams, and the stairs and elevators in this layout are on the exterior of the building, ensuring that the interior floor space is dedicated entirely to living units.

7.3.2. Interaction Between Old and New Structure

The intent with the structural system on Building 5 is to provide a solution that has no interaction between the old and new structure. The new structure was designed completely independently of the existing building.

In the event that an upgrade of the existing building is required by the AHJ, the existing building can be used to provide support by connecting the diagrid back at each floor level. The existing diaphragm can be analyzed and upgraded as required to distribute the load to the diagrid, so that the diagrid will be the main lateral support system for both the new and existing buildings.

7.3.3. Proposed Building Form

7.3.3.1. Weaknesses in the Proposed Form

This project will create significant disruption due to construction on the existing tenants, including noise and construction pollution, access restriction, and safety concerns. The intent of the design on Building 5 is to avoid modifying the existing building as much as possible, however there will be disruption at the foundation level. Building a structure above an inhabited structure will require rigorous safety protocols.

Due to the restraints caused by the existing building and the surrounding structures, there is a limited flexibility with the foundation system layout. Any possible local soil challenges will have to be addressed to accommodate the predetermined foundation lay-out.

The proposed building form requires heavy materials that can span across the existing building. The construction is complex and not typical and will require specialized construction techniques.

Sourcing mass timber in specific sizes can be difficult, as it is a specialized material that requires advanced notice to fabricate. A potential weakness in this proposed design is the ability to get mass timber to site in time, however mass timber production is a developing industry, with new manufactures emerging and existing manufactures increasing capacity.

8. Embodied Carbon

A key principle when reducing embodied carbon associated with buildings is to build less. Renovating rather than demolishing and constructing new significantly reduces embodied carbon, as it reduces the extraction, production, transportation and assembly of building materials. Demolition also creates waste and emissions, whereas renovation extends a buildings lifecycle.

By keeping the existing buildings, The existing building materials above and below grade can be reused. Re-using the existing foundation system is especially important as concrete is a very carbon intensive material.

Mass timber is a low embodied carbon material. It is also locally sourced, which minimizes emissions associated with transportation. Because the mass timber panels come to site prefabricated, construction waste in minimized as well. Mass timber is a renewable resource, and it is especially beneficial when sustainable forestry practices are observed.

Maintaining the existing buildings and renovating with mass timber will likely result in lower embodied carbon than demolishing and building new, which is essential in reducing embodied carbon associated with buildings.

9. Summary

This study reviewed the feasibility of building an additional 3 stories above an existing 3 stories, in order to provide additional housing without having to relocate existing tenants.

The proposed structural solution is an overbuild solution where the upper portion does not rely on or interact with the building below. This structural system consists of mass timber walls and floors supported by a steel diagrid exoskeleton. Exits are provided on the exterior of the building, accessing both upper and lower tenants.

Using mass timber as a construction material proved to be appropriate because of its efficiency, sustainability, locality, stability and weight.

Constructability has been considered, and further development is required to determine how this type of construction can be completed while reducing impact to existing tenants.

Appendix

Design loads

The design building loads and combinations are based on VBBL 2019 as defined below. The table below summarizes the symbols and their definitions used for loads.

Symbol	Definition
D	Dead load
L	Live load
S	Snow load
R	Rain load
W	Wind load
E	Seismic load

Load Combinations

Ultimate Limit States	Service Limit States
Gravity Cases	
1.4D	
1.25D + 1.5L+1.0S,	
1.25D + 1.5S+1.0L	
Lateral Cases	
1.25D+1.5L+.4W	
1.25D+1.5L+.4W	
1.25D+1.5S+.4W	
.9D+1.5L+.4W	
1.25D + 1.4W +.5(L/S)	
1.0D+1.0E+.5L/.25S	
.9D + 1.4W +.5(L/S)	

Dead Loads

The dead loads in the building are summarized in the table below based on key locations/uses in the building.

Occupancy – Typical Residential	Load (kPa)
Typical Build up	2.0
CLT Self Weight	0.55 kPa

Live Loads

The live loads in the building are summarized in the following table by key locations/uses in the building. Live loads are determined from VBBL 2019.

Occupancy	Load (kPa)
Typical Units	1.9
Corridors, Stairways	4.8

Snow Loads

The ground snow load and factors based on the site and building for the calculation of snow loads is summarized in the table below. Loads have been determined from VBBL 2019.

Factor	Value
1-in-50 year ground snow load, S_s	1.9
1-in-50 year associated rain load, S_r	0.3
Importance Factor, I_s	1.0
Basic Roof Snow Factor, C_b	0.8
Wind Exposure Factor, C_w	1.0
Slope Factor, C_s	1.0
Accumulation Factor, C_a	1.0

Wind Loads

The basic wind speed and wind exposure class are presented in the table below. Wind Loads are determined from VBBL 2019.

Factor	Value
Reference Velocity Pressure, q	0.45
Importance Factor, I_w	1.0
Exposure Factor, C_e	0.85
Exposure Factor for Internal Pressure, C_{ei}	0.70
Topographic Factor, C_t	1.0
Gust Effect Factor, C_g	2.0
Internal Gust Effect Factor, C_{gi}	2.0
External Pressure Coefficient, C_p	0.80 Windward, -0.50 Leeward, -0.70 Parallel
Internal Pressure Coefficient, C_{pi}	-0.45 to +0.30

Seismic Loads

The seismic site values used in the calculations of the seismic load are in the table below. Seismic design values are determined from NBCC 2020.

Factor	Value
Site Class	C
S_a (.2)	1.09
S_a (.5)	0.874
S_a (1.0)	0.507
S_a (2.0)	0.308
S_a (5.0)	0.088
S_a (10.0)	0.037
PGA	0.473
PGV	0.527

Importance Factor, I_E	1.0
Rd	1.0
Ro	1.0
SFRS Name	Steel diagrid

Structural Materials

Concrete Foundations

Compressive Strength	30 MPa @ 28 days
Concrete Density	2400 kg/m^3
Reinforcing Bars	CSA G30.18
Exposure Classification	

Steel

Wide Flange	CSA G40.20/G40.21 Grade 350W
Hollow Structural Sections	CSA G40.20/G40.21 Grade 350W

CLT

The design assumes to following CLT properties:

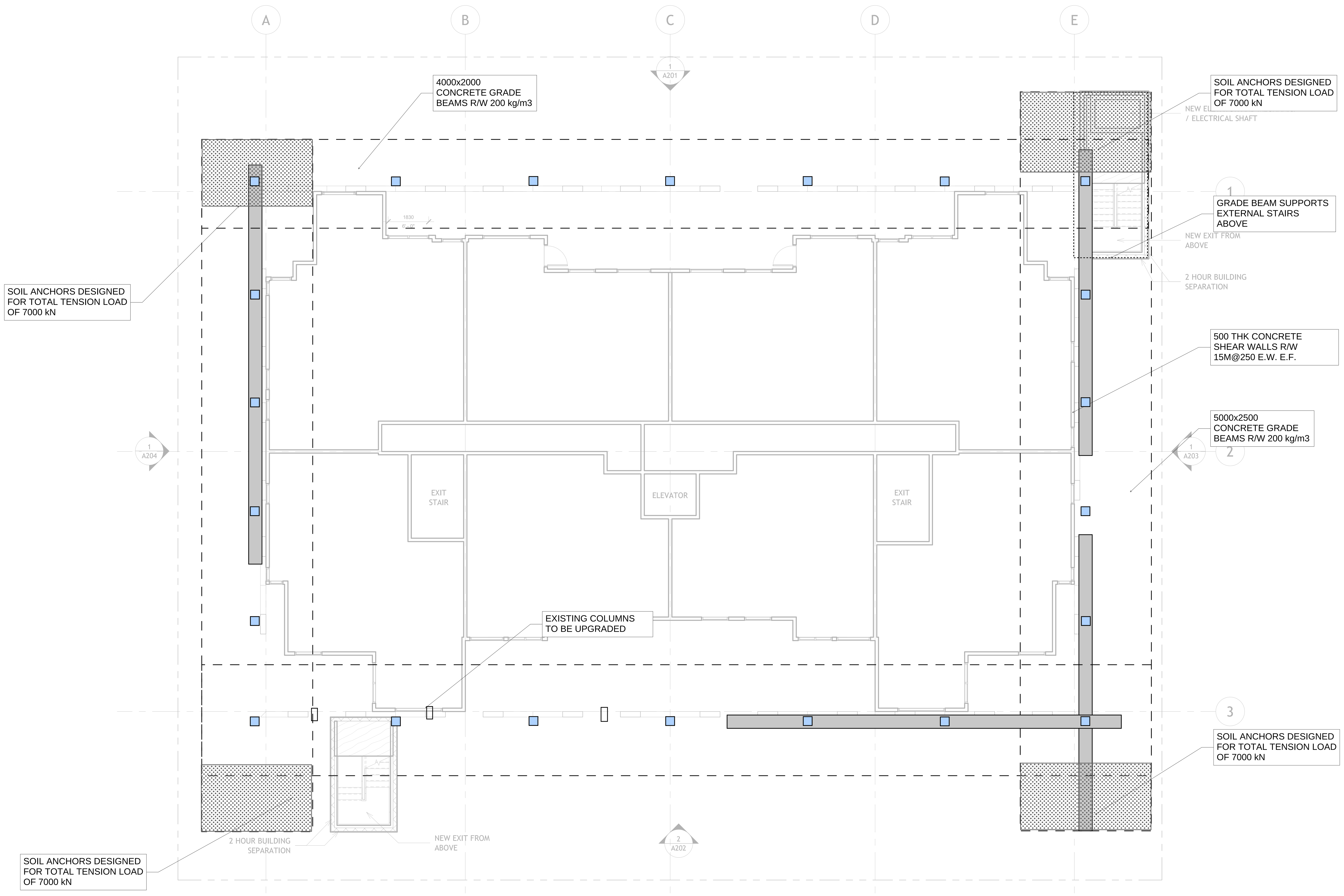
<u>Dimensions</u>
Maximum Width: 3.5m
Maximum Length: 18m

Floor and Roof Panels

Species	No.1/No.2 SPF
Grade	V2
Thickness	175mm

Wall Panels

Species	No.1/No.2 SPF
Grade	V2
Thickness	175mm



FOUNDATION PLAN

REVISIONS:

REV	DATE	DESCRIPTION	BY

SEAL:

ORIGINAL SCALE:

DATE:

APPROVED BY: Approver

CHECKED BY: Checker

DRAWN BY: Author

IF THIS BAR IS NOT 25mm LONG, ADJUST YOUR PLOTTING SCALE.

25mm

DISCIPLINE:

Fast+Epp

CLIENT:

BCNPHA
BC Non-Profit Housing Association

CLIENT REF. #:

PROJECT:

3-OVER-3 MASS TIMBER RESIDENTIAL INFILL FEASIBILITY STUDY

TITLE:

BUILDING 5 - 1856 EAST GEORGIA ST
VANCOUVER, BC V5L 2B6

FOUNDATION PLAN

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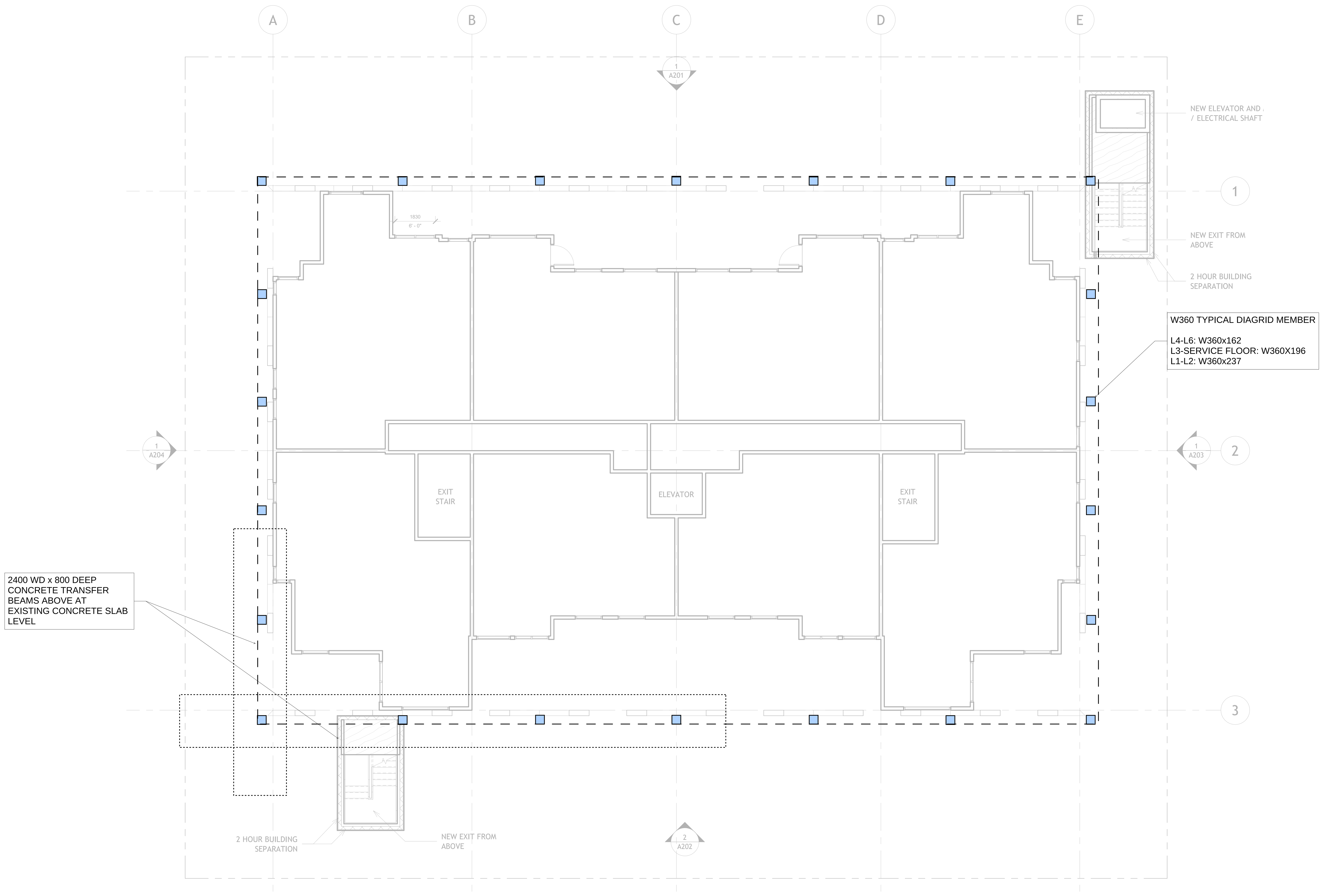

TYPICAL DIAGRID PLAN

REVISIONS:

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SEAL:

DISCLAIMER:

ORIGINAL SCALE:

DATE:

APPROVED BY: Approver

CHECKED BY: Checker

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CLIENT:

CLIENT REF. #:

PROJECT:

3-OVER-3 MASS TIMBER RESIDENTIAL INFILL FEASIBILITY STUDY

TITLE:

BUILDING 5 - 1856 EAST GEORGIA ST VANCOUVER, BC V5L 2B6

DIAGRID PLAN

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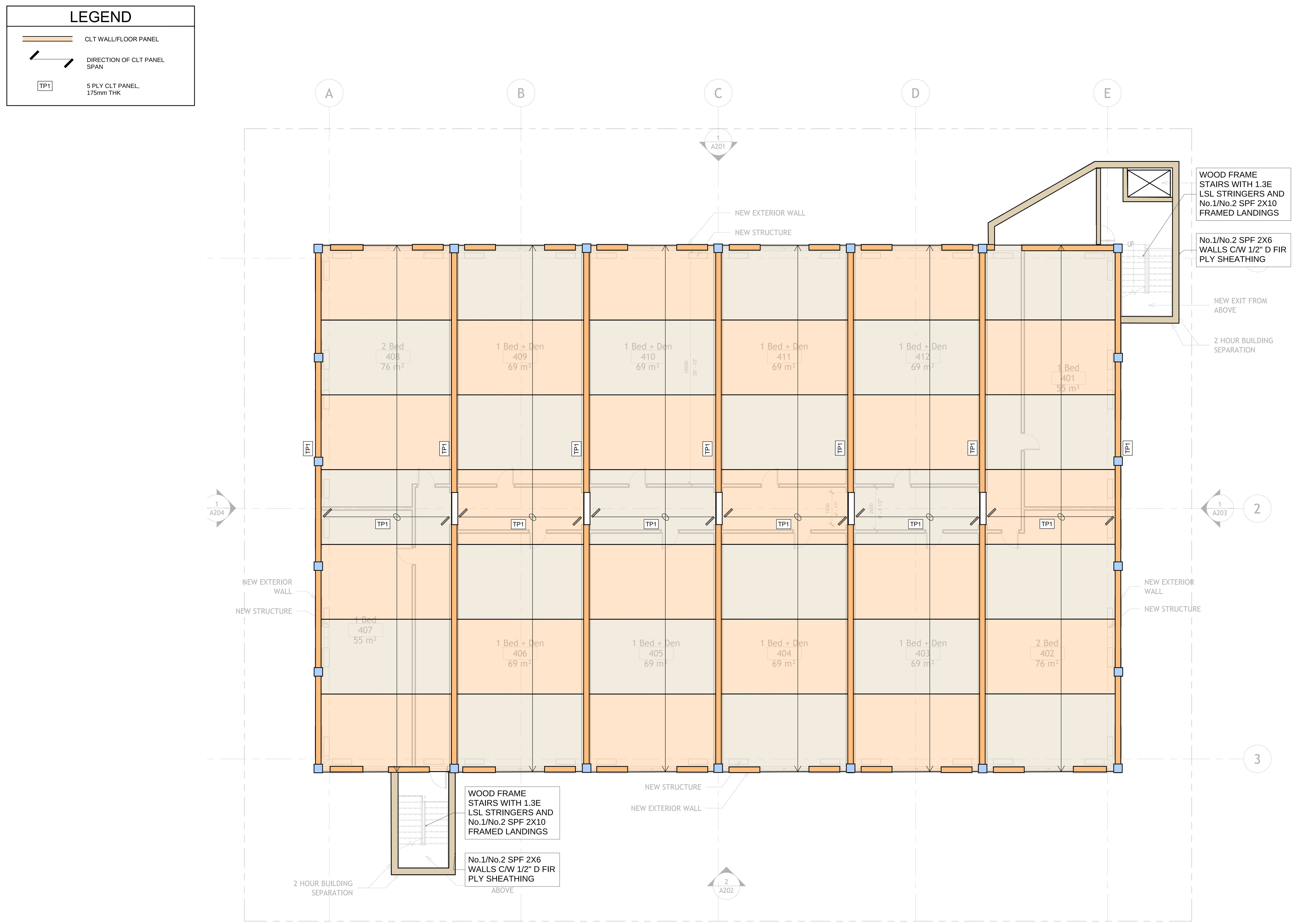

TYPICAL CLT FLOOR AND ROOF FRAMING

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PROJECT: 3-OVER-3 MASS TIMBER RESIDENTIAL INFILL FEASIBILITY STUDY

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CLT FLOOR AND ROOF FRAMING

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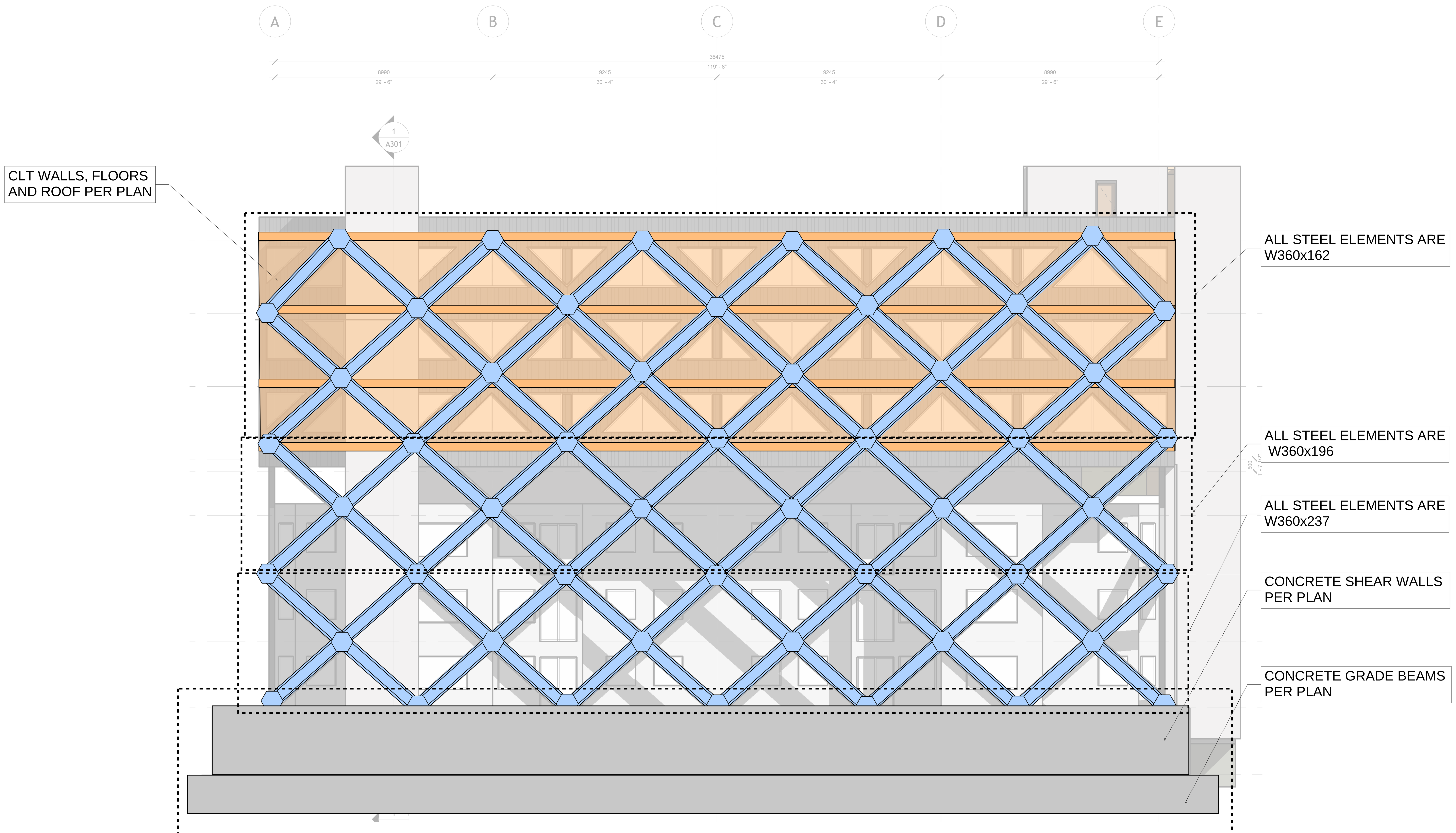

TYPICAL ELEVATION

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CLIENT:

BCNPHA
BC Non-Profit Housing Association

CLIENT REF. #:

PROJECT:

3-OVER-3 MASS TIMBER RESIDENTIAL INFILL FEASIBILITY STUDY

TITLE:

BUILDING 5 - 1856 EAST GEORGIA ST
VANCOUVER, BC V5L 2B6

ELEVATION

DRAWING NUMBER: S200

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