boston planning & development agency

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BOSTON MASS TIMBER ACCELERATOR

Final Report

The Boston Planning & Development Agency (BPDA)

The Boston Planning & Development Agency (BPDA) is the planning and economic development agency for the City of Boston. The BPDA plans and guides inclusive growth in our city - creating opportunities for everyone to live, work and connect. Through our future-focused, city-wide lens, we engage communities, implement new solutions, partner for greater impact and track progress.

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Information

For more information about Mass Timber Accelerator please visit
https://www.bostonplans.org/planning/planning-initiatives/boston-mass-timber-accelerator

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Introduction

Boston's goal to be carbon neutral by 2050 is driving a range of policy and practice actions for reducing building-related carbon dioxide emissions.

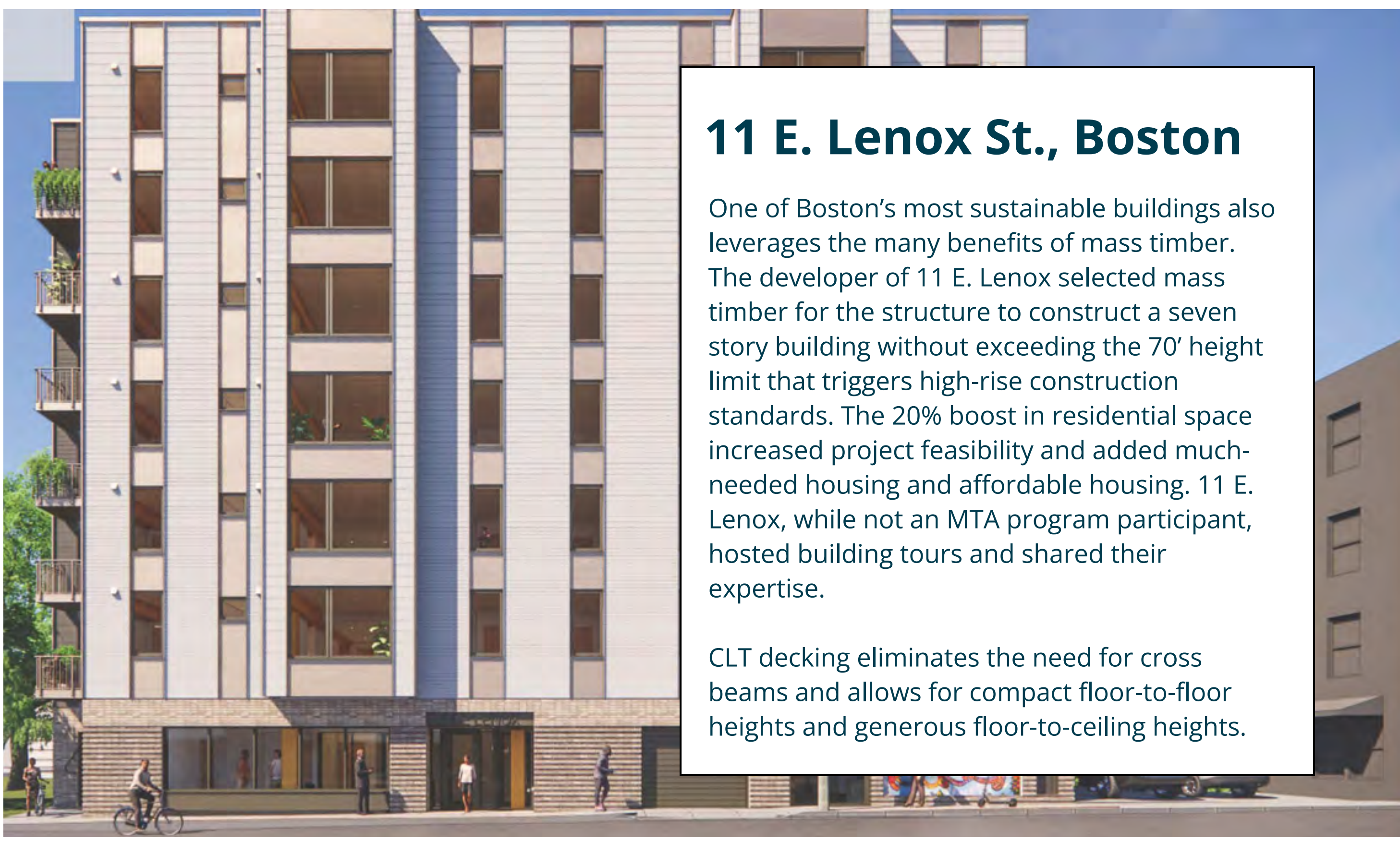
One such policy, the Net Zero Carbon Building updates to Zoning Article 37 will strengthen green building review requirements to ready for net zero carbon standard under the City's Building Emissions Reduction and Disclosure Ordinance. Recognizing the significant carbon emissions due to building construction and materials, 23% of annual global emissions, the City sees the expansion of mass timber construction practices as a critical action for reducing carbon dioxide emissions.

Using one of the most common building materials in human history, mass timber is a new version of the centuries-old practice of building with wood. Advances in building design, engineering, and wood manufacturing have transformed practices and now enable the construction of tall wood structures. The 2021 Edition of International Building Code (IBC), soon to be adopted by the Commonwealth of Massachusetts, establishes standards for tall wood structures allowing up to 18 stories and to a height of 270 feet.

The two mass timber products driving this transformation are laminated timber and cross-laminated timber. Laminated timber, also known as glulam, is made from wood glued together in layers and is designed for use as structural columns and beams. Cross-laminated timber, or CLT, is made from wood glued together in layers with the grain oriented in alternate directions for use as structural decking and sheer walls. Carefully engineered and rigorously tested, mass timber columns, beams, and decking are at once familiar and new. More beautiful and lighter in weight than their steel and concrete structural counterparts, mass timber is a low carbon, environmentally friendly, plentiful and renewable alternative.

The Accelerator

Recognizing the potential benefits and the need to better understand mass timber practices, the City of Boston proposed the Boston Mass Timber Accelerator (MTA) program. With support and funding from the USDA Forest Service, the Climate Works Foundation, and the Softwood Lumber Board, and technical assistance from Woodworks, Boston's MTA was launched in September of 2021. Ten projects selected over two rounds were awarded financial and technical assistance to explore mass timber practices for their building projects. Individual project teams investigated a range of approaches and challenges to utilizing mass timber for their projects and assessed costs, benefits, and feasibility.



11 E. Lenox St., Boston

One of Boston's most sustainable buildings also leverages the many benefits of mass timber. The developer of 11 E. Lenox selected mass timber for the structure to construct a seven story building without exceeding the 70' height limit that triggers high-rise construction standards. The 20% boost in residential space increased project feasibility and added much-needed housing and affordable housing. 11 E. Lenox, while not an MTA program participant, hosted building tours and shared their expertise.

CLT decking eliminates the need for cross beams and allows for compact floor-to-floor heights and generous floor-to-ceiling heights.

Key Takeaways

Over the course of the Mass Timber Accelerator, participants investigated the unique features and numerous benefits of mass timber and how best to integrate practices and materials into their projects. Key takeaways include:

Efficient Floor-to-Floor Height

CLT decking and glulam beam configurations can allow mechanical, electrical & plumbing (MEP) chases to run at the underside of the CLT decking. Without having to locate MEP chases below beams, tighter floor-to-floor heights can be achieved. From the reduced building heights, several benefits are realized:

- A seven-story building can be constructed without exceeding the Building Code 70' height limit that triggers high-rise construction standards.
- The reduction in exterior wall surface lowers building enclosure construction costs and related embodied carbon.

Reduced Building Weight

In comparison to conventional building structural materials, mass timber is significantly lighter. The reduced building weight allows for corresponding reductions in building foundations and substructures. In addition to lowering construction costs, smaller foundations use less concrete and further reduce embodied carbon.

Reduced Embodied Carbon

In a typical building, the structural elements can account for 50% of the total embodied carbon. Utilizing mass timber can significantly lower the embodied carbon of the structure. In two assessments, the embodied carbon of mass timber was between 35% to 80% less than the same structure built of steel. While not every solution will yield the same reduction levels, most – even hybrid systems – significantly lower embodied carbon.

Beauty and Biophilic Benefits of Wood

Perhaps one of the most compelling benefits of mass timber is the beauty and appeal of the exposed wood. The human response to the warmth of the exposed wood is both notable and marketable.

Accelerated Construction Time

The rapid assembly of mass timber structural elements and the performance characteristics of solid CLT decking are transforming construction practices. With a CLT deck in place, secondary trades can commence rough work below while structural construction continues above. Shortened construction time results in savings through lower overhead costs, interest expenses, and time-to-market risk.

Program participants also identified challenges and areas for growth.

Laboratory/Office Use Vibration Standards

Frequently initiated as “speculative development” projects, lab/office buildings are designed to meet a range of industry standards including low vibration criteria for sensitive equipment and processes. Until additional research and built projects prove mass timber vibration performance, lab/office developers are unlikely to assume the associated risk.

Supply Chain

With rising demand for mass timber materials and limited suppliers, the sourcing and cost of mass timber products is a top concern for participants. While strong demand makes this an excellent market for current and new manufactures, it will take time to increase production and stand-up new manufacturing facilities.

Building Code Updates and Adoption

While the Commonwealth of Massachusetts adoption of the 10th Edition of the State Building Code is expected this summer, until adopted, the 2021 IBC Tall Wood Structure Construction Typologies are unavailable for the design and construction of mass timber buildings. Furthermore, the 2024 IBC improvements to the Tall Wood Structure Construction Typologies may not be available for use until the next State Building Code adoption cycle.

The Ideal Candidate

The Boston Mass Timber Accelerator program attracted an unexpectedly wide range of project types and sizes and broadened our understanding of the opportunity.

Participating multifamily residential (MFR) projects demonstrated the greatest ability to leverage the benefits of mass timber. High-rise MFR buildings, 8 stories and taller, exhibit the greatest potential. Mid-rise MFR buildings, between 5 and 7 stories in height, also show great potential. At the project scale, both high-rise and mid-rise buildings can take advantage of the more efficient floor to floor height and accelerated construction benefits. Uniquely, mid-rise MFR buildings, can be built to seven stories, while remaining below the 70' high-rise Building Code threshold allowing an addition story of residential units. With the introduction of hybrid practices (e.g. CLT decking on load bearing wood or metal stud walls) more mid-rise MFR projects will be able to leverage the benefits of mass timber.

While the MTA program did not include a commercial office typology, the building use and construction practices can easily leverage the benefits of mass timber construction. With sustainable development values continuing to inform business and corporate facility decision making, commercial office buildings are ideal mass timber candidates.

Similarly, mid-rise and high-rise institutional and academic buildings can leverage the multiple benefits of mass timber construction. While the use and building conditions of this typology are more varied, the long-term position and sustainable development values are very strong. For example, the new Harvard University American Repertory Theater is a signature building that showcases both the amazing beauty and reduced embodied carbon benefits of mass timber. Driven by both institutional values and student expectations for sustainable leadership, new construction dorms and academic buildings are also ideal candidates for mass timber.

Policy, Practice, and Embodied Carbon

Greenhouse gases are emitted at every step of every product's life cycle. For building products and materials, much of it is during the manufacturing stage long before the product reaches the construction site.

The emissions associated with raw material harvesting, refining, manufacturing, transportation, and installation are collectively referred to as embodied carbon. In a building, the embodied carbon in materials, products, and construction add up and can be very significant. For a new, high-performance building, the embodied carbon – all of which is released before the building even opens – is about equal to 20 years of "operational" carbon emissions from energy use.

With mounting success in reducing carbon emissions from building operations, cities like Boston now see reducing building embodied carbon as the next critical step in reducing the drivers of climate change. As we collectively work to identify carbon reduction best practices, mass timber has emerged as a high-impact, low-effort solution.

Lumber – which can be regionally sourced, has a great strength-to-weight ratio, and requires comparatively minimal manufacturing – is an excellent low-carbon solution for building structures.

Uniquely, grown materials such as trees or lumber draw carbon dioxide out of the atmosphere as they grow and store that carbon within the material itself. When harvested and manufactured into mass timber, the carbon stored within the wood is sequestered in the built structures. With the continued expansion of sustainable forestry practices and the cycle of carbon extraction and sequestration, mass timber is a highly promising strategy to reduce atmospheric carbon and fight climate change.

The Future of Mass Timber

The growth of mass timber demand is accelerating in Boston and the region.

Based on current developer commitments, the BPDA is tracking eight active projects totaling over 1.3M sq. ft. that are to be constructed utilizing mass timber materials. Project statuses range from in construction to planned with construction starting in 2024/2025. Six of the eight projects are MTA participants.

Notably, two of the active projects with mass timber commitments are the initial buildings of much larger multi-building projects that will be built out over the next ten years. Boston's future projects with mass timber commitments amount to 22 buildings totaling over 4.3M sq. ft. of construction.

Active Projects with MT Commitments - 2023 to 2024				
Project Name	**Use**	**Status**	**Bldgs**	**Area**
Bunker Hill Housing - Building M	Residential	In Construction	1	119,635
Mary Ellen McCormack- Building B	Residential	Permitted	1	311,293
Longwood Place- Building 4	Residential	Permitted	1	185,000
Harvard ERC- Conference Center	Event	Permitted	1	61,500
Suffolk Downs- Building B16	Residential	Planned	1	205,331
Suffolk Downs- Project Q Housing	Residential	Planned	1	300,581
Shawmut TOD Housing	Residential	Planned	1	68,400
175 N. Harvard St. Performance Ctr	Theater	Planned	1	83,000
Totals			**8**	**1,334,740**

Future Projects with MT Commitments				
Bunker Hill Housing Development	Residential	Permitted	14	3,167,000
Mary Ellen McCormack Development	Residential	Planned	8	1,187,000
Totals			**22**	**4,354,000**

Potential Future MT Projects				
Dorchester Bay City Development	Residential	Planned	8	1,752,000
Suffolk Downs Residential Bldgs	Residential	Planned	8	3,308,000
Totals			**16**	**5,060,000**

Engagement and Awareness

The Boston MTA Program set out to engage area professionals, expand knowledge, broaden awareness, and build mass timber projects. Launched with a public event that featured expert speakers and the ThinkWood mobile exhibit, the Mass Timber Accelerator was widely reported on in regional news media, professional publications, and local networks.

In each of the two funding rounds, project teams participated in a kick-off orientation session, a Tall Wood Structures Code education session, and toured a mass timber construction site. Each team presented their project, initial analysis work, and preliminary findings at an interactive mid-point pin-up. Project team members were able to directly engage and learn for each other and each project. Project teams were also required to meet with representatives of Woodworks to draw on their technical expertise and assistance. At the conclusion of each round, Project Teams presented the final analysis, findings, and project solutions. Once again Project Team members were able to engage with one another and learn from the work of their peers. The end results included broader awareness and increased professional expertise. They also included establishing a cohort of developers and building professionals committed to advancing and employing mass timber practices and building more sustainable buildings.

Recognizing the success and engagement model of the Boston Mass Timber Accelerator , the USDA Forest Service is working to replicate the program and is partnering with New York City and Atlanta, GA to initiate local Mass Timber Accelerator programs.

The City of Boston / BPDA are profoundly appreciative of the opportunity to partner with the USDA Forest Service and are looking forward to future opportunities and collaborating with others to encourage the adoption of mass timber and low carbon building practice everywhere.

Appendix

BOSTON MASS TIMBER ACCELERATOR - PARTICIPANT PROJECT REPORTS

- **110 Canal Street, Bulfinch Triangle** — Quaker Lane Capital with CBT Architects: seven-story commercial office building.
- **Eliot Church, Roxbury** — Leers Weinzapfel Assoc. Architects and Eliot Congregational Church: four-story affordable housing project.
- **401 Chelsea Street, East Boston** — ThoughtCraft Architects: proposed six-story building that will include 40 units of mixed-income affordable housing with ground floor retail space.
- **Mary Ellen McCormack, South Boston** — Winn Development, Boston Housing Authority, and CBT Architects: redevelopment of a public housing project in South Boston that will add 302 units of mixed-income affordable housing.
- **150 Center Street, Dorchester** — Trinity Financial and ICON Architecture: transit-oriented development that will add 81 units of mixed-income affordable housing next to the Shawmut MBTA Station.
- **Suffolk Downs B16, East Boston** — Elkus Manfredi Architects and The HYM Investment Group: a planned eight-story building that will include market rate and affordable housing over ground floor retail space.
- **Q Communities at Suffolk Downs, East Boston** — DiMella Shaffer Assoc. Architects and Project Q Communities: also part of the Suffolk Downs development, a proposed eight-story building that will have 215 units of senior and assisted living housing.
- **Bunker Hill Housing Redevelopment** — Leggat McCall Properties (LMP) on behalf of the Bunker Hill Housing tri-party development team with Stantec: two affordable and mixed-income multi-family housing buildings at 6 and 10 stories.
- **18-32 Spice Street** — RISE with CBT Architects: proposed 365 residential units at 24 floors with 20% affordable units.
- **Longwood Place** — Skanska USA Commercial Development with Sasaki: mixed use development with three high-rise commercial buildings and two high-rise residential buildings.

THOUGHTCRAFT
ARCHITECTS

BOSTON MASS TIMBER ACCELERATOR

401 CHELSEA STREET FINAL REPORT

SUMMER 2022

EXECUTIVE SUMMARY: OVERVIEW

The proposed project ThoughtCraft Architects explored for the Mass Timber Accelerator Program is an active legacy project for a family who has owned and operated a small business on the property for nearly 100 years. They have a rare opportunity to invest in the community for the next century and aim to transform the site into a new vibrant, mixed-use building that will become a positive cornerstone to Day Square in East Boston. Balancing the growth of the neighborhood with proposed BPDA planning recommendations of improving the area with added park space and a new Silver Line T stop, the design and programming of the building is intended to directly enhance and respond to these factors while setting a higher standard. The teams' objectives are to improve accessibility to the commercial uses, provide a unique living experience that will create desperately needed high-quality housing, and be a model of environmental stewardship in a community that does not typically receive this level of investment.

Bird's eye view from the south overlooking the proposed project and Day Square on the left.

Located at the east end of Day Square in East Boston, the project site consists of redeveloping the family's wedge-shaped collection of properties. The approximately 47,000 sf, six-story structure, will include around 40 units over nearly 7,000 sf of ground floor commercial space including the family's restaurant, additional leasable area for local small businesses, and the residential lobby and support uses such as the bike and mail rooms. The building will have a basement for utilities and ancillary spaces to support the restaurant on the first floor and possibly storage lockers for the residential tenants. A publicly accessible speakeasy with outdoor space is planned on an upper level of the 63-foot-tall building overlooking the square and toward downtown.

Inspired by the rich history, scale, texture, and sense of permanence evident in the many buildings throughout Boston, ThoughtCraft has proposed a new panel clad building that encases contemporary mass timber framed spaces within with metal and glass volumes emerging at the stepped rooftops. Finding inspiration not just from the ubiquitous masonry and bay exteriors, the project team is seeking to use as many natural materials as possible including mass timber as the primary structural framing to pay homage to the turn of the century post and beam mill buildings. However, the geometry of the existing wedge-shaped site provides for a challenging use of the mass timber as compared to most other mass timber buildings because of their inherent rectilinear shapes of columns, beams, and Cross Laminated Timber (CLT) panels.

Bennington Street view looking west toward Day Square on the left.

Furthermore, by utilizing mass timber in the structure, a significant reduction of embodied carbon can be achieved. Wood is truly the only renewable construction material, as well as the only material that can remove carbon from the atmosphere for the lifetime of its usage. Natural materials such as wood have inherent aesthetic benefits due to its biophilic nature resulting in unique dwelling units instead of the typical drywall boxes being built throughout the city today. Wood not only helps create a beautiful space, but research has found that it also improves productivity, health, and wellness. With increased use of these new wood products, we hope to encourage responsible, sustainable forestry practices in the area. The project team is looking to the Low Carbon Building Best Practices and Passive House guidelines to achieve a high-performance building with a low EUI score. Combining all these efforts, the goal is to set a higher standard with greater market differentiation through better design and a better building.

BENEFITS / OUTCOMES

BUILDING PRACTICES: Building Code Strategies

The three different building types of the current building code the design team looked into were: Type III, Type IV, and Type IV-HT. Here are a few considerations:

o **Type III** permits concealed spaces and not all walls are required to have a 1-hour fire rating. A disadvantage would be that CLT is not allowed in all exterior walls. This type is a viable option for our size structure and potential hybrid CLT with other wood or steel load-bearing structure.

o **Type IV** does not permit concealed spaces and requires all interior walls to be either 1-hour fire rated or mass timber construction. An advantage is that CLT is allowed for exterior walls, as long as there is an additional FRT plywood or non-combustible layer on the outside.

o **Type IV-HT** is very similar to Type IV with the exception that concealed spaces our only permitted if provided with one of the following:

- Sprinklers are added to all concealed spaces
- One layer of gyp covering all wood in the concealed space
- Concealed space is completely stuffed with non-combustible insulation

An entirely wood structure would require **Type IV-C** based on the upcoming 2021 IBC. Another consideration was the more familiar multi-family approach of 5 over 1. If this were the case, the project would have the opportunity to either:

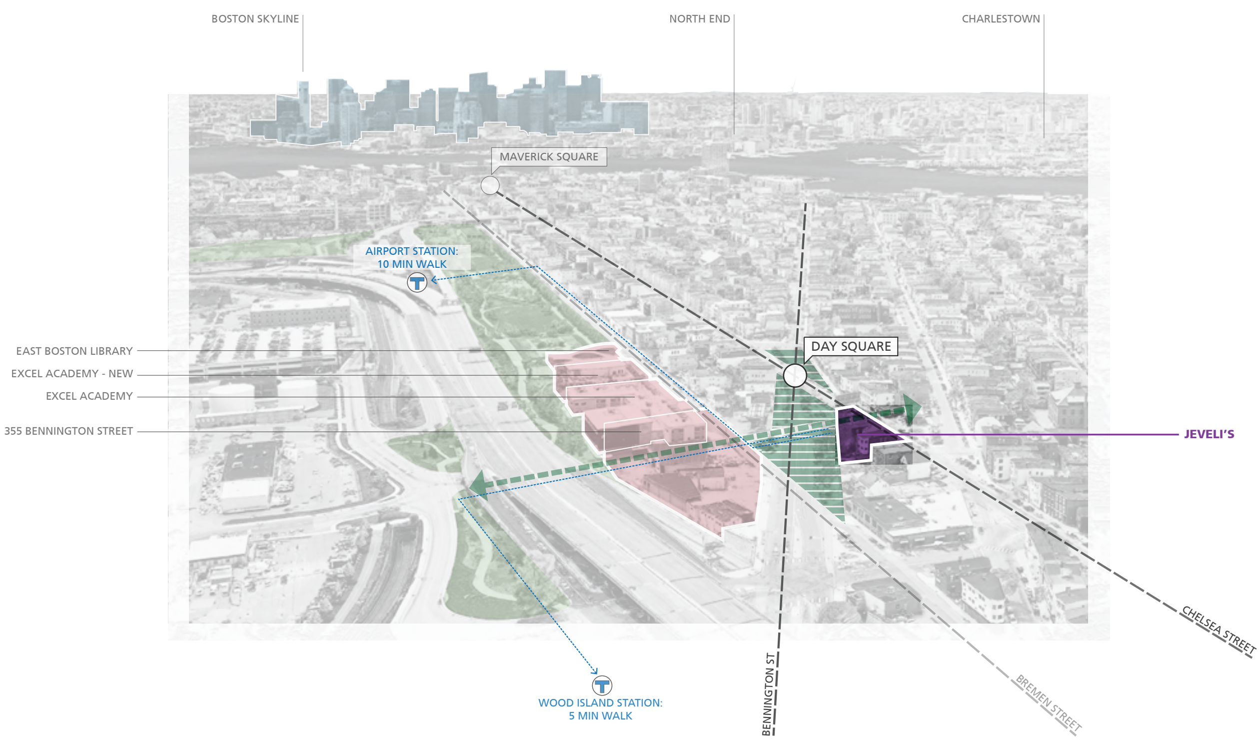
A) Pursue **Type IA** podium at the ground level retail / restaurant space with non-combustible materials and 3-hour fire separation. The five residential levels above will be constructed entirely out of timber **Type IIIA** construction.

B) Utilize steel at the ground level for structural spans and CLT decking on the second level for **Type IV-C**. The advantage to this method being that the 3-hour fire separation is reduced to a 2-hour floor and the timber may be exposed. If spans allow, glulam would also be a desirable structural option.

Concerning the roof-level Speakeasy assembly area, there would be no issues in **Type IV-C** construction. A 5-over-1 type structure would also a allow for assembly on the fifth level, since the location is technically at the fourth level of the **Type IIIA** construction above the podium. **Type IIIB** would not be allowed due to A-2 spaces only permitted in 3 stories. Regardless of construction type, all steel connections would need to be protected or concealed within the wood structure.

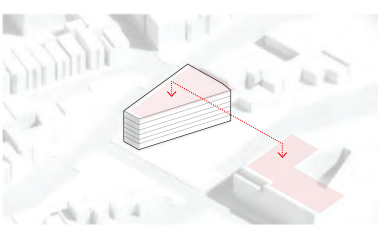
BUILDING PRACTICES: Design & Construction Strategies

The wedge-shaped site is located adjacent to Day Square and Chelsea Street in East Boston, with the narrower end offering a cityscape view of the Boston skyline. With a future multi-family development planned across the square as well as the addition of a MBTA bus stop, the design team had to consider place-making opportunities on the ground level. A stepped roof and south-facing façade design maximizes access to exterior spaces, and also opens up more daylighting and desirable views.



The project site is an optimum location for transit-oriented development.

Concept Diagrams



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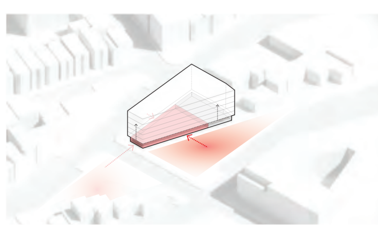
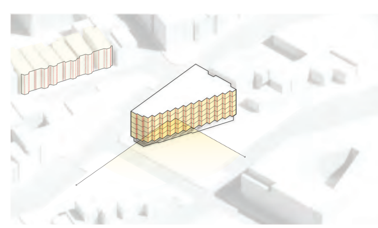
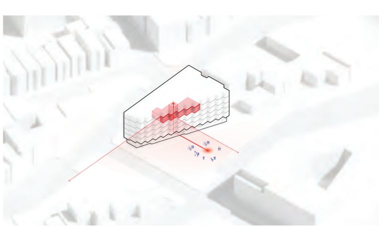


LIFT



ARTICULATION



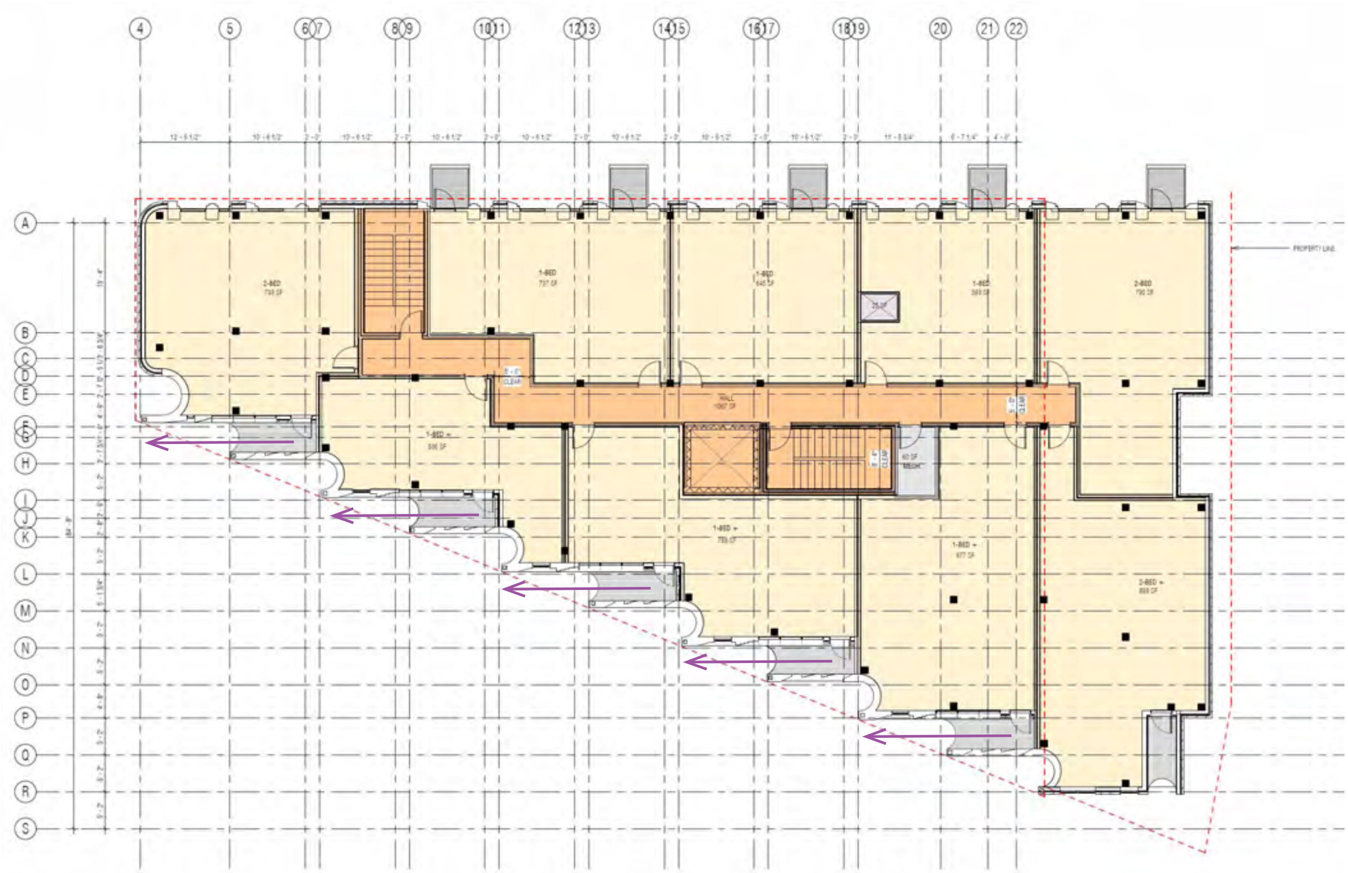
SPEAKEASY

TERRACING

TECTONICS

While the stepped façade allowed the massing of the project to conform to the wedge-shaped site and provide articulation assimilating to the context, it presented both opportunities and constraints. Opportunistically, the design is able to leverage the stepping in plan to create alternating balconies and views of the Boston skyline from each unit on the south side of the building. This also affords the opportunity to expose the underside of the CLTs on the balcony soffits, as well as the interior ceiling, to better express the use of wood inside and out to passersby.

Regarding one of the challenges with an existing wedge-shaped site, the stepped façade presented a unique geometry compared to other precedents. Symmetrical and/or rectangular floor plans are typical in most timber projects to maintain a regular structural grid. Utilizing a one-way span for the CLTs (plan left to right), we were about to use a relatively consistent grid of approximately 12'-6" which is a good spacing to accommodate typical widths of living rooms and bedrooms in housing. Additional columns were required to address the unusual layout in addition to shifting the grid across the corridor.



Typical floor plan indicating the curved balconies with downtown view that make up the south facade of the wedge-shaped building.

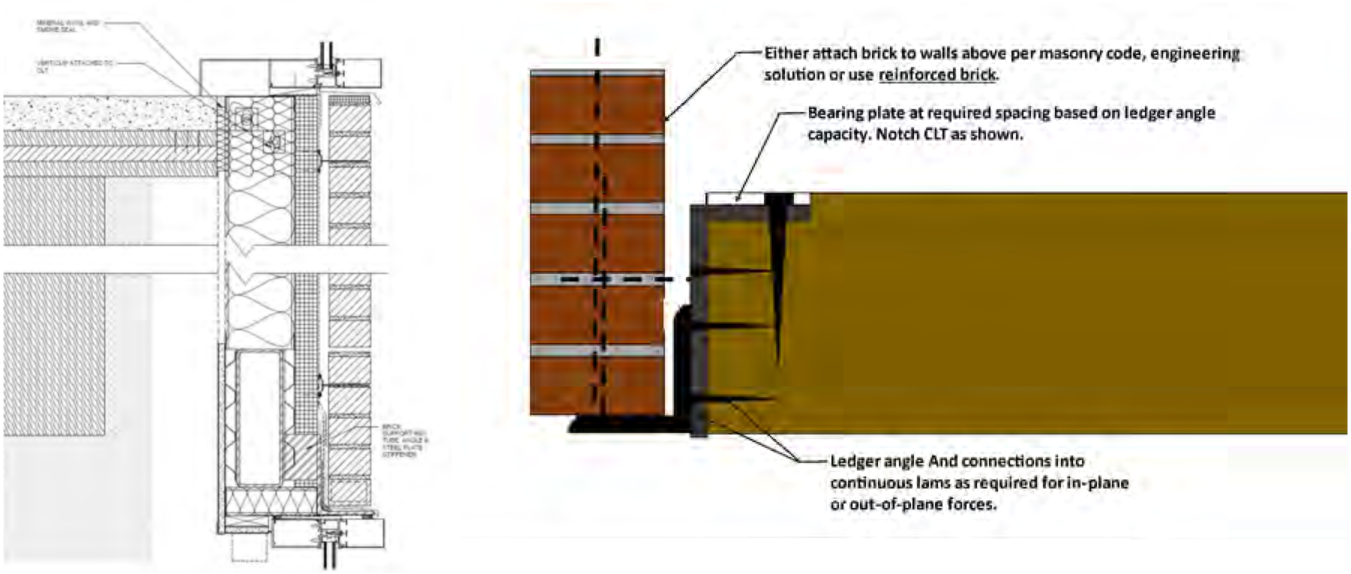
The exterior balcony spaces also present a challenging condition for properly managing water and snow, and how to carry the load of brick along the curved floor edges without adding costly complexity to the framing strategy.

Street view from Day Square and Bennington Street depicting the stepping south facade with alternating concaved balconies.

The curvature of the scalloped façade design was first addressed in the utilization of mass timber CLT panels. Through conversations with CLT manufacturers it was determined the panels can easily be CNC milled in any shape desired. This allows the floor panel structure to follow the balcony perimeter along a tight radius as intended.

The design team next explored how to frame the balcony to best manage water and snow with a step in the floor assembly. Ideas of milling down continuous CLT panels to create a step at the exterior wall as well as reducing the panel plys in the layout at the balconies were evaluated. However, framing the balcony with a separate CLT panel from the interior and primary structure to create a step down was the simplest and maintained the integrity of the design best. The separate structure requires a structural floor beam to cantilever out beneath the CLT to pick up the load of the separate panel or span to another vertical load-bearing frame along the perimeter. Since we had the exterior wing wall flanking the balconies on the outermost facade, we were able to add a secondary steel column and beam (for thinness) to support the outer edge of the CLT panel. This allows for easily shaping the balcony surface to manage water. Moisture protection (i.e. clear sealant) on the exposed soffit would be required on all exposed wood faces and ideally not have a negative effect on its appearance.

Cantilevering double glulam beams combined with steel beams and columns allowed for a separate CLT panel for the concaved balconies.



Courtesy of WoodWorks, alternative brick relief details at an intermediate CLT floor for punched oenings and bearing conditions.

Street view from Day Square and Bennington Street depicting the stepping south facade with alternating concaved balconies.

Originally with brick as an exterior finish the extra weight would require a robust attachment system, especially with a separate balcony assembly. The design team began looking at details for this condition and the cost to roll a curved steel shelf angle to carry the brick on the CLT edge proved to be too costly. Thus, the decision was made to move forward with a lighter cladding, either vertically oriented ribbed metal panel or fiber cement panels. To address the curvature, the metal panel cladding is inherently flexible to bend around a curve whereas the fiber cement panels could be arranged in a pattern of narrow vertical planks to segment the arc along the floor transitions.

COST ANALYSIS

Because the development is restricted to six stories and a height limitation due to FAA regulations as well as some economy of scale challenges, we have approached this project as a conventional 5 over 1 structure for our baseline to focus the comparison on the following alternative mass timber options:

Option #1: First floor steel podium Type I-A with 5 levels of panelized stick-built load-bearing walls with CLT floor panels as Type III-A.

Accounting for the reduction in building height and some time savings, the cost to go with CLT panels in lieu of traditional TJI framing while maintaining the panelized stick-built load-bearing walls would be a 2.2% cost increase or add $8.45/sf to the project.

Street view from Chelsea Street of the north facade looking down the new Silver Liine Way.

Option #2: First floor steel podium Type I-A with 5 levels of glulam columns and beams with CLT floor panels as Type III-A

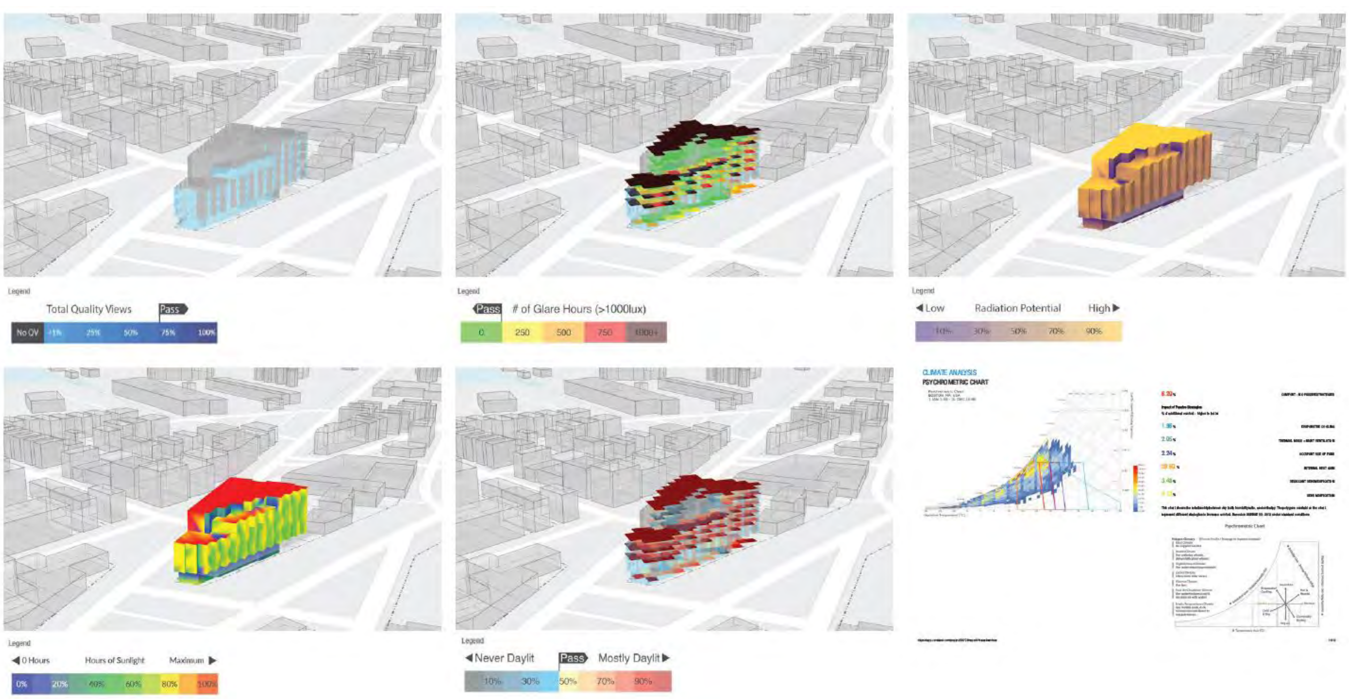
Also, accounting for the reduction in building height and more time savings, the cost to go with a full mass timber structural frame with glulam columns and beams and CLT panels for the floors in lieu of traditional TJI framing and the panelized stick-built load-bearing walls would be a 13.2% cost increase or add $49.60/sf to the project.

OPPORTUNITIES REALIZED & LESSONS LEARNED

In considering options for the structural framing, the use of mass timber did not initially seem to be suitable for the awkward shaped site. However, as we learned more about the benefits of mass timber from WoodWorks, our structural engineer, and various seminars and conferences we better understood how a prefabricated timber solution could meet our design needs and streamline construction for this unique site. As a busy urban lot limited in construction accessibility, there would be no staging area for jobsite storage. With a prefabricated system, there is great potential for reduction of time at the build site as well as a carbon reduction with workers and delivery trucks commuting to and from the site less often.

Given that this project was tracking real time with a real client along with the accelerator program, this added some complexity in our ability to guide the project in sometimes separate directions. The objective to create an above-market sustainable mixed-use building has remained a priority. The primary **opportunity realized** in this study for us is that the use of mass timber components is not an all or nothing proposition. We understand there are cost-effective limitations but there is also design flexibility.

We learned that the CLT panels for the floor structure in combination with panelized stick-built walls is a viable option and still allows us to have the integrated balconies as the project was conceptualized. Taking advantage of the panel orientation and the CLT's ability to span and cantilever showed significant promise in creating uniquely shaped buildings and footprints that don't fit the typical box form often seen in the use of mass timber.



At ThoughtCraft Architects, we use Cove.tool software to analyze design options for optimum environmental performance.

We're excited by the many known benefits of using mass timber, but one of the most inspiring and unexpected **lessons learned** with exploring mass timber for this project was our findings in calculating the carbon benefit when comparing the two structural approaches.

We learned that the more cost-effective structural solution that utilizes conventional stick-built walls has 9% more of a carbon benefit than the more comprehensive mass timber solution even with less volume of wood. This is a surprising win-win solution when comparing these two structural approaches for our project and the possibilities this hybrid solution provides!

Option #1:
First floor steel podium Type I-A with 5 levels of panelized stick-built load-bearing walls with CLT floor panels as Type III-A.

Option #2:
First floor steel podium Type I-A with 5 levels of glulam columns and beams with CLT floor panels as Type III-A.

Results from the WoodWorks Carbon Calculator comparing the use of stick-built versus glu-lam load bearing structural framing.

Regarding further energy analysis, we learned the South-facing units have the potential to utilize passive strategies and we designed those exterior walls with slightly less fenestration and the balcony walls to better shade that exposure. Investing in a higher performance envelope and HVAC systems would yield significant improvement to these primary energy consumers.

NEXT STEPS

Our outlook for this project is realistic and the client has remained committed to using mass timber on the project as long as it makes since. The volatility of the current economy and construction market have certainly become a factor driving the design team and builder to explore alternative hybrid systems to at least squeeze in some mass timber and prefabricated assemblies reducing the carbon footprint for the project. Through our efforts to refine the design and budget we have maintained the use of mass timber in the project. Specifically, the economics for a Type IIIA building using CLT floor panels over conventional panelized stick-built load bearing walls on a Type IA podium structure is the most viable option for this project and has a better carbon benefit than the alternative option. We will continue to pursue this option during the project's approval processes along with more refined energy modeling to inform the envelope and systems design.

Furthermore, we continue to expand the study and push for the use of mass timber in at least two other current projects and Passive House certification for another. We are also implementing updates to our standards that follow the Article 37 Interagency Green Building Committee's recommendation for Multi-Family Residential Low Carbon Building Best Practices.

Mary Ellen McCormack Building B

Mass Timber Accelerator Grant | July 15, 2022

The Team

Developer/Proponent : **WinnDevelopment**

Master Planner and Architect - Building B: **CBT**

Structural Engineer: **Thornton Tomasetti**

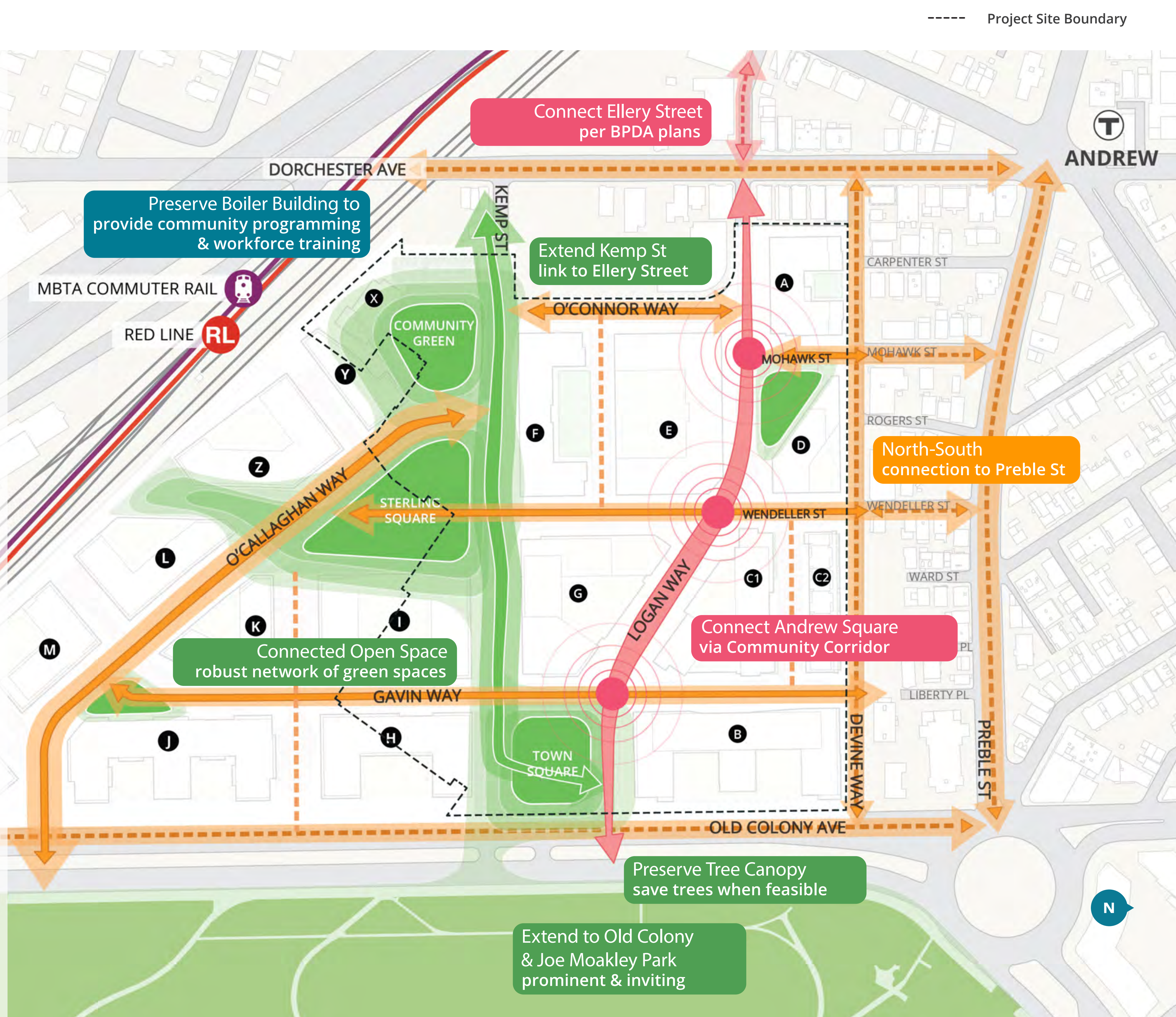
Code Consultant: **CodeRed**

Pre-Construction Manager: **Lee Kennedy/ Janey**

MASTERPLAN DESIGN PRINCIPLES

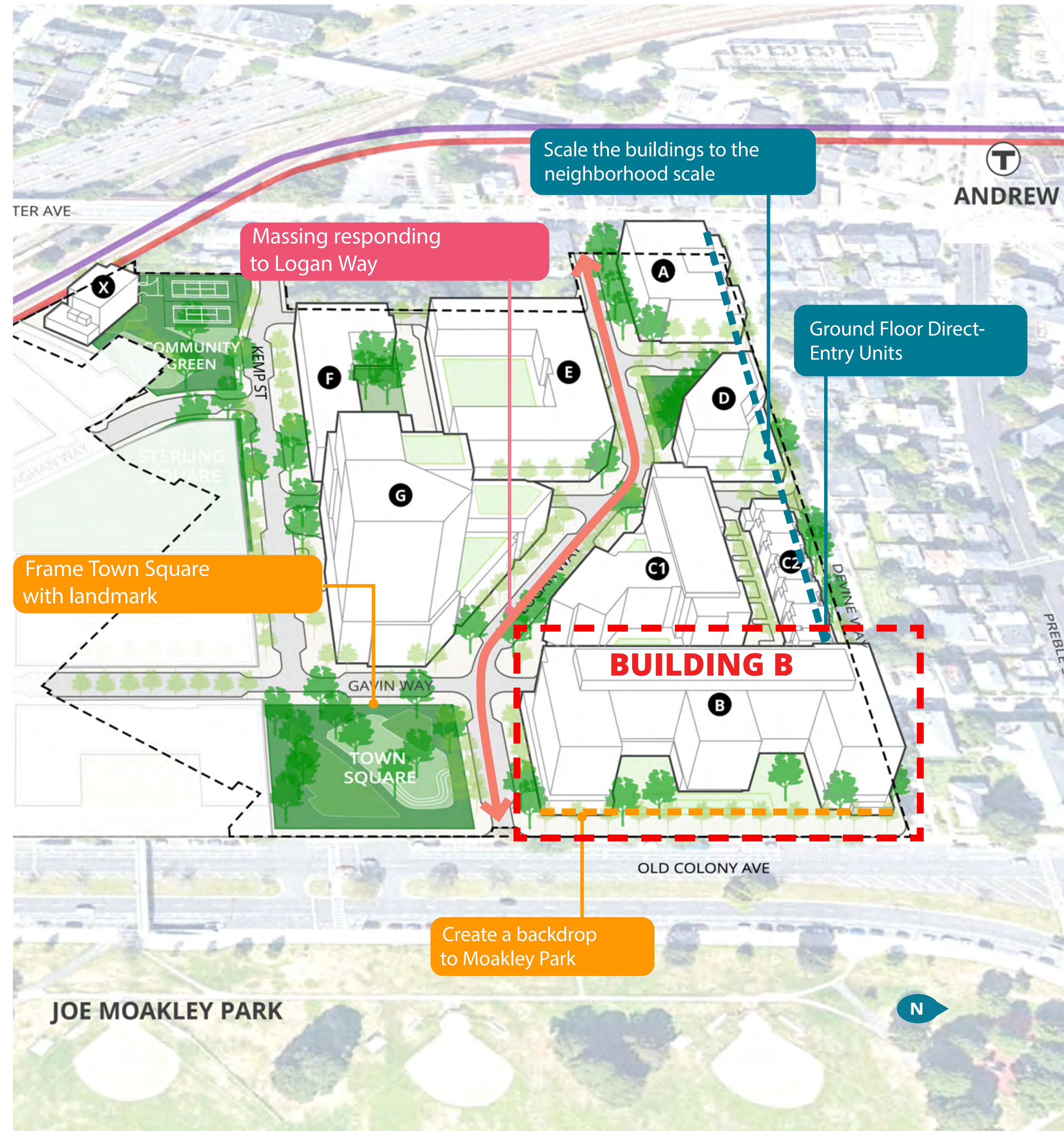
Sustainability Commitments

- **High Performance Building Design**
  - o Passive House Institute US - 2021 Certification
  - o Modeled performance < 1.8 kgCO2/W sf/year (50% better than code)
  - o **Low-carbon design,** all-electric ready
  - o Energy Star Multifamily New Construction Certification
  - o EPA Indoor airPLUS Certification
- **Sustainable Site Planning**
  - o Multi-modal Transit Oriented Development
  - o Local & Resilient Landscaping
  - o Tree Preservation & Heat Island Mitigation
  - o LEED v4 Certifiable
- **Maximizing solar PV, energy storage, and load flexibility**
  - o Resilience Hub Planning Underway
- **Prioritizing long-term community and environmental health**
- **Rigorous 3rd party verification & certification process**



PROPOSED SITE PLAN AND MASSING (PHASE 1)

Number of buildings **9**	Residential Units **1,365**
Total GFA **1,449,000**	Open Space (acres) **2.3**

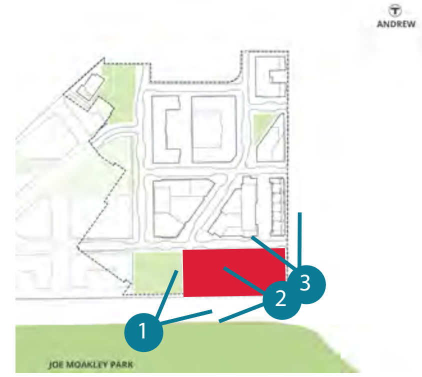


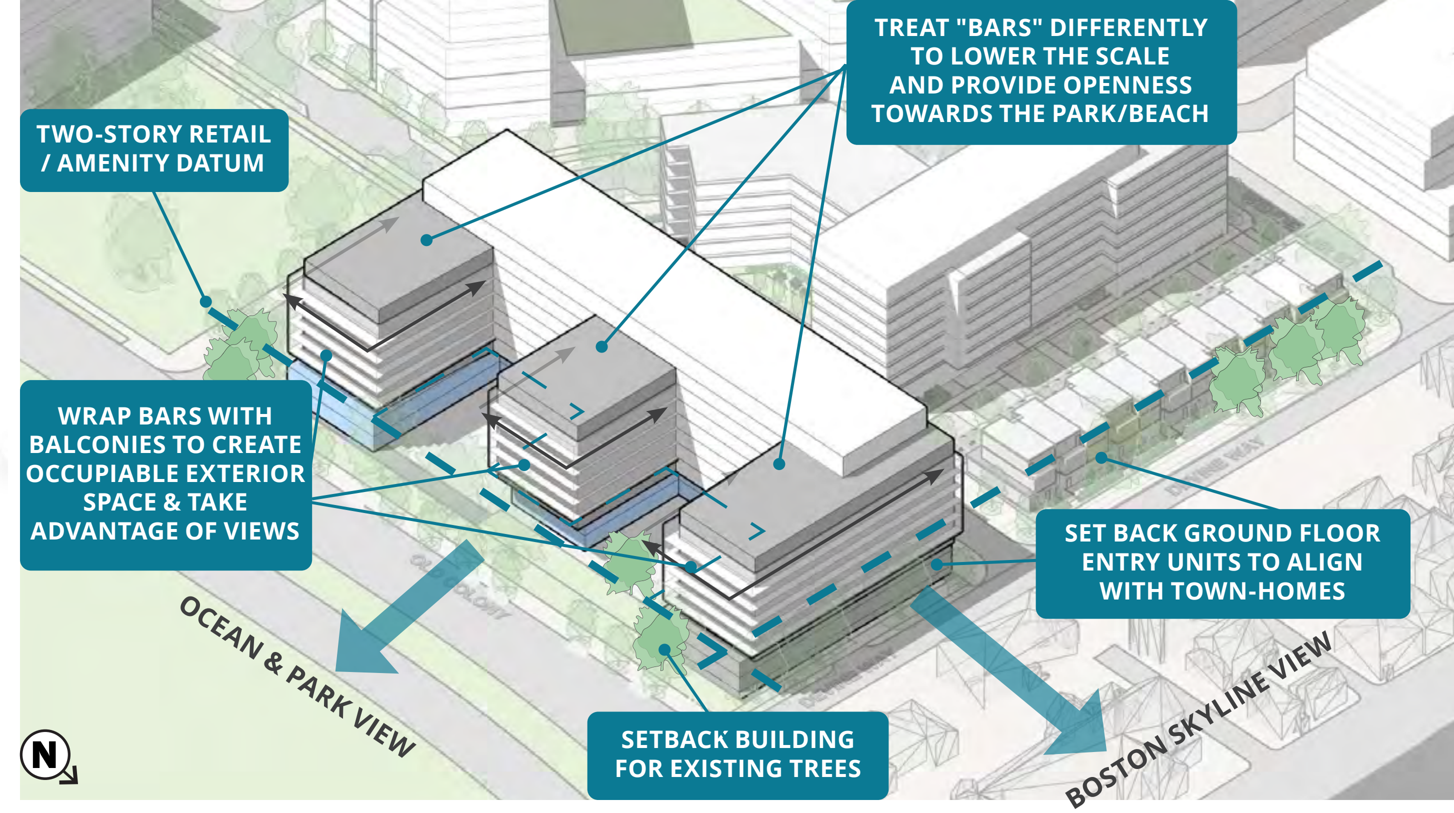
BUILDING B SUMMARY

Mixed-Income Apartments

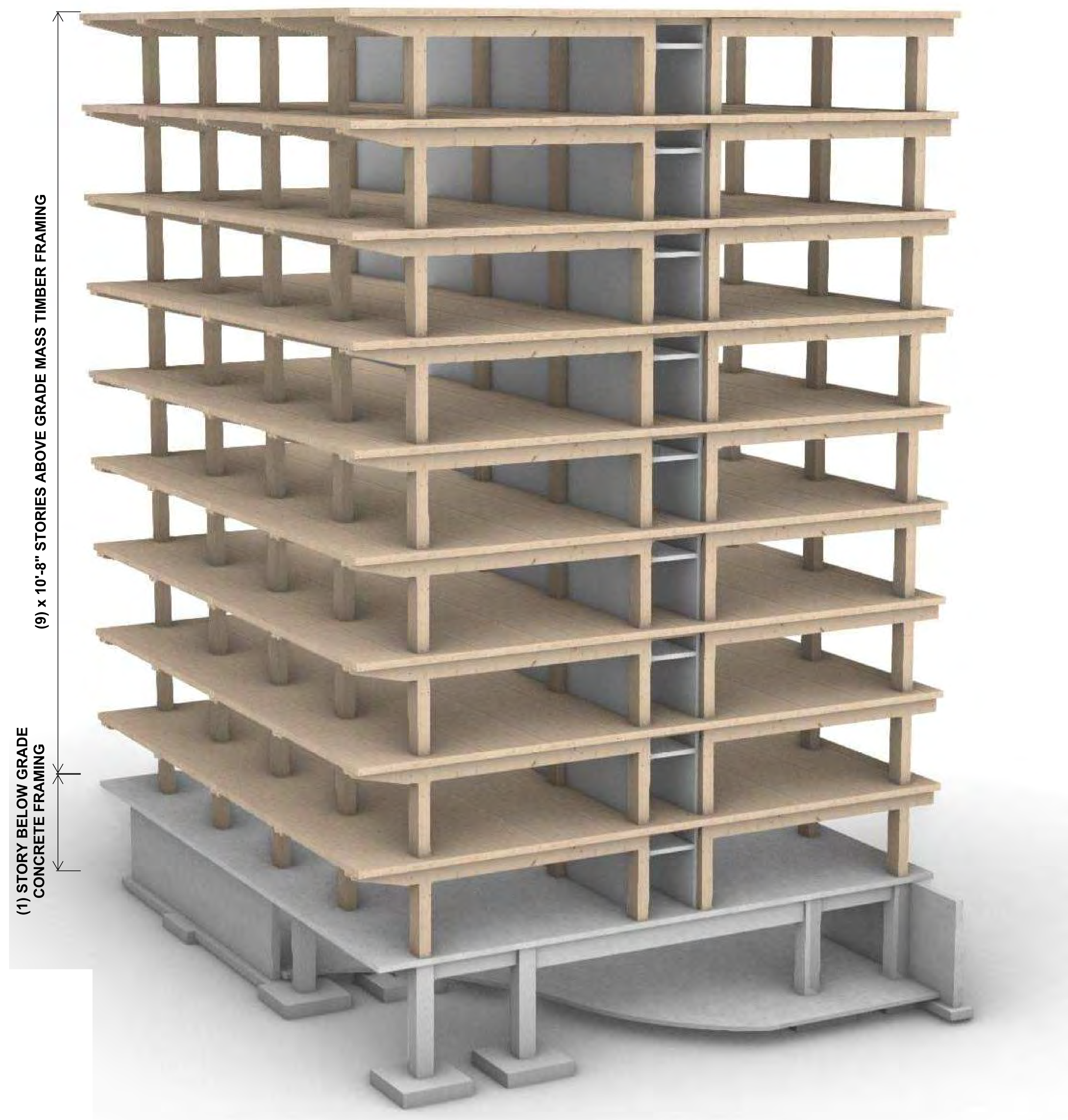
(Including 20% Boston Housing Authority Replacement Units)

322,000 sf | 302 Units





STRUCTURAL DIAGRAM



CODE SUMMARY (IBC 2021 AND 2024)

2021 IBC Requirements

The 2021 IBC contains the following major provisions relative to Type IV-B buildings:

- Cross-laminated timber is required to be labeled as conforming to the 2019 edition of the ANSI/APA PRG 320 standard (2021 IBC 602.4).

- Exterior walls are required to be of (1) noncombustible construction, (2) mass timber construction, or (3) Type IV-HT construction in accordance with 2021 IBC Section 602.4.4. Where exterior walls are of mass timber construction or Type IV-HT construction, the outside face of the exterior walls are required to be protected with noncombustible materials with a minimum assigned time of 40-minutes (i.e. 5/8" Type X Gypsum Board) as specified in 2021 IBC Table 722.7.1(1). Combustible exterior wall coverings are not permitted except water-resistance barriers having a peak heat release rate of less than 150 kW/m² (2021 IBC 602.4.2.1).

- In general, the interior faces of all mass timber elements, including the inside face of exterior mass timber walls and mass timber roofs, must be protected by noncombustible materials (2021 IBC 602.4.2.2). The protection time must contribute to a time equal to 2/3 of the fire-resistance rating of the building element, but not less than 80 minutes. Notable exceptions include the following:

    - Areas of mass timber ceilings not more than 20% of the floor area are permitted to be exposed.
    - Areas of mass timber walls not more than 40% of the floor area are permitted to be exposed unless serving as an incidental separation per 780 CMR Section 509.

    These provisions apply on a per sleeping unit or per fire area basis. A 'sum of the ratios' type equation allows for a combination of the exposed ceilings and walls to be exposed. Unprotected areas of ceilings and walls are required to be separated by at least 15 ft horizontally. Where mass timber beams exist below a mass timber ceiling, or mass timber columns exits inboard of mass timber walls, all three surfaces of such exposed members are required to be included in the exposed area calculations (2021 IBC 602.4.2.2.2).

- The floor assembly must contain a noncombustible material not less than 1" in thickness above the mass timber (2021 IBC 602.4.2.3).

- The interior surfaces of roof assemblies must be protected by noncombustible materials (2021 IBC 602.4.2.4).

- Concealed spaces are not permitted to contain combustibles other than MEP equipment permitted in plenums in accordance with IMC 602. Combustible construction forming concealed spaced must be protected with noncombustible materials with a minimum assigned time of 40-minutes (2015 IBC 602.4.3.5).

- No exposed mass timber is permitted on the inside and outside surfaces of exit enclosures and elevator hoistways in high-rise buildings (2021 IBC 602.4.2.6). Interior faces of shaft enclosures must be protected by noncombustible materials (2021 IBC 602.4.1.2 & 602.4.2.6).

- Sealant or adhesive meeting ASTM C920 or D3498, respectively, is required to be provided to resist the passage of air in the following locations (2021 IBC 703.7):
    - At abutting edges and intersections of mass timber building elements required to be fire-resistance rated
    - At abutting intersections of mass timber building elements and building elements of other materials where both are required to be fire-resistance rated

There is a change to the 2021 **IFC** (Section 3303.5) which requires certain features to be provided during construction, including installation of required protective gypsum board layers when construction has exceeded six stories above a given floor. We note that the IFC is not adopted in Massachusetts unless specifically referenced by 780 CMR, such that these requirements are not directly applicable. We are not aware of the MA Fire Code (527 CMR) being modified to include such requirements.

Increase in Exposed Ceiling Area (2024 IBC)

Although not officially finalized or published, there is a proposed code change for the 2024 IBC that has been preliminarily 'approved as submitted' that is worth noting. Via Code Change G147-21, the aforementioned limit to the amount of **ceiling area** that can be exposed will be increased from 20% to 100%. Given the common desire for wood to be exposed at the ceiling, this change would dramatically affect the aesthetic flexibility of residential unit design. Please note that, even when finalized in the printed 2024 IBC, this provision would not be a part of the 10th edition of 780 CMR, which will be based on the 2021 IBC. Additional approval/relief would have to be sought to utilize these provisions.

CODE SUMMARY - IBC 2021 EXCERPTS

TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	See Footnotes	TYPE OF CONSTRUCTION											
		Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	270	180	85	85	70	60
H-1, H-2, H-3, H-5	NS[c, d]	UL	160	65	55	65	55	120	90	65	65	50	40
	S												
H-4	NS[c, d]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	140	100	85	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	180	120	85	85	70	60
I-1 Condition 2, I-2	NS[d, e, f]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85									
I-4	NS[d, g]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	180	120	85	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	65	65	65	50	40
	S13D	60	60	60	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	270	180	85	85	70	60

TABLE 504.4—continued
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE[a, b]

OCCUPANCY CLASSIFICATION	See Footnotes	TYPE OF CONSTRUCTION											
		Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
R-1[h]	NS[d]	UL	11	4	4	4	4	4	4	4	4	3	2
	S13R	4	4									4	3
	S	UL	12	5	5	5	5	18	12	8	5	4	3
R-2[h]	NS[d]	UL	11	4	4	4	4	4	4	4	4	3	2
	S13R	4	4	4								4	3
	S	UL	12	5	5	5	5	18	12	8	5	4	3
R-3[h]	NS[d]	UL	11	4	4	4	4	4	4	4	4	3	3
	S13D	4	4									3	3
	S13R	4	4									4	4
	S	UL	12	5	5	5	5	18	12	5	5	4	4
R-4[h]	NS[d]	UL	11	4	4	4	4	4	4	4	4	3	2
	S13D	4	4									3	2
	S13R	4	4									4	3
	S	UL	12	5	5	5	5	18	12	5	5	4	3
S-1	NS	UL	11	4	2	3	2	4	4	4	4	3	1
	S	UL	12	5	4	4	4	10	7	5	5	4	2
S-2	NS	UL	11	5	3	4	3	4	4	4	5	4	2
	S	UL	12	6	4	5	4	12	8	5	6	5	3
U	NS	UL	5	4	2	3	2	4	4	4	4	2	1
	S	UL	6	5	3	4	3	9	6	5	5	3	2

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b, c]	1[b, c]	0[c]	1[b, c]	0	3[a]	2[a]	2[a]	HT	1[b, c]	0
Bearing walls												
Exterior[e, f]	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	3	2	2	1/HT[g]	1	0
Nonbearing walls and partitions Exterior	See Table 705.5											
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	$1^1/_2$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	$1^1/_2$	1	1	HT	1[b,c]	0

TABLE 705.5 FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE[a, d, g]

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H[e]	OCCUPANCY GROUP F-1, M, S-1[f]	OCCUPANCY GROUP A, B, E, F-2, I, R[i], S-2, U[h]
X < 5[b]	All	3	2	1
5 ≤ X < 10	IA, IVA	3	2	1
	Others	2	1	1
10 ≤ X < 30	IA, IB, IVA, IVB	2	1	1[c]
	IIB, VB	1	0	0
	Others	1	1	1[c]
X ≥ 30	All	0	0	0

For SI: 1 foot = 304.8 mm.

a. Load-bearing exterior walls shall also comply with the fire-resistance rating requirements of Table 601.
b. See Section 706.1.1 for party walls.
c. Open parking garages complying with Section 406 shall not be required to have a fire-resistance rating.
d. The fire-resistance rating of an exterior wall is determined based upon the fire separation distance of the exterior wall and the story in which the wall is located.
e. For special requirements for Group H occupancies, see Section 415.6.
f. For special requirements for Group S aircraft hangars, see Section 412.3.1.
g. Where Table 705.8 permits nonbearing exterior walls with unlimited area of unprotected openings, the required fire-resistance rating for the exterior walls is 0 hours.
h. For a building containing only a Group U occupancy private garage or carport, the exterior wall shall not be required to have a fire-resistance rating where the fire separation distance is 5 feet (1523 mm) or greater.
i. For a Group R-3 building of Type II-B or Type V-B construction, the exterior wall shall not be required to have a fire-resistance rating where the fire separation distance is 5 feet (1523 mm) or greater.

TYPE IV-B MASS TIMBER LAYOUT

9 STORIES WOOD OVER 1 STORY CONCRETE

FIRE RATING REQUIREMENTS FOR STRUCTURAL ELEMENTS (PER IBC 2021)

Primary Structural Frame	2 hrs
Bearing Walls	2 hrs
Floor Construction	2 hrs
Roof Construction	1 hr

WOOD VOL / SF:
5-PLY CLT = 990 in^3/sf
Glulam Beams = 196 in^3/sf
Glulam Columns = 159 in^3/sf

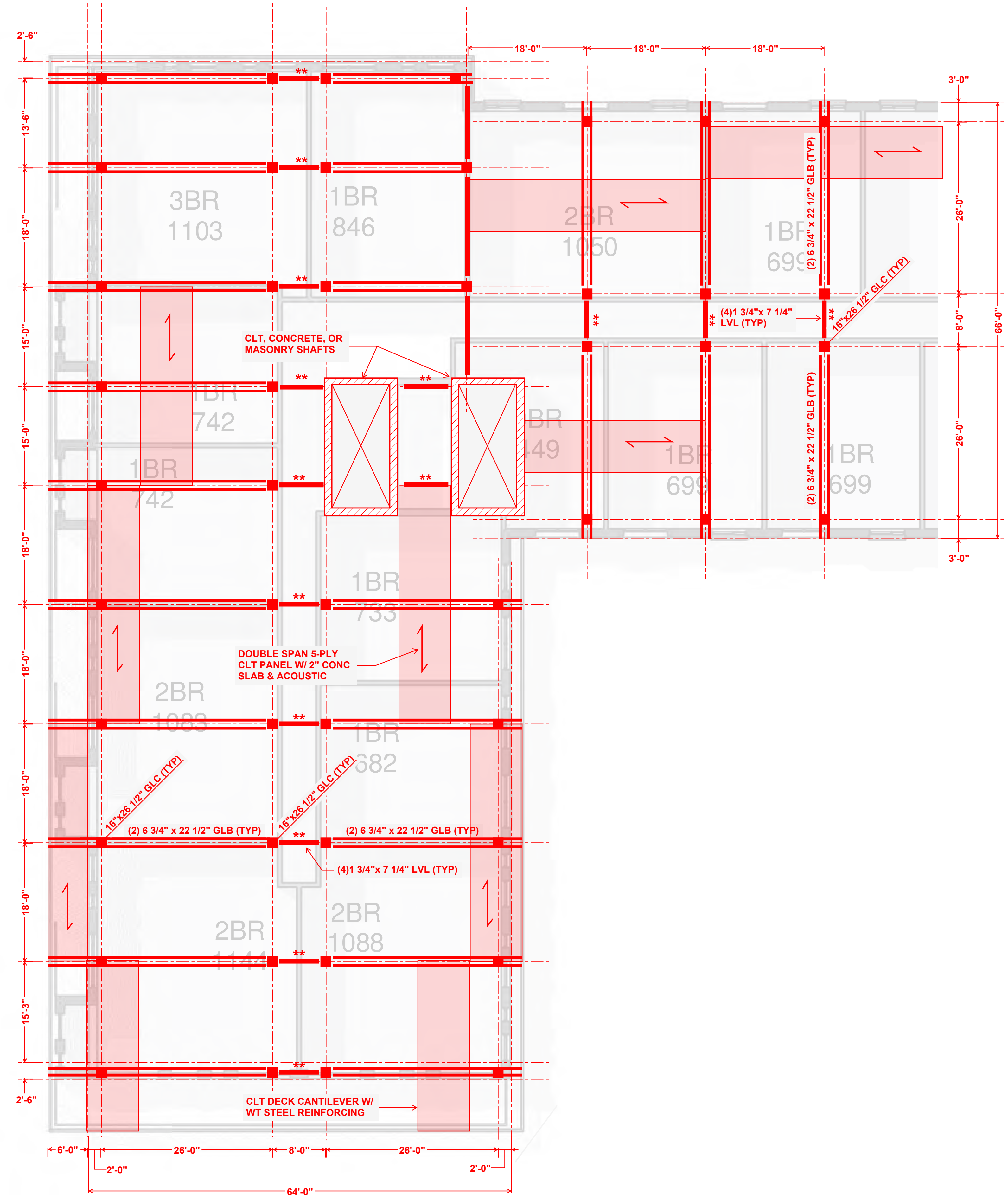
TOTAL = 1345 in^3/sf
% of framing in total wood volume = 26%

Material Assumptions:
CLT Floor and Roof Panels: *Grade E1*
Glulam Beam Framing: *Western Species Grade 24F-1.8E*
Glulam Column Framing: *Western Species Grade 2 DF-L2*

DESIGN CRITERIA:

FLOOR DEAD LOAD = 65 psf (including CLT weight)
FLOOR LIVE LOAD = 40 psf

DRAWING NOTES:
1. ⟵⟶ Indicates double span of 5-PLY Grade E1 CLT topped with 2" concrete slab and acoustic layer.
2. Column sizes reported for lowest level of wood, resulting in maximum column size. Column sizes at upper stories likely to decrease in depth.
3. ** tag on beam indicates member assumed to be fully fire protected by architectural finishes.



FLR/FLR HEIGHTS - CORRIDOR STUDY

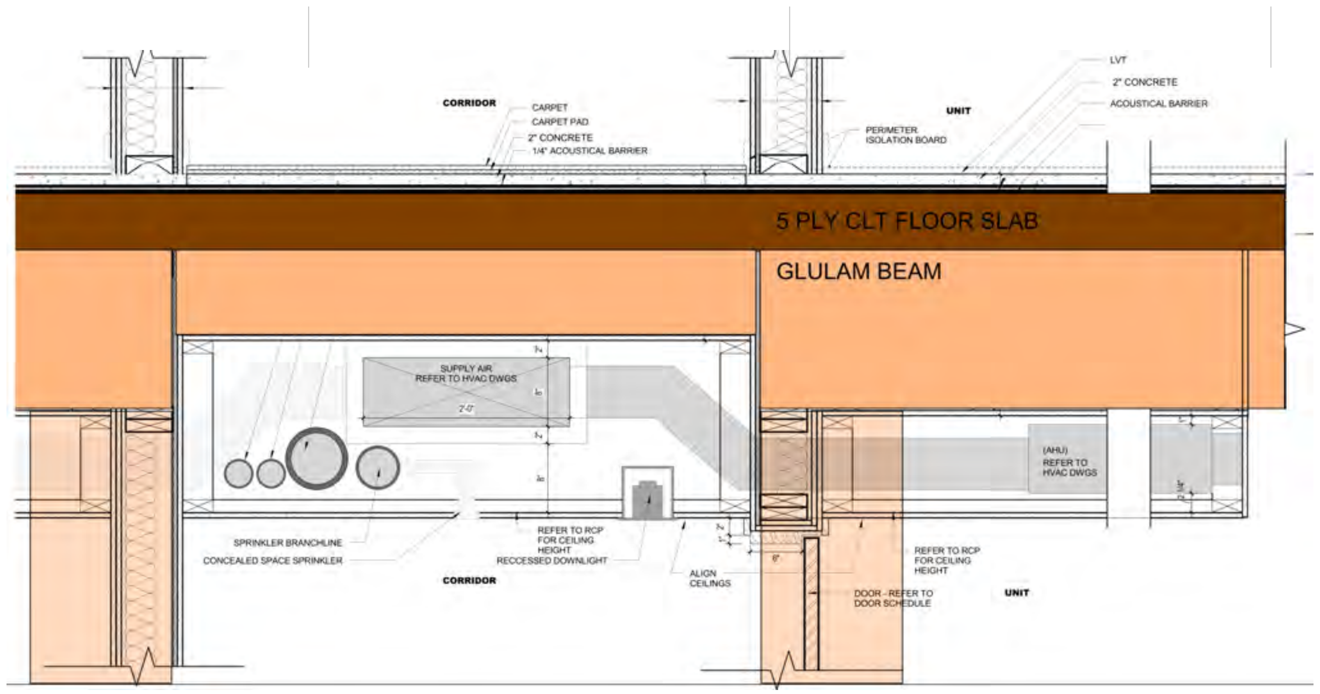
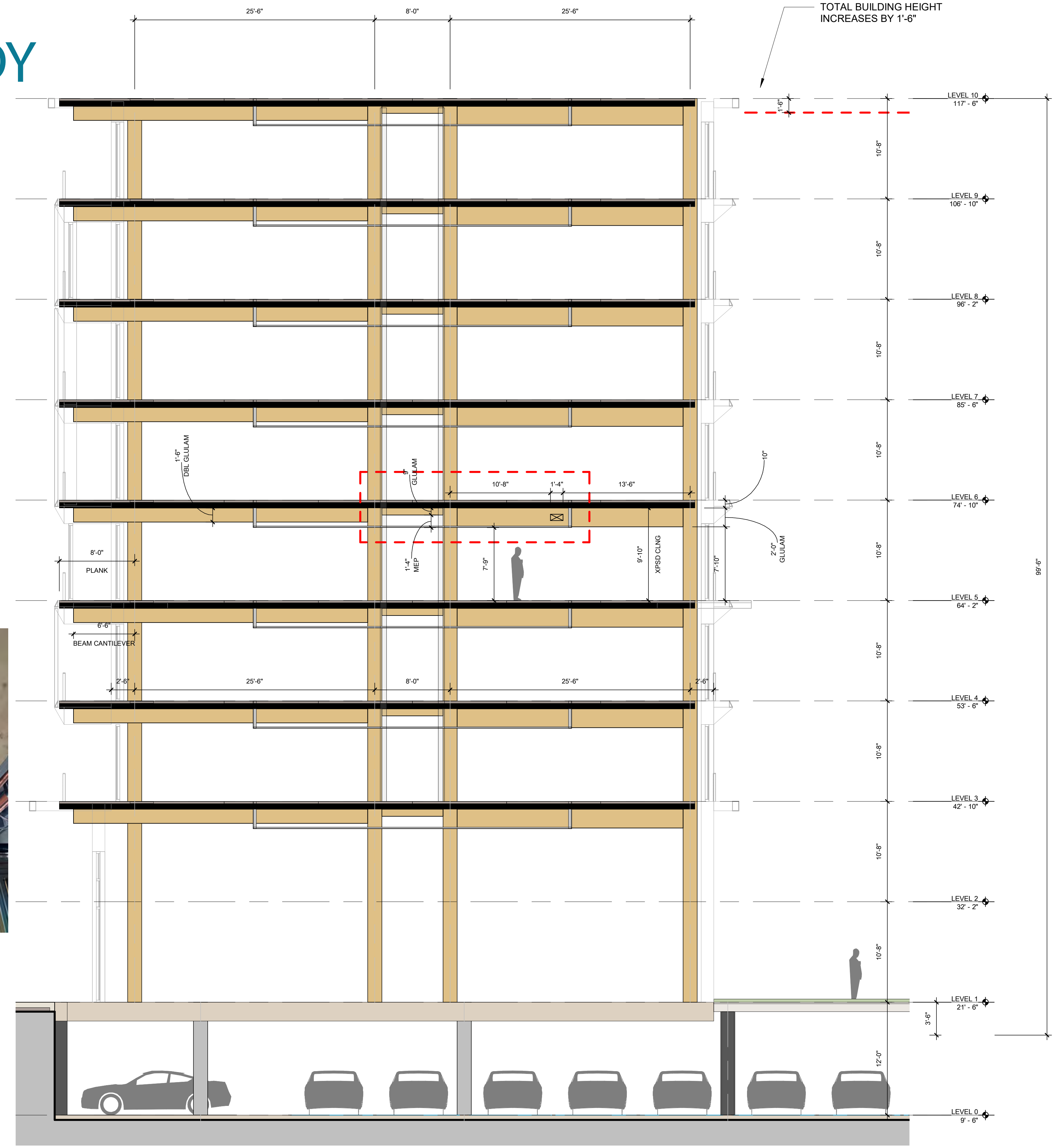


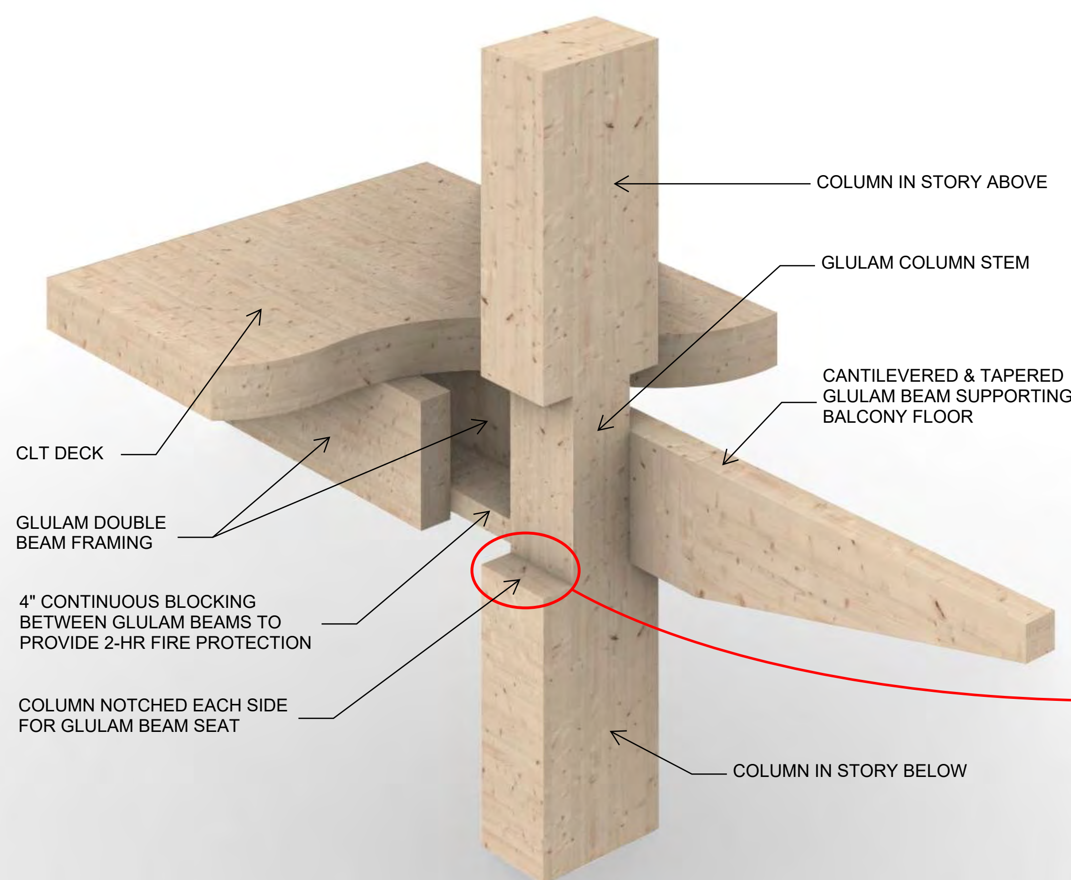
photo: WoodWorks

T3 Minneapolis utilizes a rectangular 20x25-ft grid with 2x8-ft NLT panels spanning 20 ft between glulam beams in order to allow main MEP truck lines to circulate around the central core with service trunk lines branching out in each bay as necessary. This minimizes the need for glulam beam penetrations.

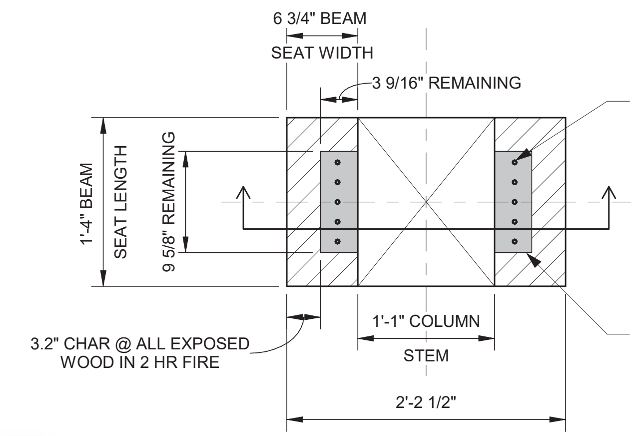
11 E Lenox corridor and beam penetrations precedent



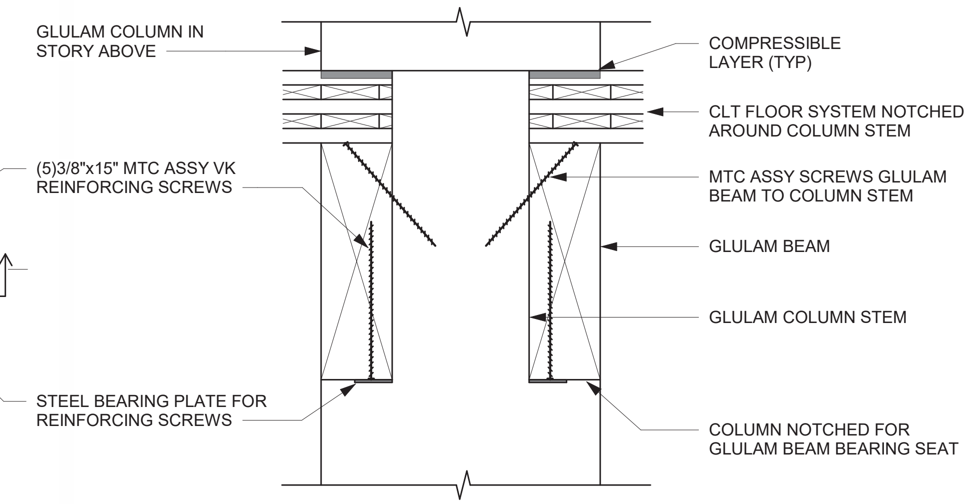
DOUBLE BEAM BALCONY CONCEPT



BEAM TO COLUMN CONNECTION

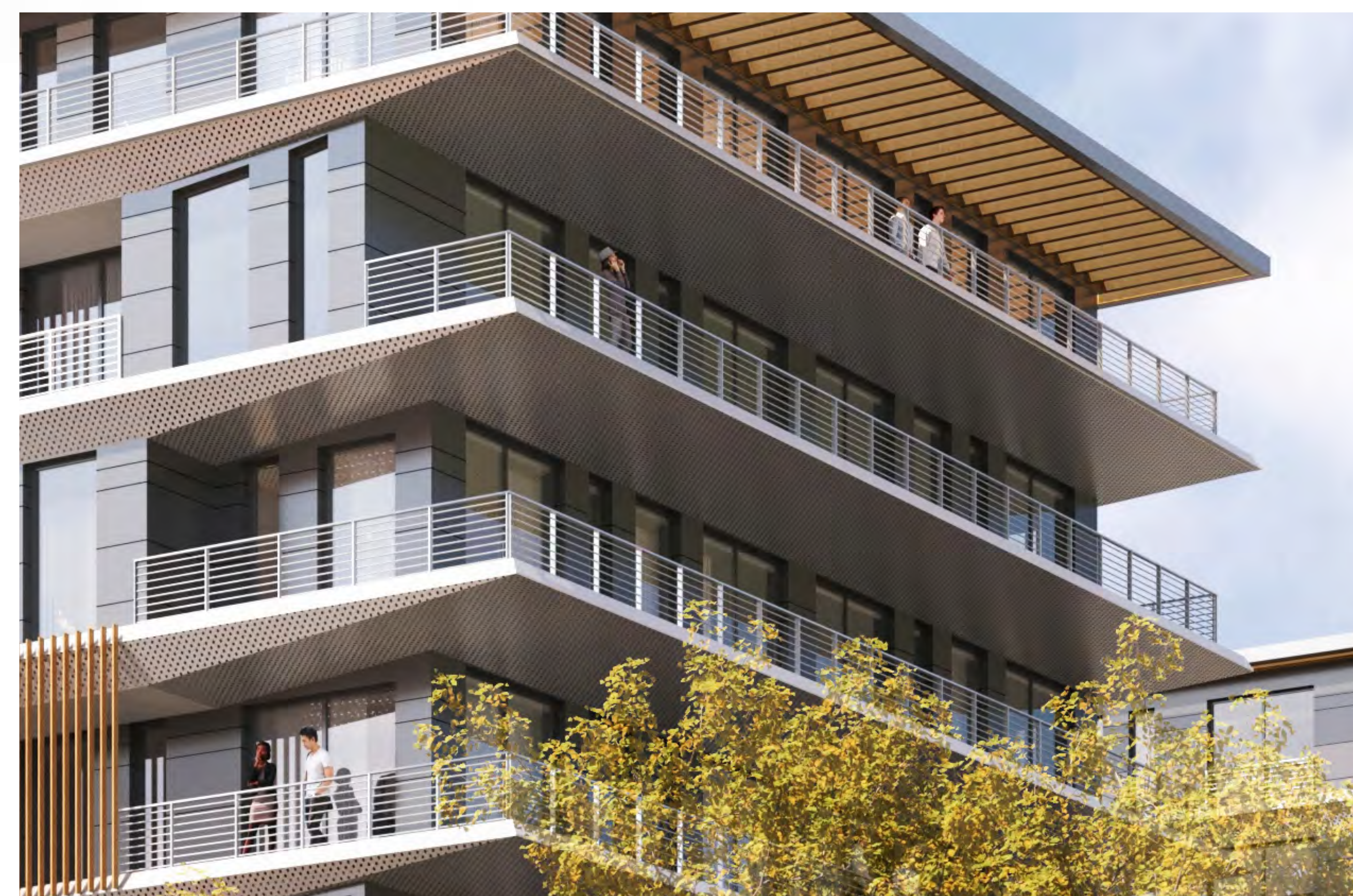


TOP OF COLUMN PLAN VIEW W/ 2-HR FIRE CHAR DEVELOPMENT



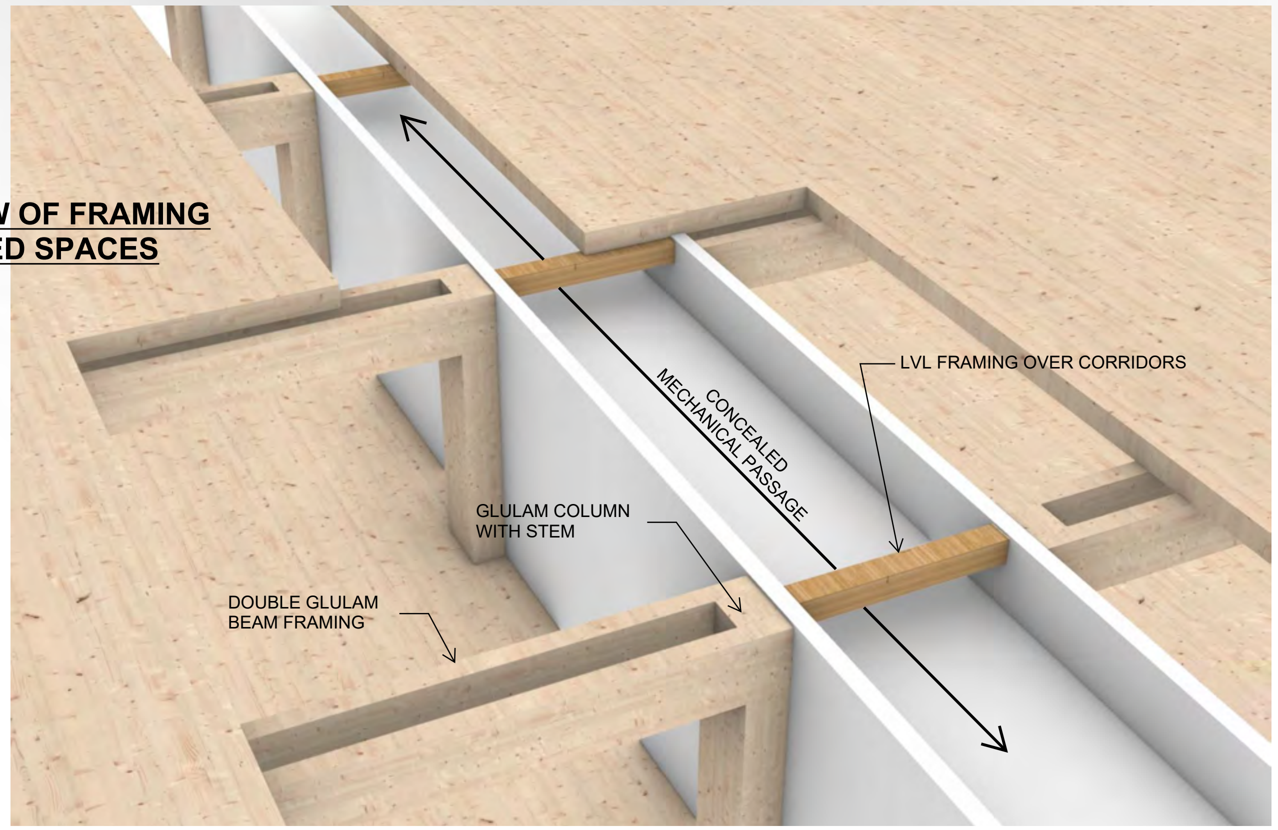
COLUMN SECTION VIEW

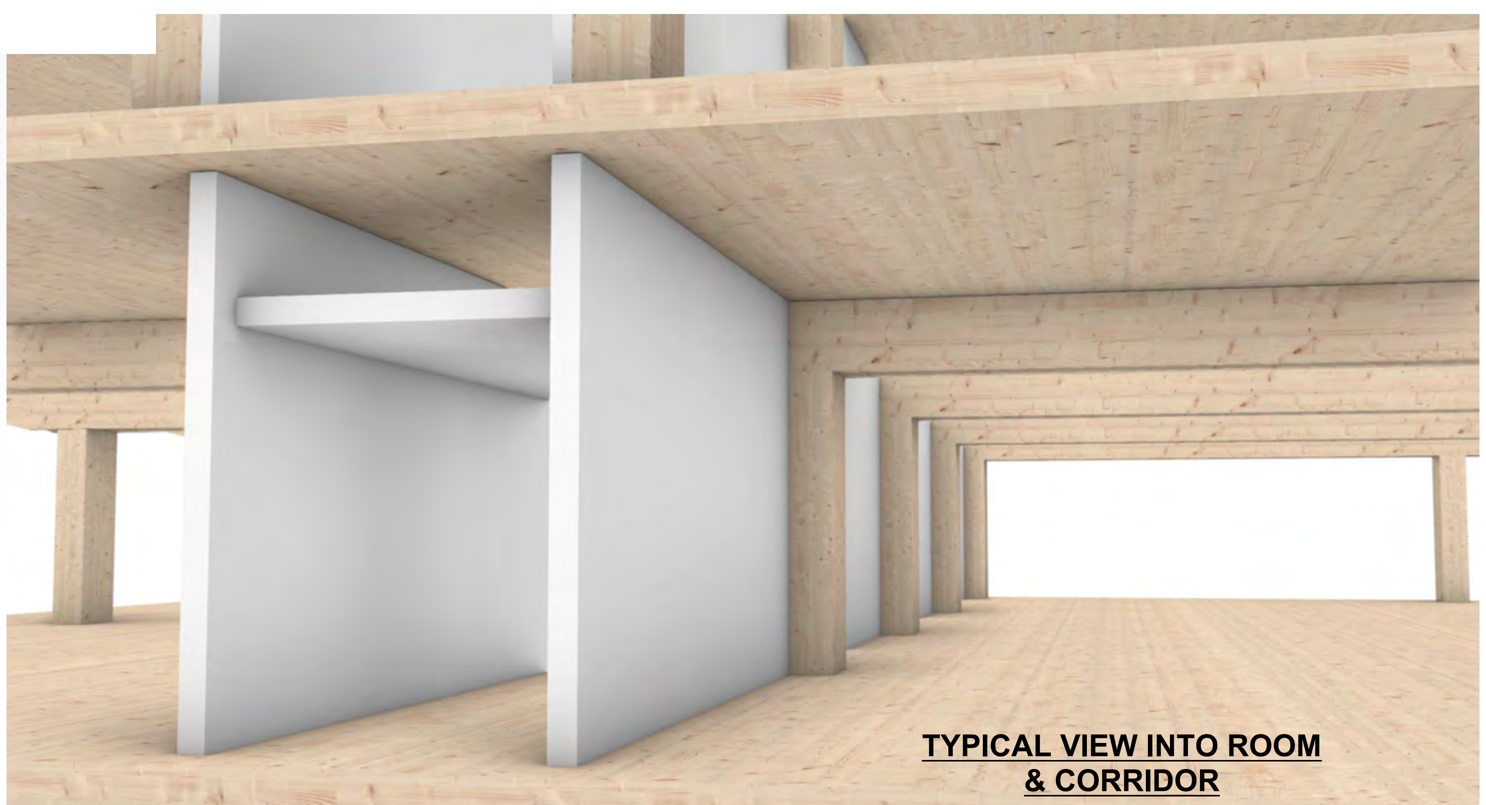
TYPICAL REINFORCED BEARING CONNECTION

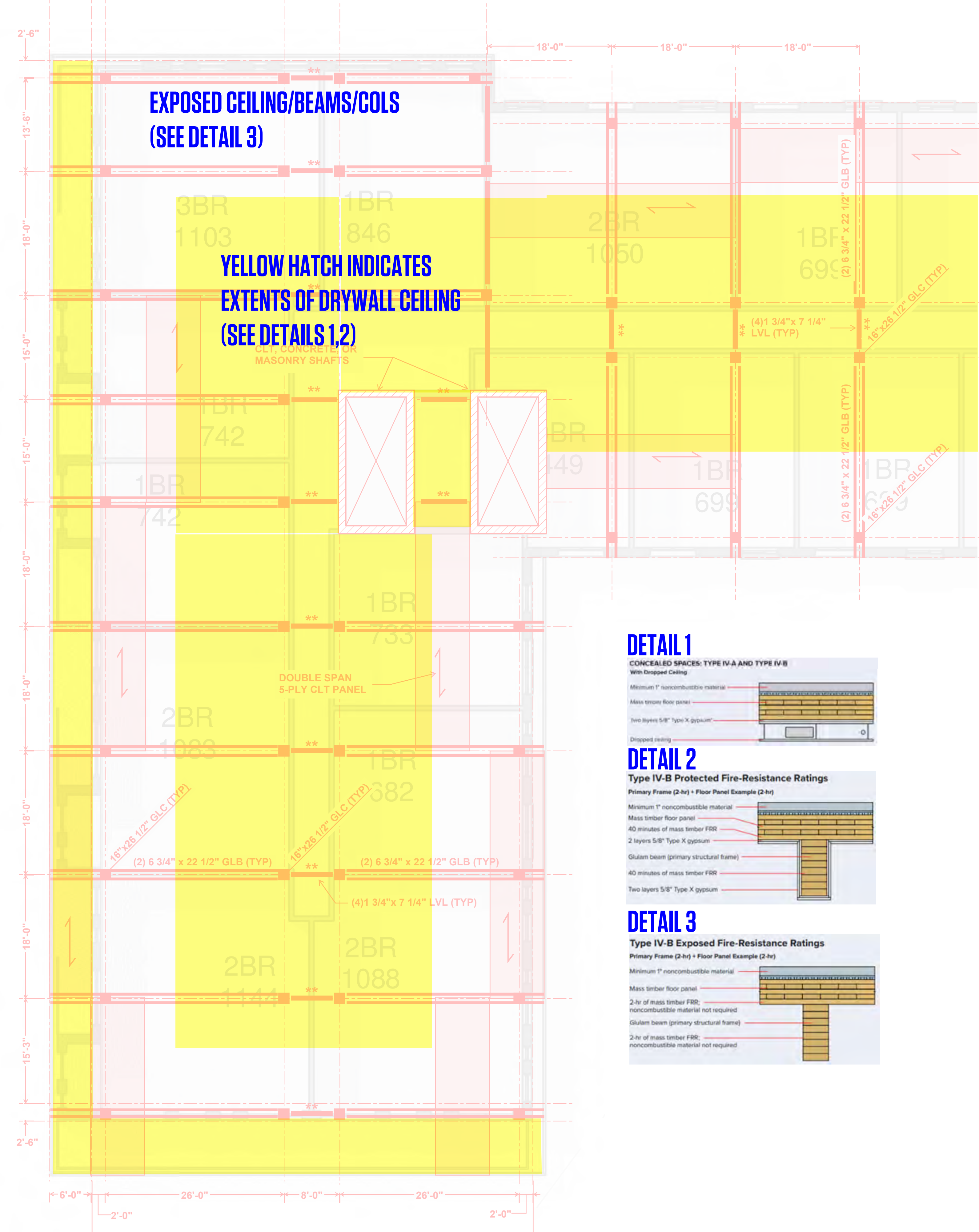


CONCEALED SPACES

OVERHEAD VIEW OF FRAMING & CONCEALED SPACES







COMPARATIVE COST ANALYSIS

	OPTION 1 **STEEL (Baseline)**		OPTION 2 **STEEL w/ CLT**		OPTION 3 **MASS TIMBER**	
Construction Type	*1A*		*1A/4B*		*4B*	
Columns/Beams	Steel		Steel		Glulam	
Floors	Composite Decking		CLT w/ acoustical mat + 2" gyprete topping		CLT w/ acoustical mat + 2" gyprete topping	
Framing TOTAL		$22,570,000		$34,080,000		$29,330,000
Foundations		$12,440,000		$12,440,000		$11,720,000
Spray FireProofing	Spray fireproofing	$ 930,000	Spray fireproofing	$ 930,000	2 layers of GWB @ concealed spaces	$ -
Ceilings	GWB with coffers between beams	$ 6,190,000	GWB only at beams, exposed CLT @ living and bedrooms	$ 2,660,000	exposed CLT @ living and bedrooms	$ 2,660,000
Interior Walls	column/beam surrounds	$ 760,000	column/beam surrounds	$ 420,000	mass timber columns	$ 180,000
Temp Fire Protection	Baseline	$ -		$ 370,000		$ 370,000
Schedule	Baseline	$ -	Baseline	$ -	Slower	$ 300,000
TOTALS		$42,890,000		$50,910,000		$44,560,000
		0%		***16%***		***4%***

MASS TIMBER CONSTRUCTION SCHEDULE

Construction speed on taller buildings using tower cranes is limited by the speed of the crane. The installer can lose speed on travel time of the crane as it needs to traverse long distances to pick and place.

Typical Mass Timber install = ~25 glulam pieces/day + ~20 CLT panels/day = ~5,000SF/day

There is a learning curve for first few floors, but steps can be taken to speed up the process as follows:

1. A mock up of the bay framing used to “train” installation crew

2. Timber elements packaged on truck in the order they need to be picked and placed

3. All components labeled, north end was marked on columns, connections pre-assembled prior to lifting

4. Beams and columns were bundled and lifted as a group, then moved about the floor plate with smaller jacks

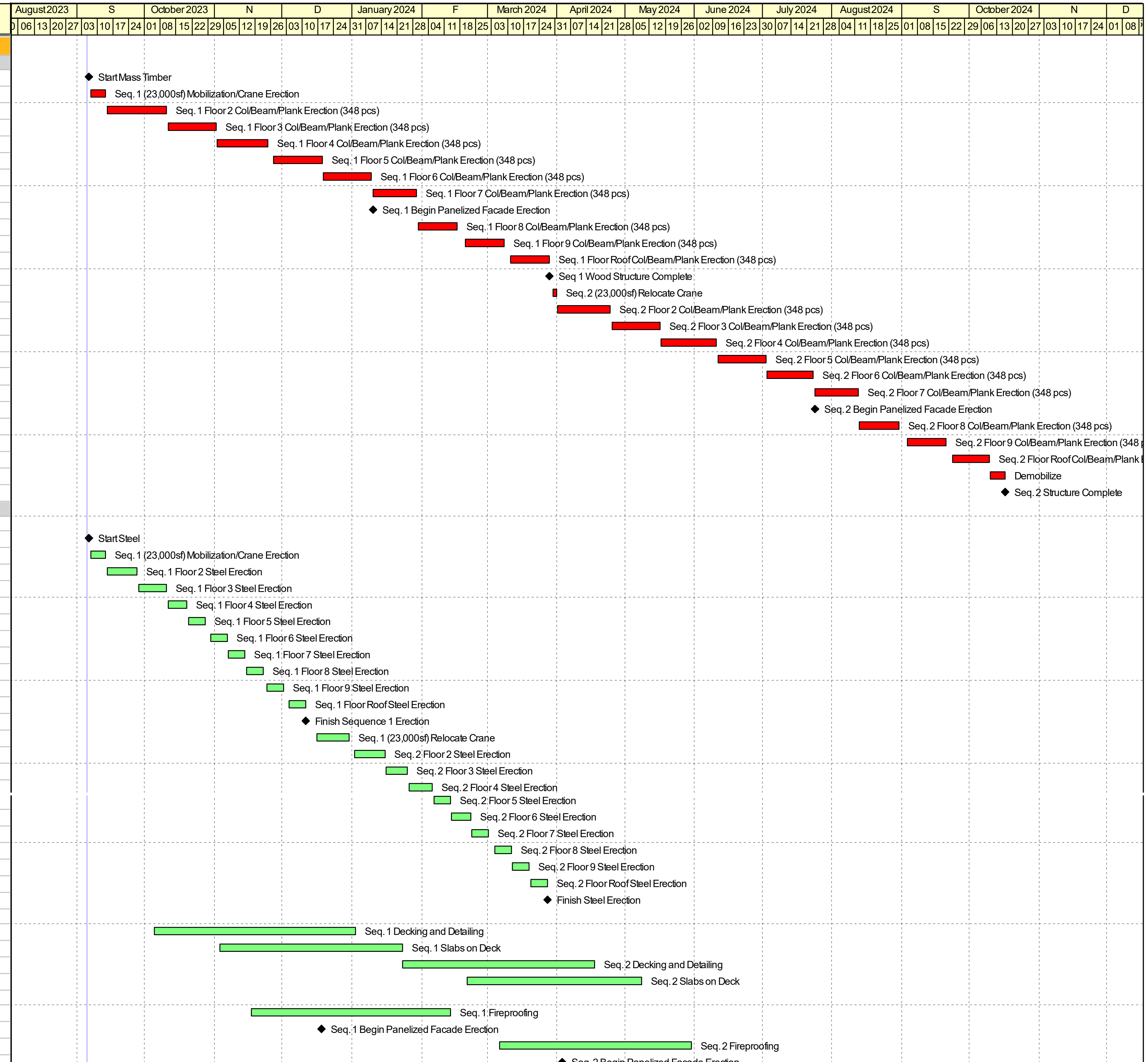
5. Firestop or other smaller in-fill pieces left for later

6. The erection crew can include one single tower crane (also used to construct the concrete cores) + timber crew includes ~10-11 iron workers/carpenters

7. The erection time = 1 day for columns, 1 day for beams and 3 days for CLT panels

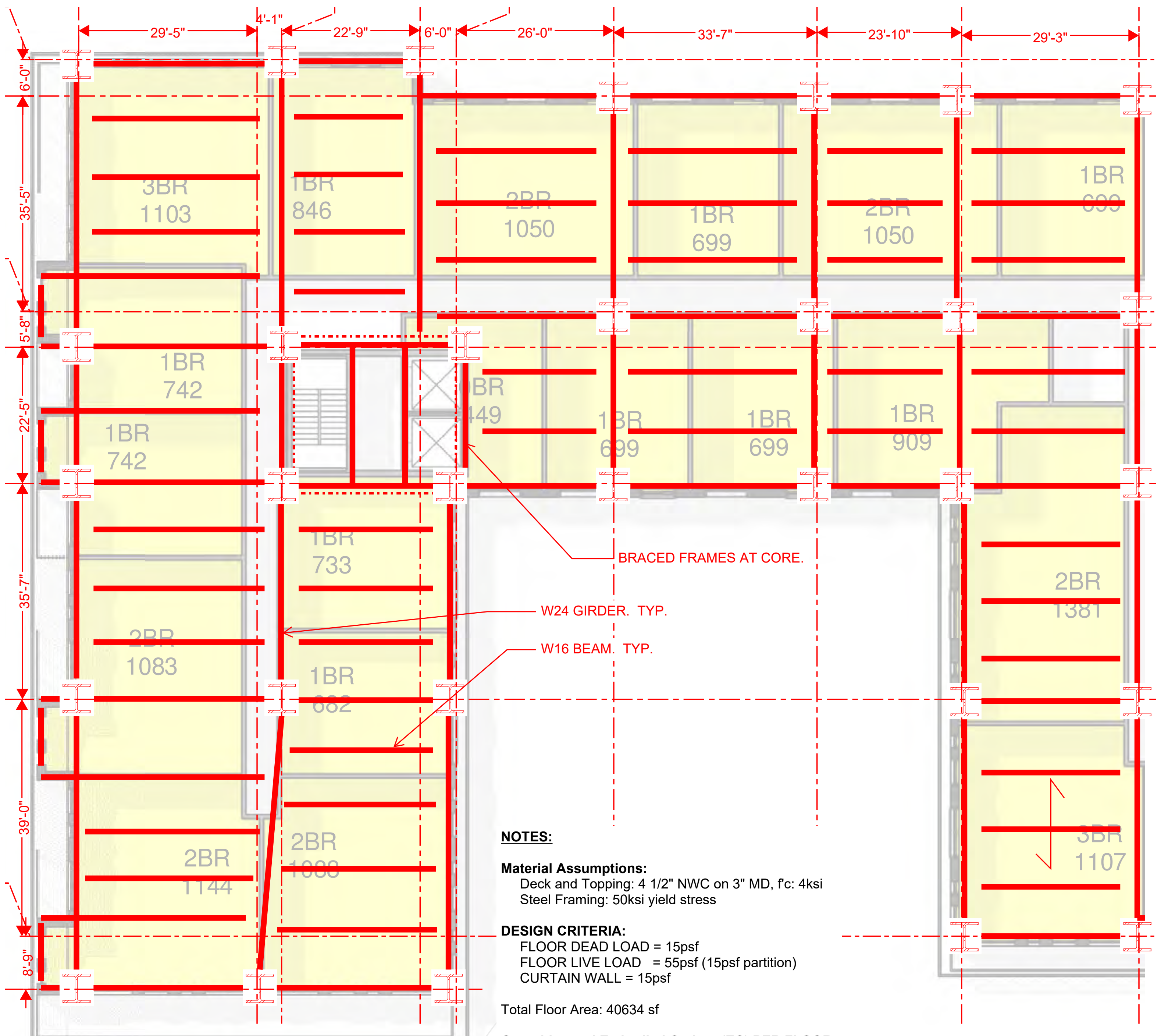
SUPERSTRUCTURE ERECTION TIME COMPARISON (MASS TIMBER VS STEEL)

Activity ID	Activity Name	Duration	Calendar	Start	Finish
Structural Analysis					
Mass Timber					
A2599	Start Mass Timber	0	Workdays	06-Sep-23*	
A2640	Seq. 1 (23,000sf) Mobilization/Crane Erection	5	Workdays	07-Sep-23	13-Sep-23
A2660	Seq. 1 Floor 2 Col/Beam/Plank Erection (348 pcs)	18	Workdays	14-Sep-23	10-Oct-23
A3120	Seq. 1 Floor 3 Col/Beam/Plank Erection (348 pcs)	16	Workdays	11-Oct-23	01-Nov-23
A2670	Seq. 1 Floor 4 Col/Beam/Plank Erection (348 pcs)	16	Workdays	02-Nov-23	24-Nov-23
A2680	Seq. 1 Floor 5 Col/Beam/Plank Erection (348 pcs)	16	Workdays	27-Nov-23	18-Dec-23
A2690	Seq. 1 Floor 6 Col/Beam/Plank Erection (348 pcs)	14	Workdays	19-Dec-23	09-Jan-24
A2700	Seq. 1 Floor 7 Col/Beam/Plank Erection (348 pcs)	14	Workdays	10-Jan-24	29-Jan-24
A3180	Seq. 1 Begin Panelized Facade Erection	0	Workdays	10-Jan-24	
A2710	Seq. 1 Floor 8 Col/Beam/Plank Erection (348 pcs)	14	Workdays	30-Jan-24	16-Feb-24
A2720	Seq. 1 Floor 9 Col/Beam/Plank Erection (348 pcs)	14	Workdays	20-Feb-24	08-Mar-24
A2740	Seq. 1 Floor Roof Col/Beam/Plank Erection (348 pcs)	14	Workdays	11-Mar-24	28-Mar-24
A2750	Seq 1 Wood Structure Complete	0	Workdays		28-Mar-24
A3130	Seq. 2 (23,000sf) Relocate Crane	2	Weekends	30-Mar-24	31-Mar-24
A3210	Seq. 2 Floor 2 Col/Beam/Plank Erection (348 pcs)	17	Workdays	01-Apr-24	24-Apr-24
A2830	Seq. 2 Floor 3 Col/Beam/Plank Erection (348 pcs)	16	Workdays	25-Apr-24	16-May-24
A2840	Seq. 2 Floor 4 Col/Beam/Plank Erection (348 pcs)	16	Workdays	17-May-24	10-Jun-24
A2790	Seq. 2 Floor 5 Col/Beam/Plank Erection (348 pcs)	16	Workdays	11-Jun-24	02-Jul-24
A2800	Seq. 2 Floor 6 Col/Beam/Plank Erection (348 pcs)	14	Workdays	03-Jul-24	23-Jul-24
A2810	Seq. 2 Floor 7 Col/Beam/Plank Erection (348 pcs)	14	Workdays	24-Jul-24	12-Aug-24
A3190	Seq. 2 Begin Panelized Facade Erection	0	Workdays	24-Jul-24	
A2820	Seq. 2 Floor 8 Col/Beam/Plank Erection (348 pcs)	14	Workdays	13-Aug-24	30-Aug-24
A2770	Seq. 2 Floor 9 Col/Beam/Plank Erection (348 pcs)	14	Workdays	03-Sep-24	20-Sep-24
A3150	Seq. 2 Floor Roof Col/Beam/Plank Erection (348 pcs)	13	Workdays	23-Sep-24	09-Oct-24
A3160	Demobilize	4	Workdays	10-Oct-24	16-Oct-24
A3170	Seq. 2 Structure Complete	0	Workdays		16-Oct-24
Structural Steel					
Erection					
A2990	Start Steel	0	Workdays	06-Sep-23*	
A3220	Seq. 1 (23,000sf) Mobilization/Crane Erection	5	Workdays	07-Sep-23*	13-Sep-23
A3230	Seq. 1 Floor 2 Steel Erection	10	Workdays	14-Sep-23*	27-Sep-23
A2870	Seq. 1 Floor 3 Steel Erection	8	Workdays	28-Sep-23	10-Oct-23
A2880	Seq. 1 Floor 4 Steel Erection	7	Workdays	11-Oct-23	19-Oct-23
A2890	Seq. 1 Floor 5 Steel Erection	6	Workdays	20-Oct-23	27-Oct-23
A2900	Seq. 1 Floor 6 Steel Erection	6	Workdays	30-Oct-23	06-Nov-23
A2910	Seq. 1 Floor 7 Steel Erection	6	Workdays	07-Nov-23	14-Nov-23
A2920	Seq. 1 Floor 8 Steel Erection	6	Workdays	15-Nov-23	22-Nov-23
A2930	Seq. 1 Floor 9 Steel Erection	6	Workdays	24-Nov-23	01-Dec-23
A2940	Seq. 1 Floor Roof Steel Erection	6	Workdays	04-Dec-23	11-Dec-23
A3290	Finish Sequence 1 Erection	0	Workdays		11-Dec-23
A3240	Seq. 1 (23,000sf) Relocate Crane	5	Weekends	16-Dec-23	30-Dec-23
A3250	Seq. 2 Floor 2 Steel Erection	10	Workdays	02-Jan-24	15-Jan-24
A3000	Seq. 2 Floor 3 Steel Erection	8	Workdays	16-Jan-24	25-Jan-24
A3010	Seq. 2 Floor 4 Steel Erection	7	Workdays	26-Jan-24	05-Feb-24
A3020	Seq. 2 Floor 5 Steel Erection	6	Workdays	06-Feb-24	13-Feb-24
A3030	Seq. 2 Floor 6 Steel Erection	6	Workdays	14-Feb-24	22-Feb-24
A2950	Seq. 2 Floor 7 Steel Erection	6	Workdays	23-Feb-24	01-Mar-24
A2960	Seq. 2 Floor 8 Steel Erection	6	Workdays	04-Mar-24	11-Mar-24
A2970	Seq. 2 Floor 9 Steel Erection	6	Workdays	12-Mar-24	19-Mar-24
A2980	Seq. 2 Floor Roof Steel Erection	6	Workdays	20-Mar-24	27-Mar-24
A3040	Finish Steel Erection	0	Workdays		27-Mar-24
Slabs on Deck					
A3260	Seq. 1 Decking and Detailing	60	Workdays	05-Oct-23	02-Jan-24
A3270	Seq. 1 Slabs on Deck	55	Workdays	03-Nov-23	23-Jan-24
A3280	Seq. 2 Decking and Detailing	60	Workdays	23-Jan-24	17-Apr-24
A3300	Seq. 2 Slabs on Deck	55	Workdays	21-Feb-24	08-May-24
Fireproofing					
A3330	Seq. 1 Fireproofing	60	Workdays	17-Nov-23	13-Feb-24
A3350	Seq. 1 Begin Panelized Facade Erection	0	Workdays	18-Dec-23	
A3340	Seq. 2 Fireproofing	60	Workdays	06-Mar-24	30-May-24
A3360	Seq. 2 Begin Panelized Facade Erection	0	Workdays	03-Apr-24	



ALTERNATIVE STRUCTURAL SYSTEM COMPARISON

STEEL BEAMS/COLUMNS W/ **COMPOSITE DECKING**



NOTES:

Material Assumptions:
Deck and Topping: 4 1/2" NWC on 3" MD, f'c: 4ksi
Steel Framing: 50ksi yield stress

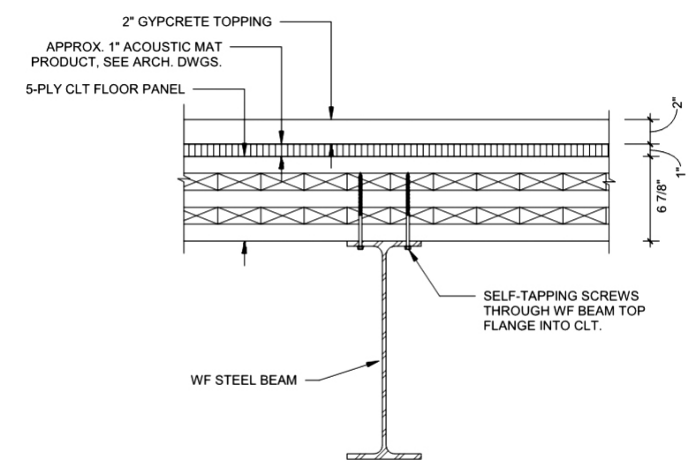
DESIGN CRITERIA:
FLOOR DEAD LOAD = 15psf
FLOOR LIVE LOAD = 55psf (15psf partition)
CURTAIN WALL = 15psf

Total Floor Area: 40634 sf

Quantities and Embodied Carbon (EC) PER FLOOR:

Item	Quantity		EC (kg CO2/unit)	EC (kg CO2)
Framing	189.0	ton	1114	210546
Decking	57.0	ton	390	22230
Concrete	752.0	CY	350	263200
			Total	495976.0

STEEL BEAMS/COLUMNS W/ **CLT DECKING**



DEAD LOAD COMPARISON

Dead Load reductions directly and linearly impact the seismic lateral forces of the building.

The podium transfer level and foundations will see a reduction in loading.

BUILDING B - GSF-1

Level	Floor Area	Floor Perimeter
LEVEL 0	50,360 SF	1003'
LEVEL 1	40,420 SF	1352'
LEVEL 2	24,900 SF	1352'
LEVEL 3	39,270 SF	1338'
LEVEL 4	39,910 SF	1418'
LEVEL 5	39,900 SF	1418'
LEVEL 6	39,790 SF	1398'
LEVEL 7	39,910 SF	1418'
LEVEL 8	39,780 SF	1418'
LEVEL 9	39,270 SF	1338'
LEVEL 10	12,710 SF	645'
Grand total: 11	406,230 SF	15128'

Area for levels being compared for study

level	area
2	24,900
3	39,270
4	39,910
5	39,900
6	39,790
7	39,910
8	39,780
9	39,270
10	12,710
total	315,440

Steel and Concrete

Dead Loads	weight (psf)
finshed floor	3
3" Deck+2" NWT Conc	45
steel framing	10
MEP	4
Fireproofing	2
ceiling	4
	68

Total dead load for floors 2 thru roof (lbs) 21,449,920

Live Loads	
Residential	40
Partitions	15

Mass Timber

Dead Loads	weight (psf)
Finished floor	3
2" concrete topping	20
isolation mat	1
5-ply	20
Glu-lam Framing	8
MEP	4
ceiling (only a portion of floor plate)	2
	58

Total dead load for floors 2 thru roof (lbs) 18,295,520

Live Loads	
Residential	40
Partitions	15

4 PSF SAVED IN DECKING

2 PSF SAVED IN FRAMING

2 PSF SAVED IN CEILINGS

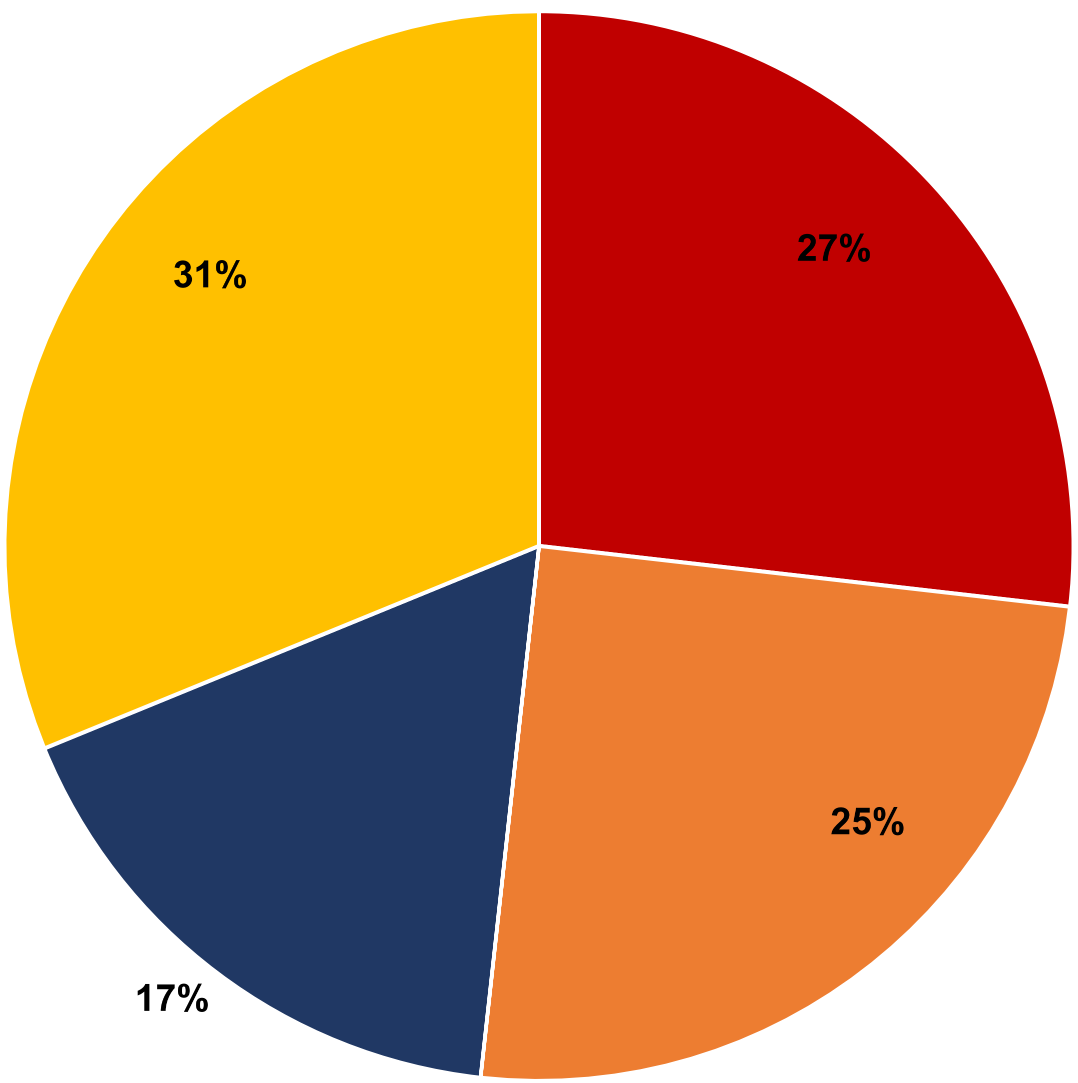
2 PSF SAVED IN FIREPROOFING

Delta 14.71%

EMBODIED CARBON COMPARISON

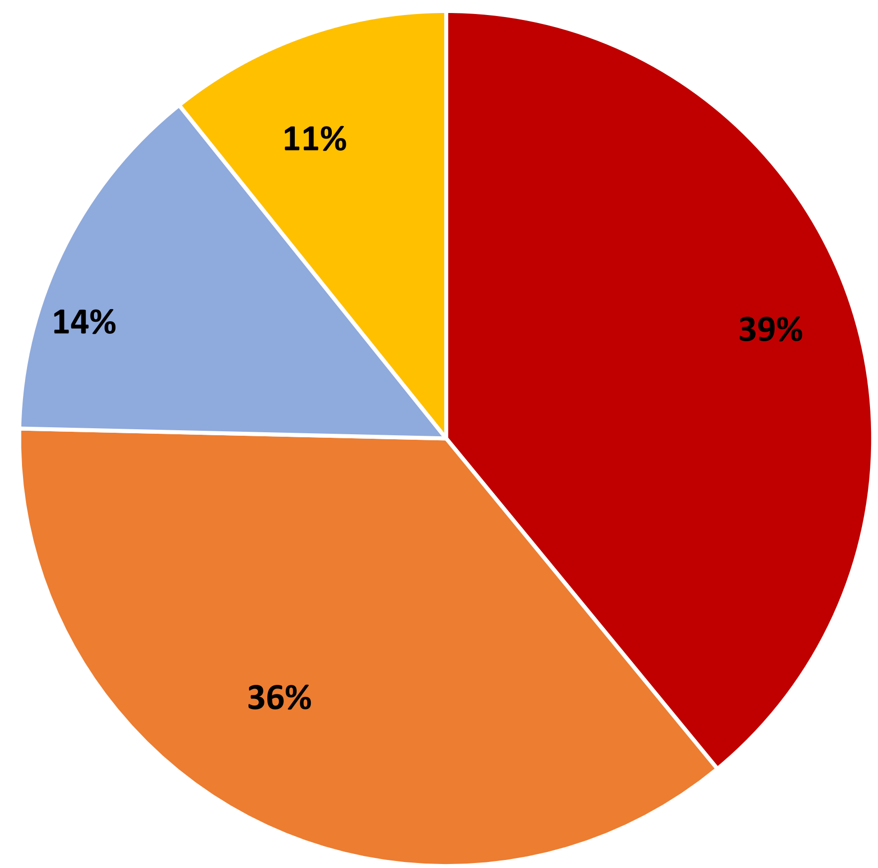
STEEL: COMPOSITE CONCRETE SLAB ON STEEL DECK ON STEEL FRAME

20.8 kg CO2e / SF



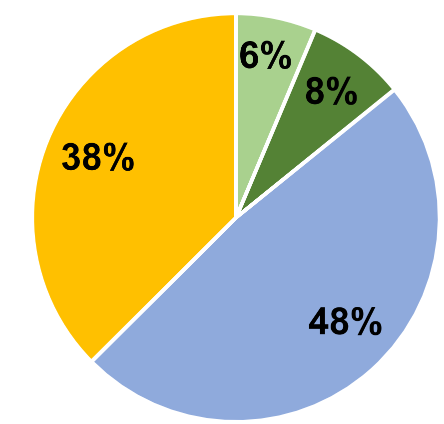
HYBRID: CLT DECK WITH 2" CONCRETE TOPPING ON STEEL FRAME

14.3 kg CO2e / SF



MASS TIMBER: CLT DECK WITH 2" CONCRETE TOPPING ON GLULAM FRAME

4.1 kg CO2e / SF



EMBODIED CARBON COMPARISON (WOODWORKS TOOL)

Carbon Summary

WoodWorks™
WOOD PRODUCTS COUNCIL

Results

Volume of wood products used:
368,503 cubic meters (13,013,493 cubic feet)

U.S. and Canadian forests grow this much wood in:
1005 minutes

Carbon stored in the wood:
327647 metric tons of carbon dioxide

Avoided greenhouse gas emissions:
126774 metric tons of carbon dioxide

Total potential carbon benefit:
454421 metric tons of carbon dioxide

Equivalent to:

96072 cars off the road for a year

Energy to operate 47985 homes for a year

Project Name: MEM_C02_Reading
Date: July 15, 2022

Results from this tool are based on wood volumes only and are estimates of carbon stored within wood products and avoided emissions resulting from the substitution of wood products for non-wood products. The results do not indicate a carbon footprint or global warming potential and are not intended to replace a detailed life cycle assessment (LCA) study. Please refer to the References and Notes' for assumptions and other information related to the calculations.

BENEFITS/ OUTCOMES

Next Steps - The Future of Mass Timber?

Thanks to the generous funding provided by the partners sponsoring this grant, the ownership and design team have agreed to continue to vet this alternative approach to the greatest extent possible. This project is mid-way through an extensive approvals process with the City of Boston and incorporating additional sustainable strategies of this nature will further enhance its public benefits. With a total of 17 buildings included in this masterplan, Building B will set the standard for what the future of Mary Ellen McCormack housing can be. This accelerator created an opportunity to explore an alternate structural system that has provided the design team with a framework to replicate additional mass timber structures at Mary Ellen McCormack. WinnDevelopment and its consultants look forward to advancing further mass timber study at MEM and in thier respective development pipeline

Our Sincerest Thanks,

Winn Development, CBT, Thornton Tomasetti, CodeRed, LeeKennedy/Janey

110 CANAL

MASS TIMBER ACCELERATOR GRANT PROGRAM

JULY 15, 2022

QuakerLane cbt Thornton Tomasetti

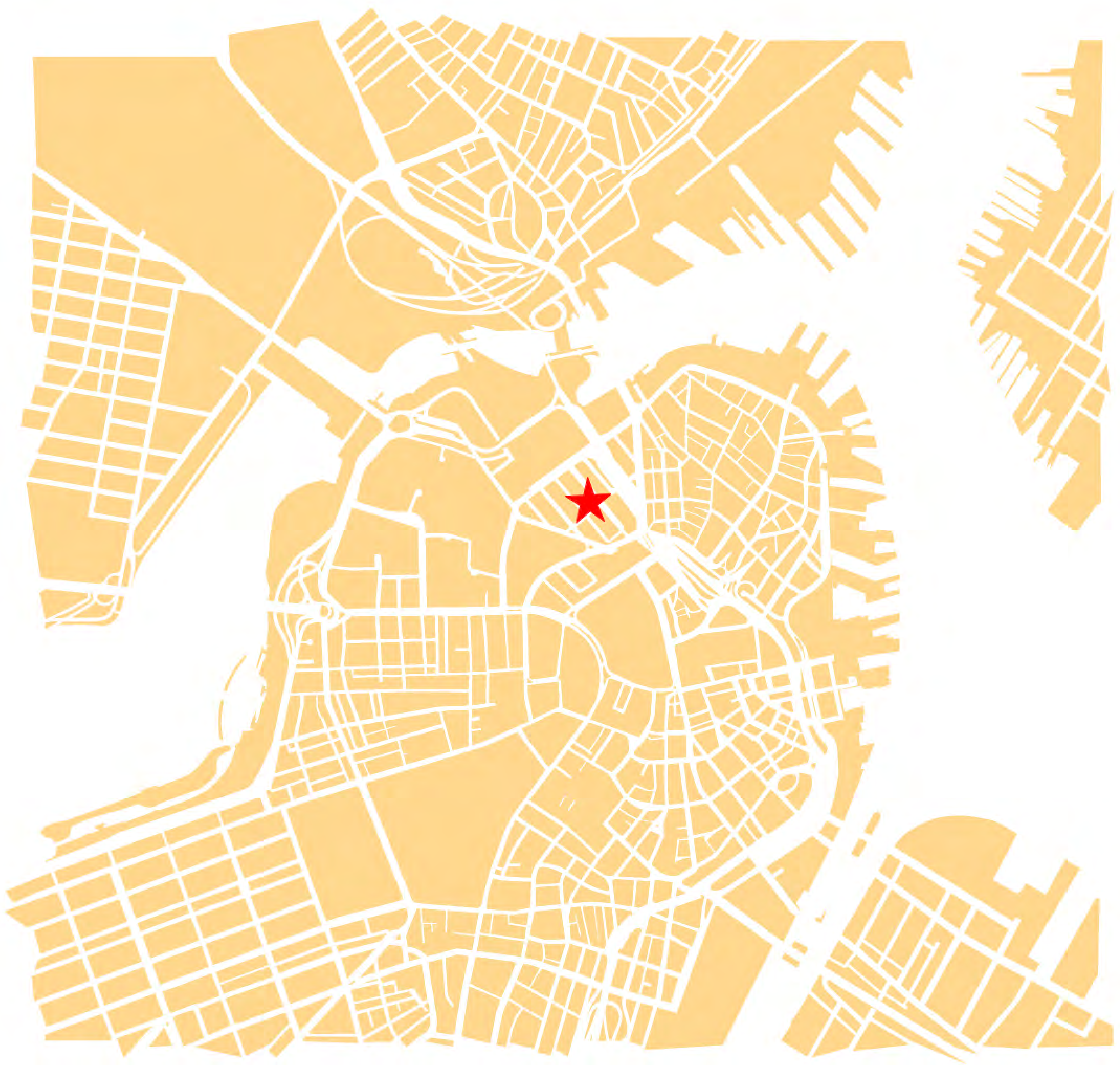
EXECUTIVE SUMMARY

110 Canal is in the vanguard of Boston's low-carbon construction, utilizing 21st-Century mass timber structure in the historic Bulfinch Triangle neighborhood.

Mass timber provides many tangible benefits to our project — from reduction of the building's carbon footprint, to versatility and speed of construction. At nine stories, the scale of the proposed structure is ideal for this construction type. Significantly, mass timber provides an architectural aesthetic ideal for great placemaking within this unique combination of historic adaptive re-use and new construction.

Unlike many other regions, the Northeast US and neighboring Canada have a special advantage of land-based access to regionally-sourced timber. The shorter shipping distances for mass timber improve the material's — and thereby the project's — overall carbon footprint by lowering the embodied carbon of the structure. With sustainable forestry practices, the production of mass timber structures contribute to an industry that is local, renewable, and carbon capturing.

Previously limited by the building codes, mass timber structures are gaining greater acceptance by cities and agencies for use in taller structures. The variety of types of mass timber components aid to the greater range of applications for wood in our buildings. Because the construction type is still relatively new, construction teams are less familiar with it. The uncertainty that comes with new products and methods adds to the cost of construction. Material costs have been a factor for clients considering mass timber projects. The last 25 months have seen (on average) an increase in timber prices by about a third, as compared with pre-2020. From a basic logistical standpoint, this increase has caused a ripple effect in the industry and in the region, which has stunted the scale of use of mass timber. We are optimistic that this trend is changing.



Map of Boston, Massachusetts

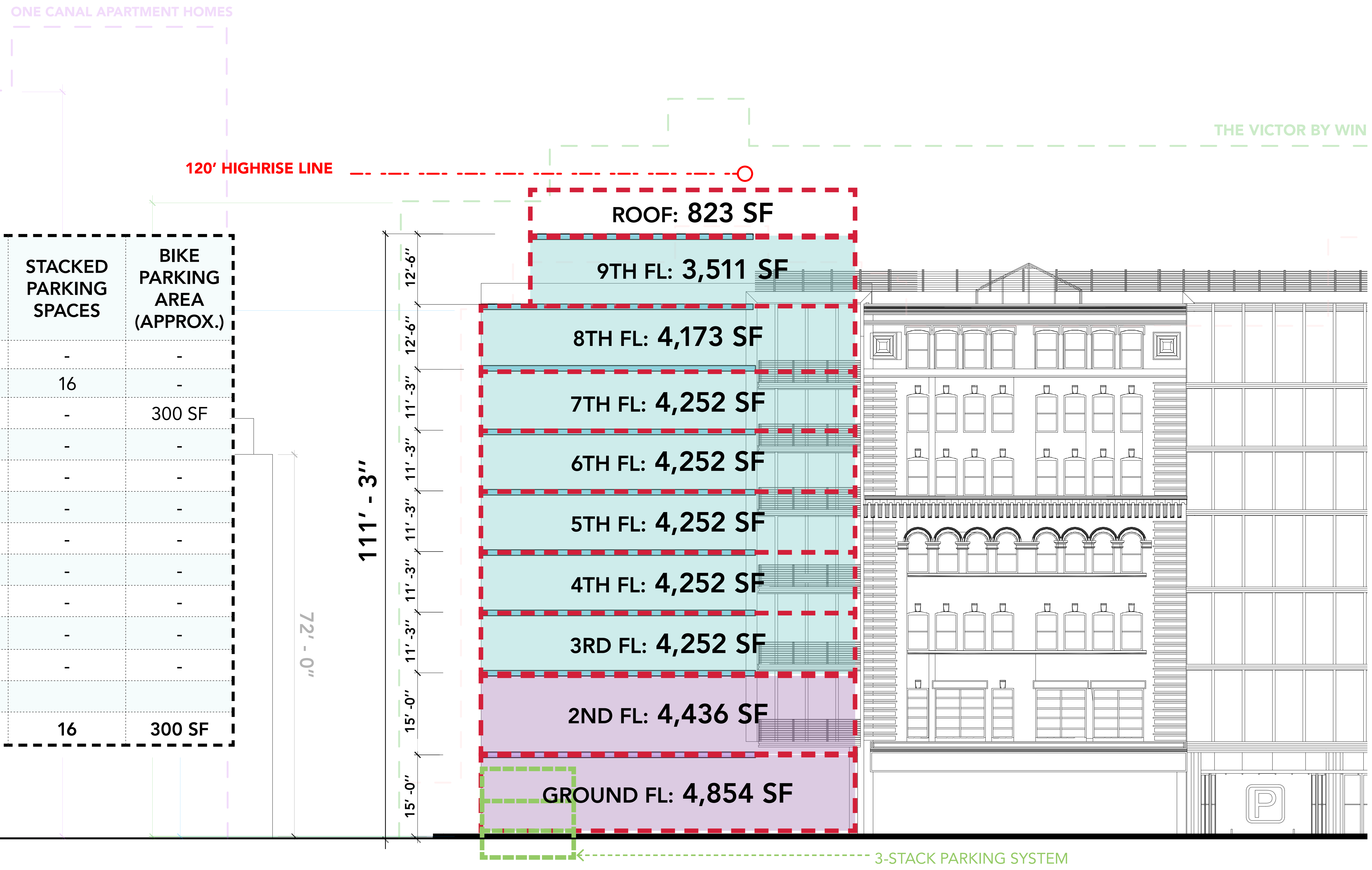
EXTERIOR RENDERINGS

ELEVATIONS AND STREET PERSPECTIVE

BUILDING MATRIX

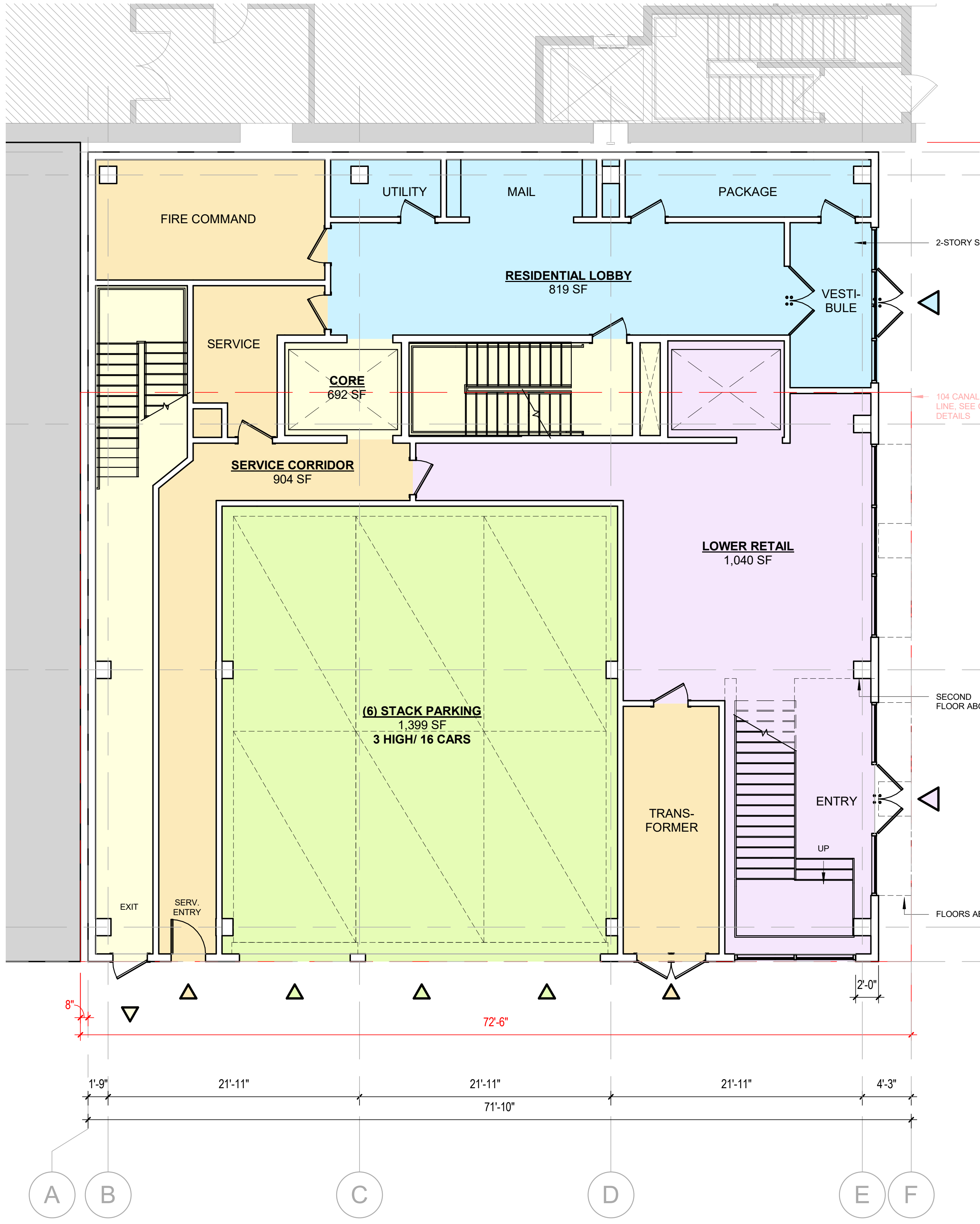
FLOOR LEVEL	GROSS SQUARE FOOTAGE (APPROX.)*	FL-FL HEIGHT	# OF UNITS	RESIDENTIAL SQUARE FOOTAGE (APPROX.)*	RETAIL SQUARE FOOTAGE (APPROX.)	STACKED PARKING SPACES	BIKE PARKING AREA (APPROX.)
BASEMENT	4,854 SF	8' - 0'' +/-	-	-	-	-	-
1	4,854 SF	15' - 0''	-	819 SF	1,040 SF	16	-
2	4,436 SF	15' - 0''	-	1,067 SF	2,628 SF	-	300 SF
3	4,252 SF	11' - 3''	4	3,429 SF	-	-	-
4	4,252 SF	11' - 3''	4	3,429 SF	-	-	-
5	4,252 SF	11' - 3''	4	3,429 SF	-	-	-
6	4,252 SF	11' - 3''	4	3,429 SF	-	-	-
7	4,252 SF	11' - 3''	4	3,429 SF	-	-	-
8	4,173 SF	12' - 6''	4	3,350 SF	-	-	-
9	3,511 SF	12' - 6''	2	2,666 SF	-	-	-
ROOF	823 SF	-	-	-	-	-	-
TOTAL	**43,911 SF**	**111' - 3'' A.G.**	**26**	**25,047 SF**	**3,668 SF**	**16**	**300 SF**

* NOTES:
1. APPROX. GROSS SQUARE FOOTAGE INCLUDES ENCLOSED BUILDING SPACES; SEE INDIVIDUAL PLANS FOR OUTDOOR AREA SF;
2. APPROX. RESIDENTIAL SQUARE FOOTAGE EXCLUDES OUTDOOR BALCONY AND UNIT TERRACE AREAS.



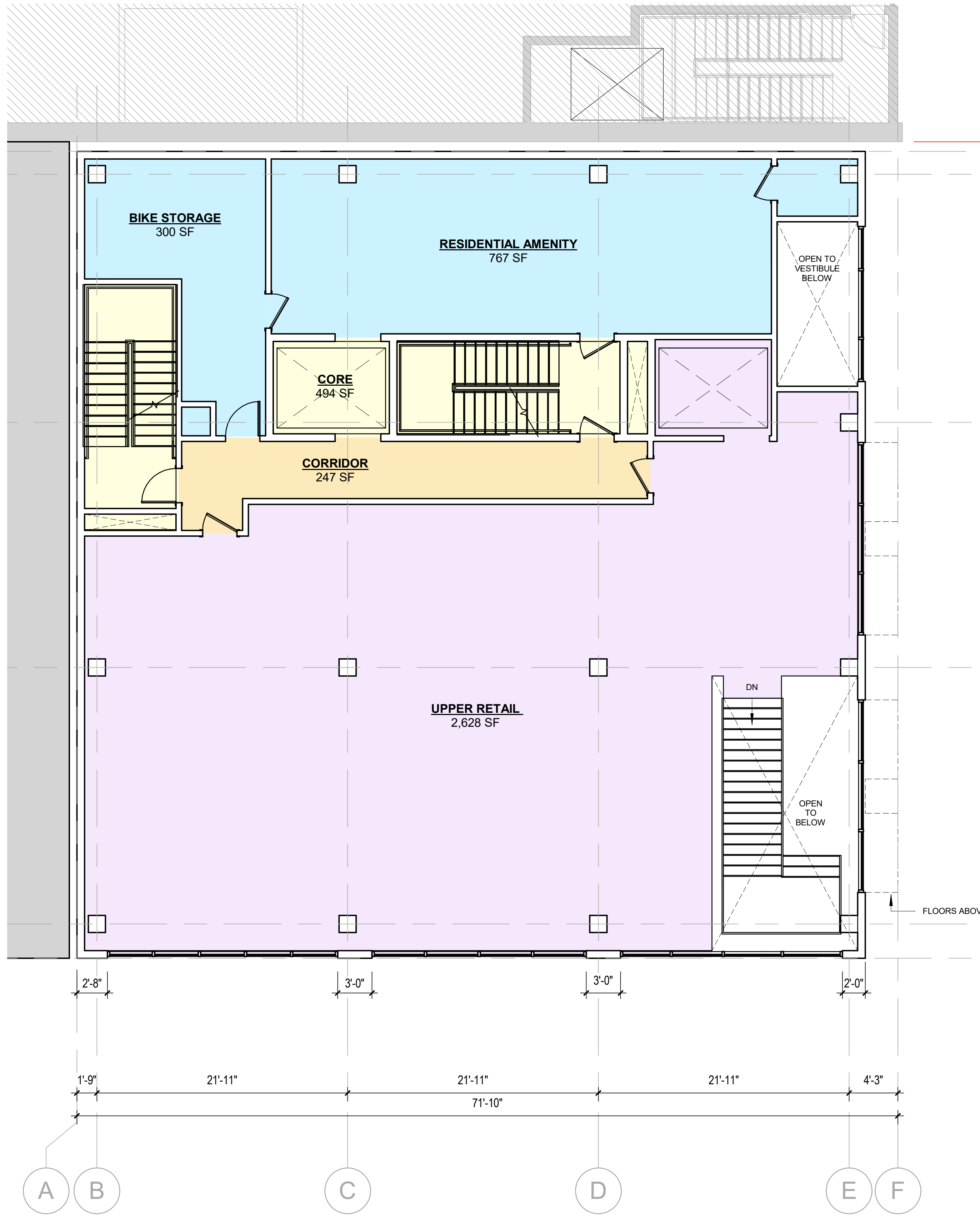
FLOOR PLANS

GROUND AND SECOND FLOOR



GROUND FLOOR

FLOOR-TO-FLOOR HEIGHT:	15' - 0''
GROSS FLOOR AREA*:	4,854 SF
TOTAL CORE&SERVICE AREA: (1X) ELEVATOR, (2X) EGRESS STAIRS	1,596 SF
TOTAL RESIDENTIAL AREA:	819 SF
TOTAL RETAIL AREA:	1,040 SF
TOTAL PARKING AREA: (6X) STACK PARKING	1,399 SF

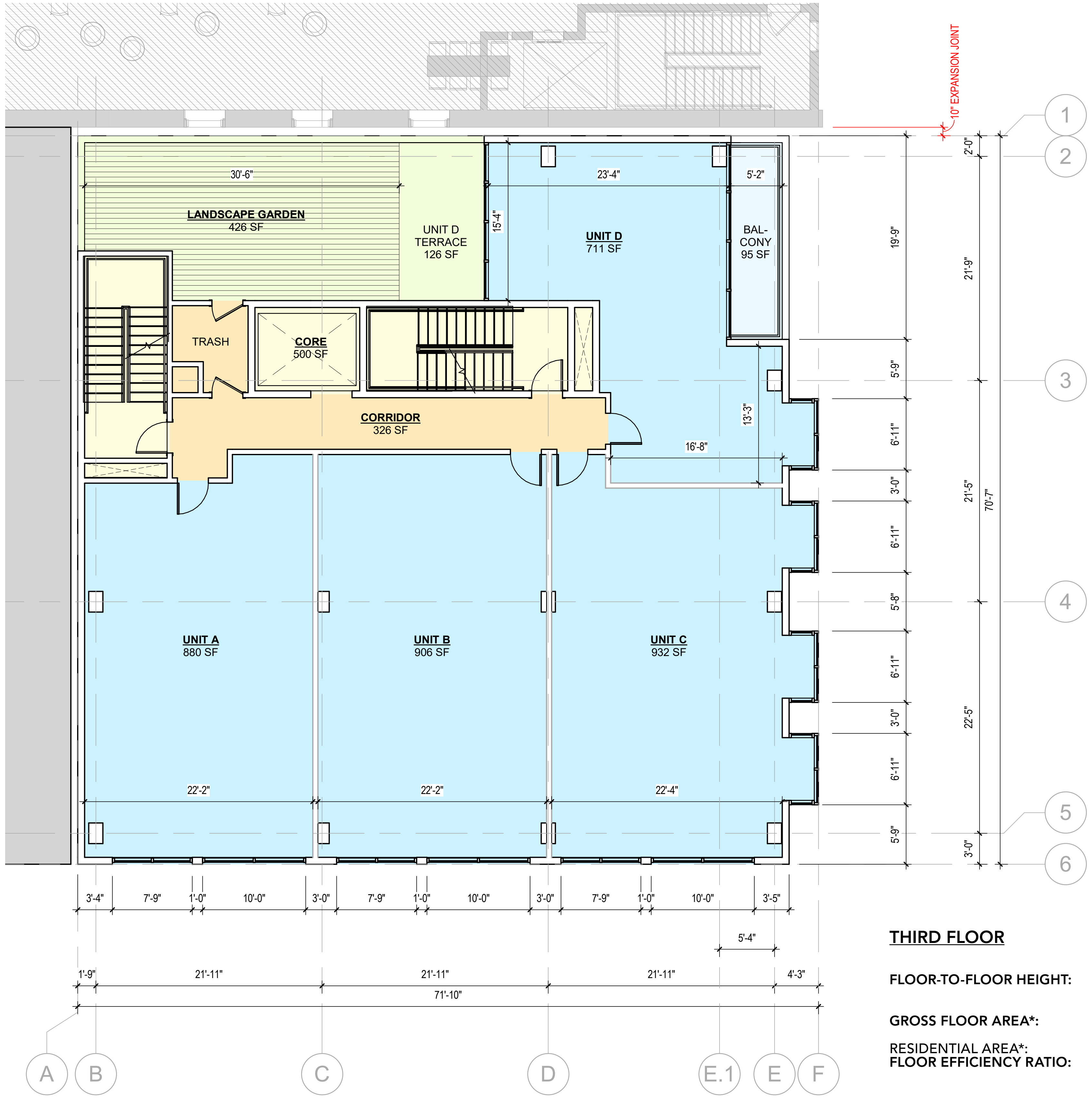


SECOND FLOOR

FLOOR-TO-FLOOR HEIGHT:	15' - 0''
GROSS FLOOR AREA*:	4,436SF
TOTAL CORE&SERVICE AREA:	741 SF
TOTAL RETAIL AREA:	2,628 SF

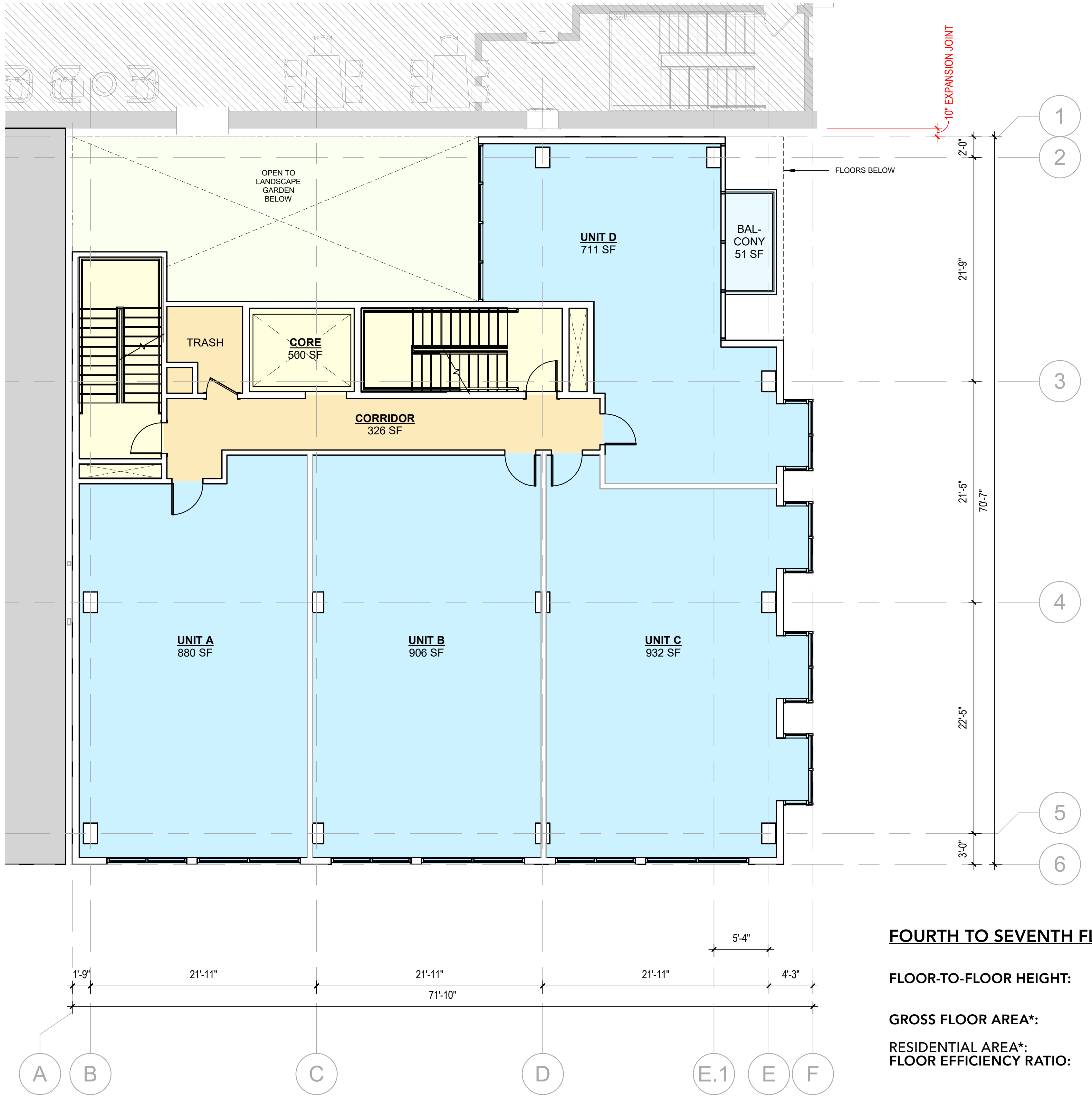
FLOOR PLANS - RESIDENTIAL FLOORS

THIRD TO SEVENTH FLOOR



THIRD FLOOR

FLOOR-TO-FLOOR HEIGHT:	11' - 3''
GROSS FLOOR AREA*:	4,252 SF
RESIDENTIAL AREA*:	3,429 SF
FLOOR EFFICIENCY RATIO:	81%

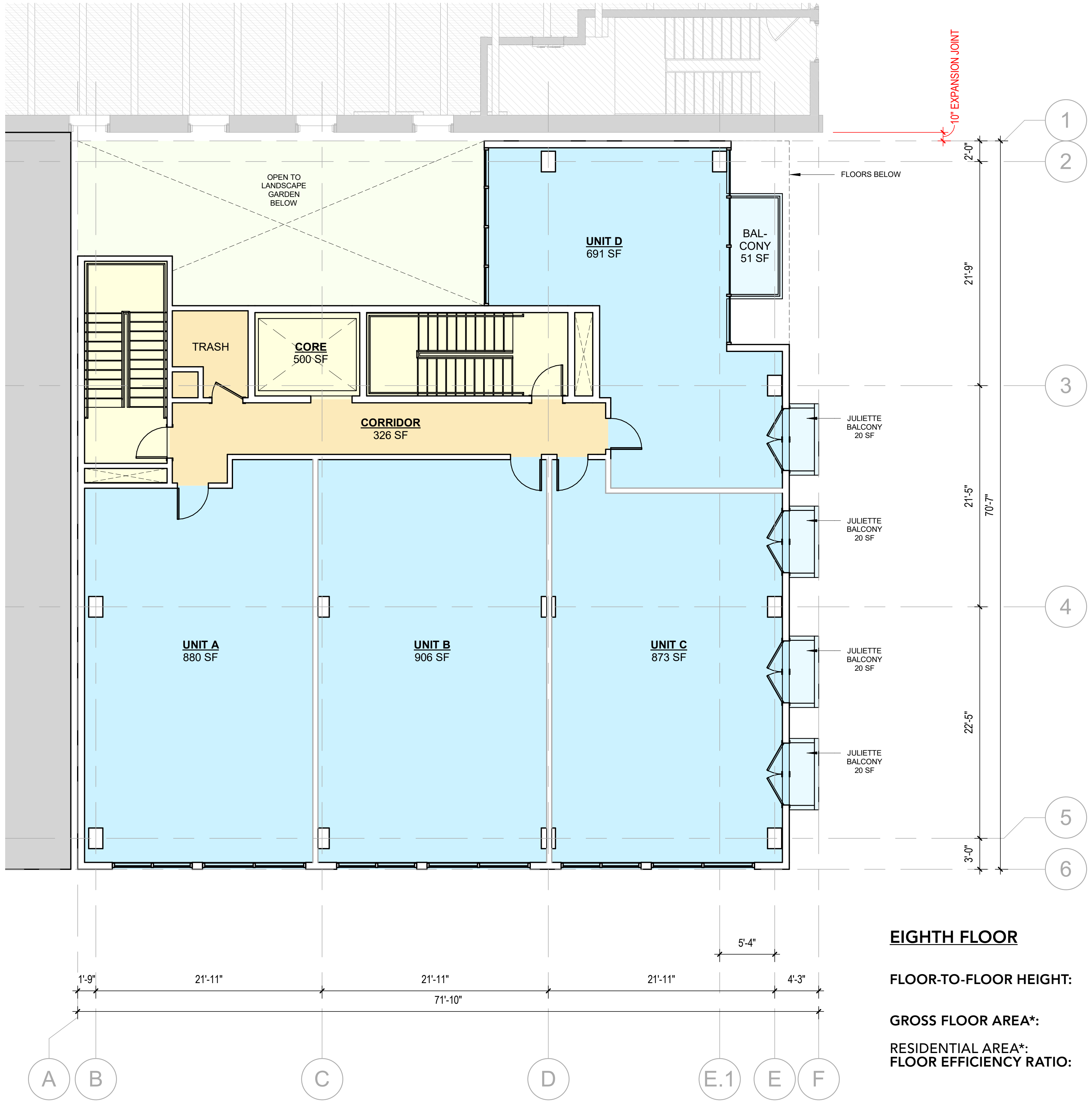


FOURTH TO SEVENTH FLOOR

FLOOR-TO-FLOOR HEIGHT:	11' - 3''
GROSS FLOOR AREA*:	4,252 SF
RESIDENTIAL AREA*:	3,429 SF
FLOOR EFFICIENCY RATIO:	81%

FLOOR PLANS - RESIDENTIAL FLOORS

EIGHTH TO NINTH FLOOR

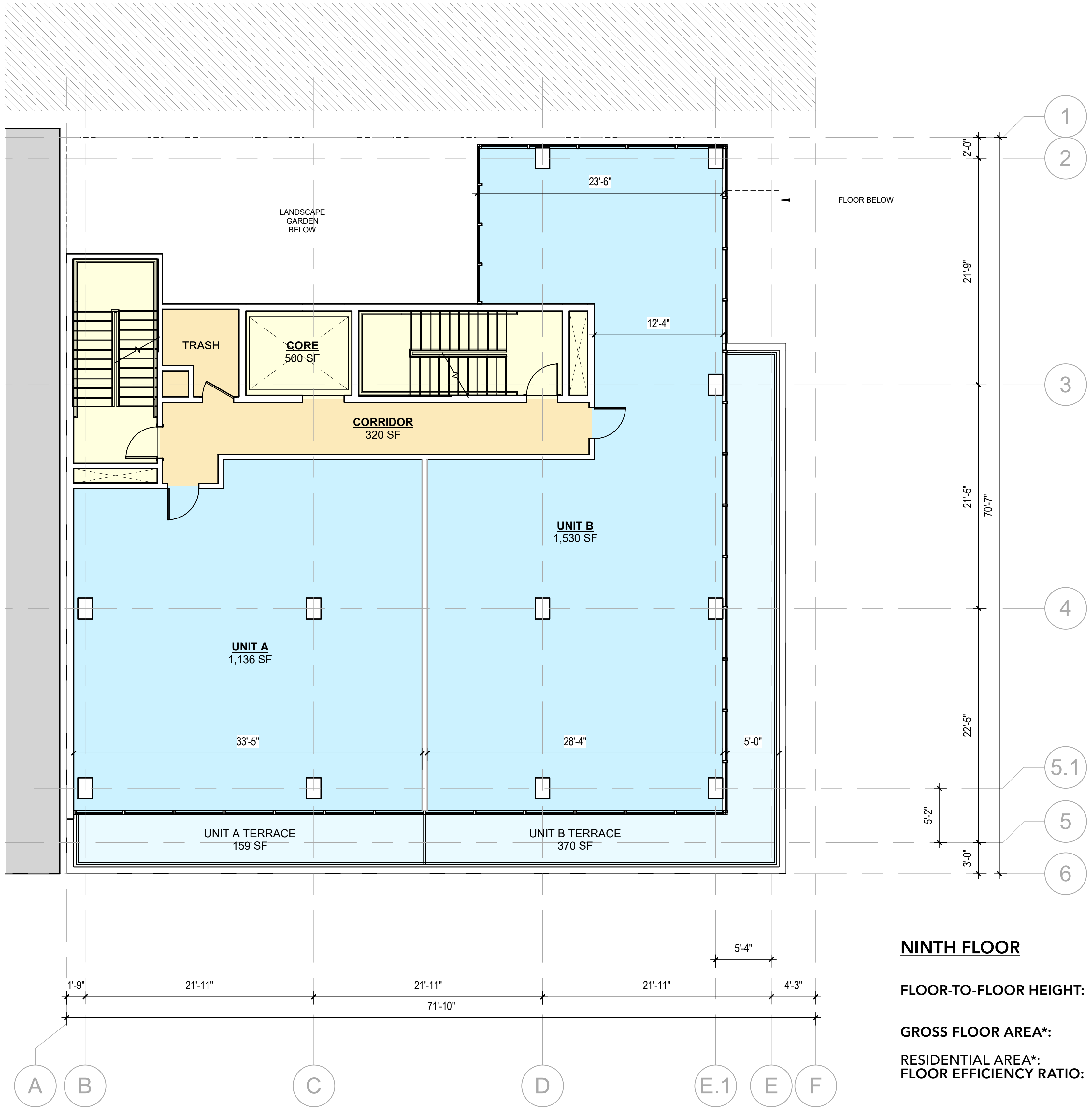


EIGHTH FLOOR

FLOOR-TO-FLOOR HEIGHT: 12' -6''

GROSS FLOOR AREA*: 4,173 SF

RESIDENTIAL AREA*: 3,350 SF
FLOOR EFFICIENCY RATIO: 80%



NINTH FLOOR

FLOOR-TO-FLOOR HEIGHT: 12' -6''

GROSS FLOOR AREA*: 3,511 SF

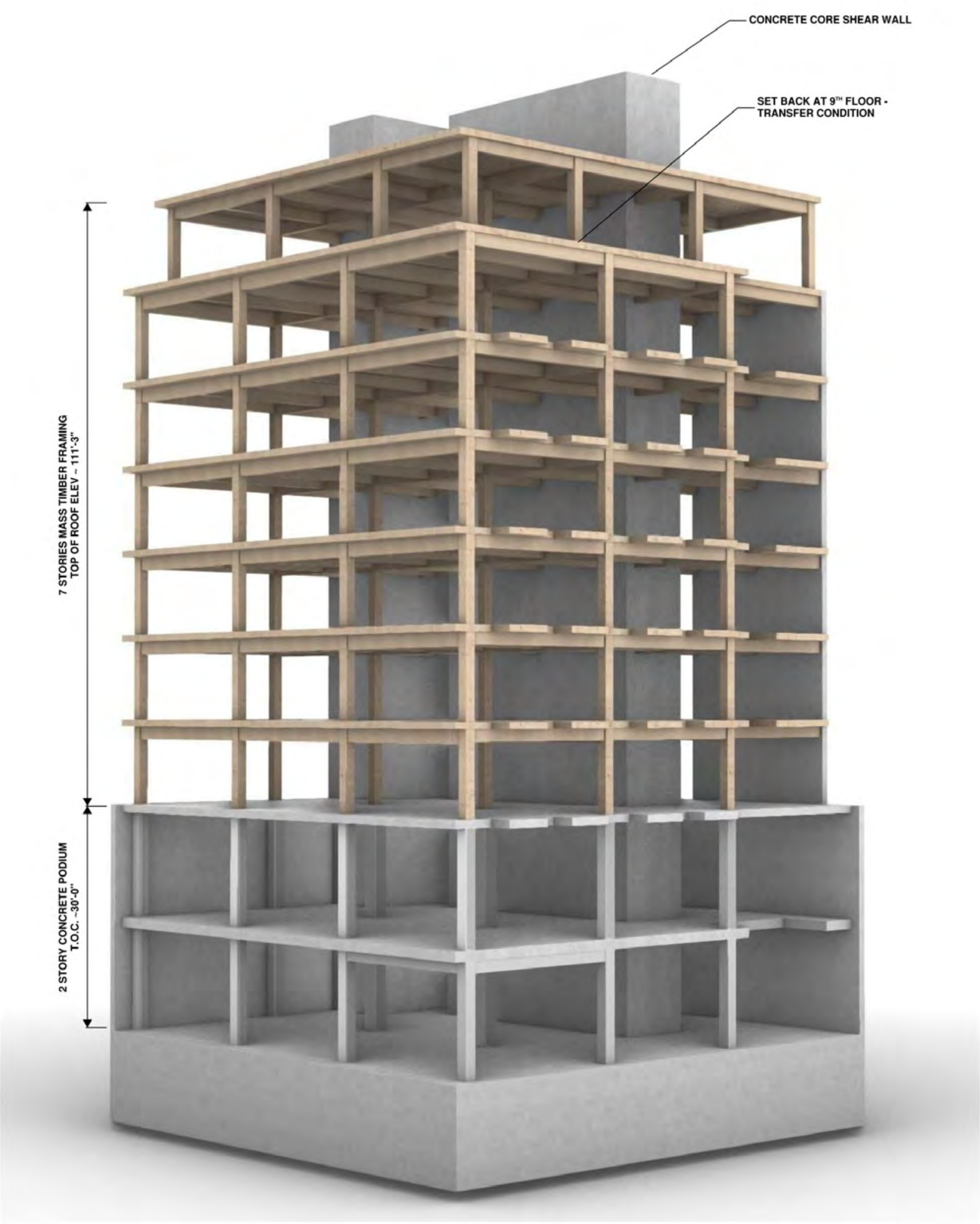
RESIDENTIAL AREA*: 2,666 SF
FLOOR EFFICIENCY RATIO: 76%

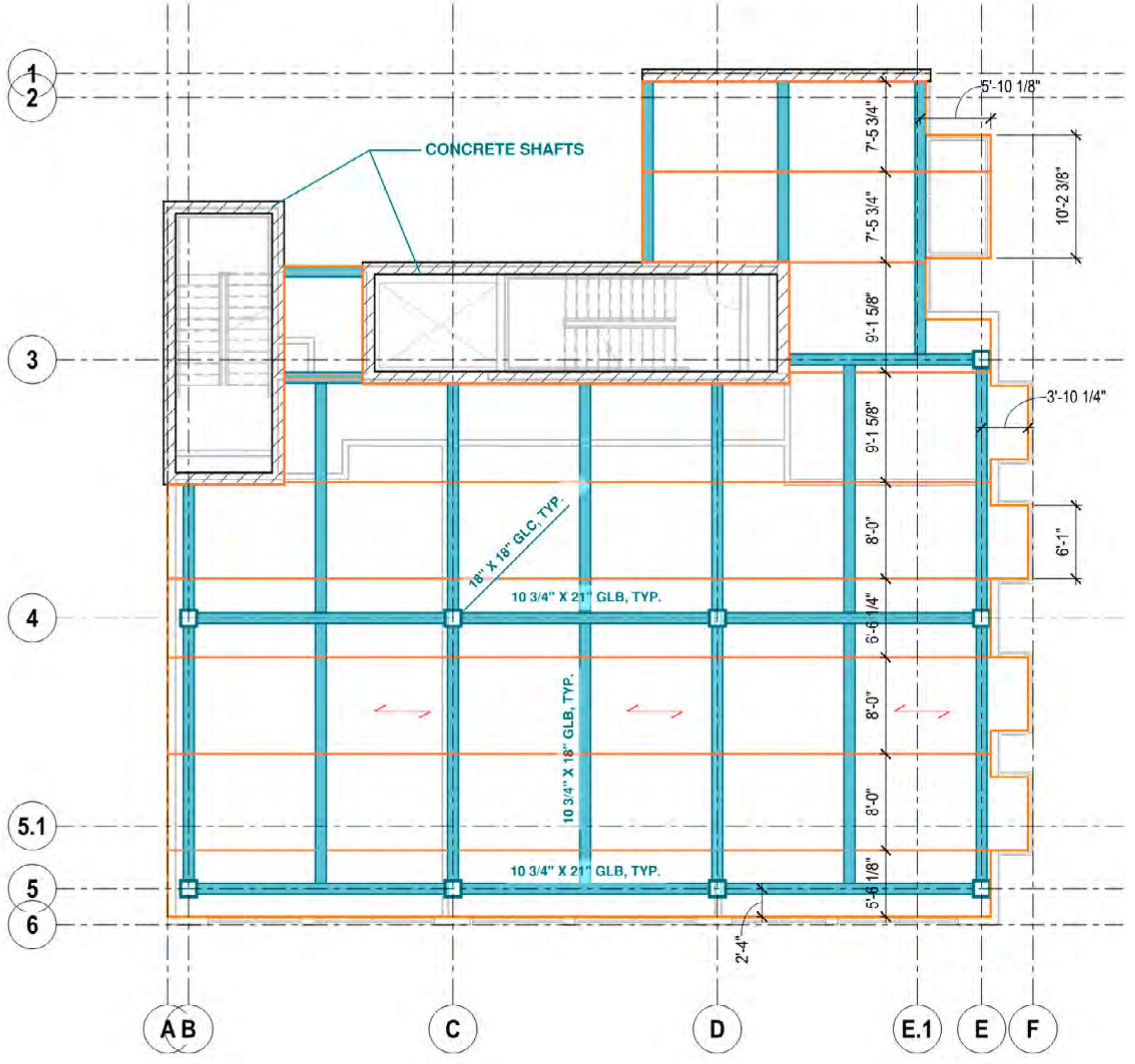
ROOF PLAN

ROOF

GROSS FLOOR AREA:	823 SF
SELLABLE RESIDENT AREA:	958 SF
COMMUNAL AREA:	2,228 SF

STRUCTURAL DIAGRAMS



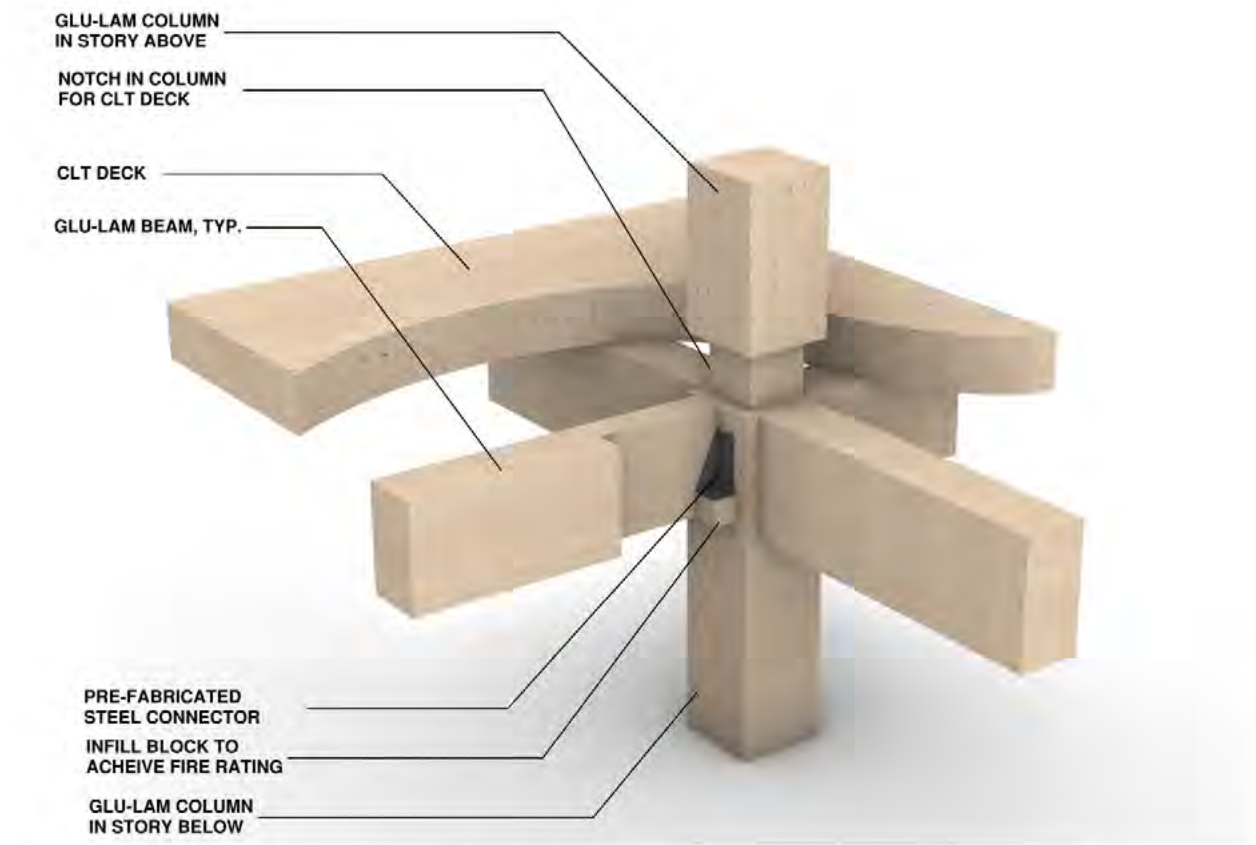


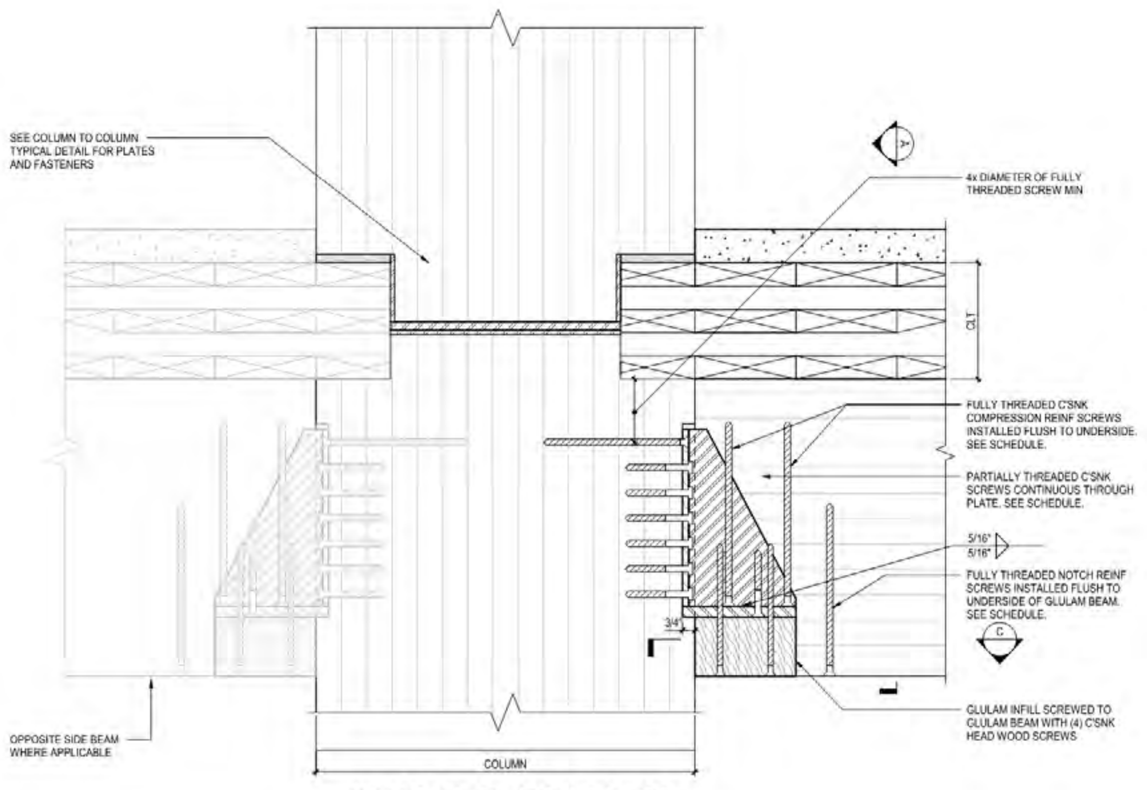
DRAWING NOTES:

1. Indicates double span of 5-PLY Grade E1 CLT topped with 2" concrete slab and acoustic layer, total thickness ~9.875"
2. Column sizes reported for lowest level of wood, resulting in maximum column size. Column sizes at upper stories likely to decrease in depth.
3. ** tag on beam indicates member assumed to be fully fire protected by architectural finishes.

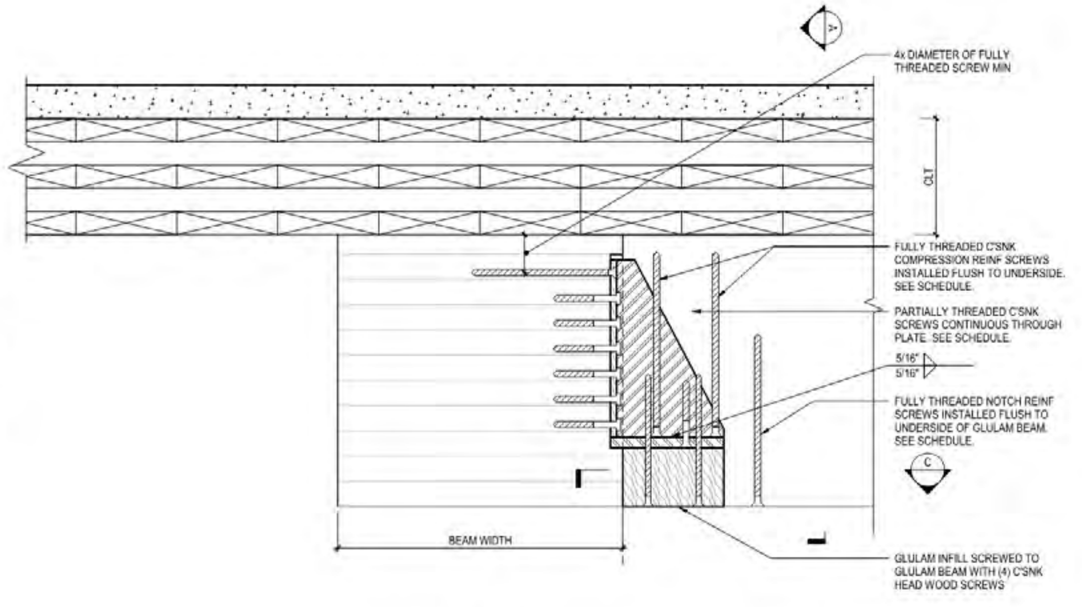
Thornton Tomasetti

STRUCTURAL DETAILS





BEAM TO COLUMN



BEAM TO BEAM

TYPICAL EXPOSED GLU-LAM CONNECTION

INTERIOR RENDERINGS

EXTERIOR RENDERINGS

PERSPECTIVES AND DETAILS

STRUCTURAL DATA

TYPE IV-B MASS TIMBER LAYOUT

7 STORIES WOOD OVER 2 STORY CONCRETE

FIRE RATING REQUIREMENTS FOR STRUCTURAL ELEMENTS (PER IBC 2021)

Primary Structural Frame	2 hrs
Bearing Walls	2 hrs
Floor Construction	2 hrs
Roof Construction	1 hr

WOOD VOL / SF:

5-PLY CLT = 990 in^3/sf
Glulam Beams = 335 in^3/sf
Glulam Columns = 120 in^3/sf

TOTAL = 1441 in^3/sf
% of framing in total wood volume = 31%

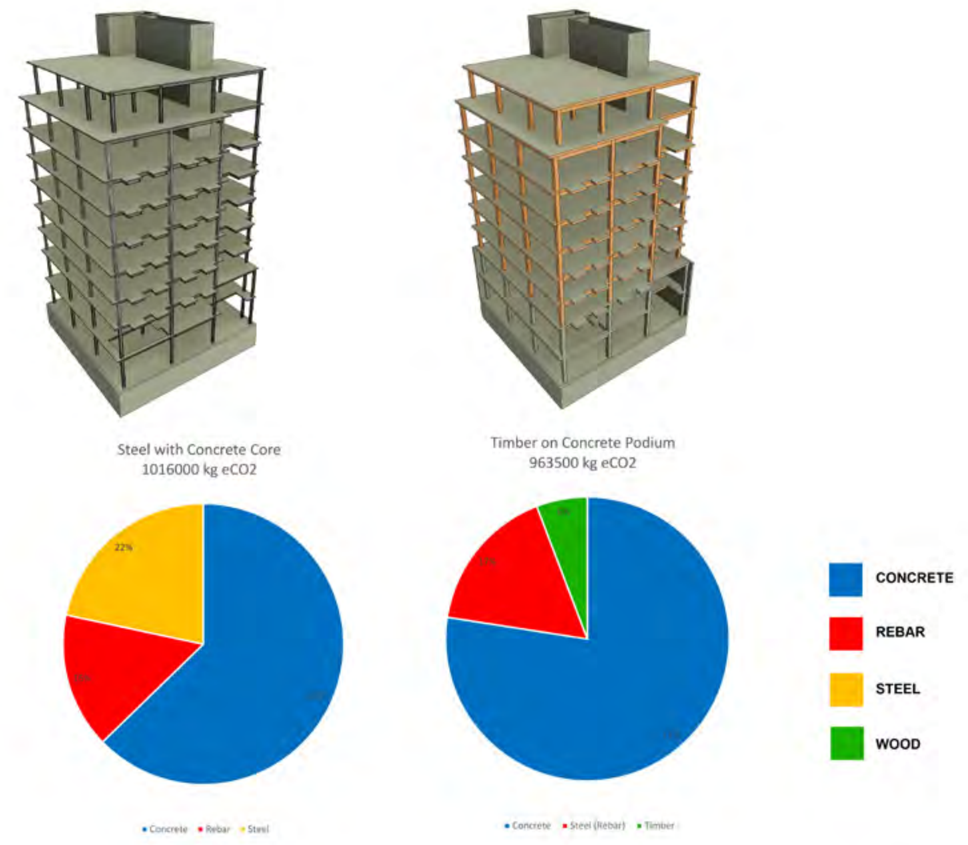
MATERIAL ASSUMPTIONS

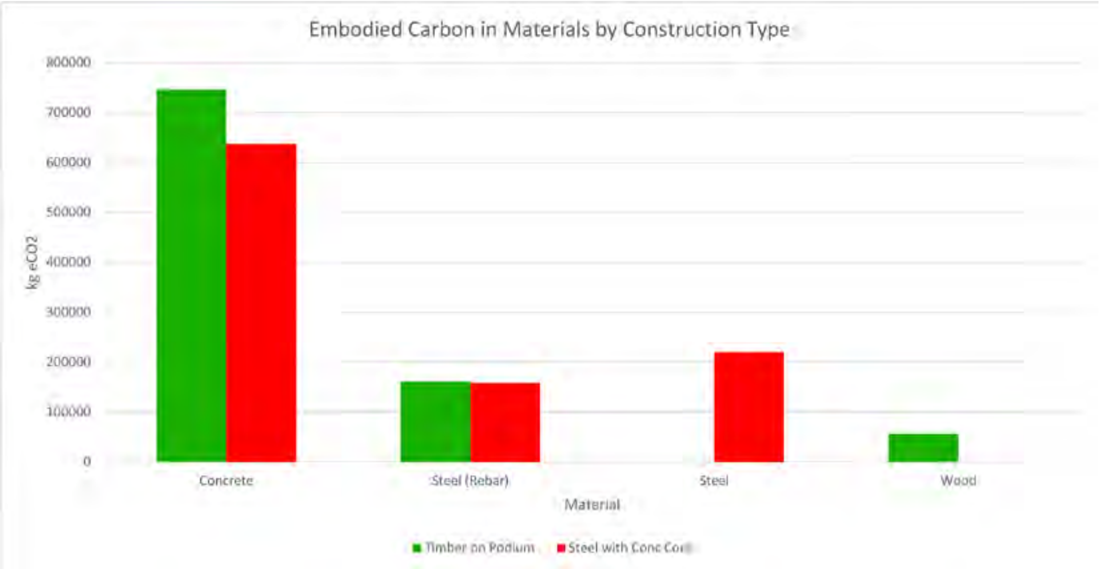
CLT Floor and Roof Panels: *Grade E1*
Glu-lam Beam Framing: *Western Species Grade 24F-1.8E*
Glu-lam Column Framing: *Western Species Grade 2 DF-L2*

DESIGN CRITERIA:

FLOOR DEAD LOAD = 65 psf (including CLT weight)
FLOOR LIVE LOAD = 40 psf (residential)
BALCONY LOAD = 60 psf

EMBODIED CARBON IN SUPERSTRUCTURE = approx 3.8 $kgCO_2e$ / sq. foot
Reference steel framed alternative with concrete slab on deck approx 12.2 $kgCO_2e$ / sq. foot





Carbon Summary

Results

Volume of wood products used:
592 cubic meters (20,906 cubic feet)

U.S. and Canadian forests grow this much wood
2 minutes

Carbon stored in the wood:
526 metric tons of carbon dioxide

Avoided greenhouse gas emissions:
204 metric tons of carbon dioxide

Total potential carbon benefit:
729 metric tons of carbon dioxide

Equivalent to:

154 cars off the road for a year

Energy to operate 77 homes for a year

Project Name:	104 Canal Street
Date:	June 14, 2022

Results from this tool are based on wood volumes only and are estimates of carbon stored within wood products and avoided emissions resulting from the substitution of wood products for non-wood products. The results do not indicate a carbon footprint or global warming potential and are not intended to replace a detailed life cycle assessment (LCA) study. Please refer to the References and Notes' for assumptions and other information related to the calculations.

WoodWorks™ WOOD PRODUCTS COUNCIL

Thornton Tomasetti

BENEFITS & OUTCOMES

Building Practices

The building proposed at 110 Canal Street is a nine-story structure designed to thoughtfully integrate with the surrounding neighborhood context, and to complement the unique blend of historic and contemporary buildings that give Bulfinch Triangle its character. At present, the building is being considered for use either as office space or as residential. Options for the building's structure on this modest footprint looked at either steel frame or wood construction.

Building Code Strategies

There will be upcoming building code changes pertaining to mass timber construction. In anticipation of these code changes for construction types IV-A, IV-B, and IV-C, the use of mass timber is considered feasible for the building at its currently proposed height.

Analysis

The costs comparing steel frame with mass timber IV-B construction are being assessed by owner's contractor. For residential use, mass timber housing units are expected to have a higher market value and a quicker lease-up schedule than conventional fit-out due to a more desirable, warmer aesthetic. In addition, the reduced carbon footprint of mass timber structure is better for the neighborhood and for the environment overall and appeals to an environmentally-conscious tenants.

Savings

In terms of construction duration, there is potential for faster construction time using mass timber as compared with steel or concrete. In addition, the lighter structure reduces the concrete needed for the foundation of the building, which lowers both the cost to construct and the project's carbon footprint.

Opportunities Realized and Lessons Learned

Takeaways from conversations with contractors included the early commitment to use mass timber as the structural system as it provides different opportunities and limitations impacting the design, and can add cost premiums if required to be accommodated further along in the design process. One example would be if a building is designed as a steel structure and the decision is made to change the structure to mass timber. The different systems have different span dimensions and there can be lost efficiency in footings and foundations without entirely reworking the design.

Another takeaway is to design some flexibility into the connection details between different materials as the wood will shrink slightly as it ages and wood, steel, and concrete all have different constructibility tolerances and the slightest delta can compound to a complex issue as buildings get taller.

Additional coordination is required in the pricing and planning phases of the project as some subcontractors have less experience with mass timber and there are unique challenges to be addressed including limitations on field changes, protection of the timbers during construction (it is a finished product), and a higher level of MEP/FP coordination than typical on smaller project as penetrations to the members in the field should be avoided.

Change In Sustainability Goals

We are dedicated to pursuing the most sustainable projects feasibly taking into account the design, material availability, project location, use, and market conditions. Mass timber is a more sustainable option for a structural system than steel as it is a renewable resource and the utilization of smaller pieces of wood in glulam or CLT members allows for the potential of higher efficiency of use of the material sourced from trees. The use of mass timber in a residential building scenario creates a marketable appeal for the rental units. The warmth of exposed timber is attractive and calming within the residences and provides a bold and compelling contrast to the dark charcoal exterior facade.

COST ANALYSIS

Structural System:

Steel	
Material Costs	$1,050,000
Construction Costs	$21,750,000
Project Costs	$27,250,000

Mass Timber	
Material Costs	$1,125,000
	Premium 7.1%
Construction Costs	$23,000,000
	Premium 5.8%
Project Costs	$28,500,000
	Premium 4.6%
	Premium $30/SF
	Premium $50,000/unit

Costs include premiums/savings for miscellaneous metals, rough carpentry, insulation, fireproofing, glass/glazing, gypsum wall board, finishes, acoustical ceilings, MEP/FP, sourcing of materials, and schedule but does not include land costs.

PROGRAM EVALUATION & IMPACT

The weekly roundtable discussions were most helpful when they were targeted education sessions. Fostering these types of conversations remotely is challenging, especially among people who are unfamiliar with each other and, more than likely, in competition with one another. Setting up the weekly calls with specific topics to discuss and then allowing the attendees the opportunity to ask questions at the end might improve the reticence to participate within the group.

Touring the mass timber project was instructional and fun. Seeing a structure in person is always the best way to appreciate it. Our tour guide did an excellent job of explaining the project's features, pointing out specific details, and sharing challenges of the construction. The visit crystallized what some of the issues might be in future designs.

The acoustic vibration presentation was good. The fact that there needs to be a presentation addressing the issue of vibration underscored the importance of this aspect of mass timber construction. The session provided good technical information that was clear and specific.

Technical assistance provided by Woodworks was, and continues to be, substantial. The book they wrote on the subject of working directly on the design and construction of a mass timber project provided a breadth of knowledge and information that is singular in its reach.

The midterm pinup was useful for providing an interim deadline and getting a glimpse of the other projects and some of their explorations. The hybrid in-person and remote presentation and attendance was sometimes limiting due to the difficulty in hearing and seeing some of the information. As with the weekly remote sessions, having discussions with people some of whom are in the room and some who are via computer can be a challenge.

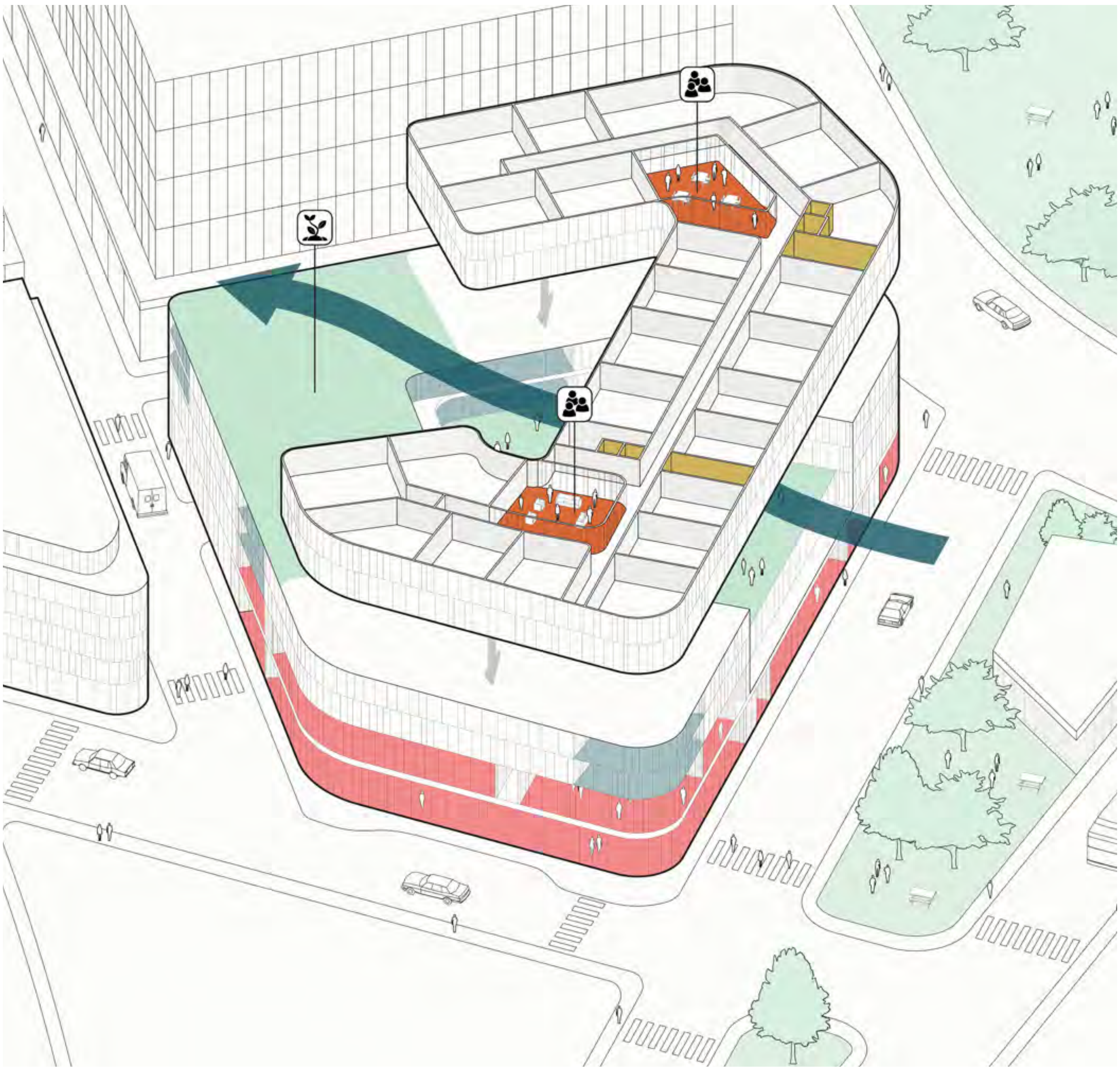
Overall, the mass timber accelerator program was terrific. We heartily applaud the spirit and implementation of it and its goal of reducing our buildings' carbon footprints. We recognize that the program required significant time and effort on the part of the organizers, which was apparent in the quality of information that was presented and made available to educate the participants. The final project presentations covered a wide range of project types and stages of design. The variety of the projects served to expose the program participants to a far greater number of examples in a short period of time than any one of us would be able to do on our own.

THANK YOU

PROJECT Q

MASS TIMBER ACCELERATOR

FINAL REPORT FOR BOSTON PLANNING & DEVELOPMENT AGENCY
AND BOSTON SOCIETY FOR ARCHITECTURE
JULY 15, 2022



DIMELLA
SHAFFER

project team

DiMella Shaffer / Architect

Project Q Communities / 501c3 Owner + Community Partner

HYM Investment Group / Development Partner + Owner of Suffolk Downs

OnePoint Partners / Development Partner

Commodore Builders / Cost Estimator

L.A. FUESS / Structural Engineer

AKF / MEP/FP + Code Consultant

table of contents

EXECUTIVE SUMMARY

SUMMARY REPORT

This report summarizes a mass timber study through the Boston Planning and Development Agency (BPDA) and Boston Society for Architecture (BSA) Accelerator Grant for one of two parcels located at Suffolk Downs in East Boston. The project is developed by Project Q Communities, OnePoint Partners, and HYM Investment Group. Project Q Communities, a 501c3 non-profit focused on developing LGBTQ friendly senior housing partnered with OnePoint Partners, a national firm who specializes in the development, marketing, and financing of senior housing, and HYM Investment Group as developers of the former Suffolk Downs racetrack. The project pioneers urban, entry fee senior housing in Boston. Project Q Communities aims to build one of the largest developments of this kind and will lead New England in providing market-rate urban housing with a focus on the LGBTQ senior community.

This partnership seeks to develop 215 units of market-rate senior housing and related amenities. The site includes parcels B018 and B019, which allow for the construction of two buildings. DiMella Shaffer focused on the eight-floor high-rise building on parcel B018. The first floor includes amenities such as the reception lobby, fitness room, restaurant, and large gathering room; the second and third floors are dedicated to assisted living and memory care units, and the upper five floors consist of independent living apartments. A large terrace is located at the second floor providing access to outdoor space, a priority of the building design. The smaller site, parcel B019, is not covered in this report.

Parcel B018 is approximately 306,700 gross square feet and given the buildings' size and complexity is the focus of the mass timber study. The original design envisioned podium construction with five floors of wood over three floors of steel and concrete. In contrast, mass timber lowers the embodied carbon, is a renewable resource, offers design opportunities, and is feasible for this occupancy type without significant added cost. In addition, mass timber contributes to a biophilic environment, establishing a connection to nature, a beneficial feature for senior living.

By designing eight floors of mass timber construction instead of the traditional steel and concrete podium, we maximized the use of the low-embodied carbon material throughout the entire building. Over a typical building life cycle, embodied carbon can have a similar importance as operational carbon emitted from heating and cooling and it is thus imperative to consider low-embodied carbon in the design process. It is also necessary for projects to understand the practicality of a mass timber approach and scaling it up for larger buildings. This study is a catalyst for future high-rise construction projects in the Boston area.

Our study shows that mass timber is applicable to both orthogonal and complex forms; mass timber is flexible and can be applied to a large range of building shapes and occupancy types, including senior living. It is also critical to balance the architecture with the structure and to review them in tandem to rationalize the structural efficiencies.

From the beginning of the study, our goal has been to use mass timber throughout the building which drove various decisions during the process. Given the mixed-use occupancy, the need is for a structure with long spans for the first floor amenity spaces, as well as stacked structure for the senior living units above. We established a bay of 25’ by 16’ by 25’, which reduces the number of columns within the amenity program and works for a typical one-bedroom independent living unit but introduces common beams. This in turn is a challenge for mechanical systems, but through the study we illustrate how this can be conceptually solved. 25’ maximizes the mass timber structural capacity and the central 16’ grid spacing allows for a column free corridor and a reduced girder depth.

Except for steel structure within the automated parking and loading dock zone at the first floor, the composite slab below the second floor terrace, and cast-in-place concrete cores for shear requirements, all other structure is comprised of mass timber. The application of mass timber includes the 5-ply cross-laminated timber (CLT) deck, 18” by 18” glue-laminated (glulam) timber columns, two 6.75” thick by 22” deep glulam girders aligned with the unit demising walls, and perpendicular 8.5” thick by 16.5” deep glulam common beams. The girders reduce in size to 6.75” by 16.5” within the corridor, facilitating MEP distribution. Two girders are necessary for an economical connection, a key component to the study.

At the second floor terrace, a long span opening was originally designed to promote airflow from the nearby ocean through the eastern façade into the elevated courtyard, and the form is carved to allow sunlight to reach the terrace floor. We evaluated multiple options for the 92’ opening and determined that the best embodied carbon approach is exposed glulam columns that follow the grid spacing above. The basis of design species is Alaskan Yellow Cedar, due to its’ naturally decay resistant properties.

Given the occupancy use classification and construction type IV-C, parcel B018 is limited to a height of 85’, which results in the following floor-to-floor heights: 12’6” (first floor), 11’ (second floor), 11’6” (third floor), 10’ (upper five floors). The 10’ floor-to-floor height is a challenge from a mechanical standpoint, which drove us to study in-unit energy recovery ventilators (ERV) for the upper five floors to minimize cross ductwork with the framing. In addition, corridor ventilation is provided by rooftop dedicated outdoor air system (DOAS) units and delivered via stacked vertical shafts and sidewall diffusers. A central ERV system provides fresh air to the lower three floors. Minimizing rooftop mechanical allows ample area for photovoltaic panels.

While it may present added challenges as described above, and lead to additional coordination by project teams earlier in the design process, mass timber is a viable construction approach to senior housing buildings. Through the study, we’ve identified several hurdles, each with a different impact on the design and construction of parcel B018. In all cases, we were able to develop solutions and strategies to overcome those challenges. We’ve learned that the earlier in the process we understand the structural approach, the better positioned we are to look holistically at how to coordinate the structural and mechanical systems supporting the building.

WOODWORKS CARBON SUMMARY

results

Volume of wood products used:
6,770 cubic meters (239,075 cubic feet)

U.S. and Canadian forests grow this much wood in: **18 minutes**

Carbon stored in the wood:
6,014 metric tons of carbon dioxide

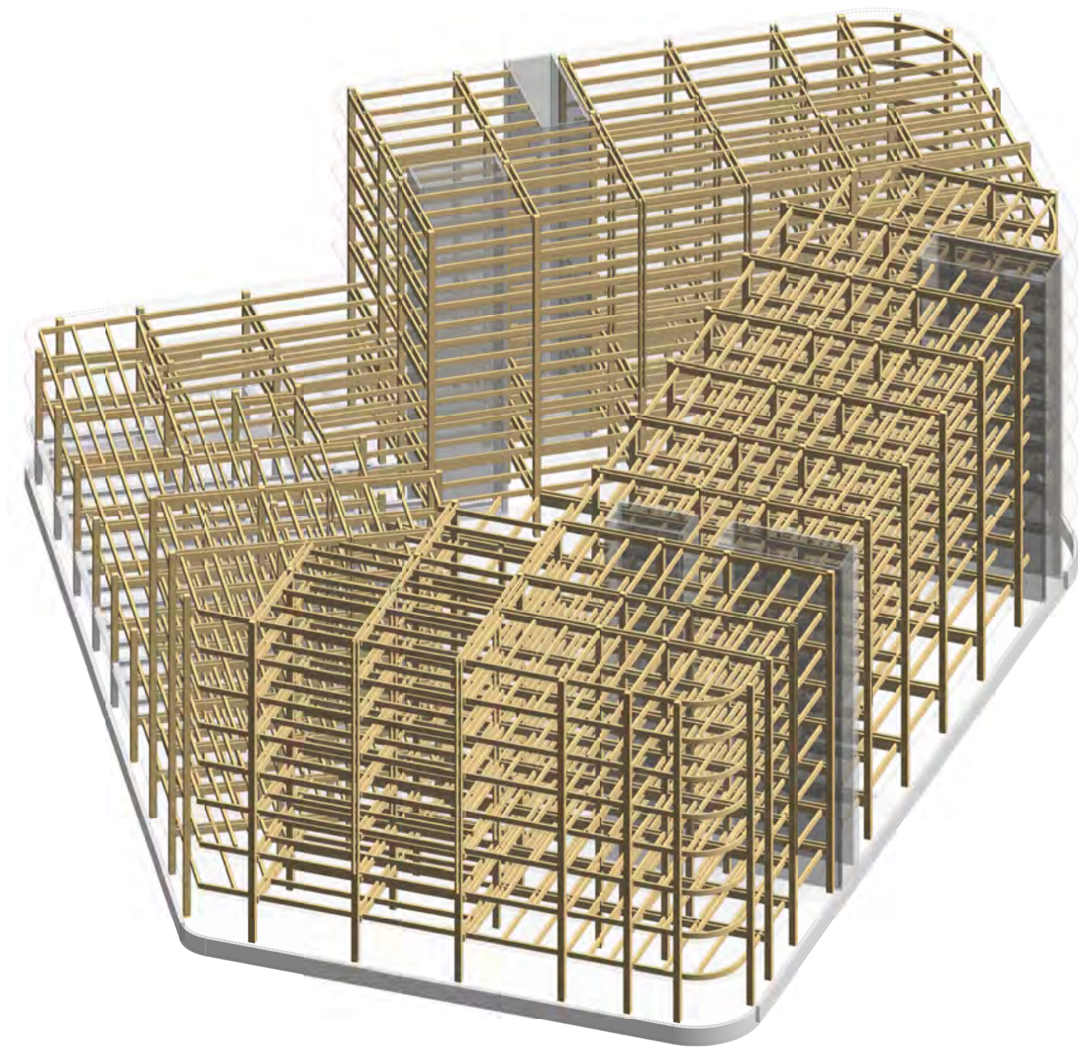
Avoided greenhouse gas emissions:
2,327 metric tons of carbon dioxide

Total potenial carbon benefit:
8,341 metric tons of carbon dioxide

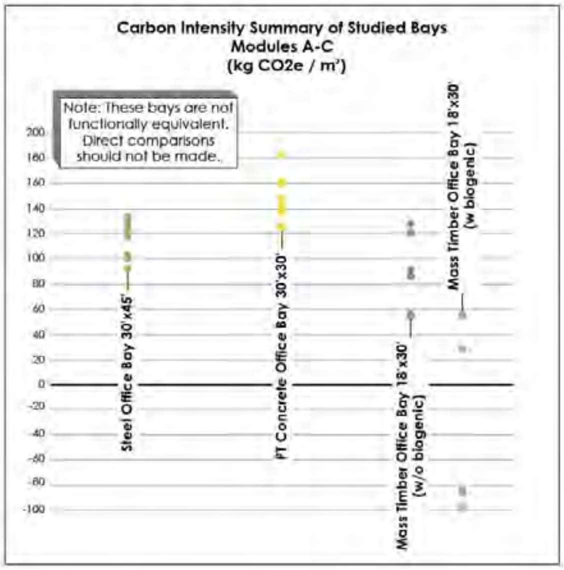
equivalent to

1,764 cars off the road for a year

Energy to operate **881 homes** for a year



LIFE CYCLE ANALYSIS



Source: SE 2050

DiMella Shaffer created two life cycle assessments using Tally, to study the following:

Analysis A (concrete cores & gypcrete)

- Includes CLT floors, glulam frame, cast-in-place concrete stair and elevator cores, composite slab at second level, slab on grade and foundation walls, steel frame at ground level, and gypcrete topping
- **2,270,632 kgCO2e** total global warming potential
- **80 kgCO2e per m2**

Analysis B (concrete cores w/out gypcrete)

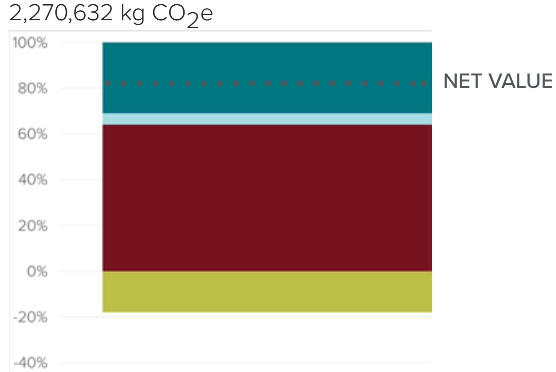
- Includes CLT floors, glulam frame, cast-in-place concrete stair and elevator cores, composite slab at second level, slab on grade and foundation walls, and steel frame at ground level
- Gypcrete is excluded because it is not a structural element and therefore this analysis provides a more direct comparison to the SE 2050 carbon intensity summary
- **1,404,406 kgCO2e** total global warming potential
- **50 kgCO2e per m2**

We assumed 30% fly ash for the cast-in-place concrete cores and 20% fly ash for the composite floor slab. The sum of the Global Warming Potential (GWP) includes Module D and is with biogenic carbon.

GLOBAL WARMING POTENTIAL

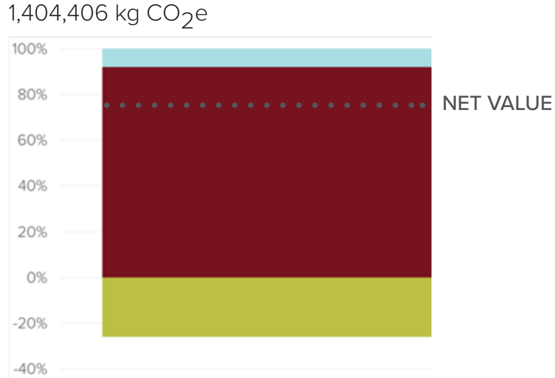
ANALYSIS A

2,270,632 kg CO_2e



ANALYSIS B

1,404,406 kg CO_2e



BENEFITS / OUTCOMES

DESIGN AND CONSTRUCTION STRATEGIES

Mass timber is often used with orthogonally stacked forms; however, orthogonality is not the only solution, and we show that more complex forms can be effectively built using mass timber.

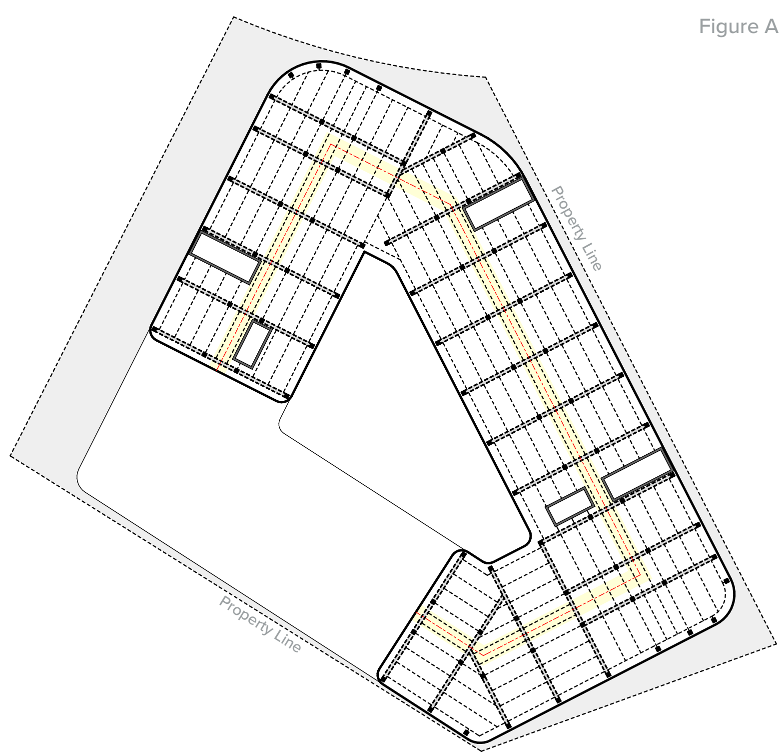
Our strategies from the beginning of the study have been to balance mass timber with the original angular form and to promote the use of mass timber throughout the entire building. The zoning designation for the site is a zero-lot line and therefore allows for maximum gross area which drove the original form. However, the site does not have 90-degree angles. To solve for angles, we needed to diagram the corridor to understand where and how the structure would intersect. We deviated slightly from the original form and site angles to rationalize the structural grid and simplify the intersections with 90- or 120-degree angles. At the lower corner of the site, the 96-degree angle is maintained to maximize the second floor terrace footprint, an important design aspect. Additional landscaping can be accommodated at the first floor when the form is not parallel with the property line.

See Figure A to the right.

The main factors in the development of the mass timber framing layout stem from the need to fit with both a typical one-bedroom independent living unit and the amenity program at the first floor. While 12’6” bay spacing would have worked for the independent living unit layout, it would have introduced too many columns within the amenity program. Therefore, typical bay spacing is 25’ by 16’ by 25’. The column centerline is setback 2’ from the face of the exterior wall, which drives the 70’ outside wall to outside wall dimension.

The L.A. Fuess team was critical to determining if this approach was structurally feasible, as well as developing the framing sizes. The 25’ bay spacing results in glue-laminated (glulam) timber girders and perpendicular glulam common beams. Common beams, while necessary to the structural system, present a mechanical challenge, which will be discussed later in the report. However, because the CLT

Figure A



floor deck needed to be 5-ply to meet the required 2-hour fire rating, a thicker floor afforded common beam spacing flexibility. In addition, common beams are located an additional 2’ in from the outermost columns, which allows for potential mechanical distribution and greater window height if desired. Where the form returns at each end, columns and beams are located 4’ in from the outside face of the wall, maintaining the exterior corner curvature.

To satisfy the shear requirements, the stair and elevator cores are designed to be cast-in-place concrete. However, based on the life cycle analysis in Tally, concrete embodies a substantial percentage of the project’s global warming potential. We have begun to explore opportunities to decrease the embodied carbon through the replacement of concrete with supplementary cementitious materials (SCM’s) and preliminarily established 20% fly ash for the concrete floors and 30% fly ash for the concrete walls. Higher strength rebar within the concrete core walls could also help to reduce the embodied carbon. We also investigated the use of steel brace frames in lieu of cast-in-place concrete; however, additional brace frames would be required beyond the core locations which was not desired from a programming perspective. Concrete masonry units were also studied but would not be able to meet the structural requirements.

At the second floor terrace, a 92’ span opening was originally designed to promote airflow from the nearby ocean through the eastern facade. The study allowed for multiple strategies to be evaluated: hybrid mass timber and steel truss, steel truss, and exposed mass timber columns. The hybrid mass timber and steel truss was determined to not be feasible due to the significant loads from the five floors above.
The steel truss would have created additional embodied carbon. Therefore, we proceeded with exposed glulam columns that follow the grid spacing above. L.A. Fuess and WoodWorks provided feasibility feedback, precedents, and helped to select an applicable wood species for the weather exposure. The team chose Alaskan Yellow Cedar for the basis of design, due to its’ naturally decay resistant properties. Some precedent examples include: The Soto, DC Southwest Library, and the Mystic Seaport Museum.

Mystic Seaport Museum

Architect: Centerbrook
Photo Credit: Jeff Goldberg/Esto

.The typical floor structure consists of a finish floor over 2” of gypcrete, over .5” acoustic mat, over 5-ply (6.875”) CLT deck. The floor assembly meets the requirements of the 2-hour floor fire rating. The glulam columns are 18” by 18”. The face of the double demising wall aligns with the face of the column. Two 6.75” thick by 22” deep glulam girders are centered along the 25’ bay spacing and coincide with the unit demising walls. The girders reduce in size at the corridor to 6.75” by 16.5”, which facilitate MEP distribution. The column is notched by 3” on each side to accept each girder, which results in a 1' gap between the girders. The notch allows for the girders to continue, which takes the shrinkage out of the connection and uses the wood naturally to do the work, and results in an economical connection. The added benefit of the 1' gap allows plumbing piping to stack throughout the building, which was also evident at 11 East Lenox. We had initially thought that the gap would be a good opportunity for mechanical ductwork but decided against the approach due to acoustic and fire considerations. 8.5" by 16.5" glulam common beams connect to the girders perpendicularly.

See Figure C below.

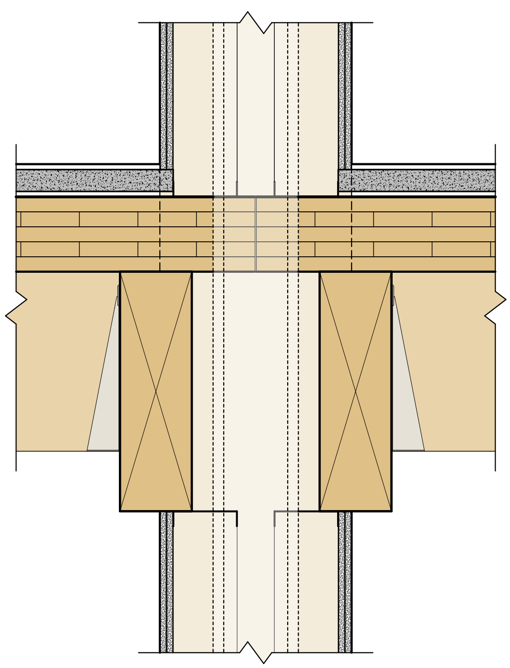


Figure C

BUILDING CODE STRATEGIES

Up until this time, the advancement of tall structures with mass timber has been limited, in part due to the building code.

IBC 2021 is a catalyst for the design of tall mass timber structures, with the addition of construction types IV-A, IV-B, and IV-C.

Initially B018 was designed to meet the requirements of the 2015 International Building Code: five floors of construction type 3A over three floors of construction type 1. With the premise of the study requiring the exploration and validity of using mass timber, the 2021 International Building Code gives us the most flexibility. Under the new building code, which is yet to be adopted, B018 is designed to meet the requirements of type IV-C construction.

With the variety of mixed-use occupancy that we have within our program, floors two and three have the most restrictive code requirements as it pertains to the type of construction as well as the type of occupancy. Occupancy type I-1, Condition 2 limits the height of assisted living program to be a maximum height of 65' and four floors tall. The independent living apartments at the upper floors have a maximum building height of 85' and eight floors.

The mechanical, electrical, plumbing and fire protection distribution was crucial for us to study with the structure of mass timber. Each independent living unit on the upper five floors will consist of an ERV unit which will have the intake and exhaust routed directly through the exterior wall. This helps to minimize the amount of ductwork compared to routing the ducts through the roof. It also aids in providing as much roof area as possible for photovoltaic panels. In addition to the ERV, each unit will be supplied with conditioned air by a rooftop variable refrigerant flow (VRF) unit. Each VRF unit will serve several living units to optimize the energy usage of the equipment. There will be one fan coil unit (FCU) in each unit as part of the VRF system. Dedicated outdoor air systems (DOAS), located on the roof, provide the corridor ventilation, and fresh air is delivered via stacked vertical shafts and sidewall diffusers. This limits the amount of horizontal distribution through the corridors to electrical, plumbing, and fire protection.

See Figure D below.

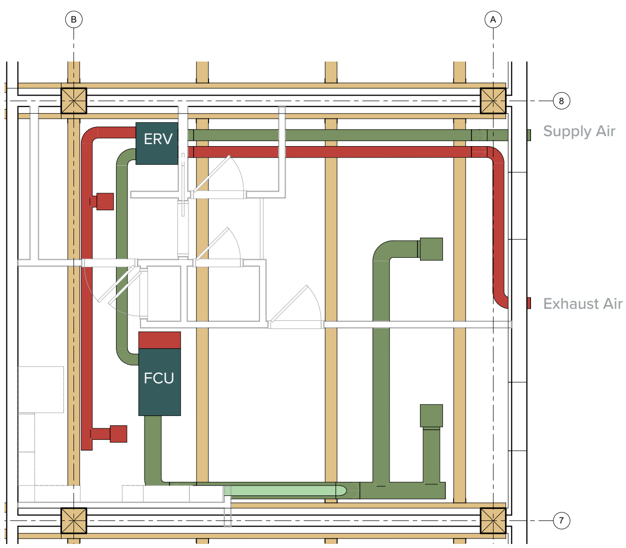


Figure D

At the assisted and memory care units on floors two and three, a central ERV system will provide fresh air as well as remove exhaust air from the units. A central VRF system will provide conditioned air to each unit. The central ERV and VRF units will be located on the roof above floor three, where there is a green roof space. We want to take full advantage of the higher floor-to-floor heights at these floors which is why we decided to use the central approach. We will run the ductwork in the ceiling space of the corridors and then into the units.

COST ANALYSIS

Typically, when the idea of mass timber is mentioned, there's an assumption that it means an increase to the cost of construction which tends to be well outside of project budgets. However, in our high-level cost comparison between the original five over three podium construction and mass timber, we found the additional cost of mass timber to be relatively low.

For the cost of construction, we worked with Commodore Builders to evaluate the price per square foot of B018. For the podium, the cost primarily includes steel framing, concrete, fireproofing, finished ceiling spaces and traditional 2x wood framing. With the gross square feet of the building at 306,700, the price per square foot is $67.72.

For the mass timber approach, the price primarily includes the limited steel framing at the parking area and loading dock, concrete, mass timber members, and the exclusion of fireproofing as well as finished ceiling spaces. The price per square foot is $79.18.

If we are to look at the cost comparison of these two construction types against the overall project budget of B018, the cost increase for mass timber construction is less than two and half percent.

OPPORTUNITIES REALIZED AND LESSONS LEARNED

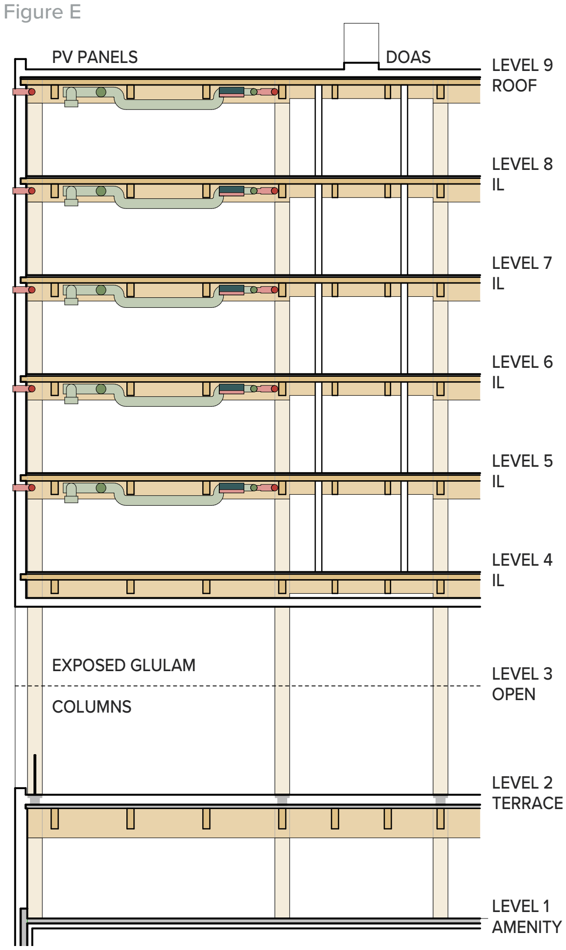
Throughout the mass timber study, the sustainability goals of DiMella Shaffer have been at the forefront of key decisions. This includes the construction type (IV-C), exposure of mass timber elements, exterior continuous insulation, efficiency in building layout and the optimization of mechanical systems.

Even though not part of the mass timber study, the team will continue to evaluate and incorporate Passive House design principles and review the potential for Mass Save Passive House incentives. In addition, the building will be all-electric with the exception of the commercial kitchen serving all building residents.

Given the occupancy use classification and construction type IV-C, as described above, parcel B018 is limited to a height of 85', which also takes advantage of labor agreements between HYM and the Carpenters Union. The floor-to-floor heights are as follows: 12'6" (first floor), 11' (second floor), 11'6" (third floor), 10' (upper five floors). The 10' floor-to-floor height is challenging from a mechanical standpoint, because the common beams provide an obstacle to the duct distribution within the units. However, a conceptual mechanical layout was established with AKF, where we determined that the Energy Recovery Ventilator (ERV) and the Fan Coil Unit (FCU) could be tucked to the underside of the CLT deck in between common beams, leaving 8' clearance below. Ductwork could bend below common beams, as needed, and run along both unit demising walls. The lowest clearance below the supply ductwork is approximately 6'9", but this occurs directly adjacent to the demising wall.

See Figure E upper ight.

Figure E



We also took this as a learning opportunity to research three other mass timber projects and apply lessons learned: 11 East Lenox, Brock Commons, and Mystic Seaport Museum. Due to construction type IV-C, non-combustible exterior framing is required. Therefore, metal studs are necessary in lieu of fire retardant treated (FRT) wood studs, which short circuits the interior insulation thermal properties within the stud cavity, and a code variance for FRT wood studs is unlikely. Taking note from 11 East Lenox, we researched the ArmorWall exterior assembly, which consists of an air and water-resistive barrier on magnesium oxide sheathing fused to a poured polyurethane insulation layer. The sheathing can accommodate various exterior claddings, which are attached directly to the sheathing instead of the stud wall and do not penetrate the insulation layer. The result is a high R-value based on different thicknesses (R-10, R-15, and R-21) and continuous insulation. The ArmorWall system has the potential to result in labor savings given that there is only one installer, one inspection, less staging required, and MEP trades can begin their work earlier than anticipated in the schedule timeline.

See Figure F below.

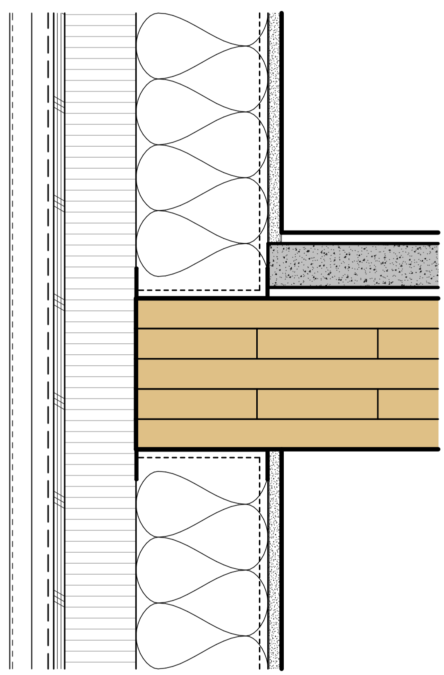
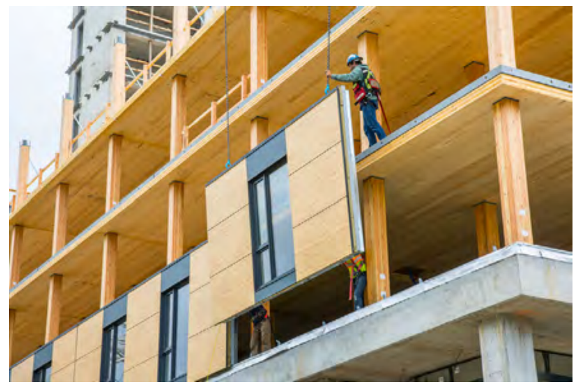


Figure F

Brock Commons is another mass timber project that capitalized on schedule savings through the installation of panelized construction. The exterior wall for Project Q could be panelized similarly and utilize the 25' bay spacing to drive the panelized exterior wall.

Brock Commons



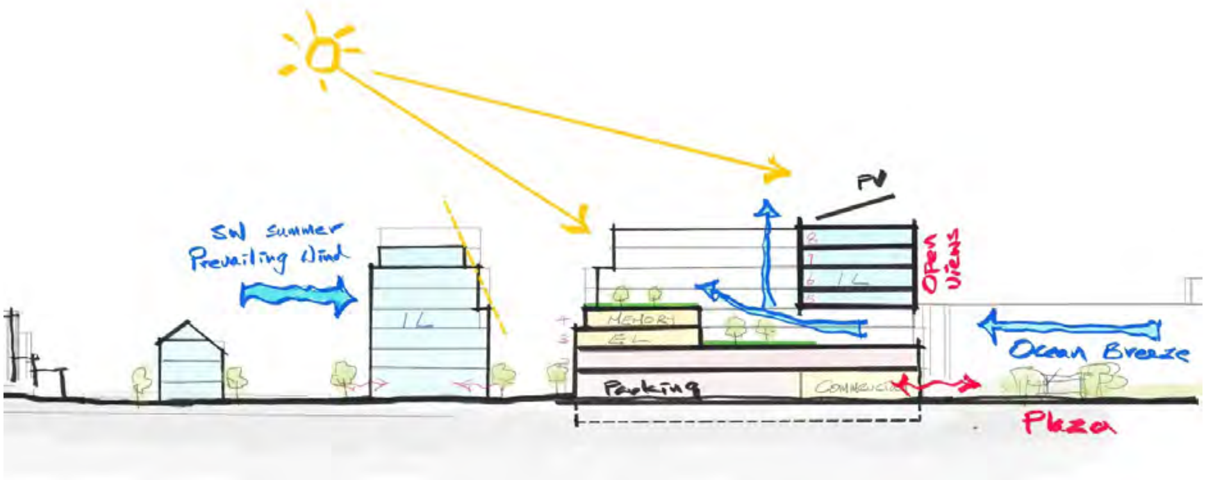
Architect: Acton Ostrey Architects Inc
Photo credit: KK Law / Naturally Wood

Mystic Seaport Museum is another mass timber project, which established concealed connections where the exposed mass timber column connects to the structure below the pavers. We would design a similar detail, where the wood is held above the waterproofing plane but the connection is covered.

NEXT STEPS

Mass timber discussions with the clients are ongoing. However, this study influences other projects in our office to consider mass timber as a structural option and provides a firm-wide educational opportunity.

PROGRAM IMPACT



PROGRAM EVALUATION AND IMPACT

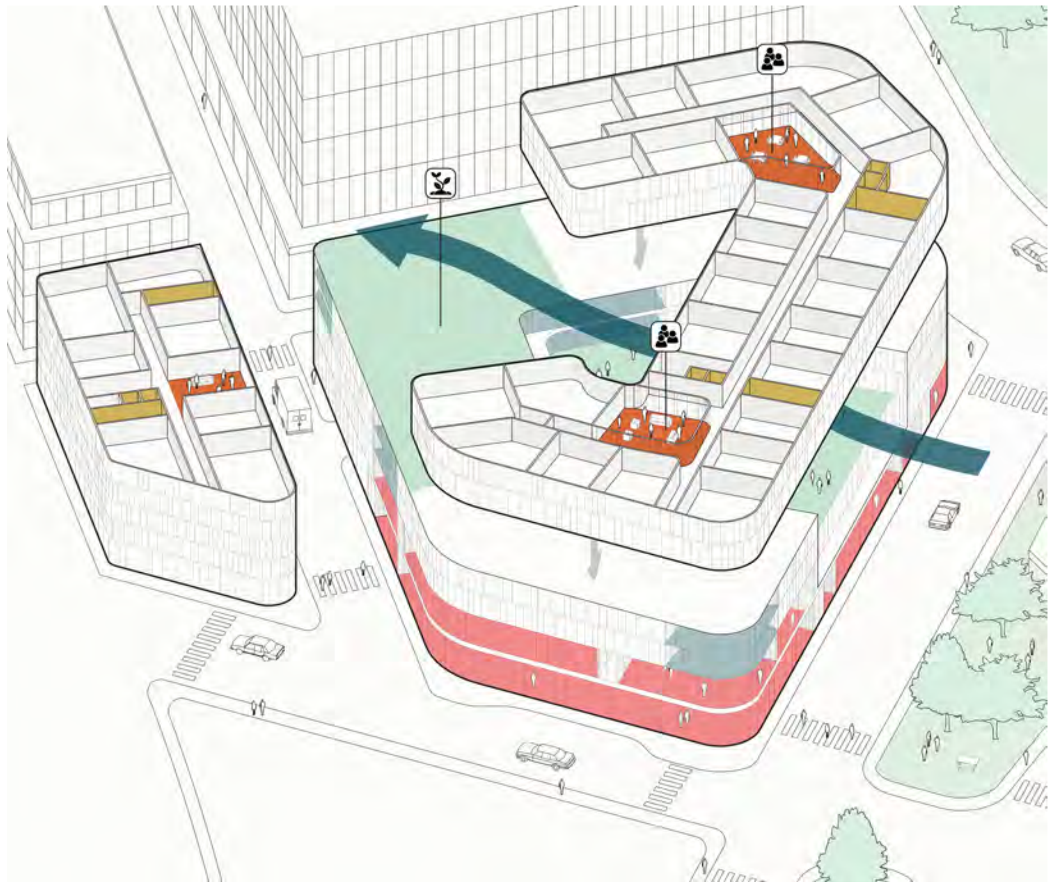
Without this grant, we may not have had the opportunity to evaluate mass timber to this level of detail and perhaps the discussion would have only surrounded cost. Questions came up such as, what is the maximum grid spacing, or when are common beams necessary, or can a 10’ floor-to-floor height work for mass timber? The depth of these discussions alone has had some of the greatest impact on our thinking and approach to mass timber. It was beneficial that we started with the most constraints because the challenges pushed us to think creatively.

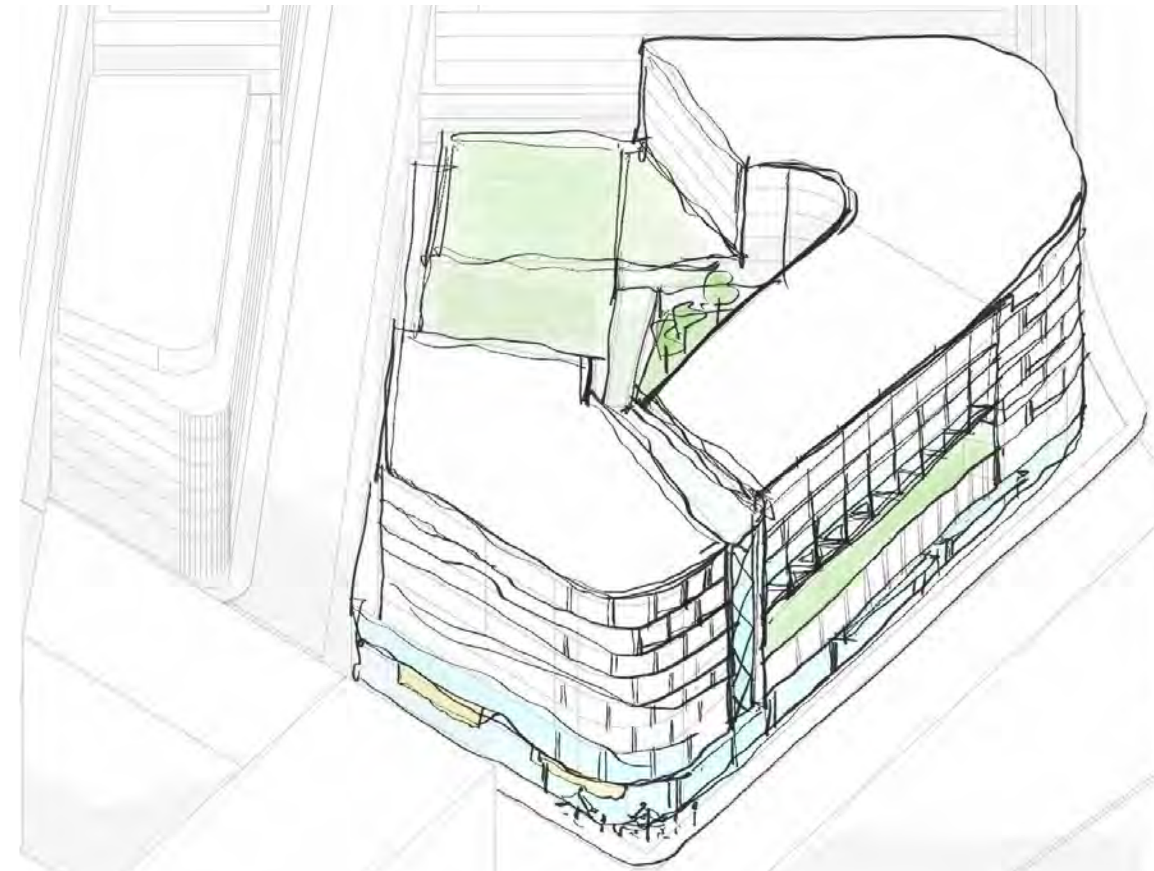
We attended many of the weekly roundtable meetings, which we thought were valuable to learning more about the upcoming 2021 IBC code update specific to mass timber, as well as the technical assistance provided during these calls. Towards the end of the study, the calls could have been bi-weekly instead of weekly, because teams were finalizing their drawings and there would not have been enough time to incorporate major feedback. The 11 East Lenox Tour provided a view into the construction realities and our team came out of the experience with a better understanding of the physical components.

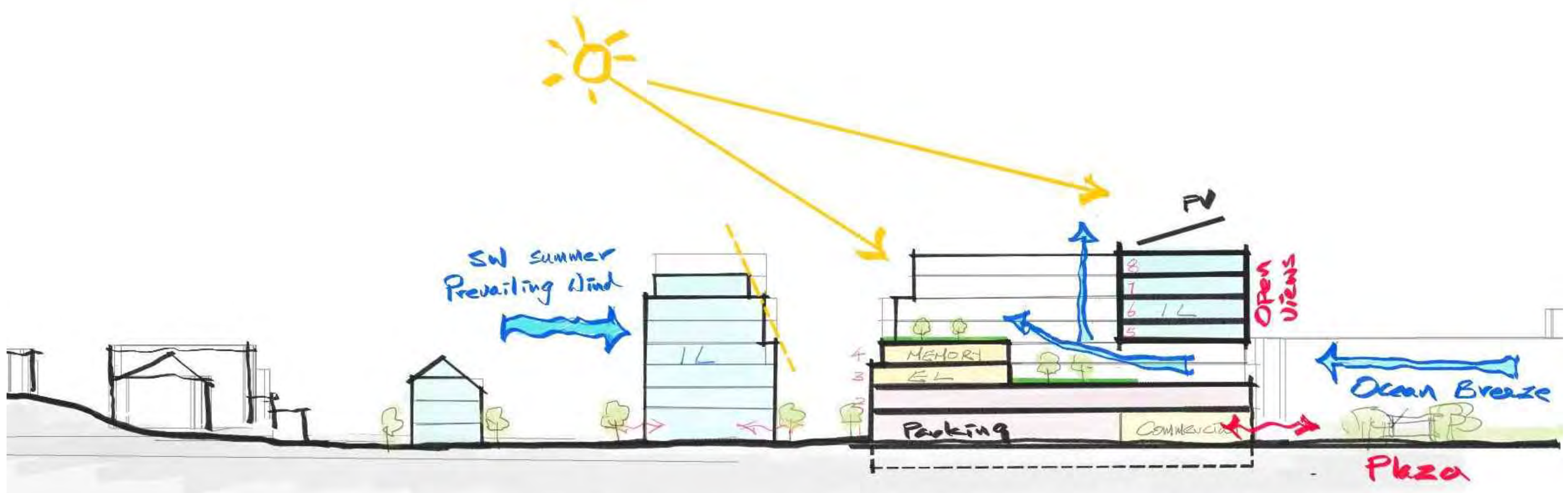
The midterm and final presentation structure were optimally organized to allow us to understand how other project teams approached mass timber and where teams had overlapping strategies. In-person meetings facilitated the presentations and discussions that occurred. This forum allowed for city-wide interaction which is crucial to the advancement of architecture.

PROJECT Q
MASS TIMBER ACCELERATOR

FINAL DRAWINGS FOR BOSTON PLANNING & DEVELOPMENT AGENCY
AND BOSTON SOCIETY FOR ARCHITECTURE
JULY 15, 2022



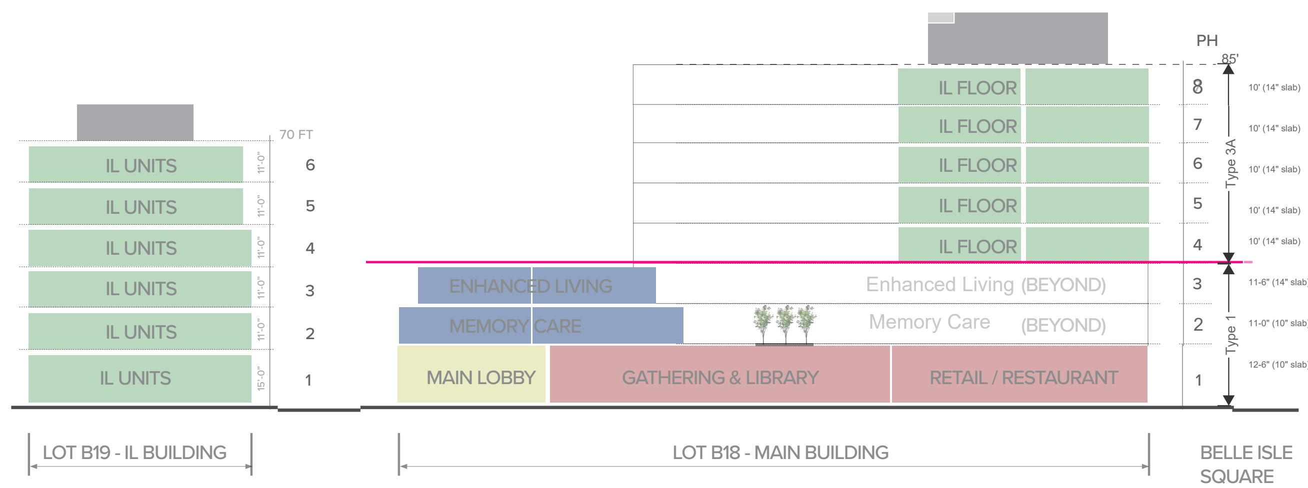


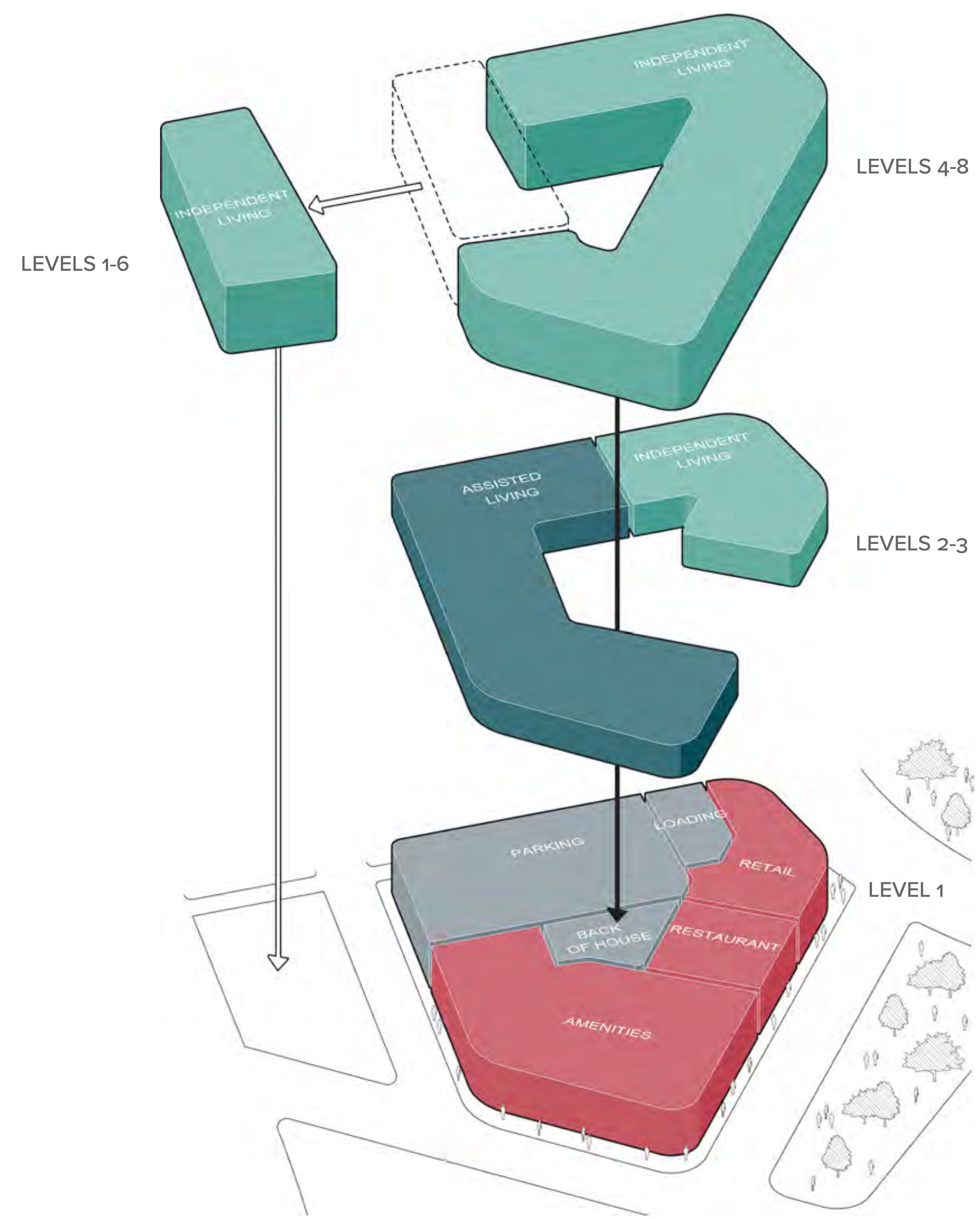


Project Q BOSTON · HYM · onepoint PARTNERS · DIMELLA SHAFFER · Commodore Builders · L.A. FUESS PARTNERS Structural Engineers · AKF

INITIAL CONCEPT

LOT B18 - PODIUM CONSTRUCTION: TYPE 3A (5 FLOORS) OVER TYPE 1 (3 FLOORS)
LOT B19 - PODIUM CONSTRUCTION: TYPE 3A (5 FLOORS) OVER TYPE 1 (1 FLOOR)





MASS TIMBER APPROACH

TABLE 504.3 ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE

CONSTRUCTION TYPE: IV-C

OCCUPANCY CLASSIFICATIONS:

- A,B,E,F,M,S,U (SPRINKLER) - 85'
- I-1, CONDITION 2 (SPRINKLER) - 65', 4 STORIES (TABLE 504.4)
- R-2 (SPINKLER) - 85', 8 STORIES (TABLE 504.4)

TABLE 504.3 ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

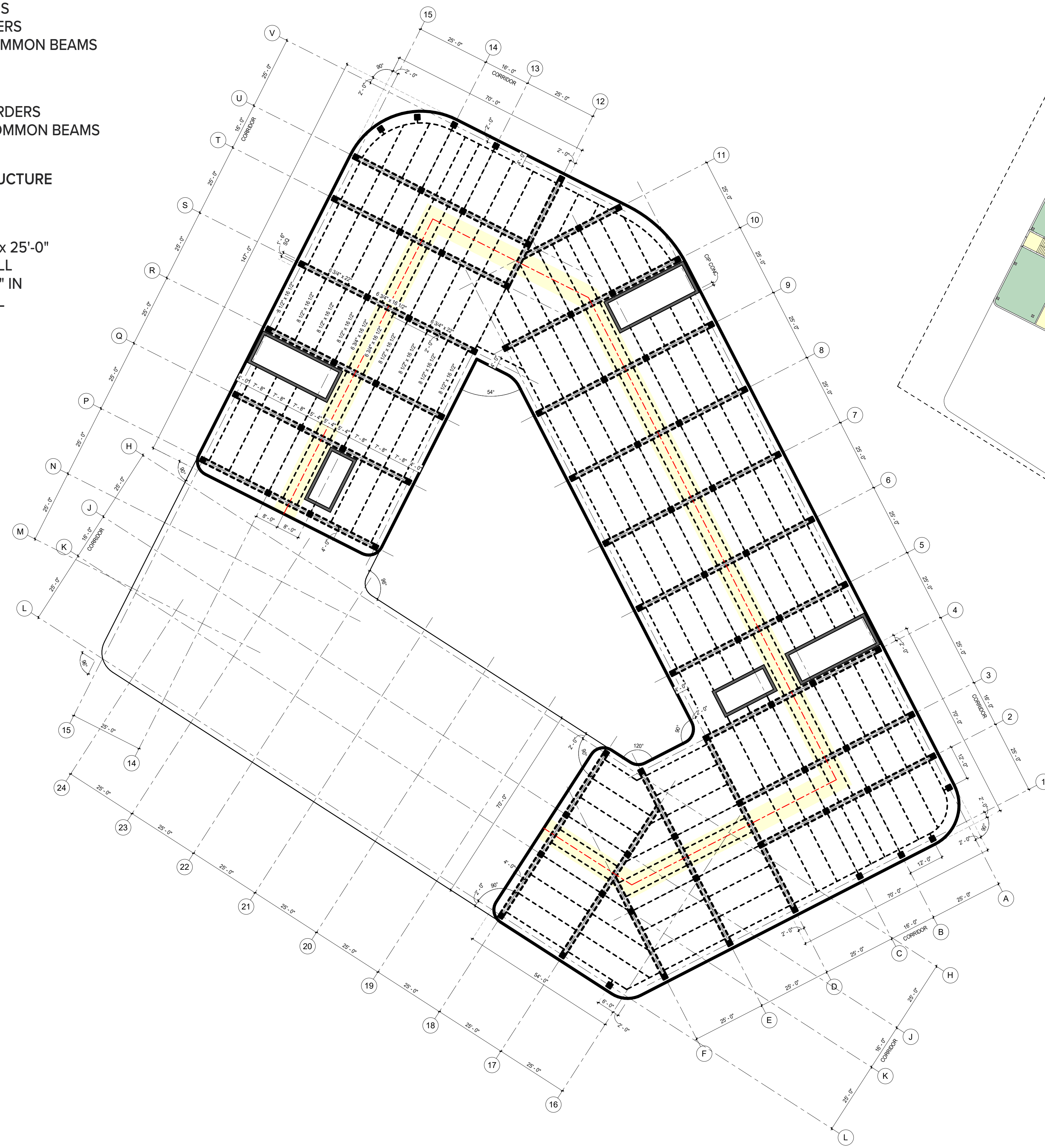
OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION												
	See Footnotes	Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	270	180	85	85	70	60
H-1, H-2, H-3, H-5	NS[c, d] / S	UL	160	65	55	65	55	120	90	65	65	50	40
H-4	NS[c, d]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	140	100	85	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	180	120	85	85	70	60
I-1 Condition 2, I-2	NS[d, e, f]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85									
I-4	NS[d, g]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	180	120	85	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	65	65	65	50	40
	S13D	60	60	60	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	270	180	85	85	70	60

UNIT STRUCTURE
- 18" x 18" GLULAM COLUMNS
- 6 3/4" x 22" GLULAM GIRDERS
- 8 1/2" x 16 1/2" GLULAM COMMON BEAMS
- 5-PLY CLT DECK

CORRIDOR STRUCTURE
- 6 3/4" x 16 1/2" GLULAM GIRDERS
- 6 3/4" x 16 1/2" GLULAM COMMON BEAMS
- 5-PLY CLT DECK

ELEVATOR & STAIR CORE STRUCTURE
- CIP CONCRETE

GRID
- 25'-0" x 16'-0" (CORRIDOR) x 25'-0"
- 2'-0" IN F.O. EXTERIOR WALL
- COMMON BEAMS ARE 4'-0" IN FROM F.O. EXTERIOR WALL



Legend

- 1 Bedroom
- 2 Bedroom
- 2 Bedroom Plus
- Back of House
- Circulation
- IL Lounge

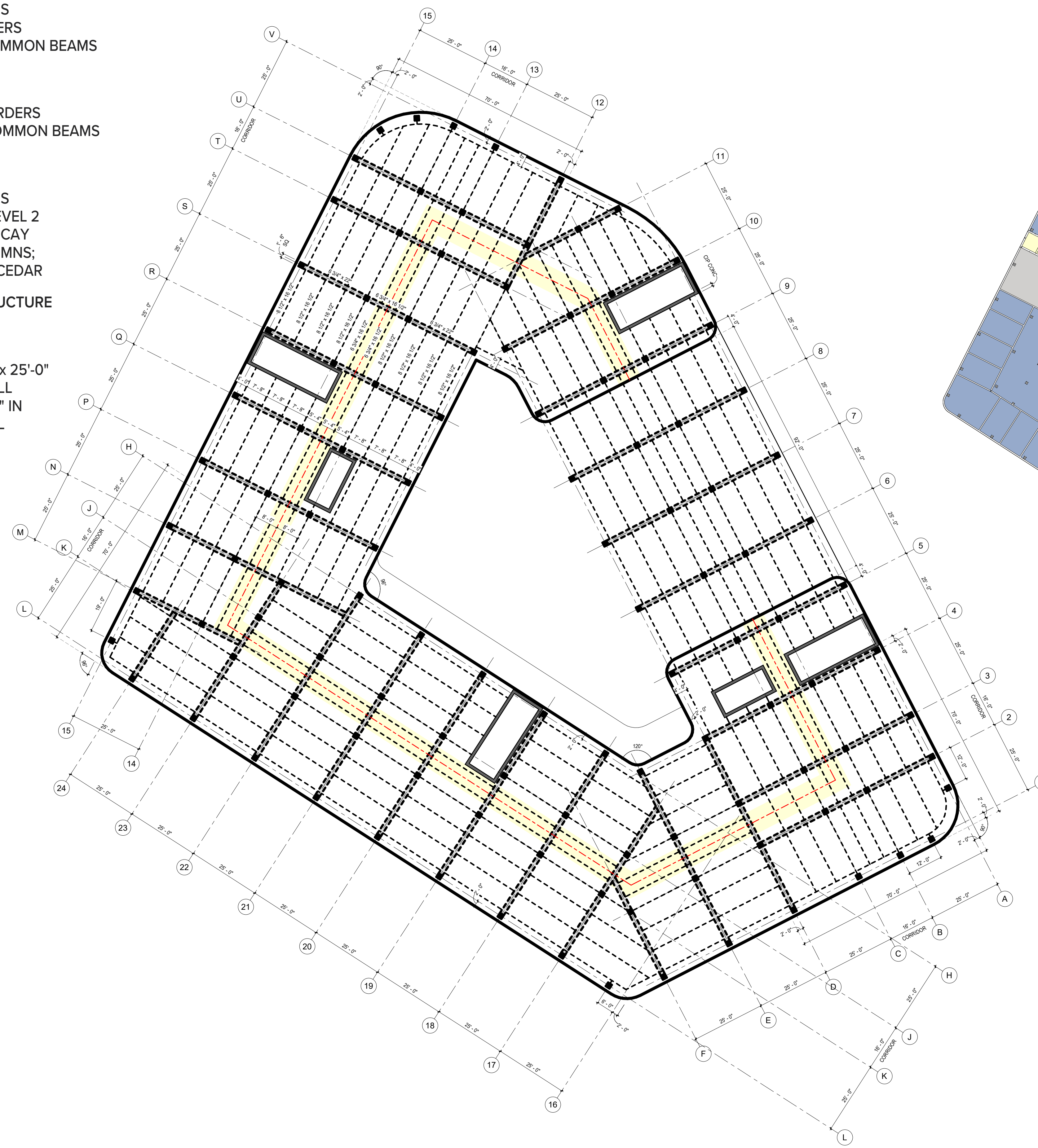
UNIT STRUCTURE
- 18" x 18" GLULAM COLUMNS
- 6 3/4" x 22" GLULAM GIRDERS
- 8 1/2" x 16 1/2" GLULAM COMMON BEAMS
- 5-PLY CLT DECK

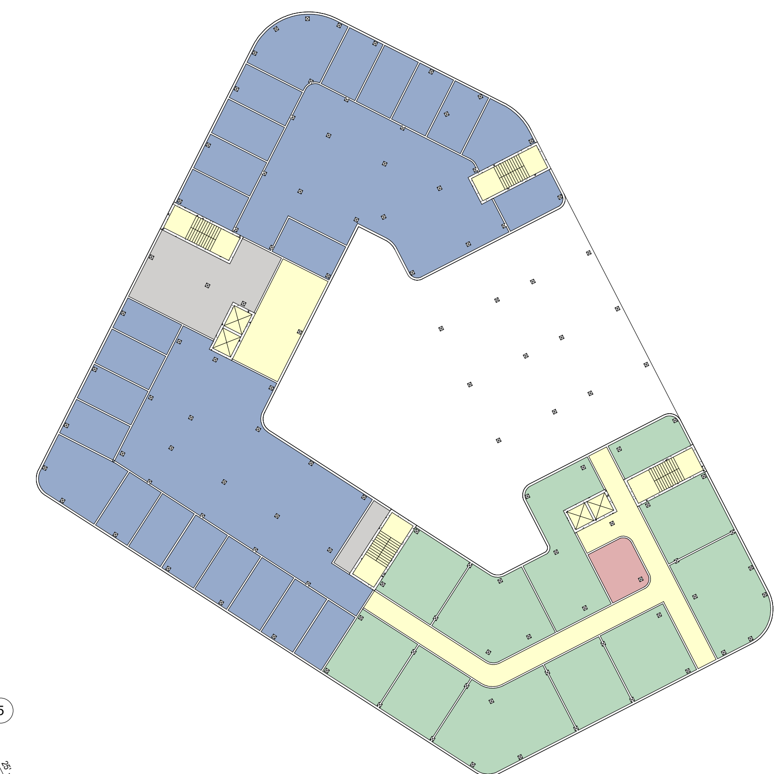
CORRIDOR STRUCTURE
- 6 3/4" x 16 1/2" GLULAM GIRDERS
- 6 3/4" x 16 1/2" GLULAM COMMON BEAMS
- 5-PLY CLT DECK

TERRACE STRUCTURE
- 18" x 18" GLULAM COLUMNS
- EXPOSED COLUMNS AT LEVEL 2 TERRACE - NATURALLY DECAY RESISTANT GLULAM COLUMNS; B.O.D. ALASKAN YELLOW CEDAR

ELEVATOR & STAIR CORE STRUCTURE
- CIP CONCRETE

GRID
- 25'-0" x 16'-0" (CORRIDOR) x 25'-0"
- 2'-0" IN F.O. EXTERIOR WALL
- COMMON BEAMS ARE 4'-0" IN FROM F.O. EXTERIOR WALL





Legend

- 1 Bedroom
- 2 Bedroom
- 2 Bedroom Plus
- Back of House
- Circulation
- IL Lounge
- Kitchen/Living/Dining
- Lounge
- MC Studio

ProjectQ BOSTON HYM onepoint PARTNERS DIMELLA SHAFFER

LEVEL 3 PLAN

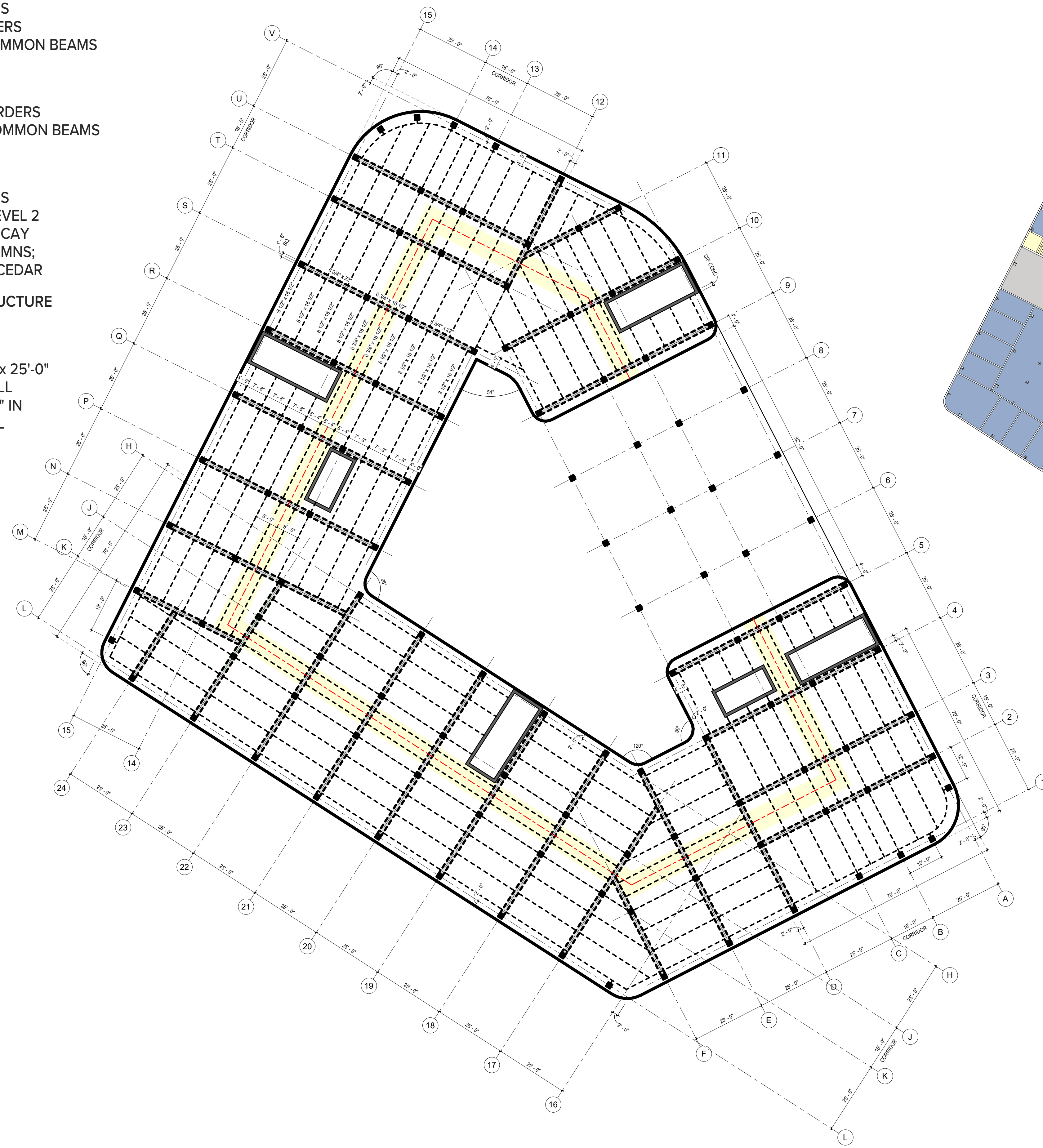
UNIT STRUCTURE
- 18" x 18" GLULAM COLUMNS
- 6 3/4" x 22" GLULAM GIRDERS
- 8 1/2" x 16 1/2" GLULAM COMMON BEAMS
- 5-PLY CLT DECK

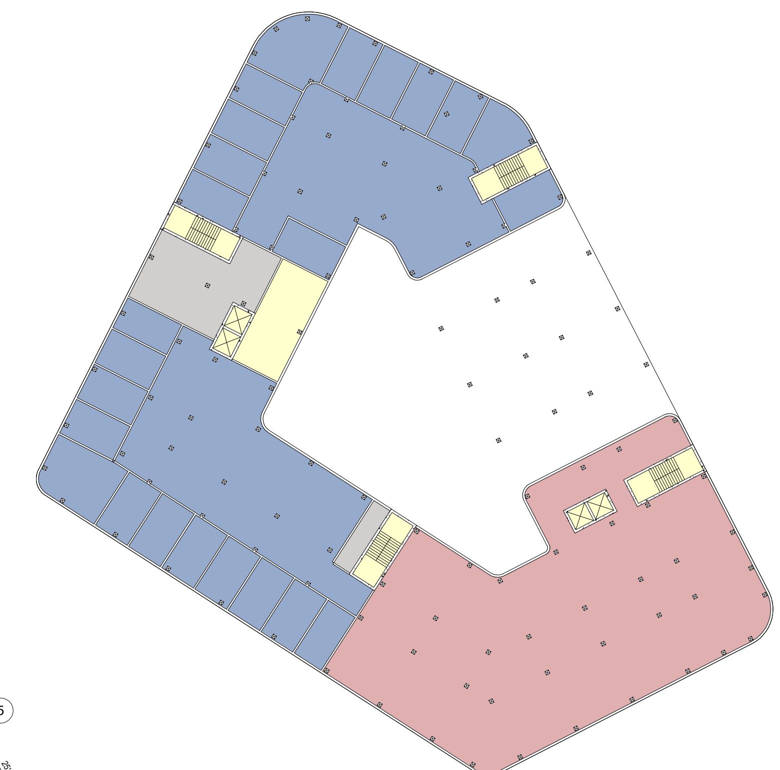
CORRIDOR STRUCTURE
- 6 3/4" x 16 1/2" GLULAM GIRDERS
- 6 3/4" x 16 1/2" GLULAM COMMON BEAMS
- 5-PLY CLT DECK

TERRACE STRUCTURE
- 18" x 18" GLULAM COLUMNS
- EXPOSED COLUMNS AT LEVEL 2 TERRACE - NATURALLY DECAY RESISTANT GLULAM COLUMNS; B.O.D. ALASKAN YELLOW CEDAR

ELEVATOR & STAIR CORE STRUCTURE
- CIP CONCRETE

GRID
- 25'-0" x 16'-0" (CORRIDOR) x 25'-0"
- 2'-0" IN F.O. EXTERIOR WALL
- COMMON BEAMS ARE 4'-0" IN FROM F.O. EXTERIOR WALL





Legend

- Admin. and Other Amenities
- Back of House
- Circulation
- EL Studio
- Kitchen/Living/Dining
- Lounge
- MC Studio

Project Q BOSTON HYM onepoint PARTNERS DIMELLA SHAFFER

LEVEL 2 PLAN

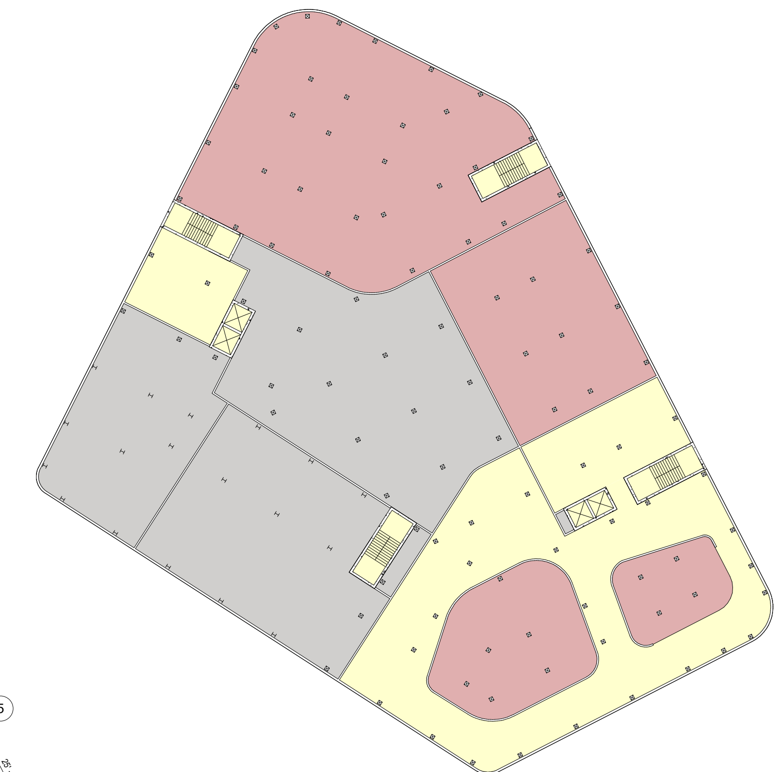
TYPICAL AMENITY STRUCTURE
- 18" x 18" GLULAM COLUMNS
- 6 3/4" x 22" GLULAM GIRDERS
- 8 1/2" x 16 1/2" GLULAM COMMON BEAMS
- 5-PLY CLT DECK

BELOW TERRACE STRUCTURE
- 18" x 18" GLULAM COLUMNS
- 8 1/2" x 35 3/4" GLULAM GIRDERS
- 8 1/2" x 24 3/4" GLULAM COMMON BEAMS
- 6 1/2" CONCRETE SLAB ON METAL DECK

PARKING & LOADING DOCK STRUCTURE
- W-FLANGE STL BEAMS & COLUMNS
- 5-PLY CLT DECK

ELEVATOR & STAIR CORE STRUCTURE
- CIP CONCRETE

GRID
- 25'-0" x 16'-0" (CORRIDOR) x 25'-0"
- 2'-0" IN F.O. EXTERIOR WALL
- COMMON BEAMS ARE 4'-0" IN FROM F.O. EXTERIOR WALL

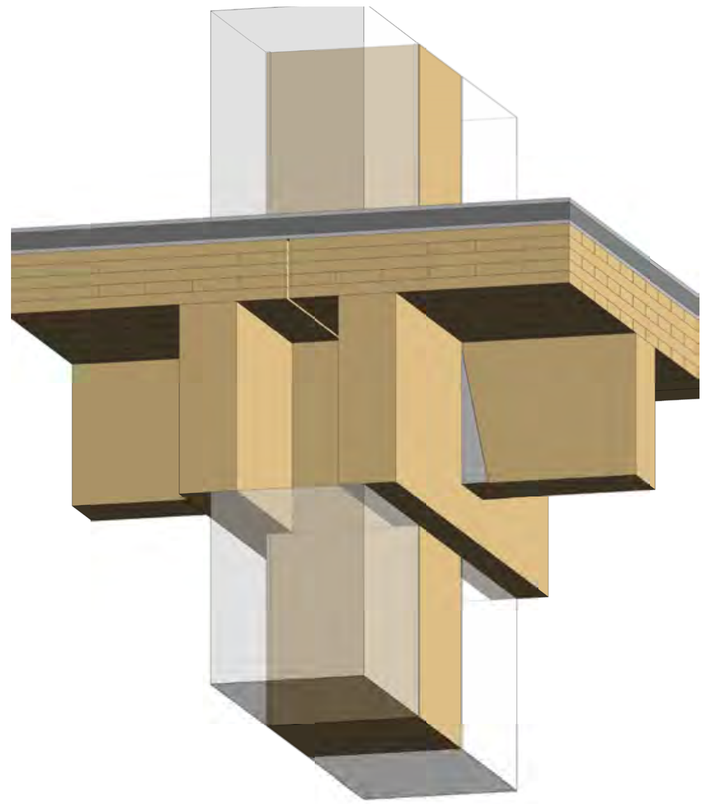


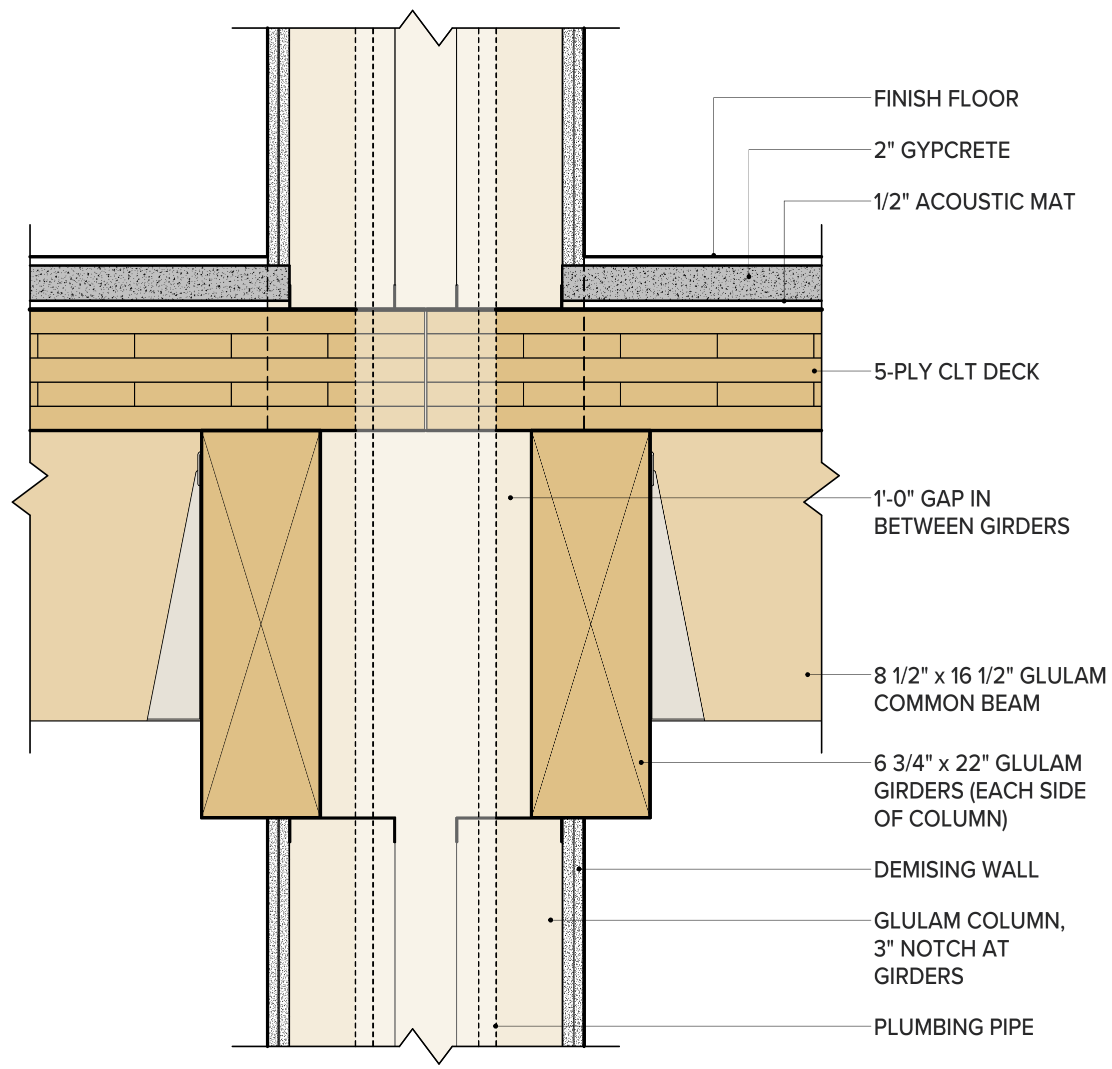
Legend

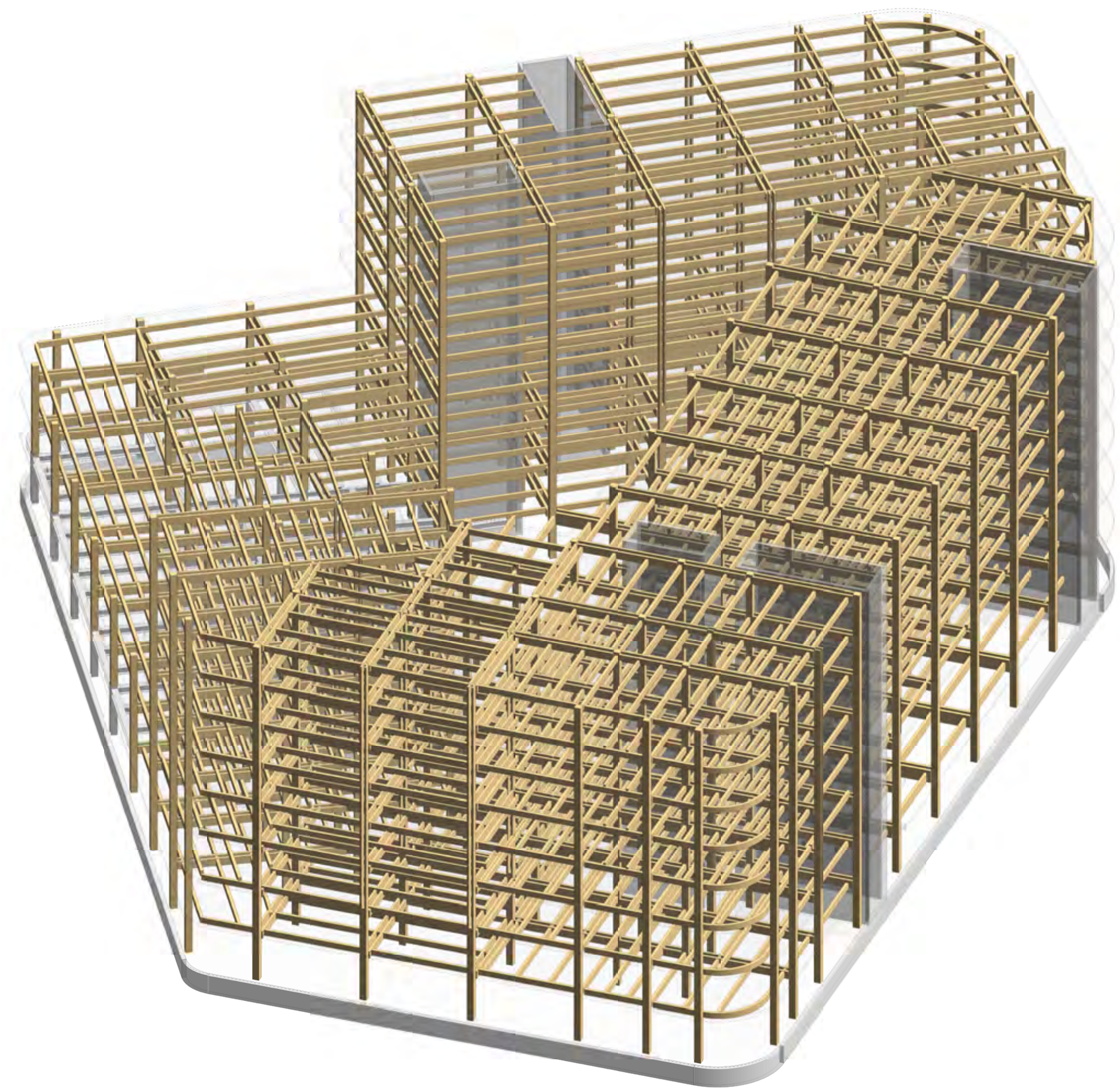
- Back of House
- Circulation
- EL Lobby
- Fitness
- Gathering
- IL Lobby
- Library
- Loading & Trash
- Parking
- Restaurant

ProjectQ BOSTON HYM onepoint DIMELLA SHAFFER

LEVEL 1 PLAN







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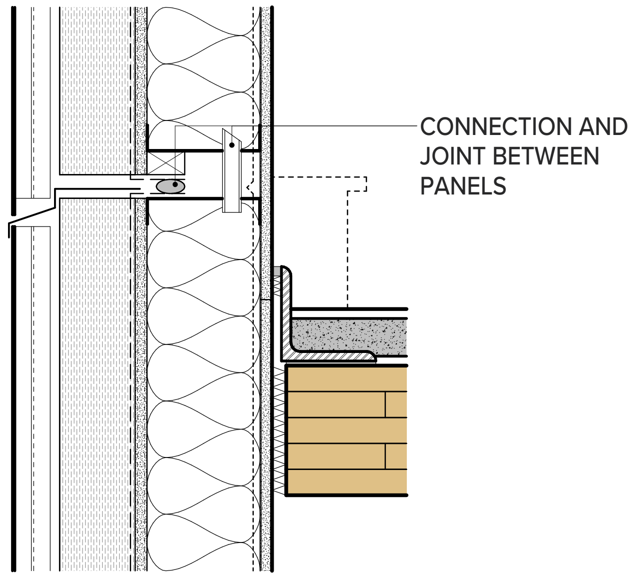
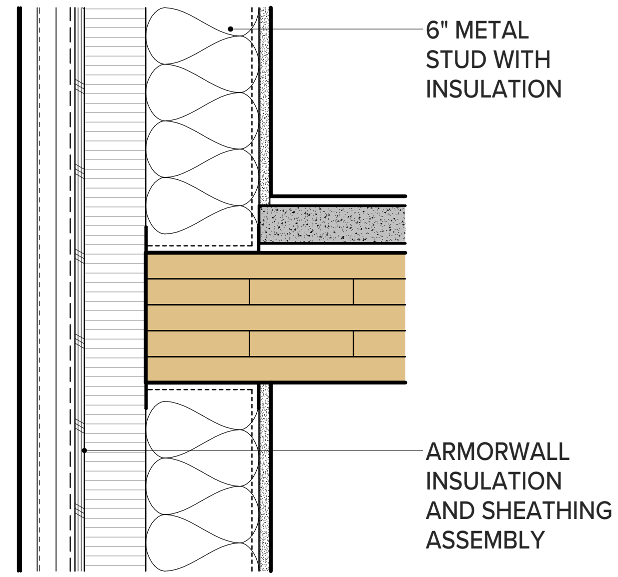
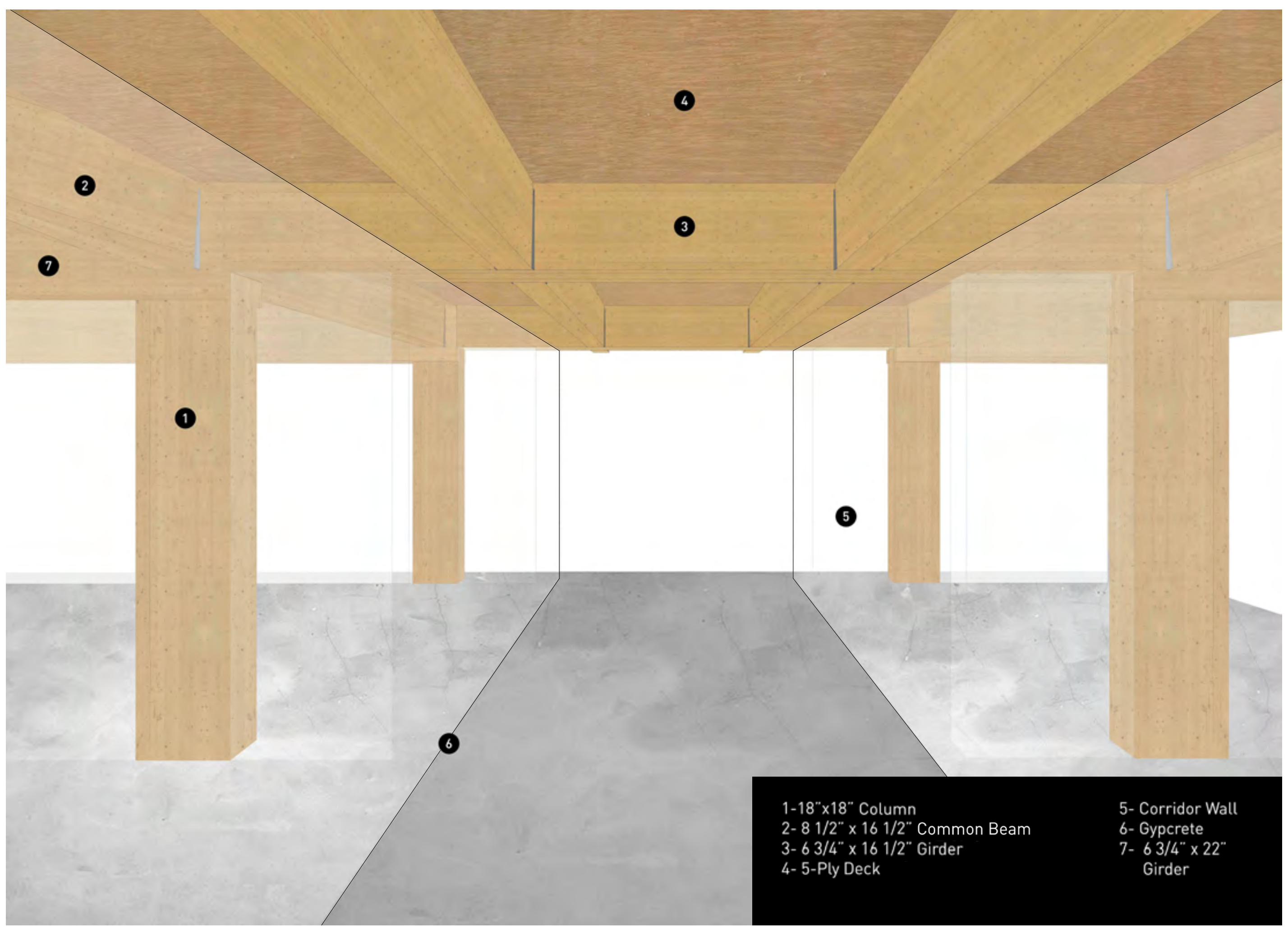
FRAMING DETAIL AND AXONS

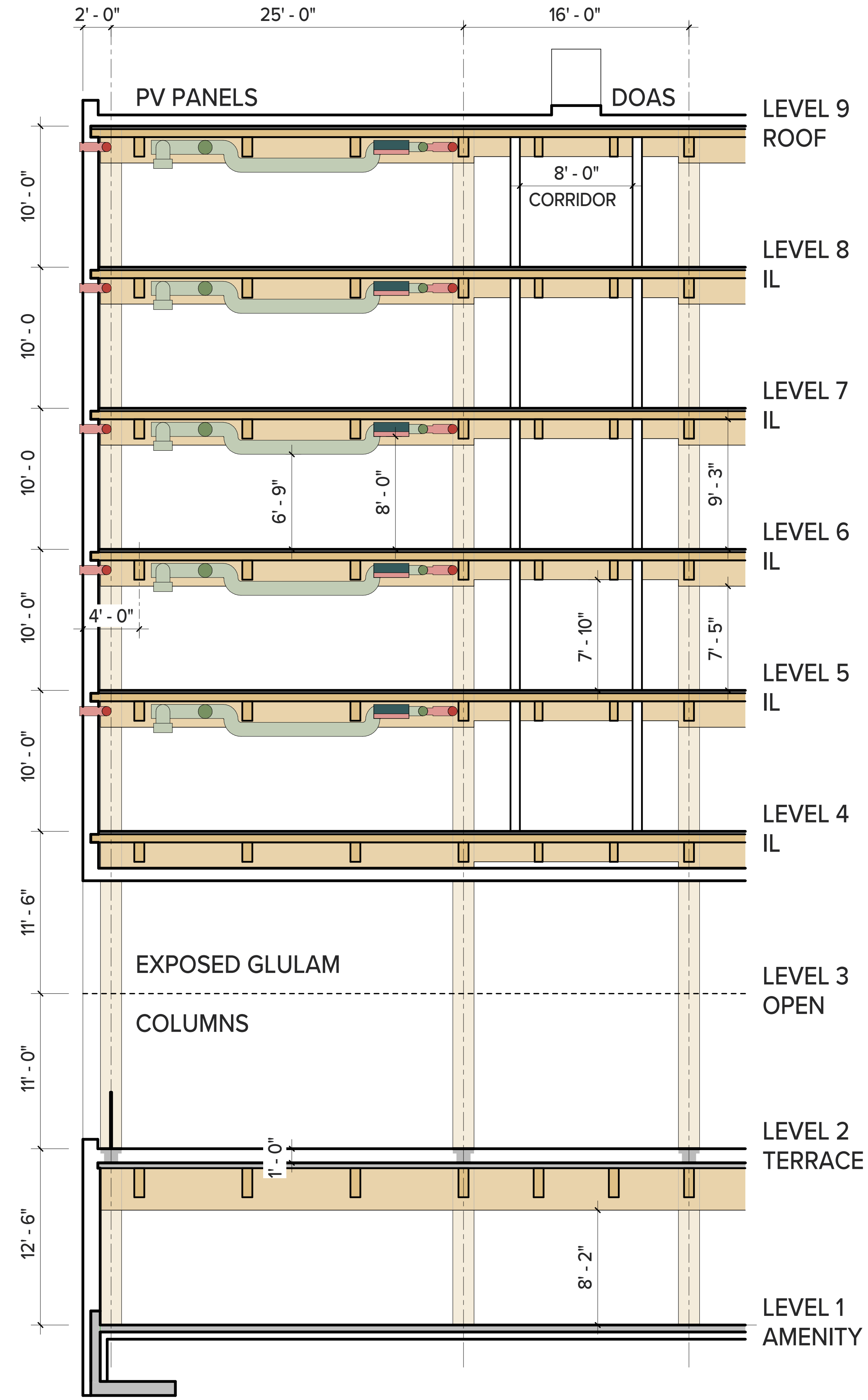


ALT. PANELIZED EXTERIOR WALL ASSEMBLY



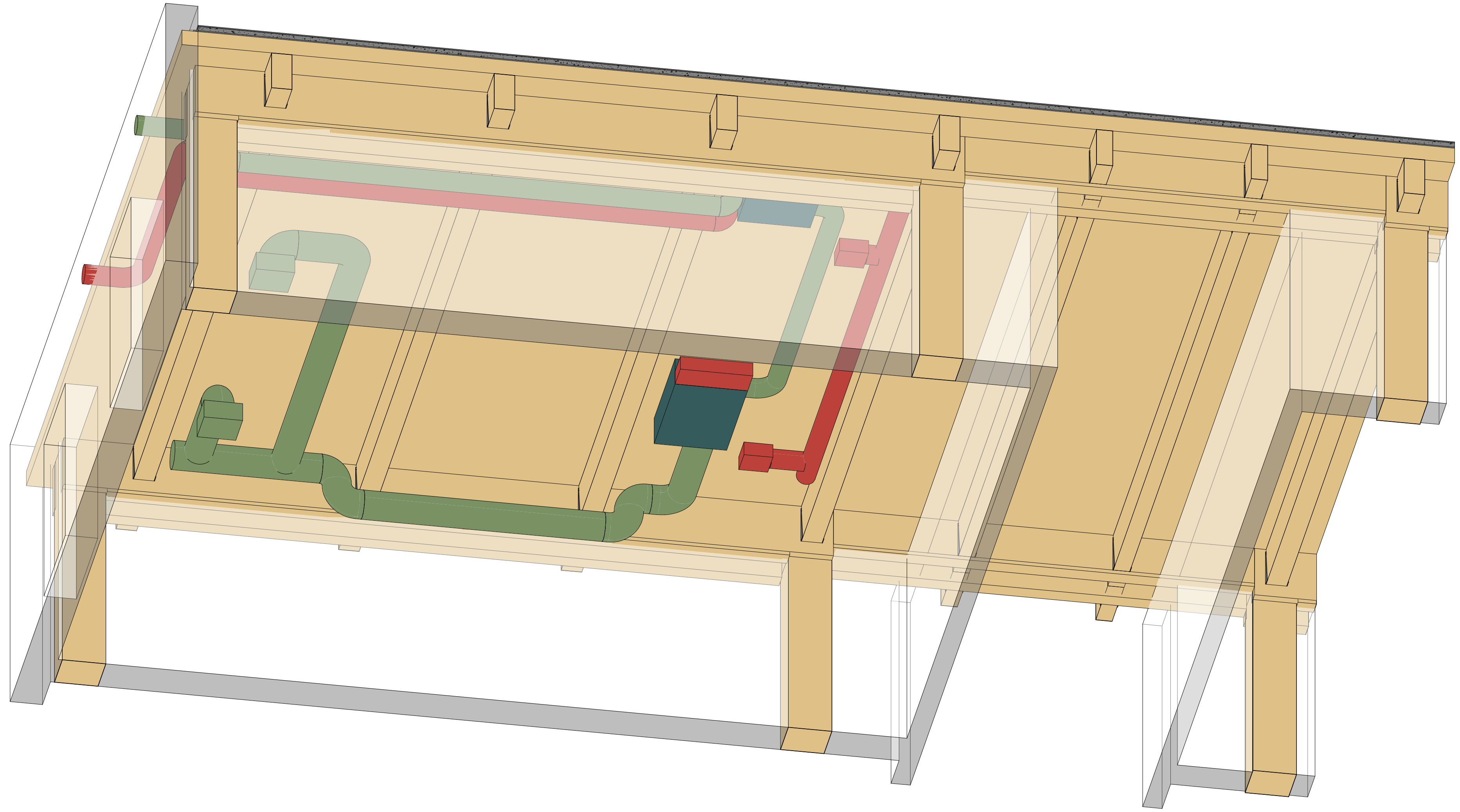
EXTERIOR WALL ASSEMBLY

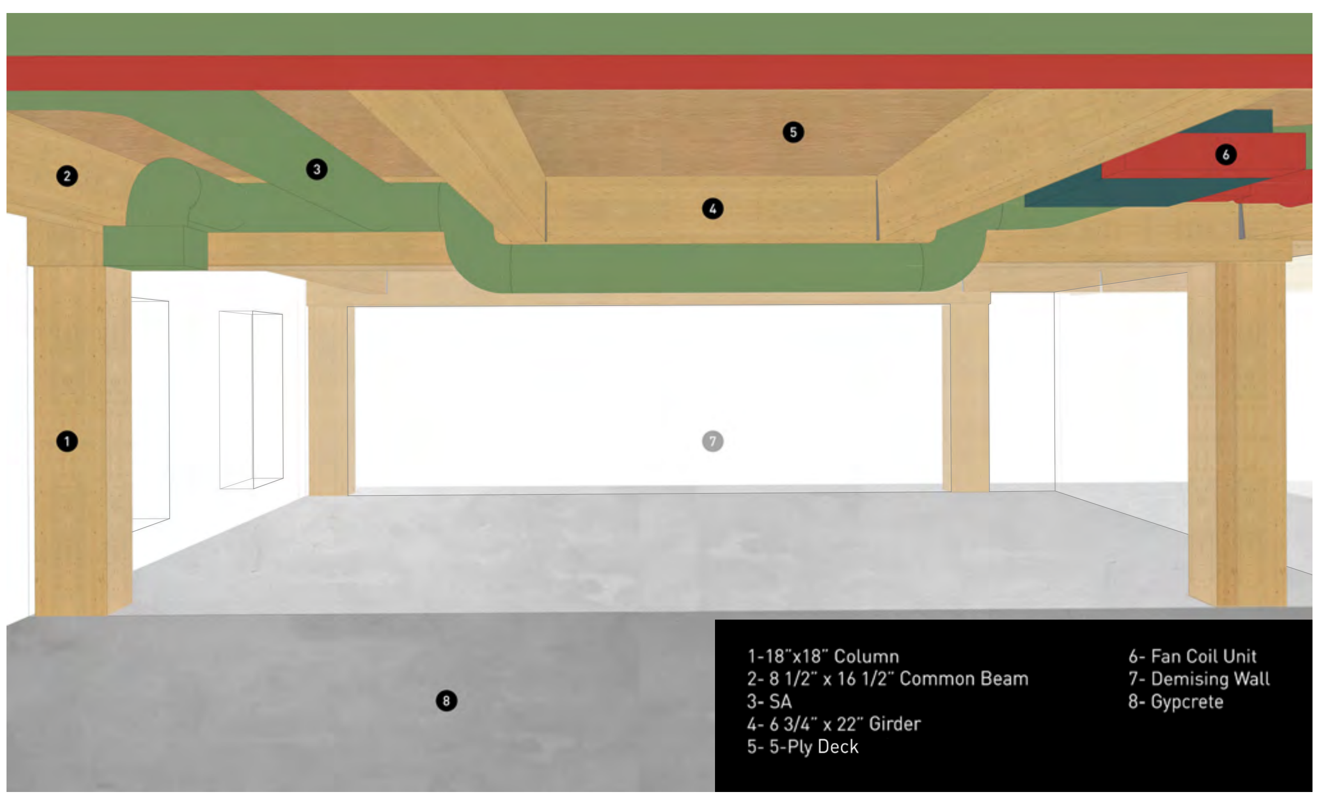




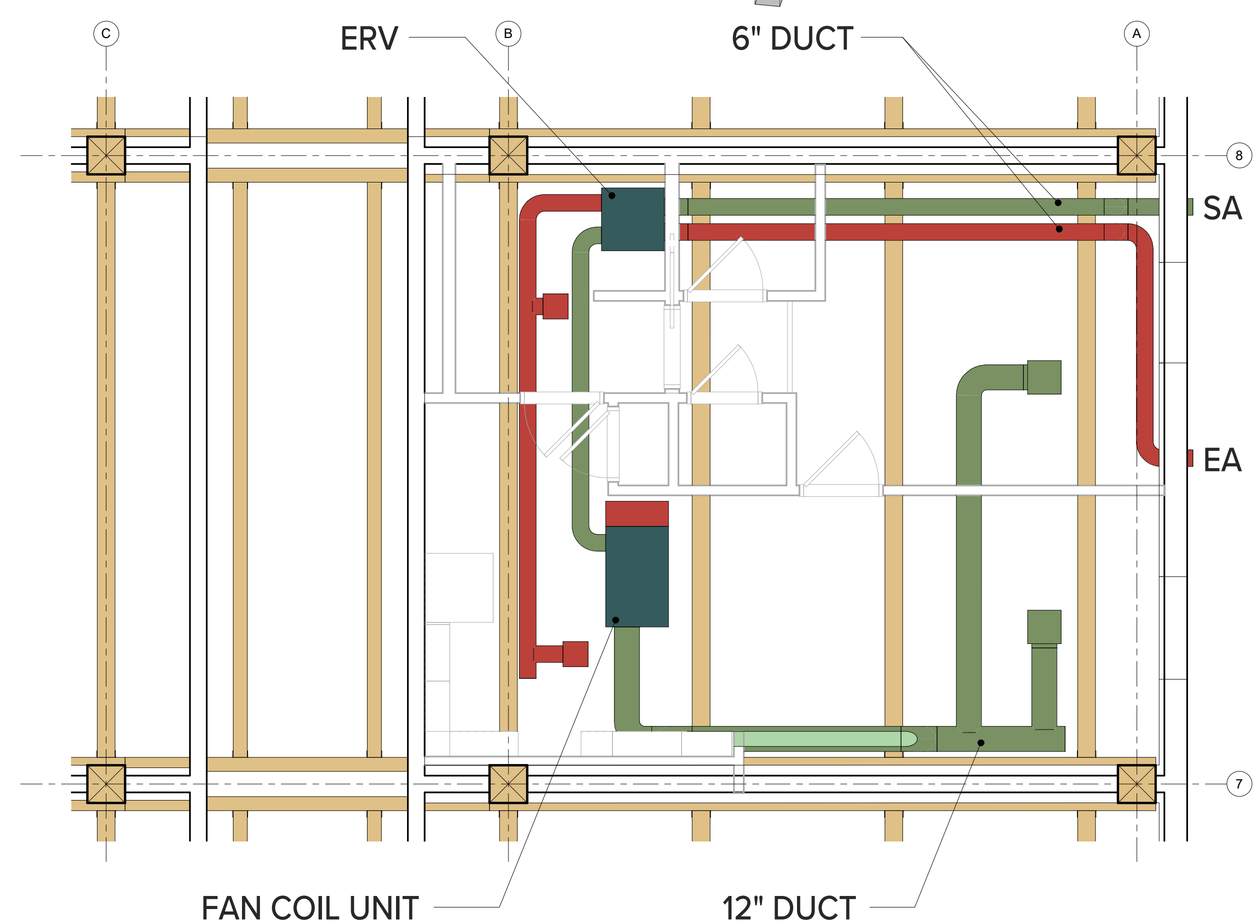
INDEPENDENT LIVING UNIT MECHANICAL LAYOUT

- INDIVIDUAL ERV W/ SIDEWALL PENETRATIONS
- GROUPED VRF AT ROOF
- FAN COIL UNIT WITHIN EACH UNIT





1- 18"x18" Column
2- 8 1/2" x 16 1/2" Common Beam
3- SA
4- 6 3/4" x 22" Girder
5- 5-Ply Deck
6- Fan Coil Unit
7- Demising Wall
8- Gypcrete



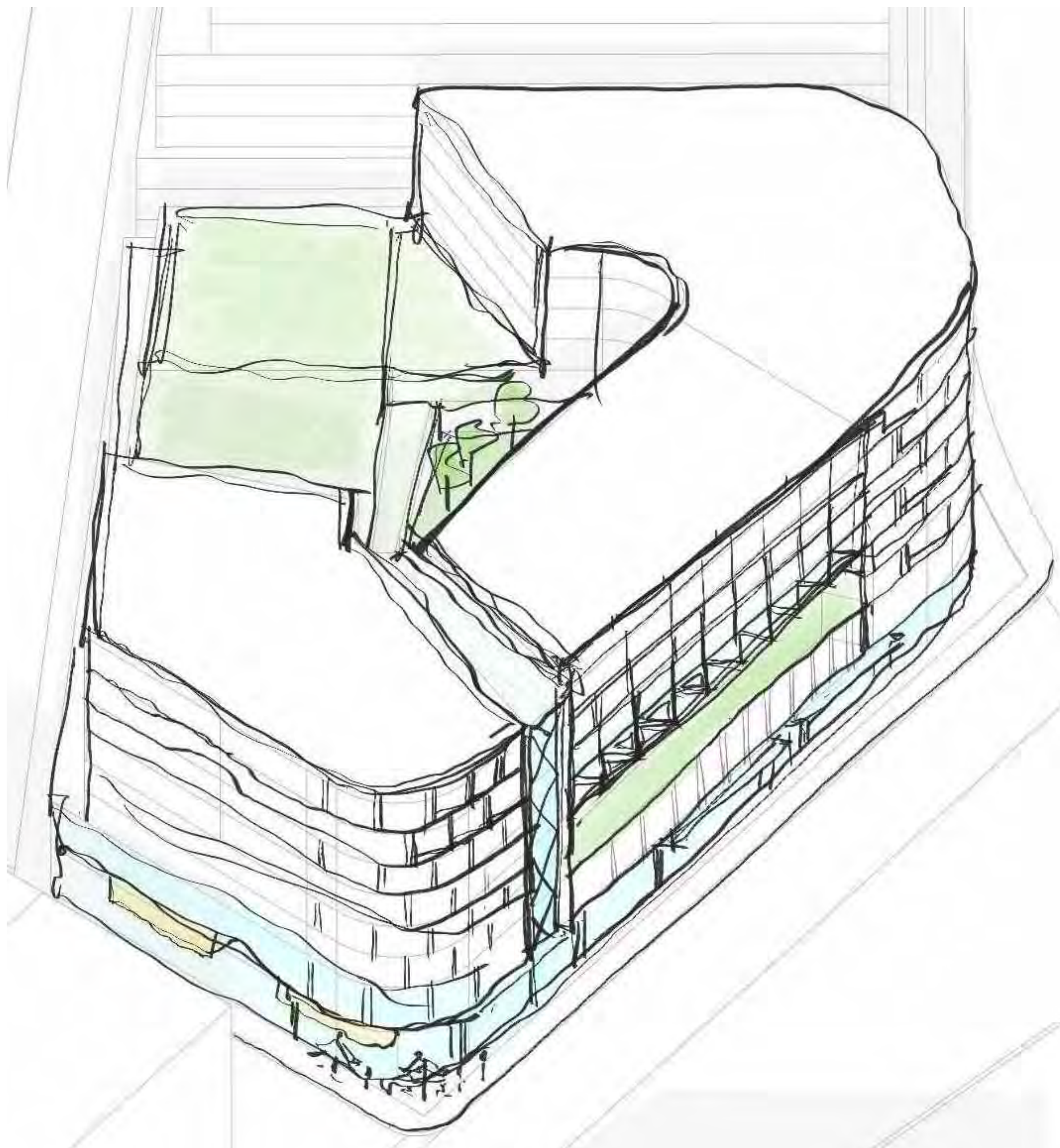
ProjectQ BOSTON HYM onepoint PARTNERS DIMELLA SHAFFER

Stick Built over Podium (L1-3):

306,700 Gross SF

$67.72 / SF

Total Cost: $20,769,724



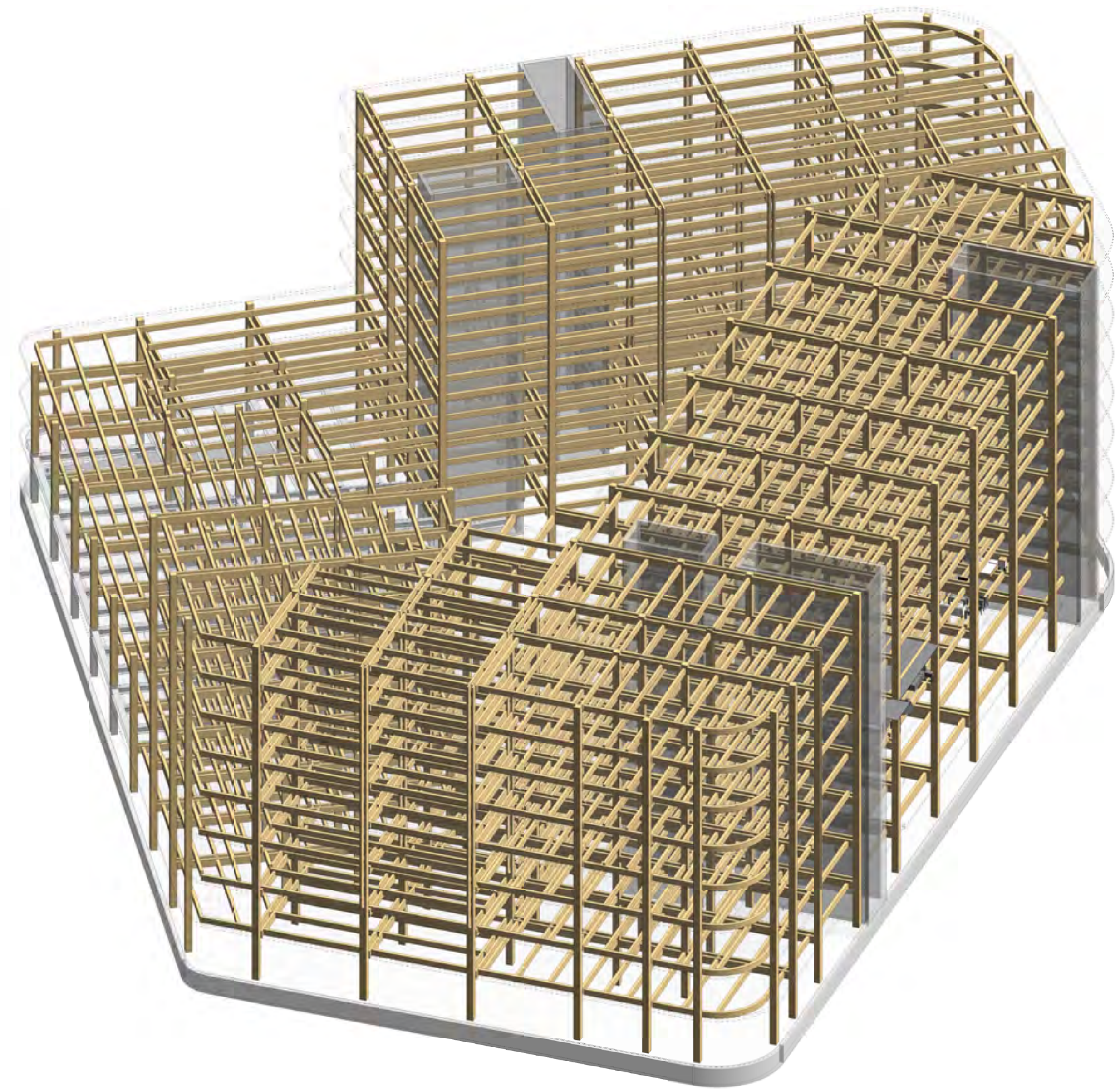
Mass Timber:

306,700 Gross SF

$79.18 / SF

Total Cost: $24,284,506
(16.9% increase)

Cost Difference: $3,514,782
Total Project Cost Impact: 2.48%



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dimellashaffer.com

ELIOT CONGREGATIONAL CHURCH

Roxbury, MA

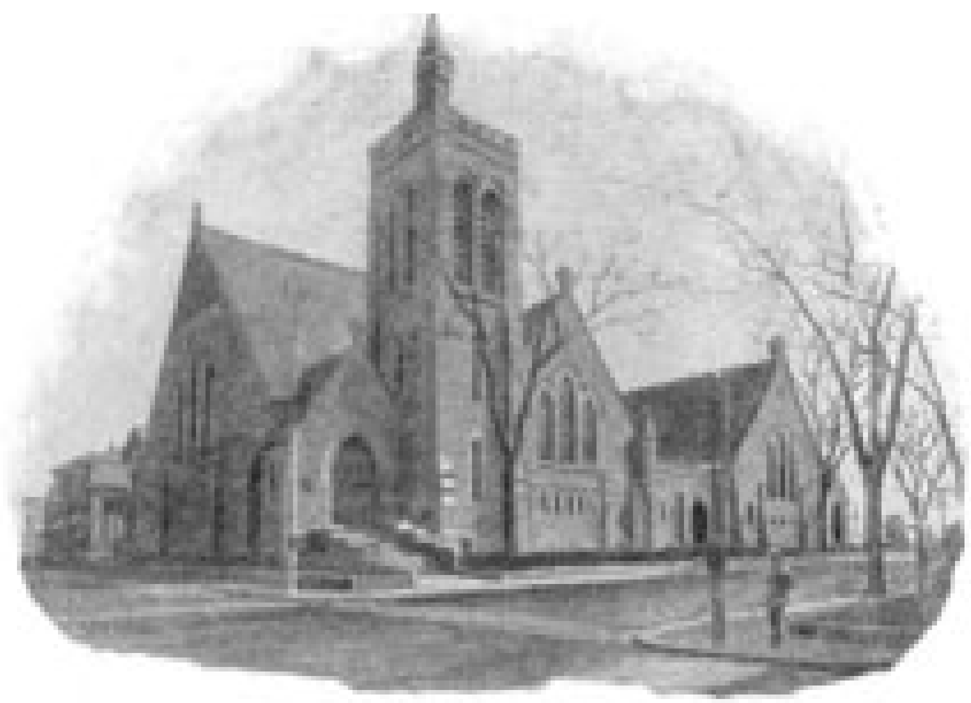
Affordable Housing Study

Mass Timber Accelerator

02.01.2023

LEERS
WEINZAPFEL
ASSOCIATES

CONTENTS



LEERS
WEINZAPFEL
ASSOCIATES

I. Executive Summary

Housing is the most basic need in our society. Affordable housing even more so for the most under-served residents in our cities and Boston is no exception. Though affordable housing must work within the funding parameters, it does not mean that it has to be a cookie-cutter solution using the least expensive materials, often not well built and below market standards. Rather we should aim to include the latest improvements in sustainability and human well-being for such projects.

Project Description, History, and Team
Affordable housing at Eliot Congregational Church in Roxbury, which is a neighborhood within the city of Boston, MA, will serve the underprivileged inner-city community in Roxbury. In addition to affordable housing units, the large, expansive existing church building can be leveraged to provide community support spaces often necessary but often overlooked with affordable housing; business incubator resource center, after-school activities, and community food pantry, to name a few which many non-profit and faith-based organizations provide. The project is intended to provide a total of twenty-four affordable housing units across an addition and renovation that would work with proposed project source funding common to affordable housing development and includes operational budget for long term viability. Ten percent of the units are planned to be affordable to households making very low income (about $30k per year) while the remaining ninety percent of the units are intended to be affordable to households making about $55 to $70 per year, well within Boston area's low-income thresholds.

The project will utilize the Church's biggest asset, which is the building itself and the land property on which it sits. The addition will leverage an underused portion of the property, a small site of around 4,500 square feet currently used as a parking lot, and provide a four-story addition with fifteen units, consistent with neighboring triple decker and multi-family residential buildings, providing a good transition from the much larger scale church building on the corner of the property. The renovation portion is intended to be in the current three-story administration wing of the Church where the existing structure and window locations are suitable for conversion to nine housing units. Since the Church is listed on the National Historic Landmark Registry, it quickly proved unfeasible to add units in the main church building as that would have required significant alterations to its exterior. This study focuses particularly on the addition aspect of the project.

Reverend Dr. Evan C. Hines is the Senior Pastor of the Eliot Congregational Church which comprises of a predominantly African American congregation serving the needs of its local community. Rev. Hines has dedicated his life as a minister to helping the people of the Roxbury community, where he grew up, to advocate for their social and economic future. He met Tom Chung, Principal of Leers Weinzapfel Associates (LWA), through Tom's graduate studio in Mass Timber design at Wentworth Institute of Technology where Tom led his students in exploring the potential of mass timber architecture for adaptive reuse and addition to the Eliot Church building and property.

Leers Weinzapfel Associates is a design firm of 30+ architects and designers based in Boston, MA. LWA aims to bring 'responsible design excellence' by focusing on the human experience, sustainability, and craft of building to ensure a solution that is right and appropriate for each project and client's schedule and budget. The LWA team brings extensive experience and leadership in mass timber. Tom understands intimately the interconnected relationships among every entity in the life cycle of mass timber and has an extensive network of connections with the wood industry, which is necessary for exploring the potential of mass timber for affordable housing. This understanding comes from LWA's two large-scale built projects: the Adohi Hall at the University of Arkansas, a student housing project, completed in 2019, which was at the time the largest cross laminated timber building in the US, and the Olver Design Building at UMass Amherst, completed in 2017, which was among the first large scale academic mass timber buildings in the US. Both projects embody the efficiency of mass timber towards a cost-effective layout and construction, that will dictate the approach necessary for this project's housing units. The key is in translating the potential and justifying the cost of mass timber, typically a large-scale building product, into a small affordable housing project.

Project Goals
So why mass timber for affordable housing?

We know that wood is fundamentally sustainable and renewable. As a tree grows, it takes carbon from the atmosphere and stores it, much of it in its trunks and branches which are the source of wood products. In addition, the overall embodied energy or carbon emissions of building with wood from extraction, processing, transportation through construction is much lower than other building materials such as steel or concrete. However, Cross Laminated Timber (CLT), among the most popular mass timber product, is made with highly automated, expensive, large-scale machinery such as CLT presses which are designed to produce large scale mass timber products for buildings in growing urban centers, as well as Computer Numerical Control (CNC) machines which

Google photos showing Roxbury's vibrant community and neighborhood characteristics cut and shape the mass timber products for a plethora of design connections: from simple to very complex joints. But there is a cost to such technology, with investments in CLT factories being in the tens of millions of dollars which ultimately has to be passed down to the customer. While that isn't as a big of a factor in large scale projects that compare with costs for steel and concrete buildings, small affordable housing mass timber projects such as ours must be comparable to light frame wood construction, which is typical for such building types and is among the least expensive structural system.

The goal of the project is to bring all the benefits of mass timber – environmental, experiential, and social to enhance the quality of life for our most underserved residents. This effort will require the experience and expertise of a seasoned mass timber design team to quickly evaluate mass timber options along with light frame wood options to provide the best balance of benefits and cost. It requires knowledge and understanding of the various mass timber suppliers and their respective processes, given that it is very much still an emerging technology with wood species varieties, proprietary lamination dimensions and layups, preferred billet sizes and an array of connections possibilities. The project is intended to incorporate core sustainability principles such as re-use of existing building and new construction with renewable material for structure: wood. Both mass timber and light frame will be used for low embodied carbon and carbon sequestration. Exposure of mass timber elements will be key in limiting additional resources for finishes while providing a space of well-being by taking advantage of wood's inherent biophilic qualities.

Project Approach

The project type and its small size was the primary factor that drove the design team to look very closely at a specific mass timber product, Nail Laminated Timber (NLT), to reduce the cost and carbon footprint even further from already sustainable mass timber products such as Crossed Laminated Timber (CLT). In an effort to afford mass timber for affordable housing, the design team went back to the basic building block, the ubiquitous 2x lumber which is the basis of light-frame wood construction and many mass timber products.

NLT is the closest in relationship to lumber as it is simply either 2x4's or 2x6's, most of which have no further postproduction other than nailing them together into wall, floor, and roof panels without use of expensive machinery. Furthermore, it could be produced nearly anywhere by any contractor with lumber, hand tools, and a worktable. Given the existing site conditions for this project, lumber could simply be brought to site and an adjacent staging area on the property could be used to set up a small tent (for inclement weather if needed) and a worktable to fabricate the NLT panels on site.

Given many similar sized empty lots and old buildings in Roxbury, the city of Boston, and cities throughout the US, the project is intended also to be a prototype that shows a blueprint for neighborhood organizations like Eliot Church, its residents and like-minded developers and their city officials to collaborate and address the issues of affordable housing that exceeds current standards, without necessarily waiting for that "big project" that require large lots and large sums of investment.

Tom S. Chung FAIA, LEED BD+C
Principal, Leers Weinzapfel Associates


Google photo of Eliot Congregational Church in Roxbury, MA

II. BENEFITS / OUTCOMES

1. BUILDING PRACTICES

Design & Construction Strategies
To make best use of NLT, while taking into consideration carbon storage, structural efficiency, design flexibility, and potential to expose the wood for a biophilic effect, NLT was used for all of the floors and roof as well as the inner shear and core walls in a structural grid of 14 to 17 feet wide that would allow for 2x4 and 2x6 lumber, which is much less expensive than 2x8s or 2x10s. These NLT floors and walls would need sheathing on one side to provide continuous structural diaphragm for the floors and lateral shear capacity for the walls. By working within a small span structural grid and containing the sheer structure to the core of the building, this allows for maximum perimeter openings to bring in as much sunlight as needed. This design flexibility which also includes various roof profiles and façade arrangements is advantageous to many different site conditions as we envisioned the project to serve as a prototype for similar small-scale developments on empty lots of similar sizes all around in neighborhoods of the city of Boston as well as other similar urban centers.

Building Code Strategies
The strategy was to maximize the buildable area on this very small lot while keeping in mind the scale of the addition in relation to its context. Preliminary analysis of zoning and context studies resulted in what was essentially an unbuildable lot. With code expert consultation and a creative look at the arrangement of the empty parcels, a strategy was developed that would allow for a credible variance approach, given the community benefits, for a maximum build of fifteen units in a four-story structure of 12,600 gross square feet.

The design team followed the unit size guidelines established by the City of Boston to be eligible for city funding and configure such units within the NLT structural framework that was established. On the ground floor, one of the corner units was eliminated to allow for an open entry area and a common space. Each typical floor above consists of various unit types: two 1-bedrooms, a 2-bedroom, and a studio, to accommodate a wide array of residents, families and single. In addition, the layout consisted of an extremely small and efficient circulation space and shear core with a single stair and elevator. Code allows for a single egress stair in this application and an elevator is not required. But the team wanted to provide equitable access to all, so an elevator was included. The compact hallway maximizes the housing unit areas and keeps the building grossing factor as small as possible, and by having it centrally located in the building, it allows for the perimeter to be freed up for maximizing window area for the bedrooms and living rooms.

2. ANALYSIS

Cost Analysis
Cost parameters ranging from $300 to $325 (number estimated at the project inception in 2020, prior to current pandemic related cost volatility) was the cost per square foot established consistent with city of Boston guidelines for affordable housing. This assumption will be updated when the city of Boston establishes new guidelines.

As mentioned previously, NLT is not a complicated product to make and requires no further postproduction, it doesn't involve expensive machinery, and could be produced almost anywhere. Based on that, the team considered the opportunity of taking advantage of the Church's property which offers a 'back lot' behind the administrative wing where a contractor can set up a workstation for the on-site manufacturing of the NLT panels. Only small construction equipment would be needed to assemble the building, no production waste would be generated, and no storage space would be necessary as the panels would be manufactured 'on-demand.' Additional transportation costs of the material assembled offsite would also be eliminated.

Environmental Considerations / Context
The environmental benefits of all the structural mass timber components in conjunction with typical light frame wood construction and other architectural building assemblies were analyzed by calculating the quantity of carbon storage. Our approach resulted in more than twice the carbon storage for a project consisting of NLT and light-frame construction as compared to the typical all light-frame building approach.

In looking at the surrounding neighborhood, analysis showed an array of vernacular small scale residential typologies of light frame wood structures such as the single family, duplex, and triple-deckers on similar small lot sizes. Given the site conditions and its immediate surroundings, the roof profile was carefully designed. It comprised of a gable and pitch, with the profile of the pitch sloping upwards with its peak towards the taller building, the Church to the right, and a gable which slopes down and has a lower roof profile adjacent to the smaller scale triple-decker neighbor to the left. The window configurations were also carefully selected from an array of options that reinforced the prototypical aspects of this building type.

3. OPPORTUNITIES REALIZED & LESSONS LEARNED

Savings, Monetarily and/or in Structure
Using exposed NLT for the roof and floors has multiple advantages. First the building's overall height would be reduced as the typical plenum spaces required in light-frame construction along with its greater comparable beam depth would be eliminated, and with careful arrangement of light fixtures and sprinklers on the side walls, the ceiling plane would be kept plain and 'clean,' which would also allow for higher-than-typical ceiling heights for the building's residents. Similarly, the NLT walls would be 'clean' and express the warmth of the wood at select areas in each unit which are determined by the locations of the shear walls. There would also be significant cost savings on finishes such as ceiling tiles and gypsum wall boards that would typically be necessary for an all light-frame construction. In addition, reduced overall height of the building would result in savings in material, especially glazing and other exterior enclosure.

Changes in Sustainability Goals or Outlook
We return to the crisis of carbon emissions in our environment today. We've made good strides (especially in Boston and Massachusetts) in recent years in addressing operational carbon with stricter

code requirements and an array of renewable energy such as hydroelectric, geothermal, solar, and wind power for much of our buildings' heating and cooling needs. Now, we must also pay attention to embodied carbon, that is the carbon emissions related to the construction of a building before the building is occupied and in use. We acknowledge that wood is the only renewable building material in the market. Furthermore, statistics show that minority communities are the ones most adversely affected by the impacts of climate change. It's not only sustainable to build with wood, but also equitable and just to use mass timber for housing for the least privileged among us so that they too can thrive and enjoy better housing and not continue to shoulder the burdens of climate change.

Unexpected Opportunities
By implementing a combination approach of using mass timber and light-frame construction, we are capitalizing on the advantages of both construction types while limiting the prohibitions that come with one or the other. For example, mass timber has many benefits such as it allows for the exposure of wood, which has biophilic qualities that promote user well-being in such spaces, promotes faster construction, reduces costs on finishes, and is a sustainable building material. However, mass timber is not the most conducive in having wall cavities to run electric conduit and plumbing, which is where light-frame component of the building comes as an advantage. Light-frame is also more cost-effective than mass timber, so limiting the mass timber only to the shear walls that can be exposed at least on one side as well as the roof/floor elements and using light-frame for all the other partitions maximizes the best qualities of each.

The project is then finished with a charred wood cladding to reduce maintenance and increase the durability of a wood cladding system without having to re-paint every 5-7 years, but one that could take on a different cladding material on other sites as appropriate. In the case of this project in partnership with Eliot Church, the charred wood cladding and its darker, black appearance can be a metaphor for celebrating the history and resilience of the African American congregation and community.

4. NEXT STEPS

We are confident that NLT is the right solution for this project type and scale. We prioritized the embodied energy aspect of this project; material production, in this case wood, from timber harvesting to debarking to cutting the logs into lumber dimensions, often is the base industrial process for the various lumber-based mass timber products like Cross Laminated Timber (CLT), Glue-laminated Timber (GLT), Dowel-laminated Timber (DLT) and Nail-Laminated Timber (NLT). Additional production processes such as wood planning, finger jointing, gluing, and associated post-production machining, all of which have additional costs as well as carbon footprint implications can be eliminated for NLT. And for such a small affordable housing project that must compete in cost to a typical all light-frame wood construction, the challenge will continue in realizing the mass timber element of this project all the way through construction to make sure it is not compromised for another alternative.

We are in the process of actively pursuing additional grants for remaining design phases as well as funding for our development consultant partner to do their work in continuing the project pro-forma and identifying a like-minded developer partner along with community and city engagement as the project develops.

III. PROGRAM IMPACT

Program Evaluation & Impact
We are honored to be selected for the inaugural round of funding by the BPDA Mass Timber Accelerator Grant Program. This enabled us to do the research and develop a credible conceptual design for the project. In addition, it was very helpful being part of a group of awardees to discuss and share information and strategies regarding various types of mass timber products and building types. This program was exactly what was needed to help jump-start Boston's architecture community in taking a serious look into Mass Timber across many project types and will continue to be in need in the coming years as Mass Timber as a new construction type, takes the necessary time to mature in the building construction industry. The seed has been planted as we aim together for a more sustainable – environmental and communal – future together.

Tom S. Chung FAIA, LEED BD+C
Principal, Leers Weinzapfel Associates


Blvd
Dudley St
0.5 mi radius
10 minute walk
Hampden St
St James St
Columbus Ave
SITE
Cedar St
Moreland St
Washington St
Walnut Ave
Warren St
M.L.K. Jr Blvd
Blue Hill Ave
Humboldt Ave
Google Earth
N

SITE OVERVIEW aerial showing the Church in relation to the available site

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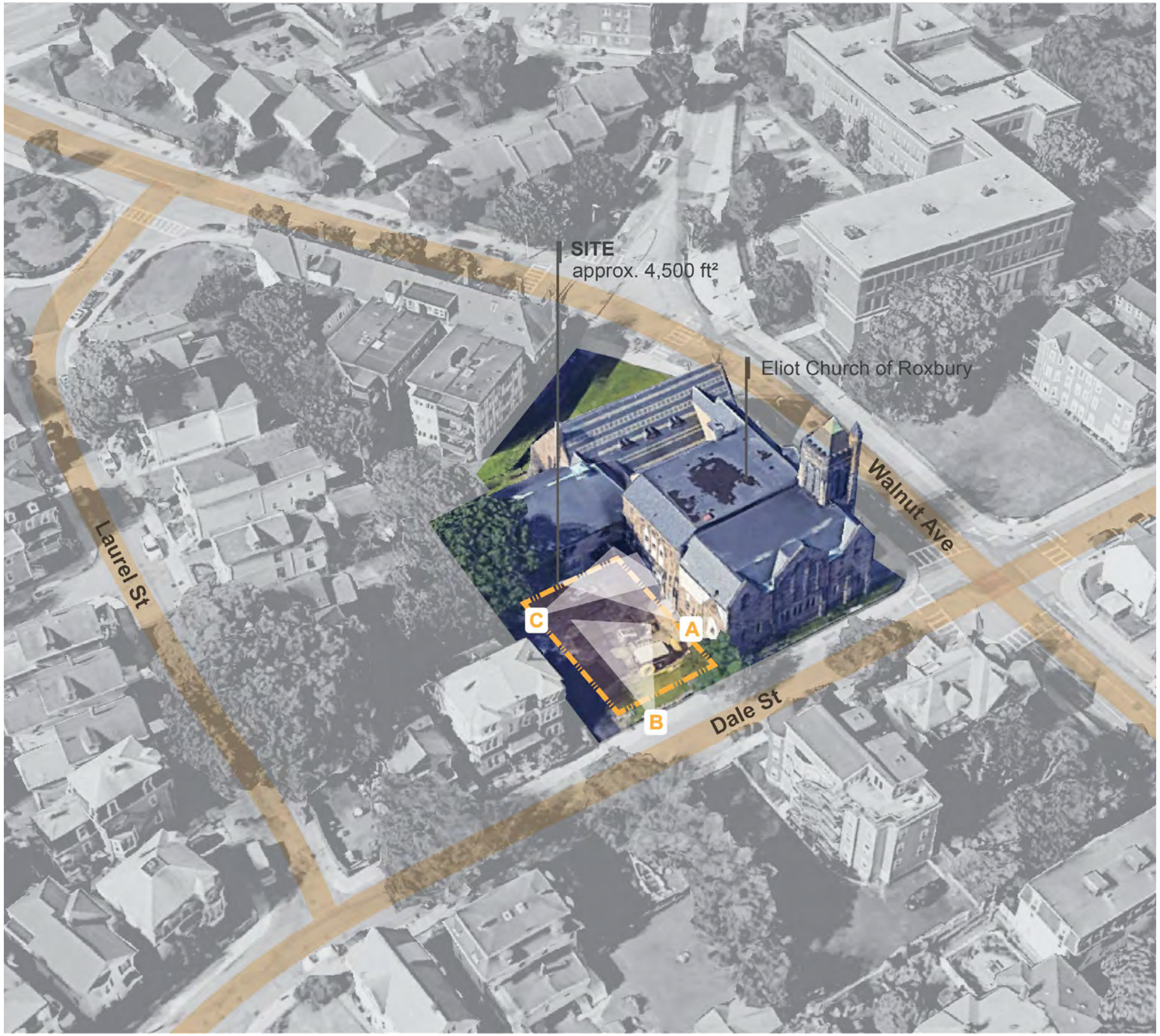
SITE OVERVIEW showing views of the site and elevations of the Church's administrative wing



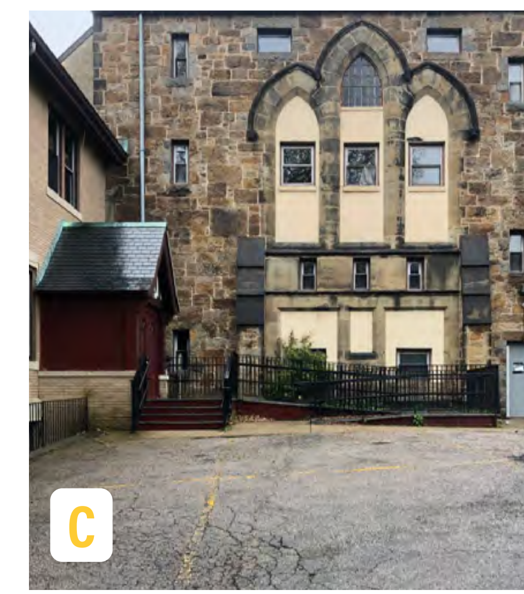


Photo of the site taken by the project team

The Church's administrative wing building shows feasibility for incorporating housing with it's bigger windows and layout.


0.25 mi radius
5 minute walk
SITE
2-story vernacular
3-story
purpose built housing
other
parks
religious

ZONING PLAN

SITE

Extend the existing lot line (red dashed line) to the church's property line (red solid line) about 15 ft east to allow for maximum buildable area, since given the current lot line, the buildable area is limited to only that shown in the dotted grey square after setbacks are factored in. A zoning variance will be required to extend that lot line.

Setback the building 10ft from the new lot line to allow for an easement.

BUILDING

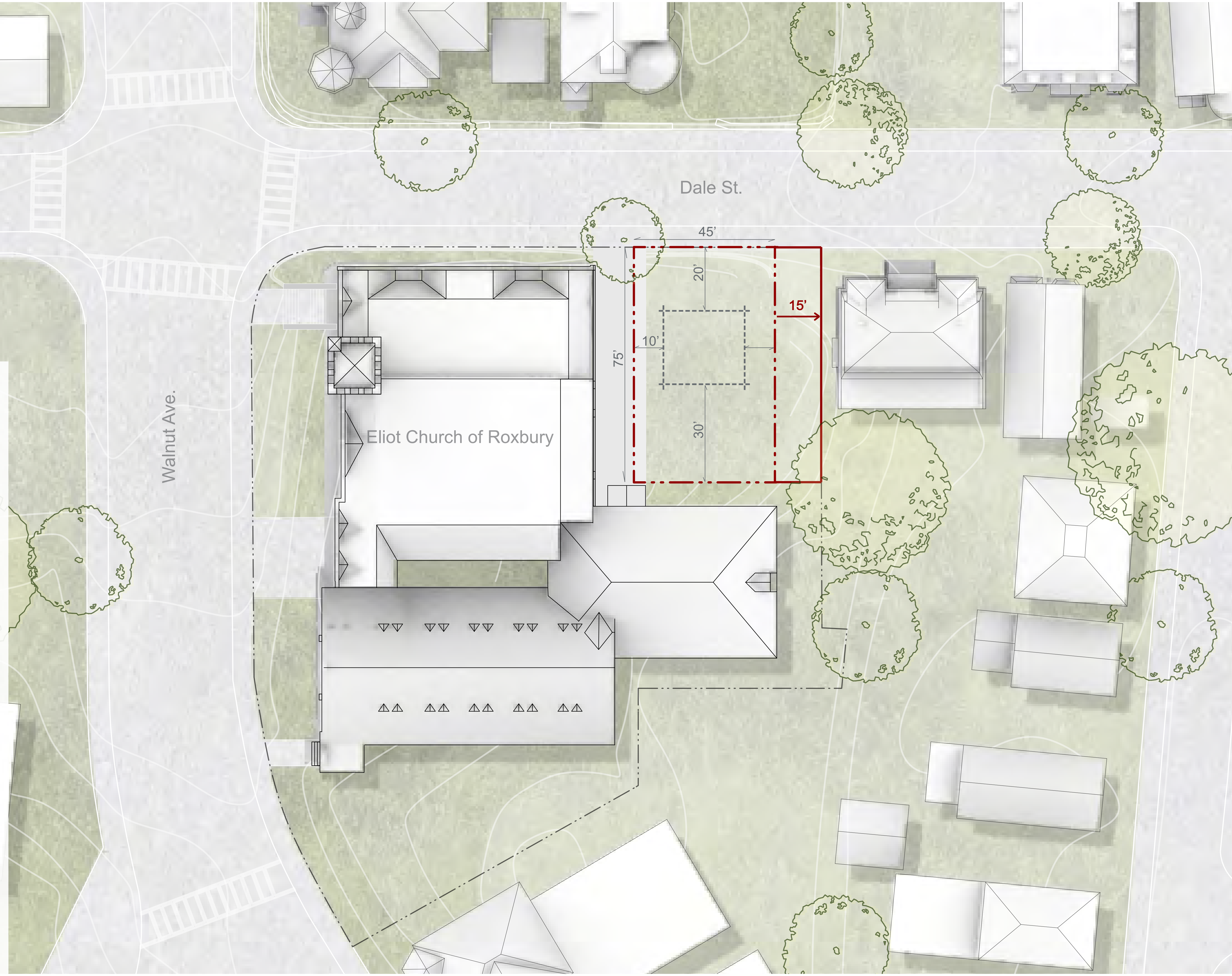
Type V construction

Fire stairs:

Only one means of egress is needed; maximum egress travel distance is <125 ft. 36-inch-wide stair is acceptable if occupancy is <50 people [assuming 200 gsf per person].

Elevator:

Not required. But still including one to allow for equal accessibility for all.



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SITE PLAN

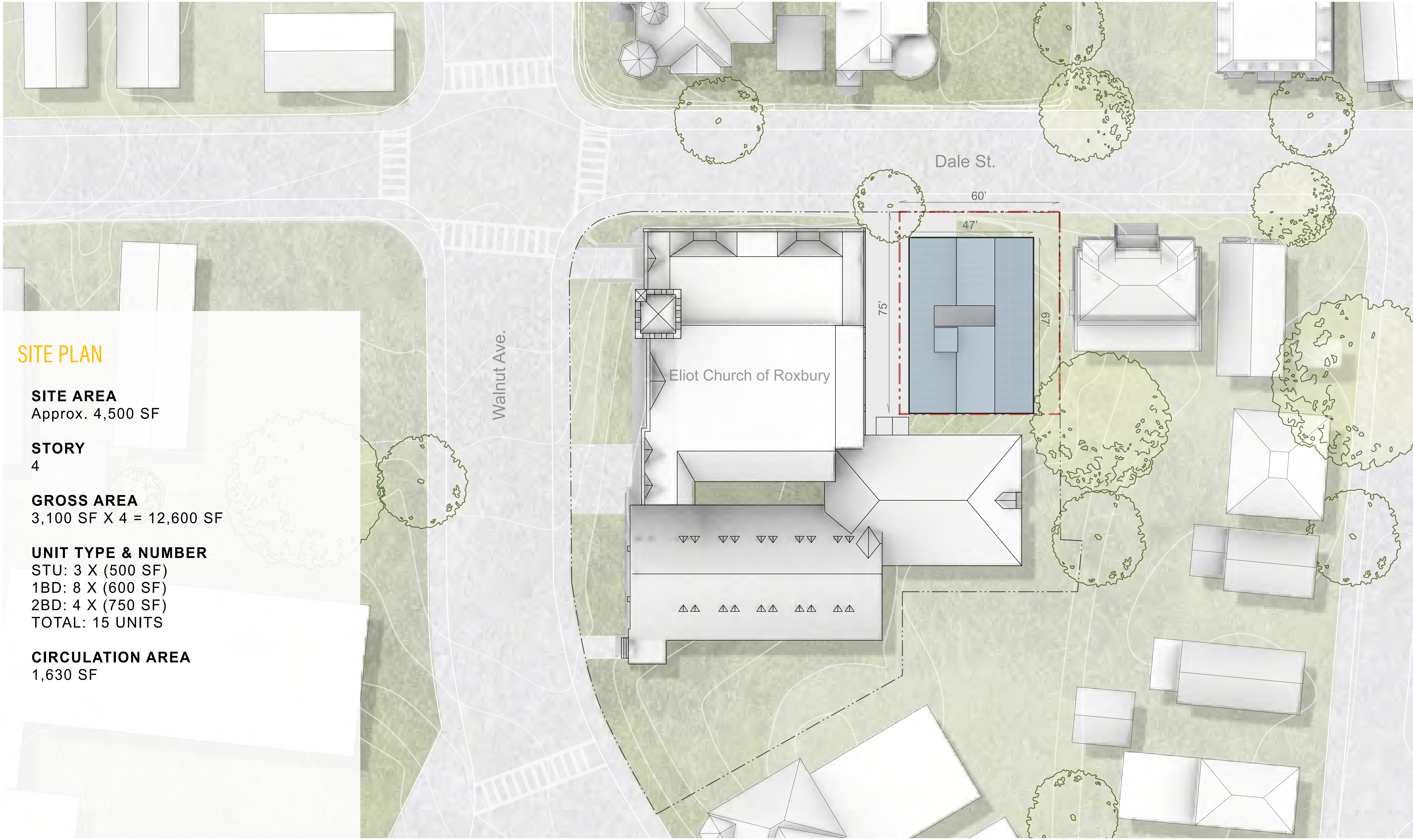
SITE AREA
Approx. 4,500 SF

STORY
4

GROSS AREA
3,100 SF X 4 = 12,600 SF

UNIT TYPE & NUMBER
STU: 3 X (500 SF)
1BD: 8 X (600 SF)
2BD: 4 X (750 SF)
TOTAL: 15 UNITS

CIRCULATION AREA
1,630 SF



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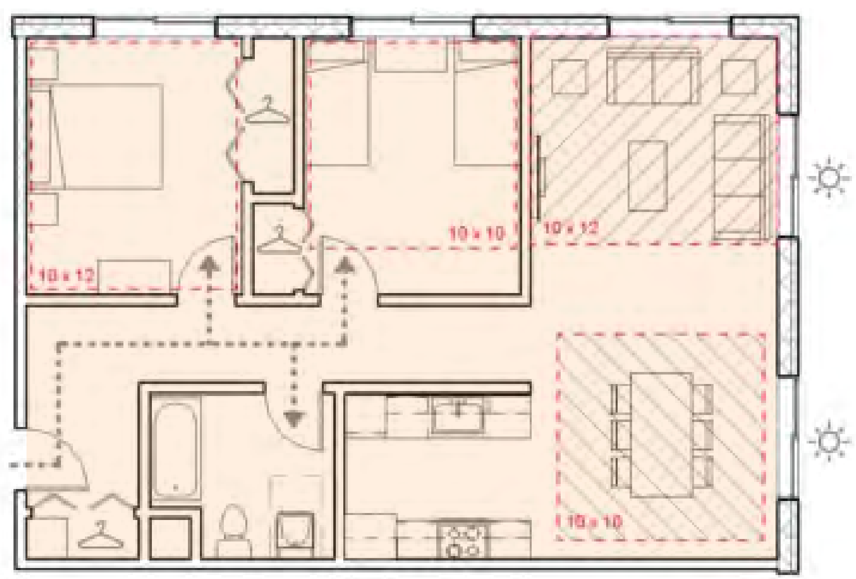
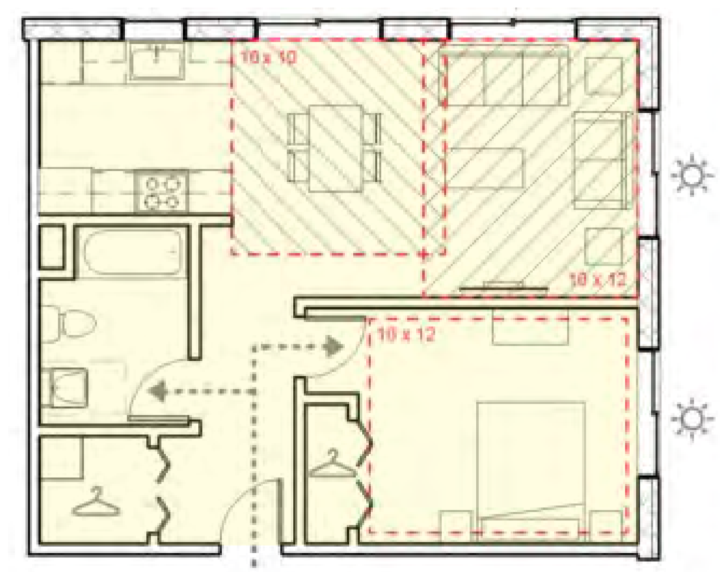
UNIT SIZES & DESIGN STANDARDS

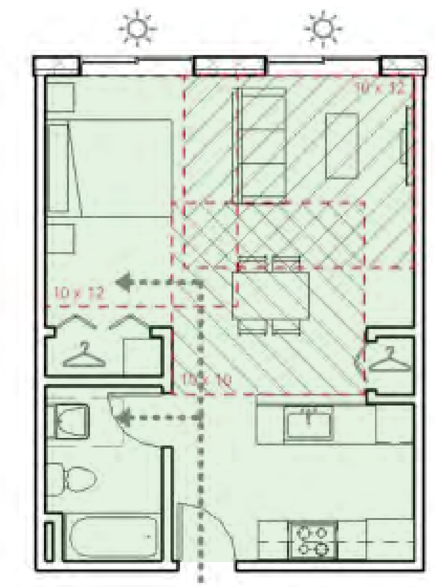
*according to Department of Neighborhood Development (DND) Design Standards 2020



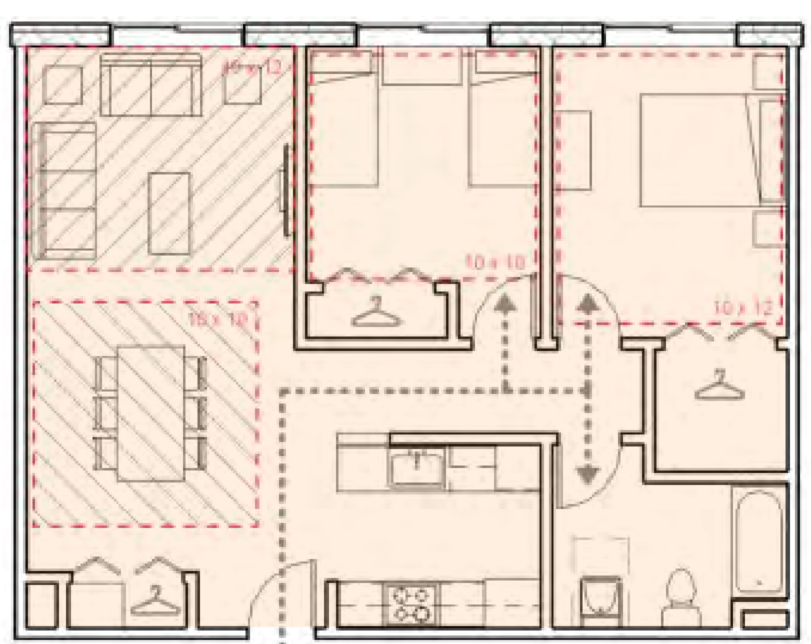
2 bedroom | corner unit



1 bedroom | corner unit

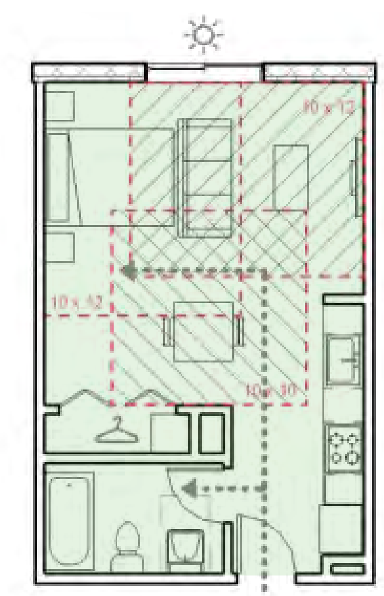


studio | typical unit



2 bedroom | typical unit

1 bedroom | typical unit



studio | typical unit

EXTERIOR BIRDSEYE VIEW

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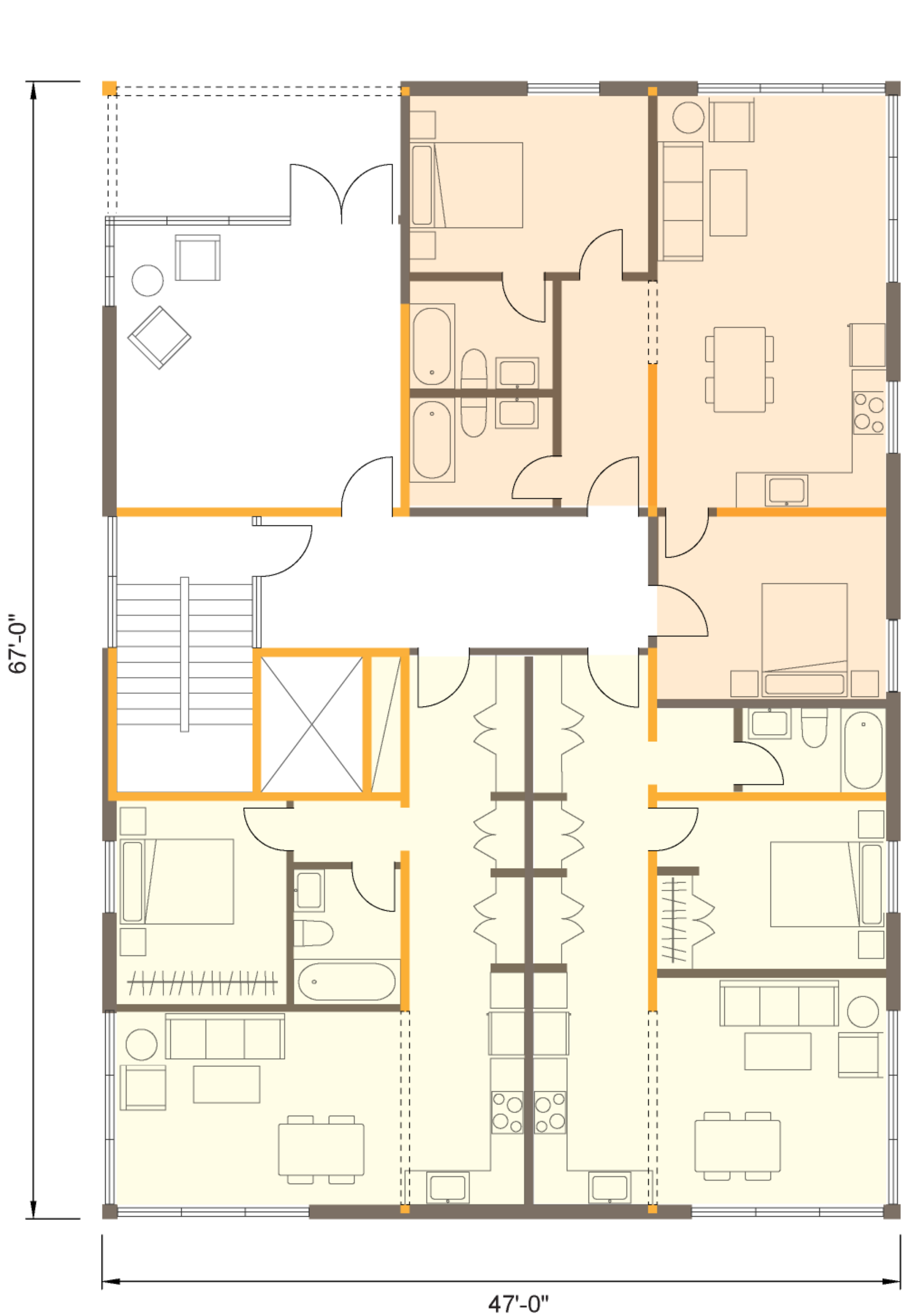
FLOOR PLANS showing unit layouts



Ground Floor

Typical Upper Floor

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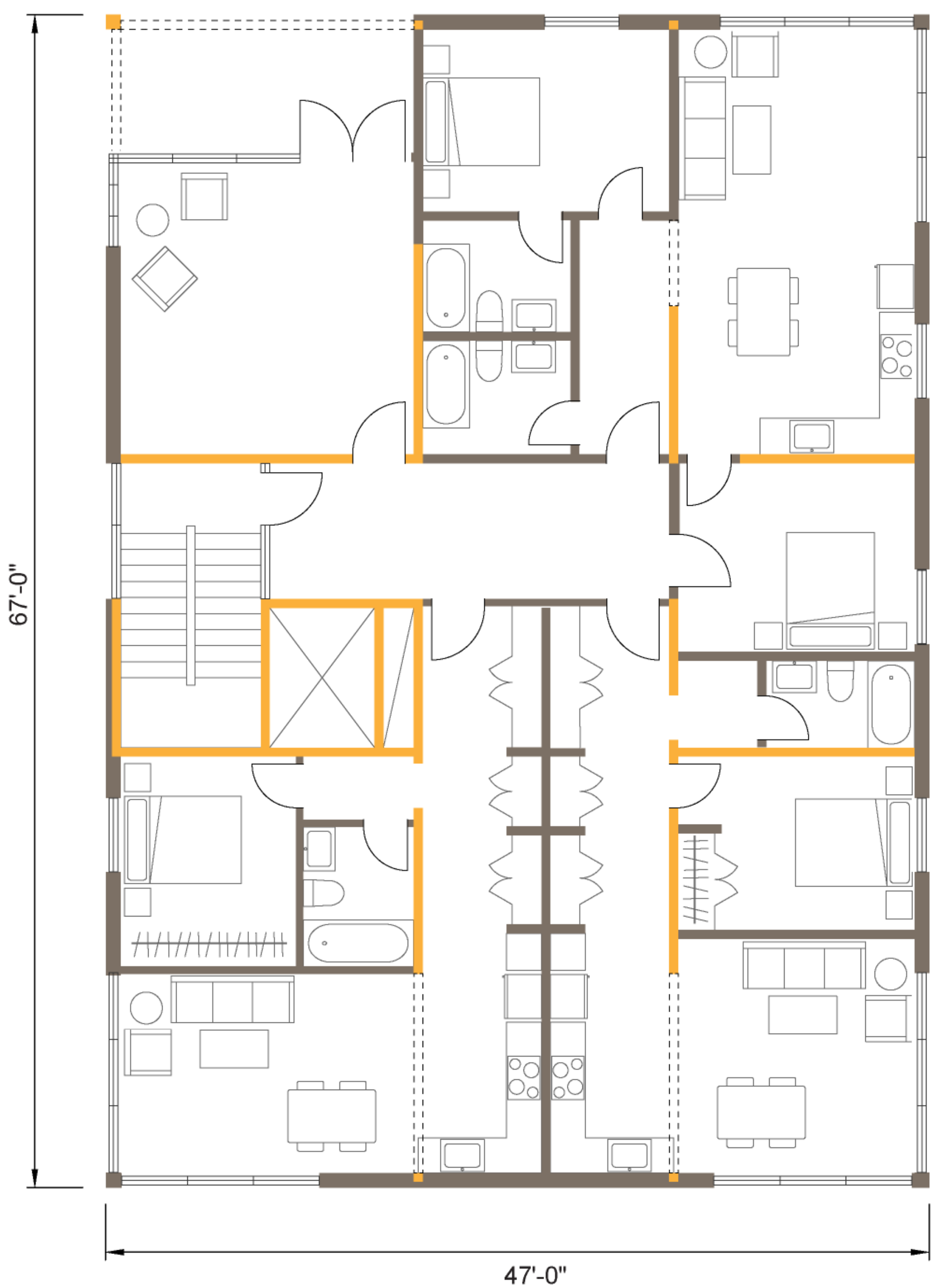
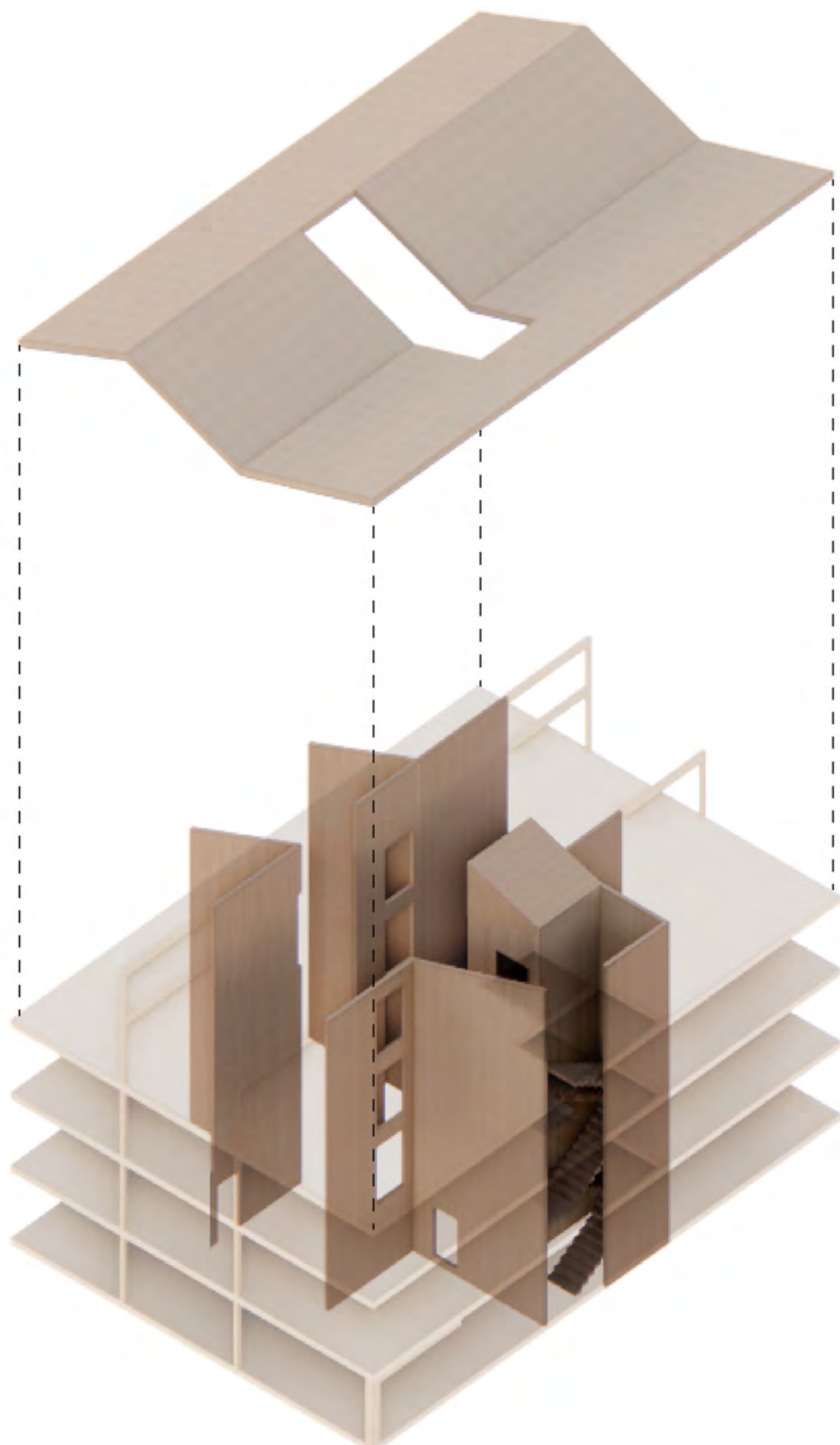
FLOOR PLANS showing shear wall locations

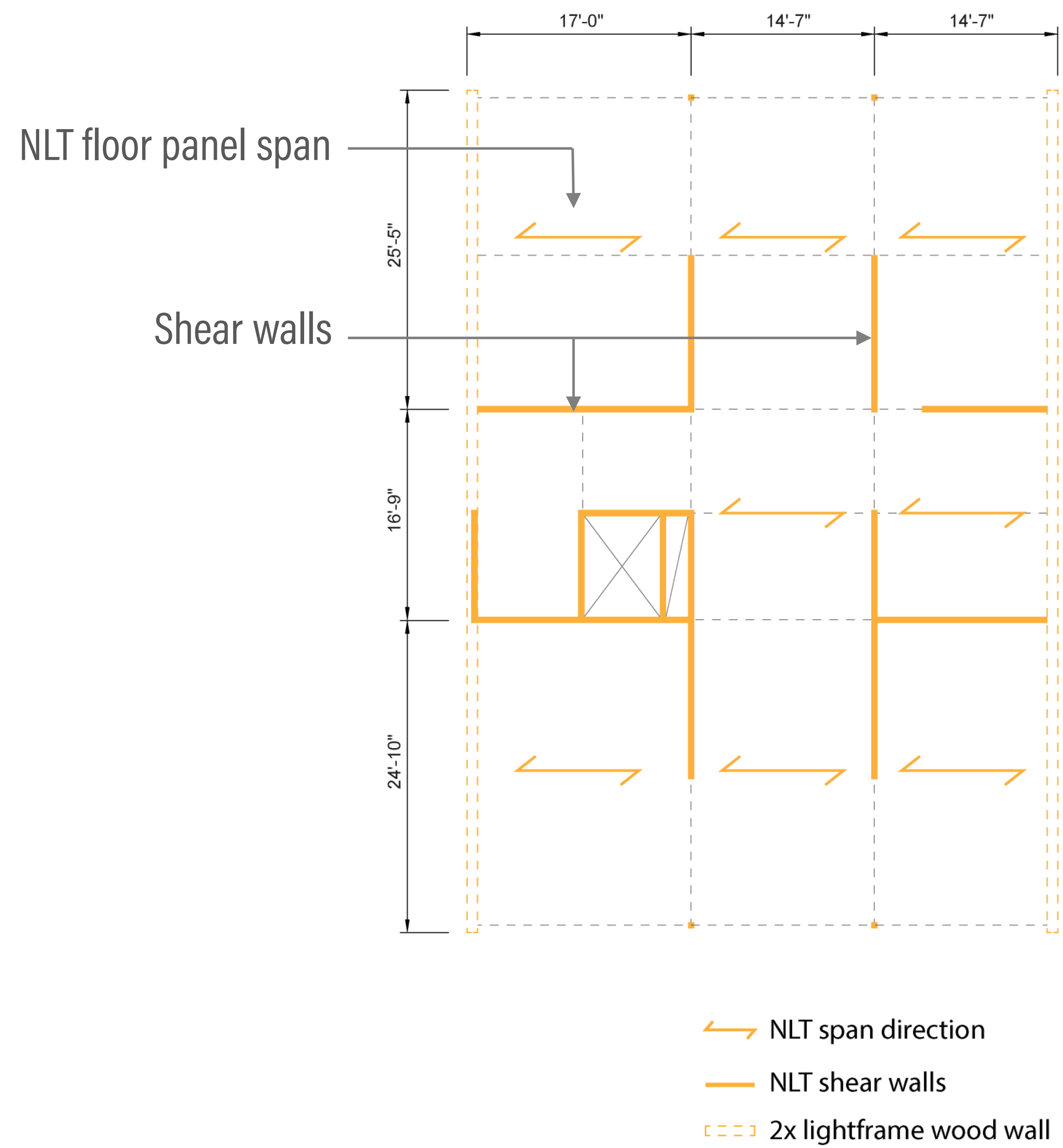


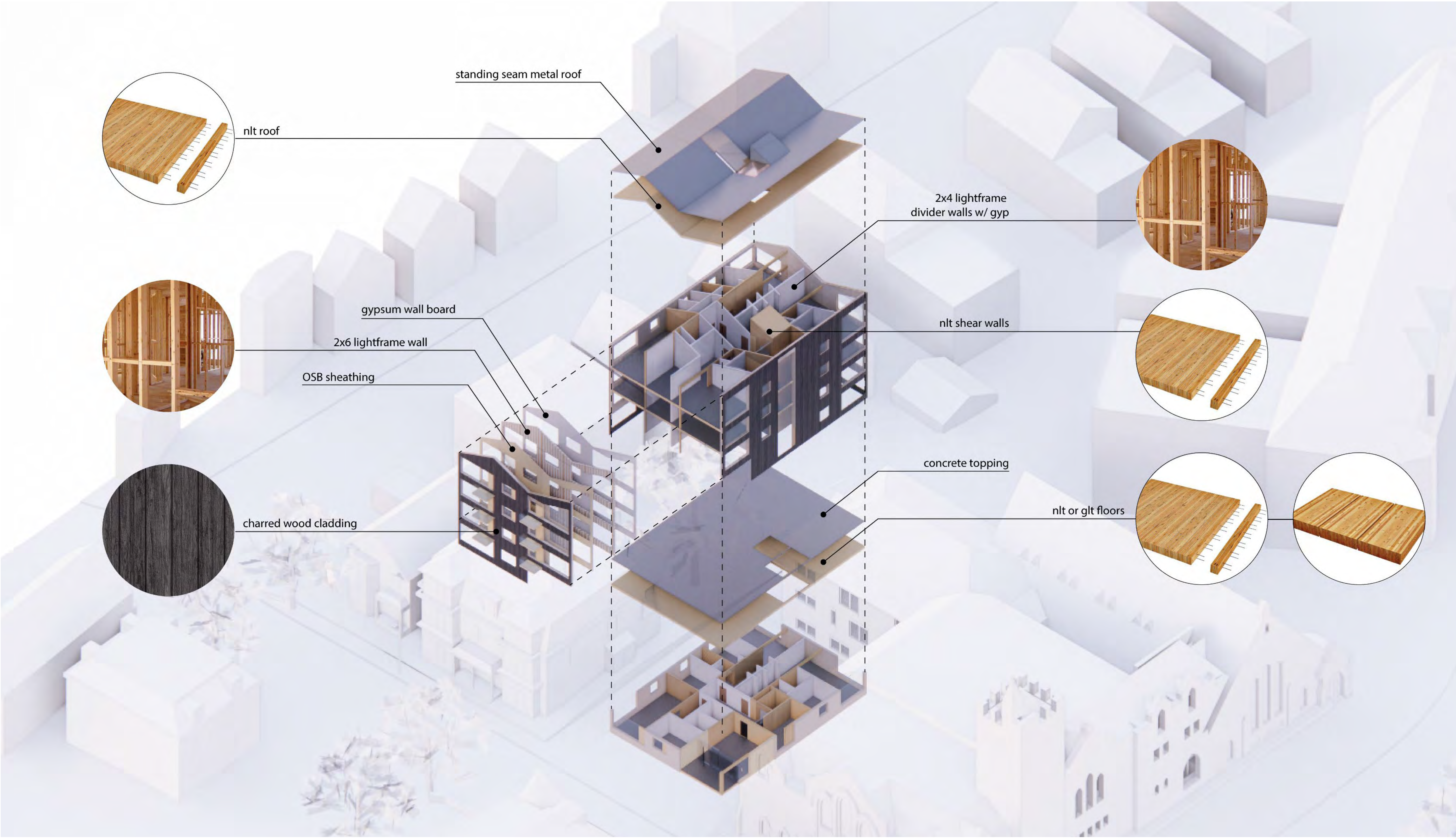
Ground Floor

Typical Upper Floor

STRUCTURAL AXONOMETRIC showing shear walls, core & floors






standing seam metal roof
nlt roof
2x4 lightframe
divider walls w/ gyp
gypsum wall board
2x6 lightframe wall
nlt shear walls
OSB sheathing
concrete topping
nlt or glt floors
charred wood cladding

ROOF & ELEVATION PROTOTYPES showing several roof and window configurations that can be combined to meet small urban lot contexts and constraints

GABLE + PITCH

SAWTOOTH

HIP

SUNKEN HIP

BASE - TYPICAL

LARGE CORNER WINDOWS

CURTAINWALL

STAGGERED

EXTERIOR STREET VIEW

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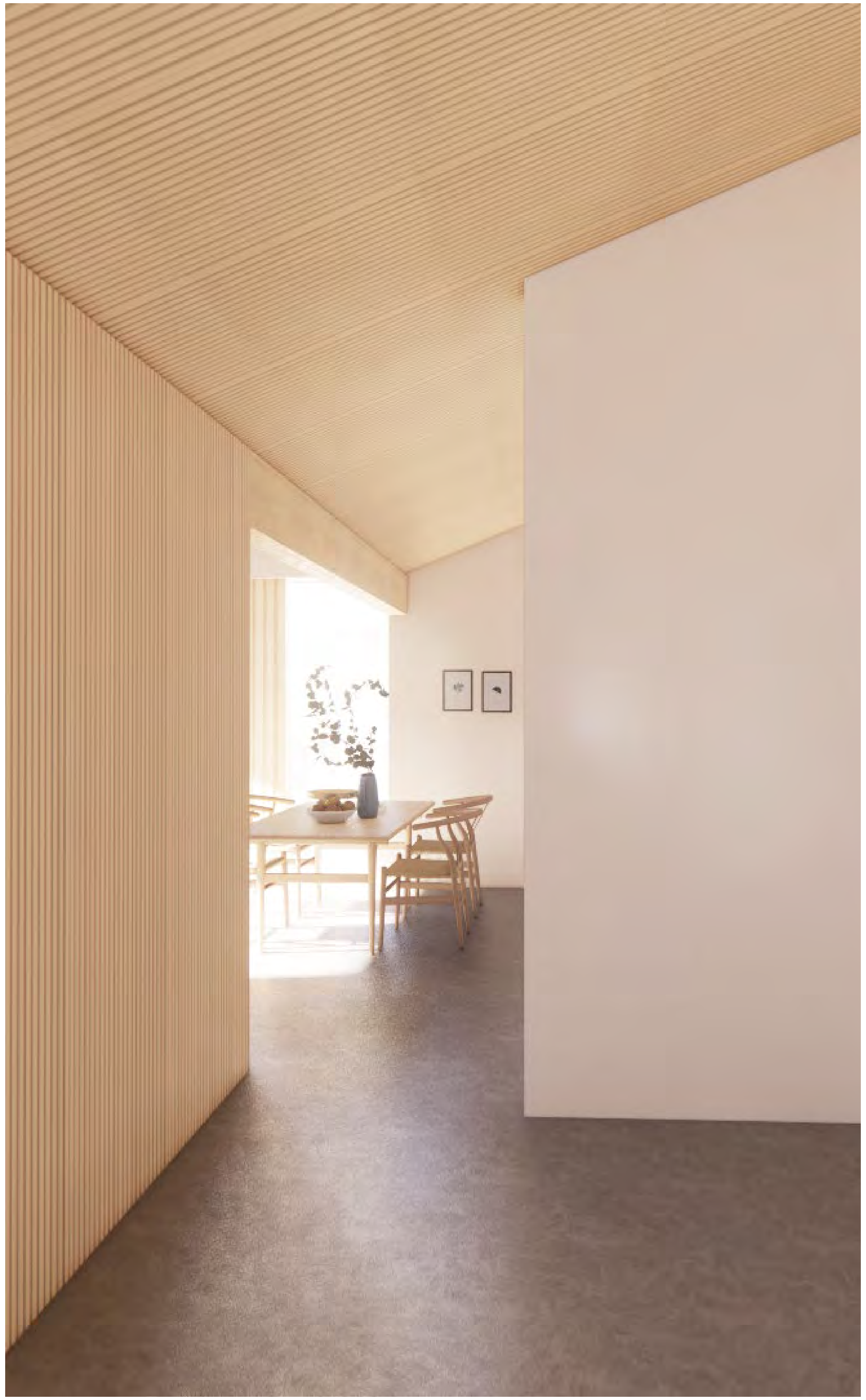
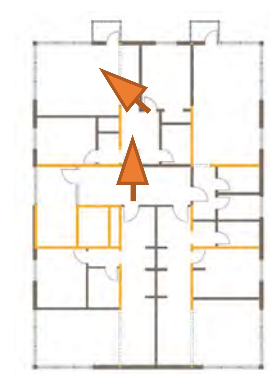
2-BD UNIT ENTRY & LIVING AREA





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2-BD UNIT BEDROOM

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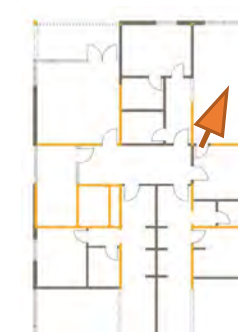
WEINZAPFEL
ASSOCIATES

2-BD UNIT GROUND FLOOR LIVING AREA



GROUND FLOOR ENTRY & STAIR/ELEVATOR LOBBY

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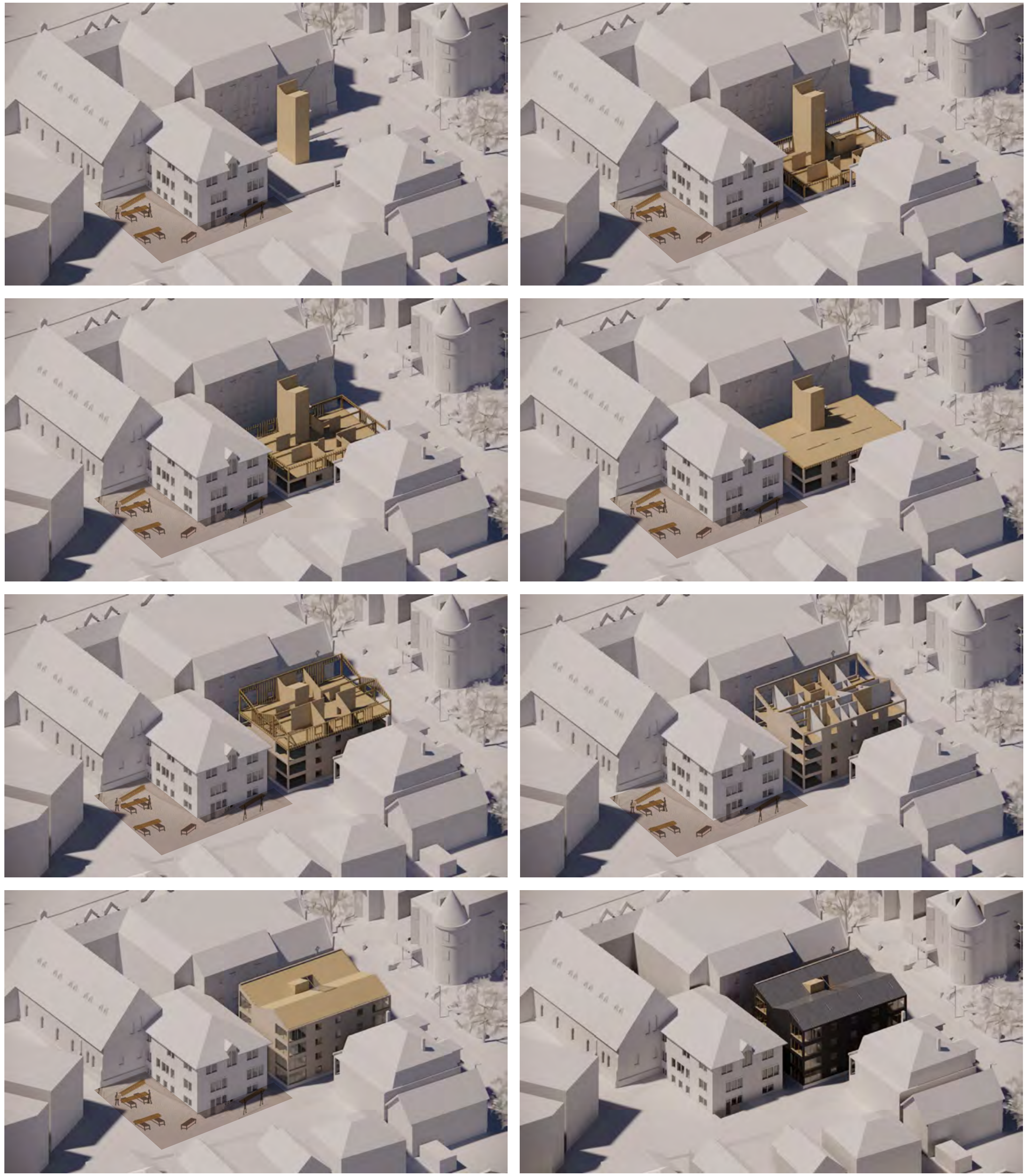
ASSOCIATES

CONSTRUCTION SEQUENCING showing NLT workstation setup

GIF STILLS



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1 of 7
Construction Type

WoodWorks WOOD PRODUCTS COUNCIL

Construction type:	Combination	
Displacement factor for structural elements except mass timber:		3.9
Displacement factor for mass timber:		0.71

Compared with other functionally equivalent buildings made of non-wood materials, wood-frame buildings typically generate less embodied GHG emissions during their life cycle. In other words, there are fewer GHG emissions associated with a wood-frame building than other building types. This difference can be quite large and can be taken as a carbon credit for the amount of CO_2 emissions that were avoided (displaced) by choosing wood over other more GHG-intensive materials.

Reference

Light-frame Low-rise or mid-rise	3.9
Post and beam Low-rise or mid-rise	3.9
Mass timber Low-rise, mid-rise or high-rise	0.71
Combination Mass timber/light-frame/post and beam	

2 of 7
Lumber

bf board feet
lf linear feet
ft³ cubic feet
m³ cubic meters

WoodWorks WOOD PRODUCTS COUNCIL

Lumber

			m³
2x4 (nominal)	bf	5515	8.5
2x6 (nominal)	bf	8384	13.6
2x8 (nominal)	lf	0	0
2x10 (nominal)	bf	0	0
3x3 (nominal)	lf	0	0
4x4 (nominal)	lf	0	0
3x6 (nominal)	lf	0	0
4x6 (nominal)	lf	0	0
Unknown or varied (actual dimensions)	ft³	0	0
Total volume of dimensional lumber			22.1

Lumber Species

	% Total Volume
Spruce-pine-fir	100
Douglas-fir-larch	0
Hemlock-fir	0
Cedar	0
Southern pine	0
Unknown	0

3 of 7
Mass Timber

ft³ cubic feet
m³ cubic meters

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Structural Composite Lumber

			m³
LVL	ft³	0	0
LSL	ft³	0	0
OSL	ft³	0	0
PSL	ft³	0	0

Structural Laminated Timber

			m³
Glulam	ft³	0	0
NLT	ft³	8097	229.3
CLT	ft³	0	0
Total volume of mass timber products			229.3

Structural Laminated Timber Species

Glulam	% Total Volume
Douglas-fir-larch	0
Hemlock-fir	0
Southern pine	0
Spruce-pine	100
Unknown	0
Total (must equal 100%)	100%

NLT

CLT

4 of 7
Panels

WoodWorks WOOD PRODUCTS COUNCIL

OSB

Thickness in Inches			m³
1/4	ft²	0	0
5/16	ft²	0	0
3/8	ft²	0	0
7/16	ft²	0	0
1/2	ft²	8892	10.5
5/8	ft²	0	0
3/4	ft²	0	0
1 1/8	ft²	0	0
Unknown	ft²	0	0

Plywood

Thickness in Inches			m³
1/4	ft²	0	0
5/16	ft²	0	0
3/8	ft²	0	0
7/16	ft²	0	0
1/2	ft²	0	0
5/8	ft²	0	0
3/4	ft²	17769	31.4
1 1/8	ft²	0	0
Unknown	ft²	0	0

OSB & Plywood by Volume

			m³
OSB	ft³	0	0
Plywood	ft³	0	0
Total volume of panels & sheathing			41.9

Plywood Species

	% Total Volume
Softwood (APA Groups 2-5)	100
Douglas-fir-larch (APA Group 1)	0
Unknown	0
Total (must equal 100%)	100%

5 of 7
Engineered Wood Products

WoodWorks WOOD PRODUCTS COUNCIL

Engineered I-joist

			m³
I-joist	lf	0	0

Structural Composite Lumber

			m³
LVL	ft³	0	0
LSL	ft³	0	0
OSL	ft³	0	0
PSL	ft³	0	0

Structural Laminated Timber

			m³
Glulam	ft³	300	8.5
Total volume of engineered wood products			8.5

Glulam Species

	% Total Volume
Douglas-fir-larch	0
Hemlock-fir	0
Southern pine	0
Spruce-pine	100
Unknown	0
Total (must equal 100%)	100%

6 of 7
Decks & Siding

WoodWorks WOOD PRODUCTS COUNCIL

Decking

Thickness in Inches			m³
1	ft²	0	0
1 1/4	ft²	0	0
1 1/2	ft²	0	0
2	ft²	0	0
2 1/2	ft²	0	0
3 1/2	ft²	0	0
Unknown	ft²	0	0
Total volume of decking			0

Decking Species

	% Total Volume
Spruce-pine-fir	100

Siding & Roofing

Thickness in Inches			m³
1/2	ft²	8892	10.5
5/8	ft²	0	0
11/16	ft²	0	0
3/4	ft²	0	0
7/8	ft²	0	0
1	ft²	0	0
1 1/4	ft²	0	0
2	ft²	0	0
Unknown	ft²	0	0
Total volume of siding & roofing			10.5

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Carbon Summary

Results

Volume of wood products used (m³):
312 m³ (11030 ft³) of lumber and sheathing

U.S. and Canadians forests grow this much wood in:
1 minutes

Carbon stored in the wood:
259 metric tons of CO_2

Avoided greenhouse gas emissions:
204 metric tons of CO_2

Total potential carbon benefit:
462 metric tons of CO_2

Equivalent to:

98 cars off the road for a year

Energy to operate **49** homes for a year

NLT + Light-frame

1 of 6

Construction Type

WoodWorks WOOD PRODUCTS COUNCIL

Construction type:	Light-frame
Displacement factor:	3.9

Compared with other functionally equivalent buildings made of non-wood materials, wood-frame buildings typically generate less embodied GHG emissions during their life cycle. In other words, there are fewer GHG emissions associated with a wood-frame building than other building types. This difference can be quite large and can be taken as a carbon credit for the amount of CO_2 emissions that were avoided (displaced) by choosing wood over other more GHG-intensive materials.

Reference

Light-frame Low-rise or mid-rise	3.9
Post and beam Low-rise or mid-rise	3.9
Mass timber Low-rise, mid-rise or high-rise	0.71
Combination Mass timber/light-frame/post and beam	

2 of 6

Lumber

bf board feet
lf linear feet
ft³ cubic feet
m³ cubic meters

WoodWorks WOOD PRODUCTS COUNCIL

Lumber

	Unit	Quantity	m³
2x4 (nominal)	bf	8491	13.1
2x6 (nominal)	bf	8384	13.6
2x8 (nominal)	lf	0	0
2x10 (nominal)	bf	5346	8.7
3x3 (nominal)	lf	0	0
4x4 (nominal)	lf	0	0
3x6 (nominal)	lf	0	0
4x6 (nominal)	lf	0	0
Unknown or varied (actual dimensions)	ft³	0	0
Total volume of dimensional lumber			35.4

Lumber Species

	% Total Volume
Spruce-pine-fir	100
Douglas-fir-larch	0
Hemlock-fir	0
Cedar	0
Southern pine	0
Unknown	0

3 of 6

Panels

WoodWorks WOOD PRODUCTS COUNCIL

OSB

Thickness in Inches

	Unit	Quantity	m³
1/4	ft²	0	0
5/16	ft²	0	0
3/8	ft²	0	0
7/16	ft²	0	0
1/2	ft²	13842	16.3
5/8	ft²	0	0
3/4	ft²	0	0
1 1/8	ft²	0	0
Unknown	ft²	0	0

Plywood

Thickness in Inches

	Unit	Quantity	m³
1/4	ft²	0	0
5/16	ft²	0	0
3/8	ft²	0	0
7/16	ft²	0	0
1/2	ft²	0	0
5/8	ft²	0	0
3/4	ft²	12819	22.7
1 1/8	ft²	0	0
Unknown	ft²	0	0

OSB & Plywood by Volume

	Unit	Quantity	m³
OSB	ft³	0	0
Plywood	ft³	0	0
Total volume of panels & sheathing			39

Plywood Species

	% Total Volume
Softwood (APA Groups 2-5)	100
Douglas-fir-larch (APA Group 1)	0
Unknown	0
Total (must equal 100%)	100%

4 of 6

Engineered Wood Products

WoodWorks WOOD PRODUCTS COUNCIL

Engineered I-joist

	Unit	Quantity	m³
I-joist	lf	7050	22.6

Structural Composite Lumber

	Unit	Quantity	m³
LVL	ft³	0	0
LSL	ft³	0	0
OSL	ft³	0	0
PSL	ft³	0	0

Structural Laminated Timber

	Unit	Quantity	m³
Glulam	ft³	0	0
Total volume of engineered wood products			22.6

Glulam Species

	% Total Volume
Douglas-fir-larch	0
Hemlock-fir	0
Southern pine	0
Spruce-pine	100
Unknown	0
Total (must equal 100%)	100%

5 of 6

Decks & Siding

WoodWorks WOOD PRODUCTS COUNCIL

Decking

Thickness in Inches

	Unit	Quantity	m³
1	ft²	0	0
1 1/4	ft²	0	0
1 1/2	ft²	0	0
2	ft²	0	0
2 1/2	ft²	0	0
3 1/2	ft²	0	0
Unknown	ft³	0	0
Total volume of decking			0

Decking Species

	% Total Volume
Spruce-pine-fir	100
Cedar	0
Southern pine	0
Redwood	0
Ipe	0
Unknown	0
Total (must equal 100%)	100%

Siding & Roofing

Thickness in Inches

	Unit	Quantity	m³
1/2	ft²	8892	10.5
5/8	ft²	0	0
11/16	ft²	0	0
3/4	ft²	0	0
7/8	ft²	0	0
1	ft²	0	0
1 1/4	ft²	0	0
2	ft²	0	0
Unknown	ft³	0	0
Total volume of siding & roofing			10.5

6 of 6

Carbon Summary

Results

Volume of wood products used (m³):
108 m³ (3800 ft³) of lumber and sheathing

U.S. and Canadians forests grow this much wood in:
18 seconds

Carbon stored in the wood:
93 metric tons of CO_2

Avoided greenhouse gas emissions:
184 metric tons of CO_2

Total potential carbon benefit:
277 metric tons of CO_2

Equivalent to:

59 cars off the road for a year

Energy to operate **29** homes for a year

Light-frame only

TOTAL BF of Lumber				
	COMBINATION NLT + LIGHT FRAME		100% LIGHT FRAME	
INTERIOR WALLS	COMBINATION	25315	8491	light frame
EXTERIOR WALLS	2X	9633	8384	light frame
ROOF	NLT	20234.00	5346	2x10
FLOORS	NLT	55613.38	12561	I joist/ 2x10
TOTAL (BF)		**110795**	**34782**	

TOTAL NLT Volume		
INTERIOR WALLS	1650	ft3
EXTERIOR WALLS	126	ft3
ROOF	1686	ft3
FLOORS	4634	ft3
TOTAL:	**8097**	**ft3**

Total Panels				
Floors and Roof	3/4" Plywood			
Floor dims:	67			
	47			
Area per floor	3149	sf		
Total floor area	9447	sf		
Roof area	3372	sf		
Total Area	**12819**	**sf**		
Exterior Walls	1/2" OSB			
Wall	length	height	Area	
North	47	39	1833	sf
South	47	39	1833	sf
East	67	36	2412	sf
West	67	42	2814	sf
Total Area			**8892**	**sf**
NLT Shear Walls	3/4" Plywood			
Floor	Area			
1	1035			
2	1174.5			
3	1174.5			
4	1566			
Total Area:	**4950**	**sf**		

EXTERIOR WALLS

2X6 EXTERIOR WALLS
AT 16" STUD SPACING

	FLOOR 1	FLOOR 2	FLOOR 3	FLOOR 4	SUM
North					
LENGTH	47	47	47	47	
HEIGHT	9	9	9	12	
BF	414	414	414	499	
South					
LENGTH	47	47	47	47	
HEIGHT	9	9	9	12	
BF	414	414	414	499	
West					
LENGTH	67	67	67	67	
HEIGHT	9	9	9	15	
BF	583	583	583	821	
East					
LENGTH	67	67	67	67	551
HEIGHT	9	9	9	9	
BF	583	583	583	583	
Total BF	1994	1994	1994	2402	**8384 bf**
area of ext NLT wall					
length	9		9		
height	9	109	15	154	**263 bf**

NLT EXTERIOR WALLS

	FLOOR 1	FLOOR 2	FLOOR 3	FLOOR 4	SUM	X12 = BF
North						
LENGTH	47	47	47	47		
HEIGHT	0	0	0	0		
THICKNESS	0.333333	0.333333	0.333333	0.333333		
VOLUME FT3	0	0	0	0	0	
South						
LENGTH	47	47	47	47		
HEIGHT	0	0	0	0		
THICKNESS	0.333333	0.333333	0.333333	0.333333		
VOLUME FT3	0	0	0	0	0	
West						
LENGTH	9	9	9	9		
HEIGHT	9	9	9	15		
THICKNESS	0.333333	0.333333	0.333333	0.333333		
VOLUME FT3	27	27	27	45	126	
East						
LENGTH	67	67	67	67		
HEIGHT	0	0	0	0		
THICKNESS	0.333333	0.333333	0.333333	0.333333		
VOLUME FT3	0	0	0	0	0	
TOTAL BF					126	**1512**

FLOORS

NLT FLOORS			I Joists or 2x10		
LENGTH	67	ft		67	ft
WIDTH	47	ft		47	ft
THICKNESS	0.5	2x6	16" SPACING		
VOLUME	1574.5	ft3		804	in
ELEVATOR SHAFT				50.25	ft
LENGTH	6.92			2361.75	LF per floor
WIDTH	8.58		**TOTAL:**	**7085.25**	**LF**
THICKNESS	0.5				
VOLUME	29.68	ft3			
VOL PER FLOOR	1544.82	ft3			
VOL TOTAL	**4634.45**	**ft3**			
BF PER FLOOR	18537.79		per floor =	4187	
TOTAL (X3)	**55613.38**	**bf**		**12561**	**bf**

ROOF

	NLT ROOF				2X10 ROOF	
	1 PANEL	2 PANEL	3 PANEL			
WIDTH	16.167	16.75	17.417		AVG WIDTH	16.75
LENGTH	67	67	67			67
THICKNESS	0.5	0.5	0.5	2x6	18" SPACING	
VOL	541.58	561.13	583.46			
VOL Total ft3	**1686 ft3**					
BF	6499	6733.5	7001.5			
					each plane	1782
TOTAL BF	**20234 bf**					**5346 bf**

INTERIOR WALLS

		NLT INTERIOR WALLS		2X4 INTERIOR WALLS		BF : COMBINATION	BF : 100% 2X WALLS
		FT	IN	FT	IN		
		15	6	9	6		
		8	7	5	5		
		8	7	15	6		
		19		31	4		
		15	6	15	5		
		10	5	14	5		
		19		5	5		
		14	5	14	5		
		9	1	6			
		10	5	9	1		
				11	6		
				9	1		
				13	9		
				7	5		
				14	2		
				14	2		
				15	10		
				10			
				16	4		
subtotal:		127	42 in	232	81		
			3.5 ft		6.75 ft		
LENGTH (1s flr)	115			212.42			327.42
LENGTH (2-4 flrs)		130.5		238.75			369.25
HEIGHT		9					
WIDTH		0.333333333	2x4				
VOLUME (FT3) per floor	345	391.5	at 2,3 flrs				
VOLUME (FT3) Total		**1650.0**	**ft3**				
BF (1)		4140		1207			1840
BF (2)		4698		1345			2077
BF (3)		4698		1345			2077
BF 4	522	6264		1618			2497
TOTAL (BF)		**19800 bf**		**5515 bf**		**25315 bf**	**8491** bf

LEERS
WEINZAPFEL
ASSOCIATES

Bunker Hill Housing Redevelopment
Boston Mass Timber Accelerator
Final Report 2023

June 2, 2023

Project Team:

Development Partner: Leggat McCall Properties
Architect: Stantec
Sustainability Consultant: Integrated Eco-Strategy

Table of Contents

Executive Summary

Of the three projects in Boston’s 2023 Mass Timber Accelerator cohort, the Bunker Hill Housing Redevelopment (“BHHR”), a tri-party public private partnership between Leggat McCall Properties, the Boston Housing Authority (“BHA”) and the Charlestown Resident Alliance (“CRA”), was the furthest along in the design and construction process. Unlike others whose participation was primarily to explore the use of Mass Timber as a viable material, BHHR had already made the commitment to utilize CLT. From the inception of BHHR the team has been committed to high standards of sustainability, including Passive House certified design in addition to the use of CLT. This commitment to sustainability resulted in various added costs and challenges to the project. However, the opportunity to participate in the accelerator served to alleviate some of the pressures faced by undertaking this task of redeveloping an affordable housing project in a truly sustainable manner. This report summarizes findings, knowledge and insight gained from participating in the accelerator.

Built in 1940, the existing Bunker Hill Housing development is the largest public housing development in New England. Located on an approximately 27-acre parcel owned by the BHA in the Charlestown neighborhood, the existing development is severely depreciated with many of the buildings in disrepair. These buildings will be replaced with new residential apartments, retail, and community space, as well as green spaces and connections to the surrounding Charlestown neighborhood.

Building M is the first building in the redevelopment of the BHHR project. It will be a 100% affordable building with 102 units and associated amenities spaces. The building will be constructed utilizing prefabricated elements to the greatest extent possible, including prefabricated exterior and interior load bearing and demising walls, prefabricated stair and elevator cores and prefabricated CLT floor framing.

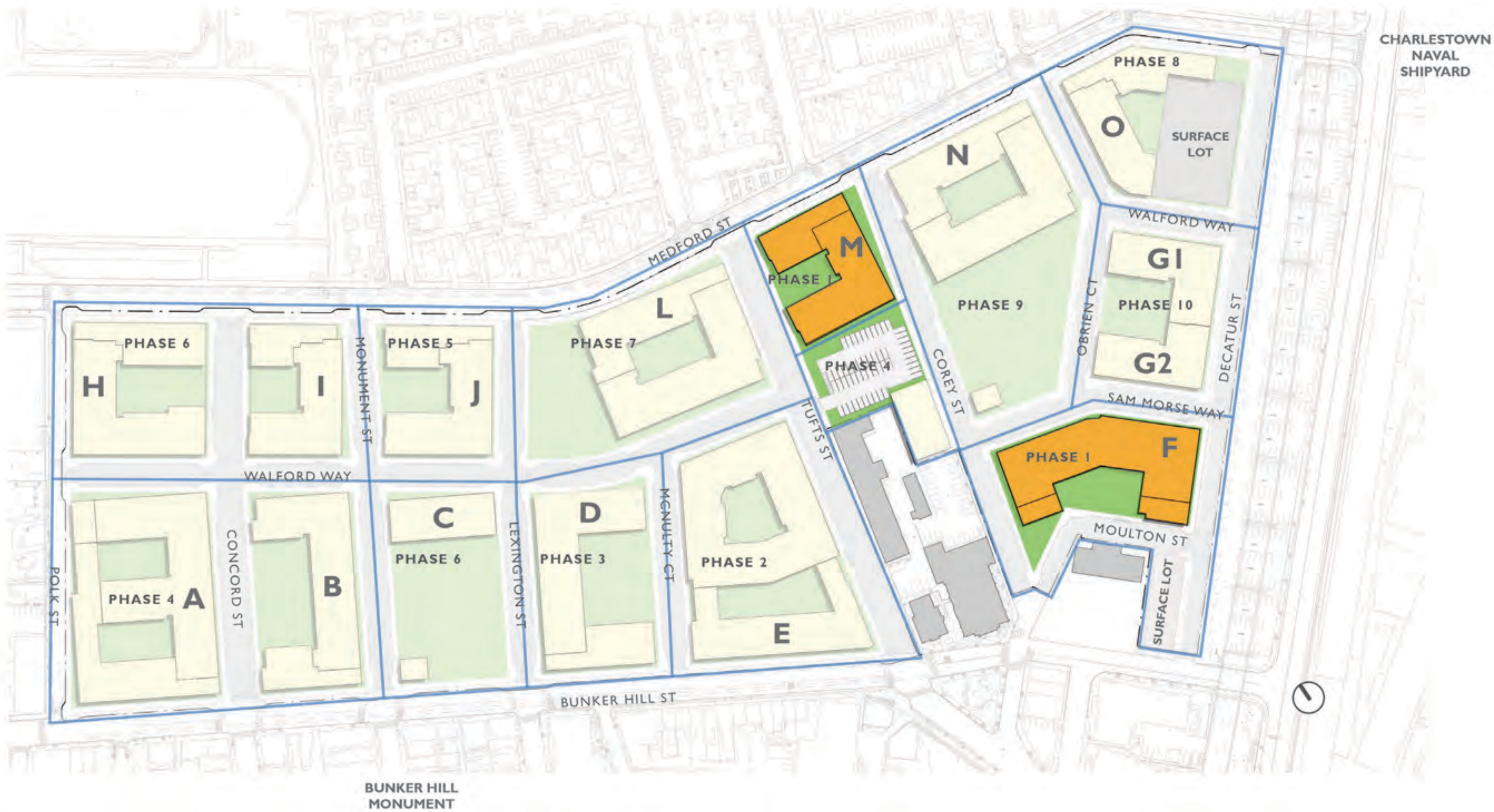
At completion, the master Bunker Hill Housing Redevelopment would replace 1,010 public housing units in 15 buildings and add:

- 1,689 market-rate units,
- 45-55,000 square feet of neighborhood retail,
- A 14,000 square-foot community center, and 2.8+ acres of new, publicly accessible open space.

Additionally, the buildings’ Passive House design would result in a 50%+ reduction in energy consumption versus current code.

See current BHHR phasing plan on the following page.

Bunker Hill Housing Redevelopment Phasing Plan



Embodied Carbon Analysis

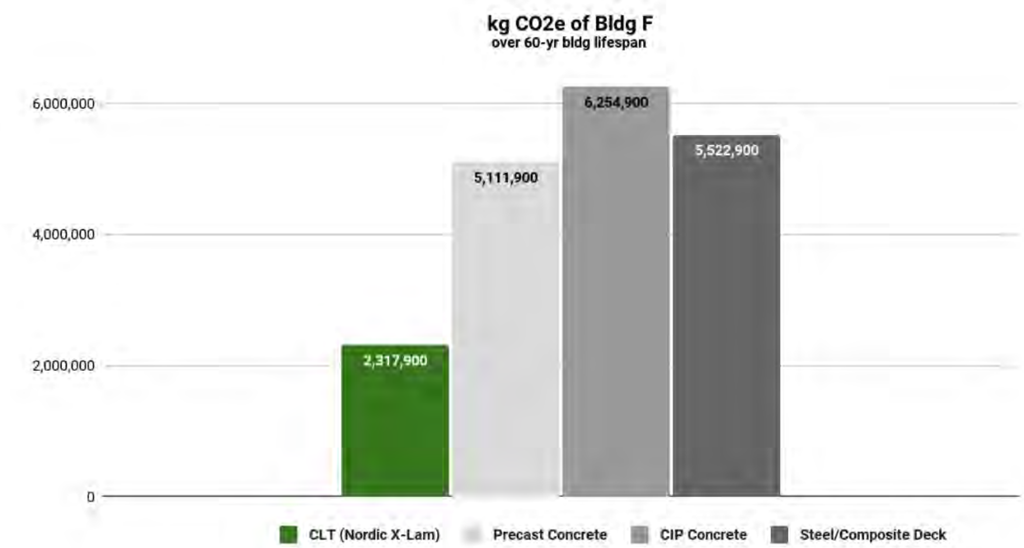
BHHR Building F

To better understand the benefits of CLT use, the BHHR team carried out a life cycle assessment using the Athena Impact Estimator that demonstrates the embodied carbon benefit of a Cross Laminated Timber (CLT) floor and roof structure compared to three potential alternative structural systems:

1. Cast-in-place concrete
2. Steel/composite deck
3. Precast concrete

This analysis excludes elements unrelated to superstructure, i.e. wall assemblies and finishes.

Athena Impact Estimator forecasts a 55-63% savings in embodied carbon over the 60-year lifespan of the building when using CLT floor and roof panels compared to alternative structural systems.



In addition to a significant reduction in embodied carbon over the lifespan of the building, the use of CLT offers the added benefit of carbon sequestration beyond the building lifespan. The WoodWorks Carbon Calculator estimates the potential carbon benefit of a CLT structure for Building F:

Results

Volume of wood products used (m^3):
4948 m^3 (174737 ft^3) of lumber and sheathing

U.S. and Canadians forests grow this much wood in:
13 minutes

Carbon stored in the wood:
3813 metric tons of CO_2

Avoided greenhouse gas emissions:
1476 metric tons of CO_2

Total potential carbon benefit:
5289 metric tons of CO_2

Equivalent to:

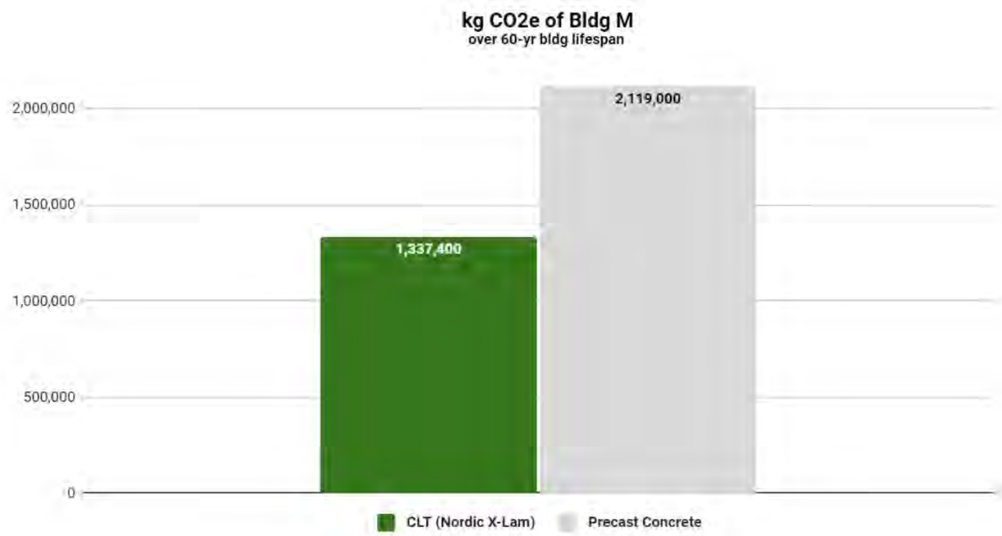
1118 cars off the road for a year

Energy to operate **558** homes for a year

BHHR Building M

A life cycle assessment using the Athena Impact Estimator demonstrates the embodied carbon benefit of a Cross Laminated Timber (CLT) floor and roof structure compared to a traditional precast concrete structure. The analysis of Building M includes core, shell, and interior partitions. Product-level decisions, such as the use of gypsum board with a lower embodied carbon than industry-standard products, were also incorporated into the assessment.

Athena Impact Estimator forecasts a 37% savings in embodied carbon over the 60-year lifespan of the building for the CLT model compared to the precast concrete baseline.



In addition to a significant reduction in embodied carbon over the lifespan of the building, the use of CLT offers the added benefit of carbon sequestration beyond the building lifespan. The WoodWorks Carbon Calculator estimates the potential carbon benefit of a CLT structure for Building M:

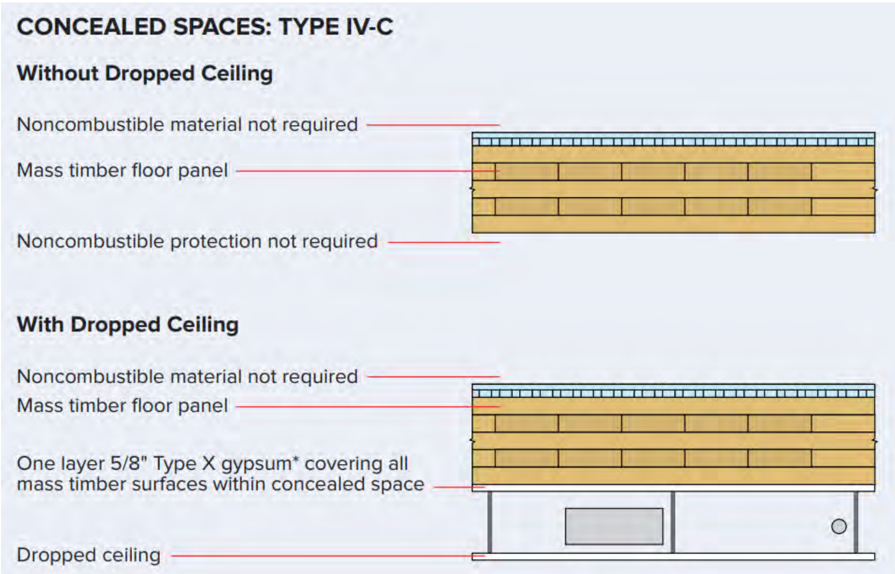
Benefits and Outcomes

Design and Construction Strategies

Building M, a 6-story building with 102 public housing units, is planned to break ground during the summer of 2023. One of the biggest challenges the team faced was designing a structural system that could be replicated over the entire master plan and allow for speed of construction. After various studies, the team decided to implement a 7-ply 62’ long by 86’ wide CLT plank that spans from exterior wall to exterior wall. The demising and corridor walls as well as exterior walls are all prefabricated systems with structural metal studs supporting the CLT planks.

A current rendering of Building M is below:

A typical floorplan



The typical floor structure in Building M consists of a finish floor over 1 ½” of gypcrete, over an acoustical mat, on top of the 7-ply CLT plank, which meets the required 2-hour fire rating. Concealed spaces, such as those created by dropped ceilings in a floor/ceiling assembly have specific requirements from the International Building Code. IBC 2021 Type IV-C does not allow exposed combustible materials in concealed spaces, which is why the floor/ceiling assembly at those locations include one layer of 5/8” Type X gypsum below the 7-ply plank generating a significant impact in construction time, sequence, and cost.

Another consideration when using CLT planks is the poor acoustical performance due to the lack of mass inherent in the panels; for example, a 5-Ply CLT plank has an STC rating of 41 and an ICC rating of 25. In multi-family buildings the IBC requires an STC rating of 50 and an ICC rating of 50, this is why bare mass timber floor/ceiling assemblies are rarely used. Exposing CLT structure, where allowed, offers large biophilic advantages which means that any acoustical component needs to be installed on top of the assembly, which is why Building M is implementing an acoustical layer along with 1 ½” of gypcrete above the 7-ply plank.

Moisture protection during construction is critical as wood is hygroscopic (meaning it can absorb and release moisture) resulting in significant problems such as checking cracks, staining, decay, and schedule delays. Our team considered various approaches of protection including field applied wood sealers, manufacturer fully adhered weather barrier, and sealed lap joints. If the panels are exposed to extreme weather such as big snow loads or heavy rain events, a careful and slow drying process is necessary, and it is important to consider this as part of the construction process. Due to this hygroscopic quality, mass timber elements also have the potential to change dimensionally, which is why our team worked closely with Nordic structures and McNamara Salvia Engineers to accommodate the potential of differential movement and shrinkage at the edge of CLT slab intersection with exterior walls and with concrete shear walls, addressed by leaving ½” gap at both locations.

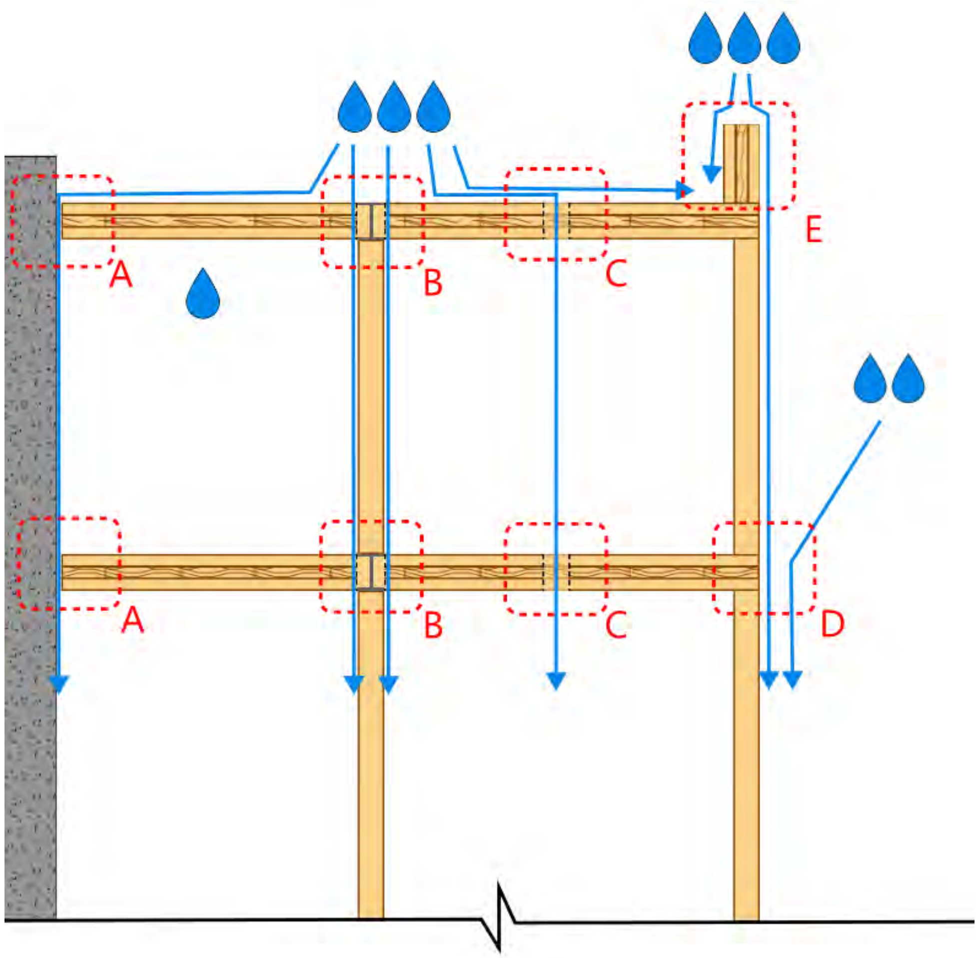


Image Source: RDH Moisture Protection Plan

This building section references locations of potential water penetration studied by the team which required various techniques for CLT protection.

Building Code Approach

Building M has been designed to meet the requirements of 2021 IBC Type IV-C construction under a variance granted by the Boston Redevelopment Authority. 2021 IBC code known for being the impetus of timber construction, has included multiple new construction types under type IV construction. Additionally, it has revised the definition and materials allowed under the heavy timber construction category in which "the exterior walls are of non-combustible materials and interior building elements are of solid or laminated wood".

Building M has been permitted as fully sprinklered group R-2 and considered as a mixed-use structure, with a rated separation at level 1 that allows it to meet height and area requirements encountered by the Storage occupancies in this level. Furthermore, Type IV-C construction requires a 2-hr rated primary structural frame, 2-hr rated interior and exterior bearing walls, 2-hr rated floor assemblies, and a 1-hr rated roof assembly.

Opportunities Realized and Lessons Learned

With BHHR's development timeline being ahead of the typical accelerator participant, the questions and problems that were posed by the BHHR redevelopment team focused on barriers related to technical detailing issues as the team was experiencing them in real time. The sessions were a benefit for future phases as they gave insight into problems faced by other teams. The main benefits of the accelerator for the BHHR team were:

1. Knowledge sharing and information gathering: Connection with other teams in the cohort aided in learning about alternative approaches to certain issues. Learning about structural challenges and considerations across use types as well as code and variance approaches across a range of heights was incredibly valuable and will be particularly meaningful when design commences for future phases.
2. Connection with other opportunities: Exposure gained from participating in the accelerator resulted in the Bunker Hill Housing Redevelopment receiving discretionary funds from the U.S Forest Service as well as information on additional grant opportunities. BHHR is a unique and innovative project, and its interconnected nature of housing and sustainability is emblematic of development in the future. This exposure would not be possible without the BPDA and the Mass Timber Accelerator.
3. Huge support of the city and relationship building: Having direct access to the BPDA, Woodworks and their resources was a great benefit during our Building Permit process. This resulted in a smooth Inspectional Services Department building permit approval process due to direct support from John Dalzell.
4. Builders risk insurance carriers and premiums: through support from the accelerator and Woodworks we were able to educate insurance providers on CLT benefits, which resulted in a successful reduction of the insurance premium we were being quoted.
5. Review of future code modifications to address cost prohibitive practices.

Next Steps

The Bunker Hill Housing Redevelopment is a decade-long project that will deliver best in class, sustainably sound residential buildings to the Charlestown community, and a major aspect of that sustainability is the use of CLT in the buildings. As it stands now with the project moving forward, our immediate next steps are:

- Continued demolition and building permits issued for Building M
- Abatement & Demolition of Phase 1 existing buildings is underway.
- Builders Risk policy is bound with a Premium akin to Type 1 Construction.

In the longer term, we intend to pursue the following efforts:

- Solve Concealed Space Code Issue
- Lobby for lifecycle carbon emissions incentives with focus on material inputs.

Program Impact

The Mass Timber accelerator benefitted the BHHR in many ways, primarily as a reinforcement for the team at Bunker Hill Housing. Due to the cost implications of CLT compared to wood stick construction, the option to advance traditional wood stick construction has often been suggested as a way to reduce costs of Building M in the currently challenging economic climate. However, the team is committed to CLT both from a sustainability perspective and given the likely cost savings that CLT will provide compared to structural steel in the project’s high-rise buildings (all but 3 of the 15 buildings).

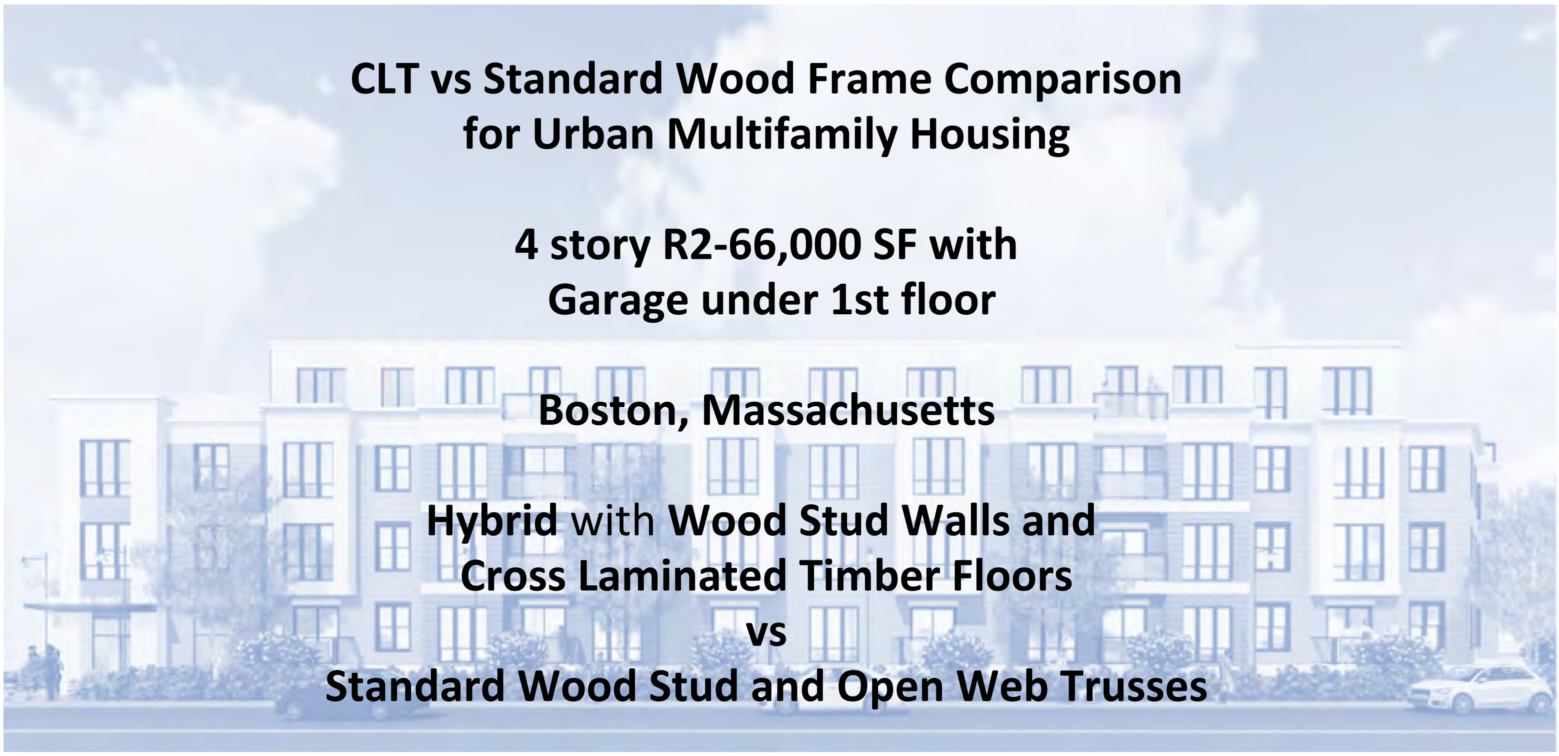
Attending the working sessions at the BSA provided a space for the team to share problems with others who were more knowledgeable of the issues faced by the team. The cross sharing of ideas among program participants will allow for the process for future buildings to be streamlined.

Some areas that the accelerator could improve:

- Provide more resources for technical detailing, particularly for teams who have moved beyond the schematic design phase;
- Increase the availability of experts from organizations like Woodworks and U.S Forest Service; and
- Increase opportunities for interactions among participants.

Boston Mass Timber Accelerator

SHAWMUT TOD - CLT Feasibility



Fast + Epp

ICON ARCHITECTURE

TRINITY FINANCIAL

MWB Construction Advisors

ICON ARCHITECTURE

Shawmut Station - Trinity

Figure 1

Figure 2.
Plan View

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Figures and Tables

I: Introduction

The overall goal of this project is to maximize the efficient use of CLT to make it cost competitive with light frame wood construction for 4 to 6 story buildings.

In the Northeast, 35% of all housing is multifamily (Urban Institute) which is higher than the National average of 31.4%(NAHB). 50% of all multifamily buildings in the Northeast are 4 stories and above (POYRY for NEFF). The share of multifamily housing that is wood stood at about 65% in 2017((POYRY for NEFF). All this points to growth and opportunity for wood construction of multifamily housing, especially for CLT in the Northeast and other parts of the United States in urban and suburban areas.

For the reasons above, we want to concentrate on CLT for 4 to 6 story multifamily housing. Shawmut TOD (transit-oriented development) will be a multifamily building; 4 stories, 66,000 SF, 74 dwelling units with a mix of studio, 1-bedroom, 2-bedroom and 3-bedroom units. There will be a parking garage below the 1st floor.

Model codes have allowed 4 story light frame wood (LFW) construction for many years. Since 2012, IBC codes allow 4 or 5 story LFW above one- or two-story non-combustible podiums. CLT has gathered recognition by governing codes since 2018 and is further expanded in the 2021 IBC to include new Type IV Mass Timber, aka Tall Wood, up to 18 stories.

While Tall Wood is a great new opportunity, the bulk of multifamily housing will be in the 4 to 6 story range as it is more suited to urban areas outside the city center as well as suburban areas. For this reason, we are looking at the use of CLT in 4 to 6 story multifamily buildings. While this building type using LFW is not unique, the purpose of our research is to explore the viability of CLT used for floors in the 4 to 6 story buildings. As such, we have designed a 4 story wood stud bearing wall/CLT floor structure (Hybrid) and compared it to a 4 story wood stud bearing wall building using open web trusses(LFW). The latter is a building type seen in construction throughout Boston and its suburbs.

The major issue controlling the use of CLT is span length. Generally, strength and deflection criteria can be met with 5 ply- 6 7/8” planks for spans up to 26’. However, vibration, even though it is not a code requirement, will govern the span length, thickness and grade of the CLT planks. Our study found that for 26’ spans, 7 ply 9 5/8” planks are required to meet vibration criteria.

For the cost comparison of framing systems alone, CLT is considerably more than LFW. However, when other cost savings for other trades are taken into account plus the savings in overall project duration, the differential narrows to between 2.5% and 5% more costly than LFW. This does not take into account possible savings in financing and other soft costs because of a shorter overall duration. This can narrow the gap even further.

We are hopeful that increased manufacturing volume and efficiency can lower the overall cost of CLT so that it is on par with the cost of LFW.

Boston Mass Timber Accelerator
Shawmut TOD

Summary Objectives:

The purposes of the project to evaluate Shawmut TOD as 4 story multifamily are:

I. Create a design that is repeatable on other projects.

II. Determine the financial viability of using CLT in hybrid construction as compared to standard light frame wood.

III. Determine Carbon Sequestration comparing standard LFW and CLT Hybrid

II. Design considerations

i. Layout of CLT planks and gravity load elements.

A primary design consideration determining the choice of span direction was flexibility of interior apartment layout. Accordingly, we chose to run the planks in a staggered layout in the transverse direction from exterior wall to corridor wall. (Fig. 5) There have been recent CLT hybrid projects that have been framed in the longitudinal direction, 90 degrees from this project's plank orientation. This direction is used to reduce the span of the planks thus obviating issues with respect to vibration and potentially using 5 ply planks. It was our view that this limits layout flexibility of unit demising walls. Interior apartment walls that would otherwise be non-bearing are needed as bearing elements. This engenders difficulty developing a consistent gravity load path as well as code required offset restrictions for lateral force resisting systems and the need to drag forces to lateral elements.

Often, as designs are developed, layout of apartments change due to architectural choices and reconfiguration of the unit mix by the owner. This can cause repeated revisions of the structural design which can be costly and cause delays. A design in which the planks clear span I the transverse direction can obviate repeated re-design. Furthermore, a less complicated and repetitive layout will lead to greater efficiency during erection which leads to cost savings.

ii. Structural.

The major thrust of the design was to maximize the long span capabilities of CLT. Most multifamily projects consist of double loaded corridors. The typical depth of a dwelling unit is between 26' and 28' from exterior wall to corridor wall. In the case of Shawmut TOD, there is a one-story garage under the 1st floor. The framing above and its load path had to accommodate parking dimensions. The team settled on a 58' dimension from outside face of exterior to the opposite exterior wall (Fig. 2). Therefore, the team chose a bearing direction of the CLT planks from exterior wall to corridor wall in the building transverse direction. This transfers at the first-floor level using steel girders and beams as the loads are too great to be carried by Glulam beams (See Figure 3). The first floor, uses CLT planks in lieu of a concrete slab on metal deck. (See Fig. 3)

ii. Design Considerations (cont.)

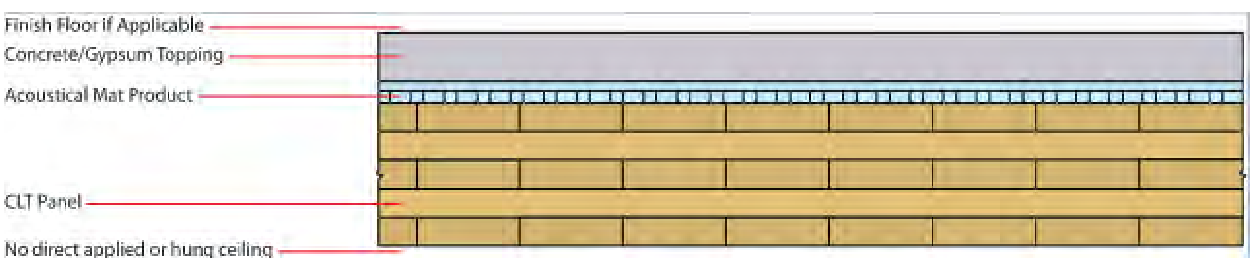
ii. Structural (cont.)

Multiple structural models were created to determine both the strength and deflection characteristics of the CLT spans (Fig. 5 and 6). Rather than use manufacturer's span tables, we calculated the expected moment and deflection for various configurations using PRG-320-2019. Given the 26' span, it is possible to use 5 ply 6 7/8" (175 mm) E1 with respect to strength and deflection.

iii. Sound transmittance

CLT floors do present challenges with respect to sound transmittance. Traditional open web trusses have the advantage of deep air space that increases resistance to sound transmission (STC). In the case of Shawmut TOD, the team chose to use a floor assembly using 1 ½ inches of gypsum concrete floor topping with a 3/8" acoustical under-mat. With respect to IIC, LVT flooring will provide the required rating.

STC ratings were taken from Reference; WoodWorks Acoustically-Tested Mass Timber Assemblies, Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed. The chosen assembly shown below provides an STC of 50 which meets code.



iv. Vibration

Vibration limits are not a code required parameter. However, occupant comfort and tolerance are important considerations for design. Occupant sensitivity is subjective, but dynamic response in the form of large displacements or accelerations under a given dynamic load case may make a structure uncomfortable or even compromise strength and stability. As such, design guidelines exist that provide guidance for typical occupant sensitivity to structural vibrations. (See Woodworks U.S Mass Timber Floor Vibration Design Guide)

CLT floors are lightweight with relatively low stiffness when compared to steel or concrete. Material weight and stiffness are key factors that determine how a structure will function in a dynamic load case, such as walking. The cadence of normal walking pace is between 1 and 2 Hz, corresponding to a footfall every 1 to 2 seconds. (Fig.7) Resonant response (or resonance) occurs when the applied loading is likely to coincide with the natural frequency of the supporting structure– this is said to be the response that causes most vibration serviceability problems related to human comfort.

The CLT floor structure at Shawmut TOD is relatively light floor, approximately 22.3 psf with another 20 psf of additional mass provided by the topping. As a result the natural frequency of the system is low and is sensitive to normal footfall due to resonance (see Fig 9.).

Figure 9 shows 3 damping conditions for 2%, 3% and 5% critical damping. One of the major variables in determining the building response to footfall excitation is the amount of damping provided by building elements other than the floors. Elements such as walls, furnishings and finishes provide damping. Fast and Epp built a model of the floor to determine the maximum response using a 5% damped condition, with spring models at partition walls to include the damping effect of partitions. While 5% damping is often used as an upper bound, it is possible that these elements provide a greater amount of damping. We did not go beyond 5% as a greater amount of damping will need to be proved by full scale mockups.

Based on the dynamic analysis model provided by Fast+Epp, a 5 ply 175 mm (6 7/8”) E1 plank will meet strength and deflection requirements, however given the 2 span condition, 5 ply planks were found to be beyond the guidelines for vibration comfort. Modeling found that given the 26’ span, we would need a 7 ply CLT E1. This could be either 7 ½ “ (191mm) or 9 5/8” (245mm). It was determined from feedback from manufacturers that 191mm was not a product that they were setup to produce readily and therefore would be more expensive.

It was found that given the 2 span 7 ply E1 layout that vibration excitation in one dwelling unit did not carry into adjacent units or from the corridor into dwelling units. (Fig.10). Therefore pricing was done using 7 ply CLT planks on floors 2,3 and 4 (see Scheme 1 below) . An alternate for 5 ply CLT was also priced. (See Scheme 2 below)

III. Cost

An estimate of the cost of the project was calculated comparing LFW and CLT Hybrid using 3 models:

- CLT Hybrid *Scheme 1* with:
  - 2x6 bearing walls at the exterior with ½" OSB sheathing
  - 2x6 bearing walls at the corridor
  - 2x4 shear walls sheathed with ½" OSB
  - 7 ply - 245mm EI CLT at 2nd, 3rd,4th floors
  - 5 ply -175mm V2 at the 1st floor over the garage
  - 5 ply – 175mm E1 at the roof.
- CLT Hybrid *Scheme 2* with:
  - 2x6 bearing walls at the exterior and corridor
  - 2x4 shear walls
  - 5 ply - 175mm EI CLT at 2nd, 3rd,4th floors
  - 5 ply -175mm V2 at the 1st floor over the garage
  - 5 ply – 175mm E1 at the roof.
- LFW:
  - 2x6 bearing walls at the exterior with ½" OSB sheathing
  - 2x6 bearing walls as the corridor
  - 2x4 shear walls sheathed with ½" OSB
  - 2x4 open web floor trussed with ¾ T&G Advantech sheathing.

The cost of the project was estimated using a full quantity take-off based on conceptual plans and unit layouts. Current pricing for the following trade items were provided by regional subcontractors:

- Concrete
- Wood Framing
- Steel
- Cementitious floor topping
- Roofing
- Metal Stud and Gypsum Board Assemblies
- Finish Carpentry
- Doors and Windows
- Plumbing
- HVAC
- Electrical
- Other items were priced based on unit price allowances based on recent data.

III. Cost (cont.)

Cost Parameters and Basis of the Estimate.

- All structural walls including shear walls are 2x6 wood stud walls.
- All non-bearing walls are 25ga metal studs.
- All demising walls are double stud walls for sound transmittance purposes.
- Floor Framing spans from exterior wall to corridor wall.
- Earthwork assumes spoils are typical urban fill. (RCS-1)
- Earthwork contractor employs union labor.
- Structural Carpentry Labor Rates are Boston Union Residential Rate.
- Trades allied with Carpenters' Union such as drywall, flooring and glazing use a blended commercial/residential rate.
- All other trades are open shop.
- Finishes are mid-priced.
    - Galley Kitchens/Laminate Counters
    - Ceramic tile bath floors and tub surrounds
    - LVT flooring in apartments
- 5% Contingency of Total Construction Cost included.

Pricing was done with full quantity take-offs for all trades with quotes or unit prices from subcontractors in all trades

The CLT was priced by Element 5. This included design assist, shop drawings, hardware allowance and transportation.

It should be noted that prices in the current market are volatile and this is a snapshot of current conditions.

III. Cost (cont.)

Savings line items for Shawmut TOD using CLT vs LFW (For a full tabulated cost comparison for items affected by using CLT in lieu of LFW see Table 1 and Table 2)

- **Concrete on metal deck over the garage eliminated.**
- **CMU Elevator and Stair shafts eliminated.**
- **Reduction in Structural Steel at the 1st floor over the garage due to lower weight o CLT.**
- **Reduced steel requires less fireproofing.**
- **Shorter building allowing:**
    - **Reduction of insulation and air barrier.**
    - **Reduced area of exterior cladding.**
- **Elimination of spray foam insulation under deck in garage.**
- **Elimination of acoustical ceiling in the garage. CLT remains exposed.**
- **Reduction in ceiling gypsum board and painting of same.**
- **Elimination of sprinkler head in interstitial spaces of open web floor trusses.**
- **Reduction in General Conditions due to faster erection of structure.**
- **Reduction in project finance cost due to shorter duration. (not included in pricing)**
- **Reduction of weather-related delays for concrete and CMU not used with CLT (not included in pricing)**

Increased cost items for Shawmut TOD using CLT vs LFW

- **Structural frame. Primarily due to large volume of wood for CLT. This is offset partially by the decrease in labor cost.**
- **Increase thickness of gypsum underlayment to achieve required STC 50.**

Highlights of the pricing comparison are:

1. Use of CLT for 1st floor framing over the garage in lieu of concrete reduced cost by $200,000. It also displaced a significant volume of a carbon intensive material. One other advantage is that CLT is not as weather sensitive as concrete. Concrete slabs in particular are vulnerable to freezing in cold weather. The cost of freeze protection and increased duration due to cold weather delays for concrete pours was not included in the pricing but is an important consideration and should always be kept in mind.
2. Steel framing of the garage floor was reduced by 35% from 55 tons to 35 tons by using CLT at the 1ST floor. This also allowed reduction in spray fireproofing.
3. Ceilings in Living/Dining and Bedrooms are exposed using CLT thus eliminating gypsum board on ceilings. There are additional savings eliminating paint on the LR/DR and BR ceilings.

III. Cost (cont.)

4. CLT on the 1st floor exposed in the garage eliminated the use of an acoustical ceiling and insulation under the floor.
5. CLT stair and elevator shafts eliminate CMU shafts which decreases cost and project duration. CLT shafts can be erected in 2-3 days whereas CMU shafts require 10 -12 days and are weather sensitive which can increase cost and duration.
6. Trucking costs for CLT are currently a significant portion of cost. For CLT it currently constitutes 25% of the cost of the material.
7. The overall height of the building using CLT is reduced by 4’ plus. This results in a savings in framing and cladding. It may also be an advantage for municipal and community approvals.
8. For Light Frame wood vs. CLT Hybrid, the cost of CLT on a structural system only basis is 115% greater for Scheme 1 CLT and 80% greater for Scheme 2 CLT. However, when reductions in other line items are included, the difference in cost between LFW and CLT Hybrid is approximately 2.5 -5 %.

IV. Carbon Calculation

Carbon calculations were run using the WoodWorks Carbon Calculator. Volumes of wood material were taken directly from the Bill of Materials report from the structural model. The Calculator does not take into account the CO2 emitted by the production of concrete used on the 1st floor slab on metal deck in the LFW model. Concrete production emits 400 lbs of CO2 per cubic yard of concrete. Given a 5 ½” slab on 3” metal deck, the 1st floor slab at Shawmut TOD uses 215 cy of concrete. This represents 86,000 lbs of CO2 emitted which equals 39,100 Kg-CO2. Accordingly, the amount of carbon stored in wood in the LFW model has been reduced by that amount.

CLT Quantities

							Scheme 1			Scheme 2		
		m²	mm	m³		ft²/m²	ft²	in	ft³		in	ft³
Flr 2-4	7 ply	4,352	0.245	1066.2		10.76	46,844	9.63	37,573	As 5 ply	6.875	26,838
Roof	7 ply	1,689	0.245	413.81		10.76	18,180	9.63	14,582	As 5 ply	6.875	10,416
Stair Shaft	5 ply	175	0.175	30.625		10.76	1,884	6.88	1,079	5 ply	6.875	1,079
Elev/Stair Shaft	5 ply	337	0.175	58.975		10.76	3,627	6.88	2,078	5 ply	6.875	2,078
Subtotal							**70,536**		**55,313**			40,411

Garage	ft3	wt-lbs
5 ply CLT	9,689	
Glulam	772	
Steel		71000

Walls	ft3	
Interior bearing-258 cf/floor	1,187	From VA- 258CF per floor plus 15% waste etc
Ext Walls 2x6	1,710	10' high x 750 lf of wall at 1 stud/lf x .057 cf/lf x 4 floors
Shear walls 2x6	1,029	12' high x 376lf of wall at 1 stud/lf x .057 cf/lf x 4 floors
Wall sheathing	1,313	1/2"

Floors	ft3
Wood Truss floor	

Wood Truss floor	12,250	305 cf per 1480 sf= .2 cf/sf
2 x 8 at corridor	331	8 cf/1480 sf = .0054 cf/sf
Floor Sheating	3,828	3/4 " Advantech
CLT Floor Scheme 1	55,313	
CLT Floor Scheme 2	40,411	

Carbon calculations were run for all three cost models, LFW, CLT -Hybrid 7 ply (Scheme 1), CLT-Hybrid 5 ply (Scheme 2):

	Unit	LFW	CLT/Hybrid Scheme 1	CLT/Hybrid Scheme 2
Volume of wood products used:	m^3	613	1715	1293
U.S. and Canadian forests grow this much wood in:	minutes	2	5	4
Carbon stored in the wood: *	Kg-CO_2	468,900	1,388,000	1,047,000
Avoided greenhouse gas emissions:	Kg-CO_2	1,079,000	2,950,000	2,226,000
Total potential carbon benefit:	Kg-CO_2	1,587,000	4,338,000	3,273,000
Cars off the road per year	Cars	335	917	692
Equivalent Homes operated per year	Homes	168	458	346

*Stored carbon reduced by 39,100 Kg-CO_2 for concrete slab at 1^{st} floor.

Stored carbon is 296% greater than LFW for 7 ply Scheme 1

Stored carbon is 224% greater than LFW for 5 ply Scheme 2.

V. Conclusion

The next step is to build Shawmut TOD. It is clear that at this point that CLT for midrise structures is more expensive than standard LFW. However, when the advantages of CLT that accrue to the project beyond the structure itself are included, the price differential is within a reasonable range of 2.5% to 5% greater than LFW.

There are also less tangible cost items such as avoidance of weather delays and reduction of time sensitive soft cost and finance costs that can only be realized once CLT/Mass Timber becomes more widely adopted. It is the authors' opinion that additional savings can be realized in MEPFP systems as CLT flat slabs will make installation of these systems faster once those trades have experience with CLT/Mass Timber.

Further study and introduction of prefabrication of exterior walls with elements such as windows, weatherproofing and cladding, could reduce costs and project duration even further.

The report shows significant reduction in cost if 5 ply 175 mm planks can be used. At present, calculations for vibration show that 5 ply planks are beyond accepted limits for vibration. Since manufacturing and transportation limitations preclude the use of 3 span planks, a method of end joining the planks is a possible solution to provide a 3 span condition. There is a current technology called TS3 https://www.ts3.biz/en/technologien/ that could enable the 3 span condition thus saving considerable cost. It is currently under approval for use in the U.S.

Vibration comfort is a subjective criterion. The use of 5ply CLT would make the CLT Hybrid model in the transverse configuration more cost competitive with LFW. Calculations show that the 3-span condition 5 ply system remains above published vibration limits. However, residential use has aspects that can reduce vibrations. It is possible that partitions and other items such as furniture and fixtures in residential construction may add more damping than currently accounted for. A full-scale mockup with 3 floors of a typical apartment layout is suggested as a next step to prove this system.

CLT has clear advantages in terms of carbon sequestration and speed of construction over LFW. It is our hope that the CLT Hybrid system using the layout and design suggested for Shawmut TOD can serve as a template for other projects in New England and beyond.

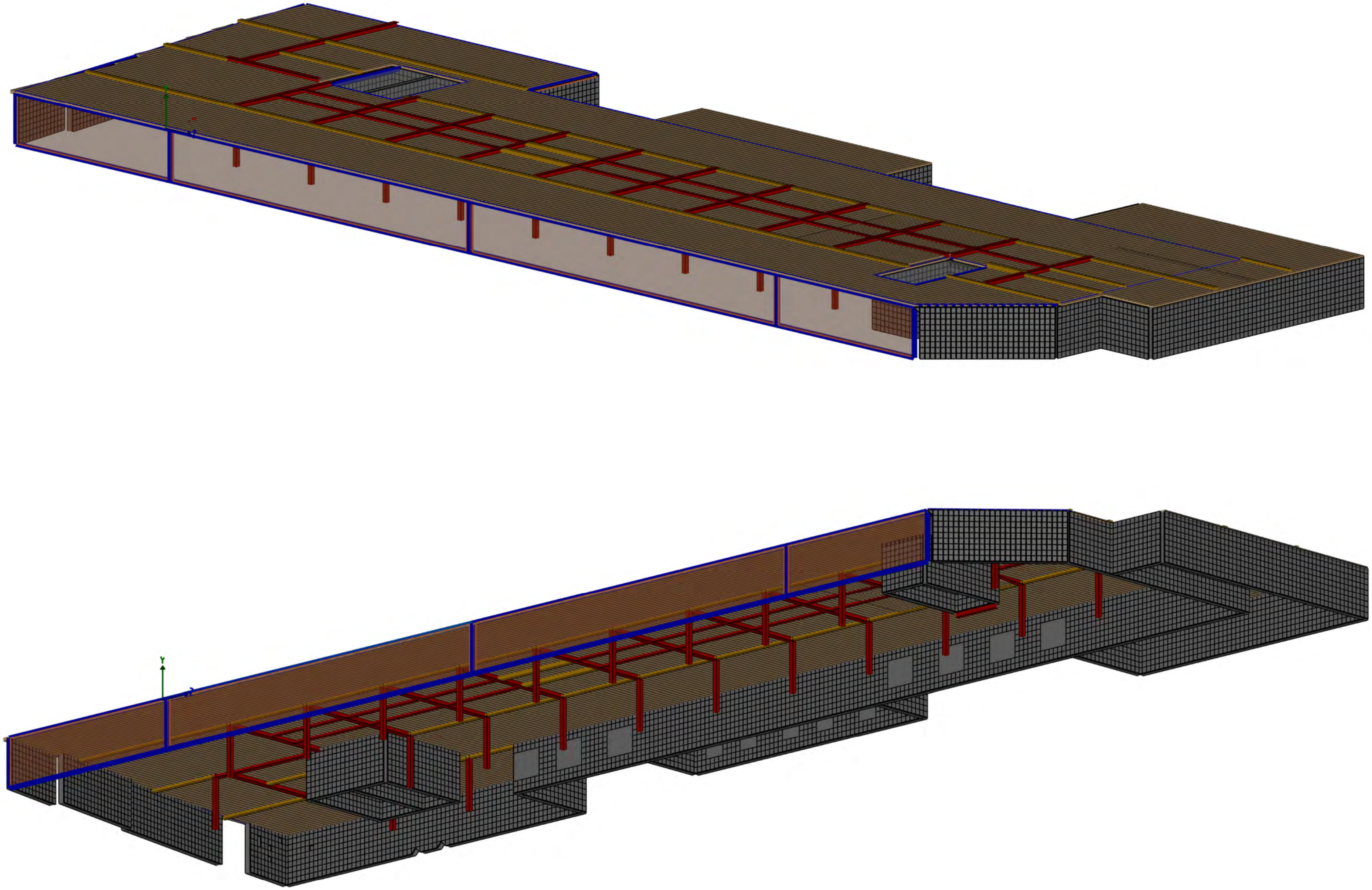


Figure 3
Garage Framing

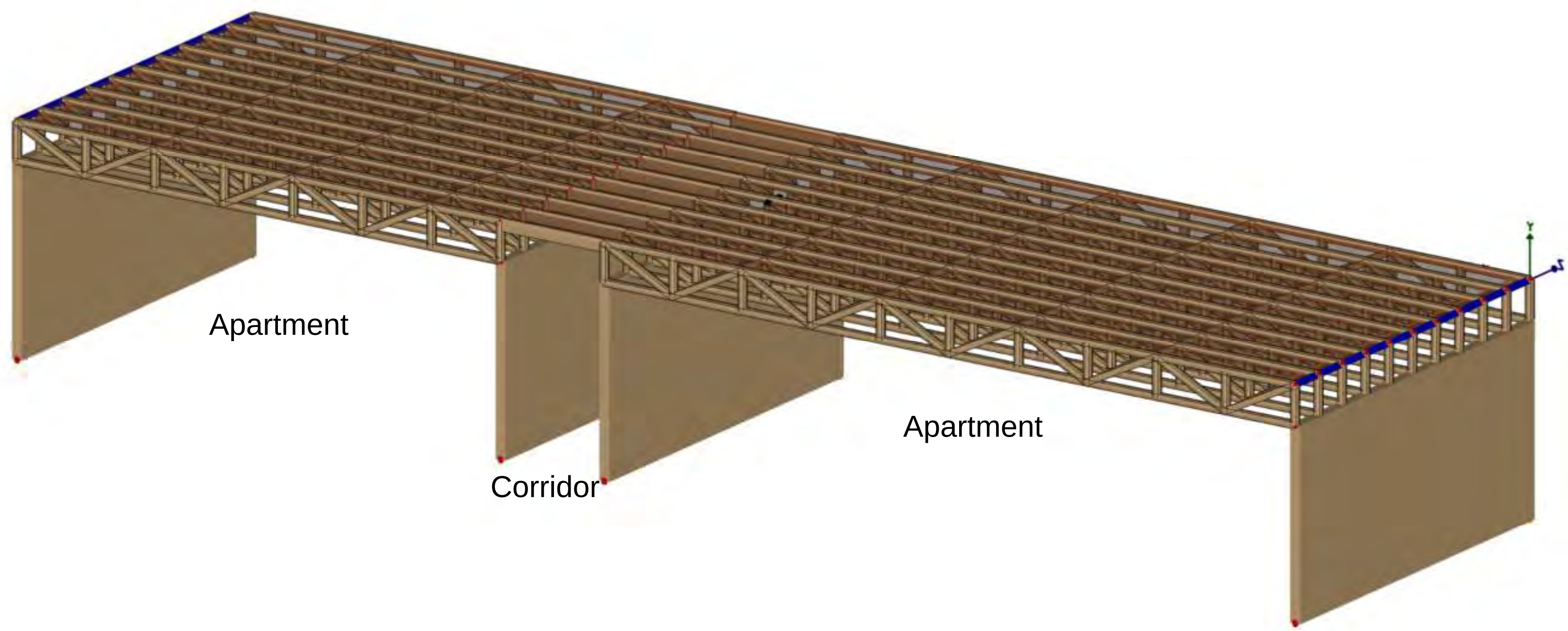
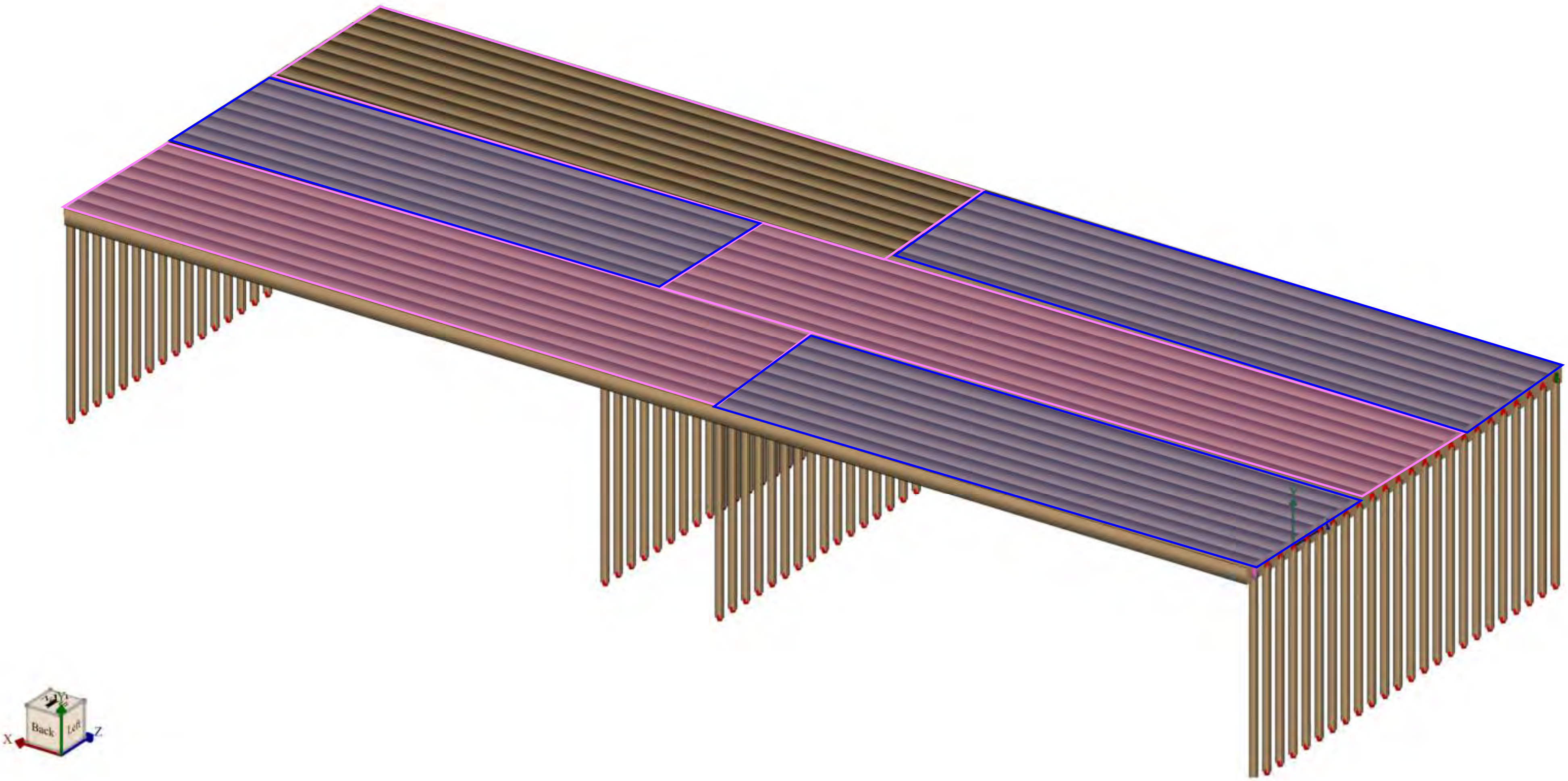
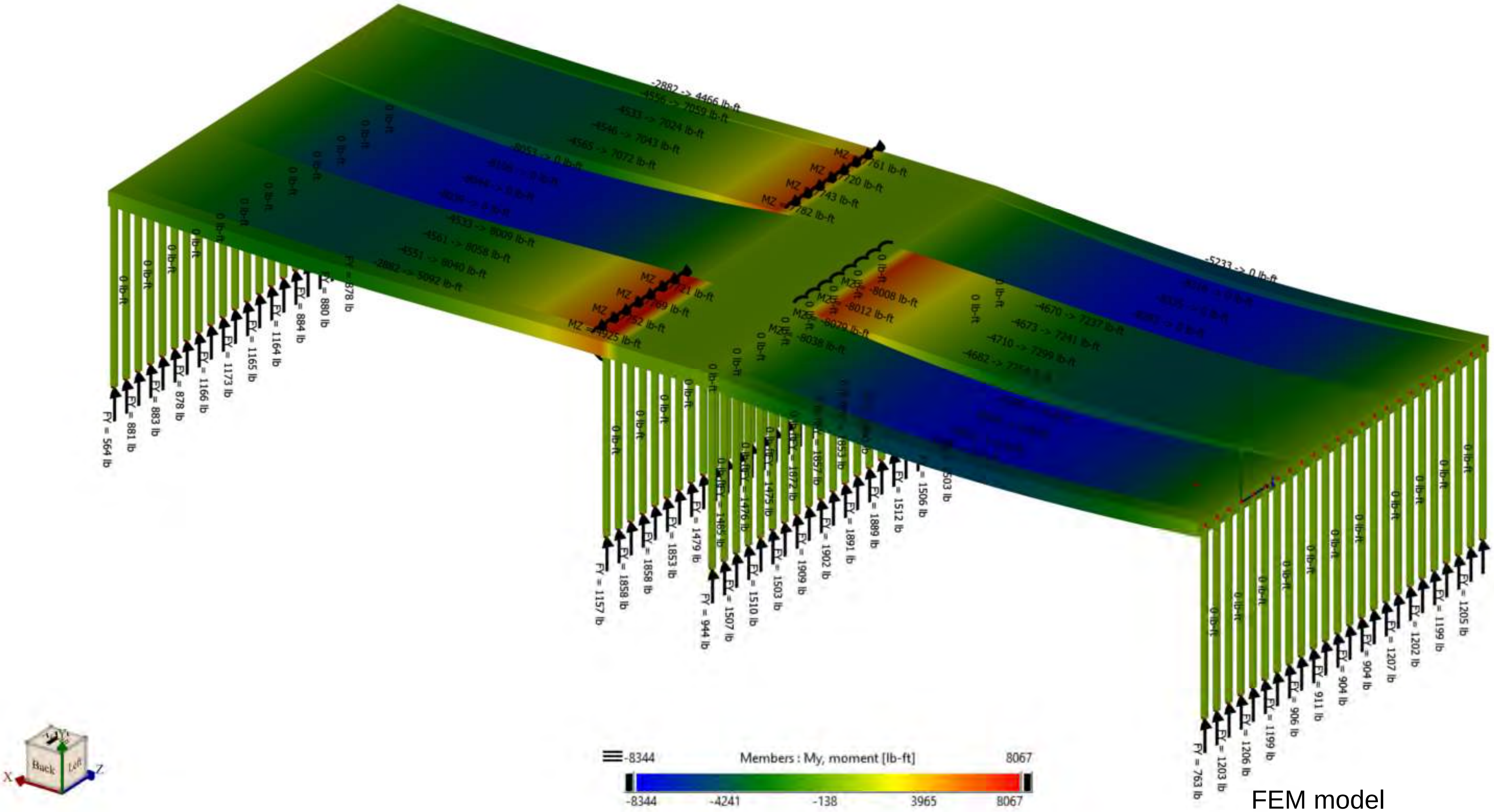


Figure 4
Typical Open
Web Truss
Layout



Shawmut TOD
FEM model
7 ply CLT/ Hybrid bay study

Figure 5
Typical Plank
Framing



FEM model
7 ply E1 CLT/ Hybrid bay
study

Figure 6
Moment Diagram

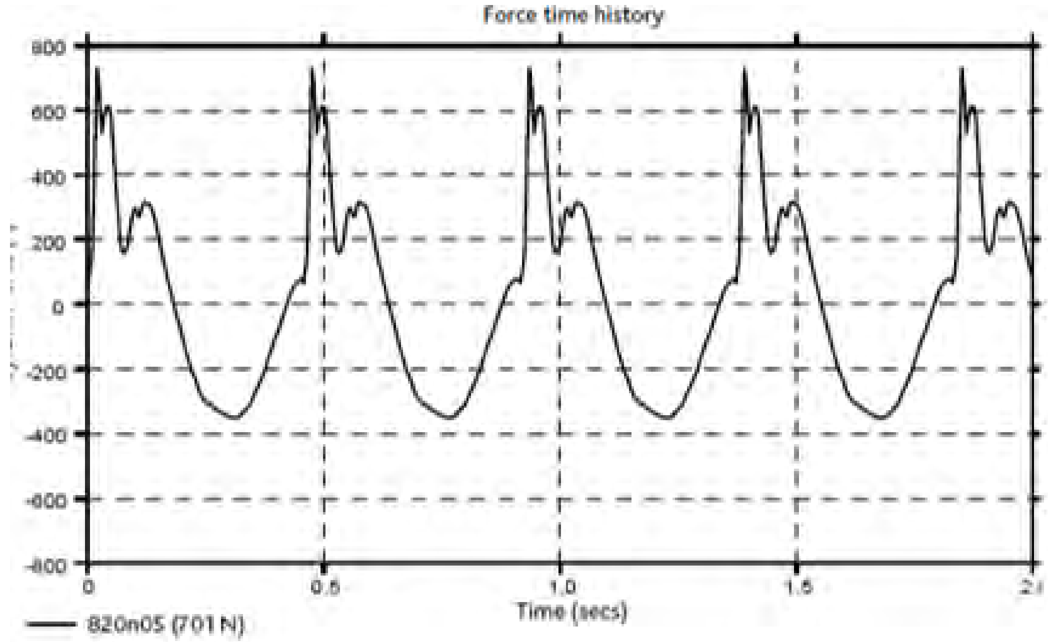


Figure 7
Walking Frequency

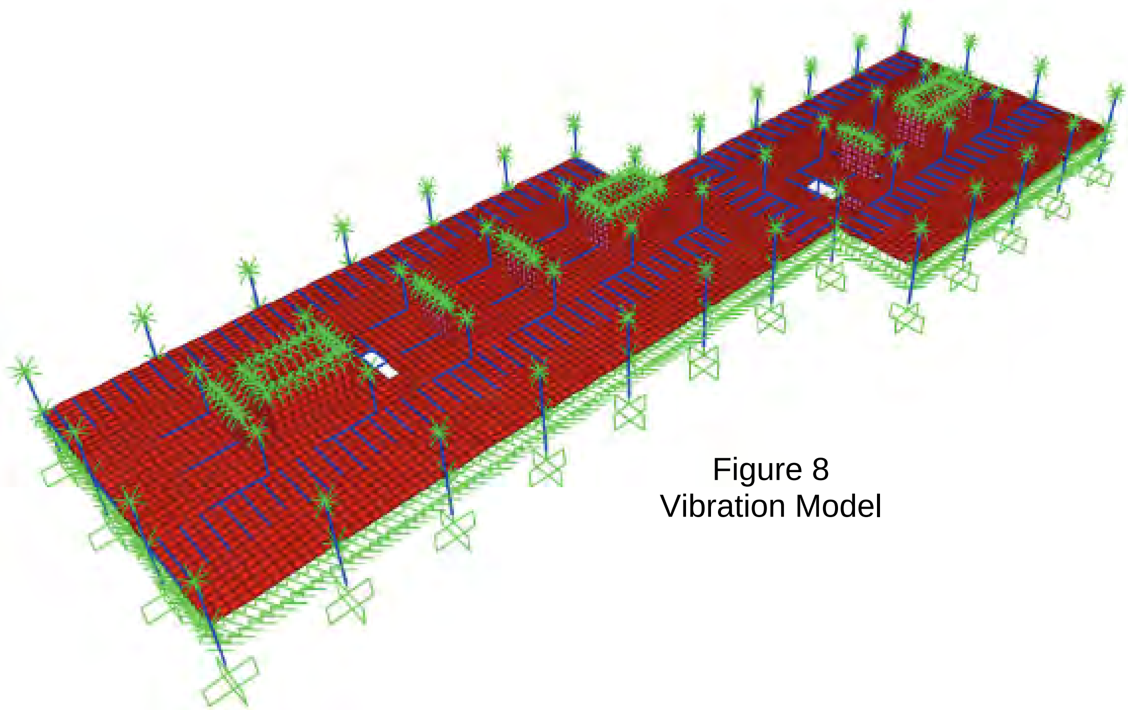


Figure 8
Vibration Model

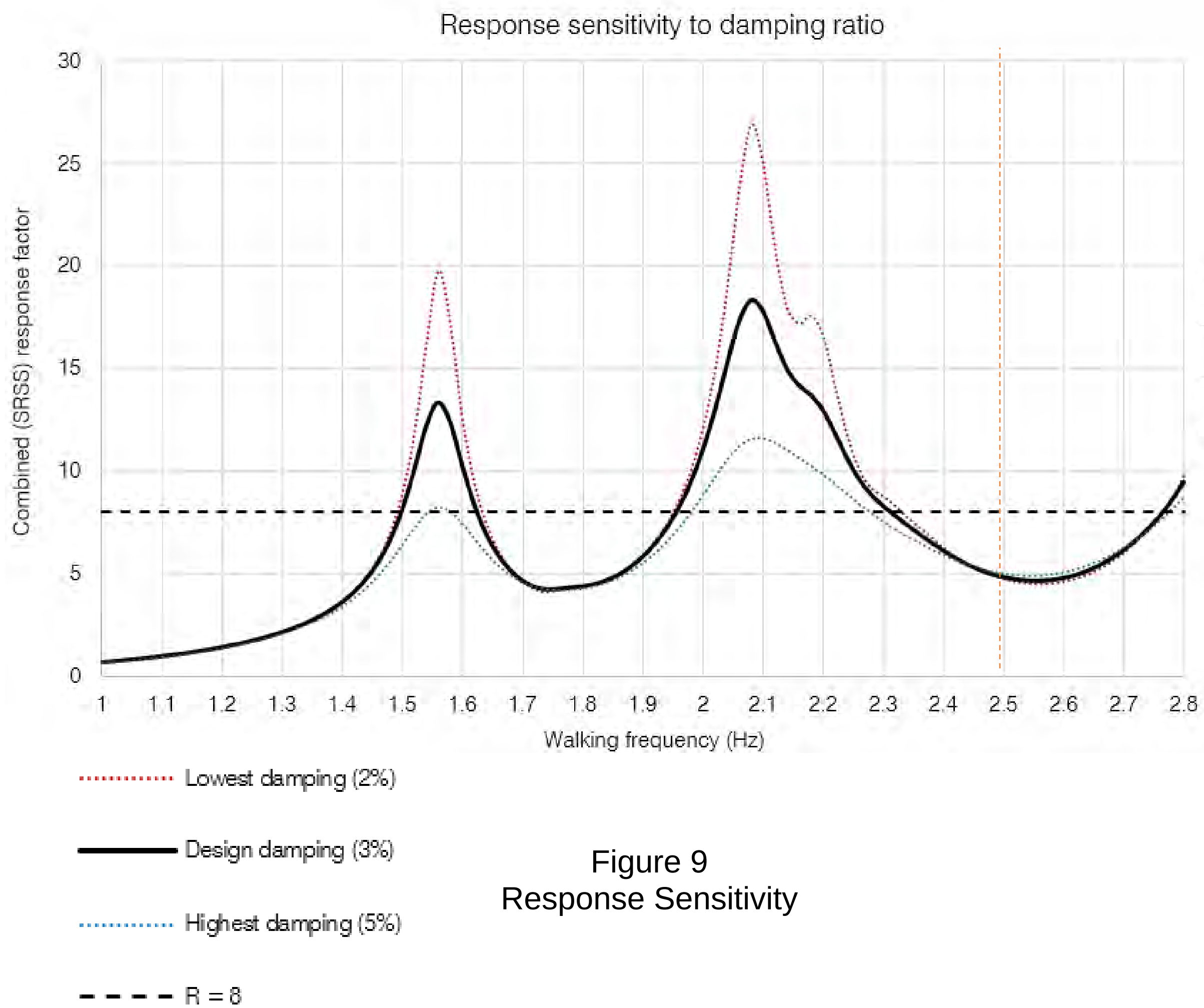


Figure 9
Response Sensitivity

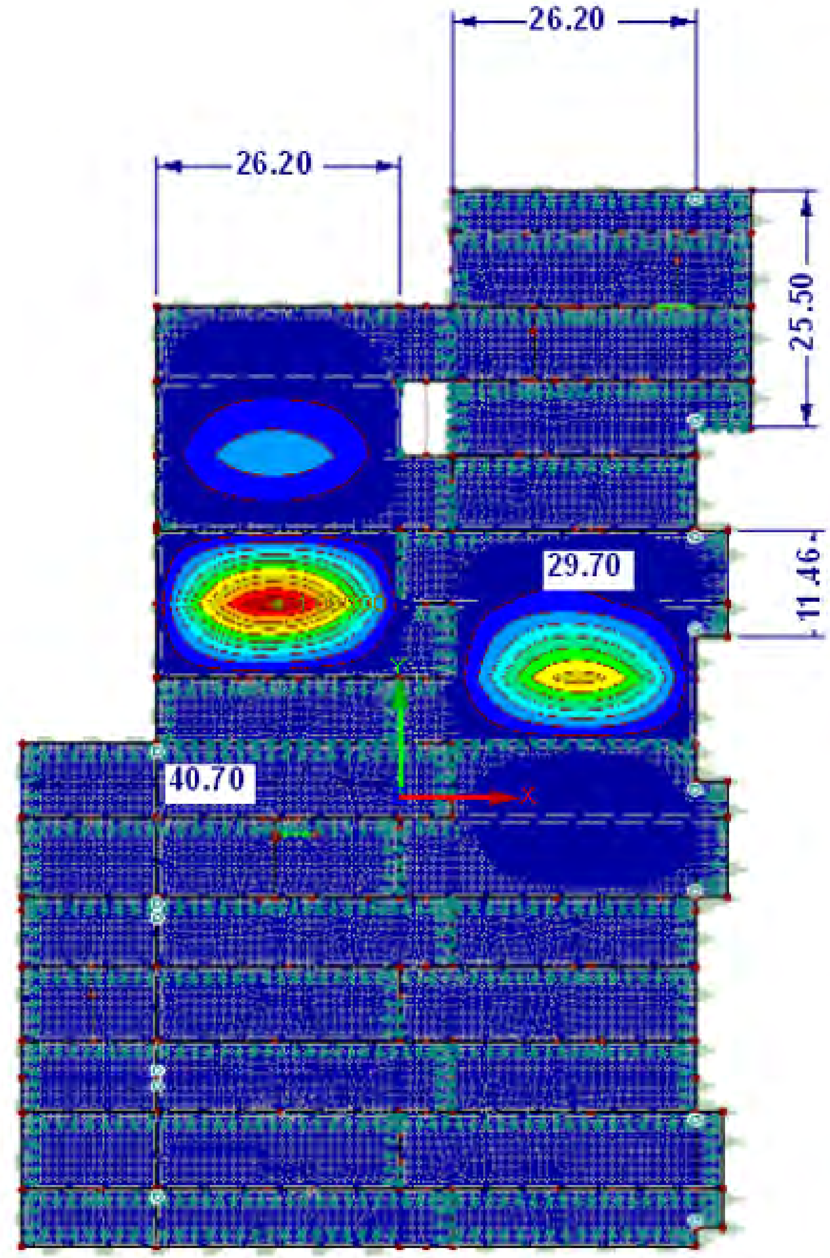


Figure10
Response Sensitivity

Shawmut TOD Schecule of Values Scheme 1

Reductions attributed CLT

Increases attributed CLT

Div	Trade Item	LFW	CLT	Delta	Description	LFW $/DU	LFW $/sf	CLT $/DU	CLT $/sf	% Diff
3	Concrete	$1,366,085	$1,166,085	-$200,000	Foundations and slabs/CLT 1st floor	$18,973	$21	$16,196	$18	-15%
4	Masonry	$189,000	$18,750	-$170,250	Stair and Elev Shafts CMU vs CLT.Inc 75lf of CMU in garage	$2,625	$3	$260	$0	-90%
5	Metals			$0		$0	$0.00	$0	$0.00	
	Structural Steel	$387,000	$287,000	-$100,000	Garage Steel	$5,375	$6	$3,986	$4	-26%
	Misc Metals	$20,000	$20,000	$0		$278	$0.30	$278	$0.30	0%
6	Rough Carpentry					$0	$0.00	$0	$0.00	
	Structural Frame	$1,945,440	$4,079,156	$2,133,716	**LFW-1st floor as concrete;CLT 1st floor as CLT**	$27,020	$29.25	$56,655	$61.34	110%
	Misc Rgh Carpentry	$40,000	$40,000	$0		$556	$0.60	$556	$0.60	0%
6	Finish Carpentry	$328,964	$328,964	$0	sills, install cabinets/doors/specialties	$4,569	$4.95	$4,569	$4.95	0%
7	Waterproofing	$101,081	$101,081	$0	caulking, misc	$1,404	$1.52	$1,404	$1.52	0%
7	Insulation		$0	$0		$0	$0.00	$0	$0.00	
	SPFM in Walls- 5 1/2"	$148,649	$133,784	-$14,865		$2,065	$2	$1,858	$2	-10%
	Exterior Rigid EPS 1.5" on walls	$123,874	$111,486	-$12,387		$1,720	$2	$1,548	$2	-10%
	SPFM garage ceiling	$79,772	$0	-$79,772		$1,108	$1	$0	$0	-100%
	1" Rigid Insulation on CLT over garage			$0	included in gypsum underlayment	$0	$0.00	$0	$0.00	
	Steel Fireproofing	$22,928	$16,049	-$6,878		$318	$0	$223	$0	-30%
7	Roofing	$322,695	$322,695	$0		$4,482	$4.85	$4,482	$4.85	0%
7	Sheet Metal and Flashing	$3,000	$3,000	$0	Gutters & Downspouts	$42	$0.05	$42	$0.05	0%
7	Exterior Siding	$1,002,880	$888,320	-$114,560	CLT lower bllg ht by 4'	$13,929	$15	$12,338	$13	-11%
8	Doors	$384,769	$384,769	$0	includes frames and hardware	$5,344	$5.79	$5,344	$5.79	0%
8	Windows	$379,797	$379,797	$0	Fiberglass windows	$5,275	$5.71	$5,275	$5.71	0%
8	Glass	$25,000	$25,000	$0	Storefronts and entries	$347	$0.38	$347	$0.38	0%
9	Lath & Plaster			$0		$0	$0.00	$0	$0.00	
9	Drywall	$1,869,099	$1,710,039	-$159,060	Includes metal studs, tape & finish	$25,960	$28	$23,751	$26	-9%
9	Tile Work	$301,399	$301,399	$0	Tile Bath Floors inc Water proofing @ $30/sf. Tub surround 6'high, 3x5 subway tile. Tile in Lobby/Amenity @$25/sf installed	$4,186	$4.53	$4,186	$4.53	0%
9	Acoustical Ceiling	$113,750		-$113,750	2x2 ceiling in garage	$1,580	$2	$0	$0	-100%
9	Acoustical Underlayment			$0				$0	$0.00	
	Gypsum U/L w mat at floors 2,3,4	$113,419	$201,246	$87,827				$2,795	$3.03	$1
	Gypsum U/L 1st floor over garage		$48,749	$48,749	3/4 gypcrete vs 2" plus 2" rigid at 1st floor	$1,575	$2	$677	$0.73	
9	Wood Flooring			$0		$0	$0.00	$0	$0.00	
9	Resilient Flooring	$248,120	$248,120	$0		$3,446	$3.73	$3,446	$3.73	0%
9	Carpet	$35,320	$35,320	$0	Corridors-Carpet @ $ 5.00 sf	$491	$0.53	$491	$0.53	0%
9	Paint & Decorating	$304,556	$274,402	-$30,153	All walls, ceilings, trim, exteriors	$4,230	$5	$3,811	$4	-10%
10	Specialties	$58,700	$58,700	$0	Toilet accessories, mailboxes, etc	$815	$0.88	$815	$0.88	0%
11	Special Equipment	$30,000	$30,000	$0	Trash Eq	$417	$0.45	$417	$0.45	0%
11	Cabinets	$387,200	$387,200	$0	Kitchen cabinets, vanities. Granite tops@ $40/sf	$5,378	$5.82	$5,378	$5.82	0%
11	Appliances	$320,400	$320,400	$0	Dwelling unit inc Ref, DW,Range,W/D	$4,450	$4.82	$4,450	$4.82	0%
12	Blinds & Shades	$45,045	$45,045	$0	at all residential windows	$626	$0.68	$626	$0.68	0%
13	Modular/Manufactured			$0		$0	$0.00	$0	$0.00	
13	Special Construction			$0	SOE	$0	$0.00	$0	$0.00	
14	Elevators or Conveying Syst.	$307,560	$307,560	$0		$4,272	$4.62	$4,272	$4.62	0%
15	Plumbing & Hot Water	$1,788,750	$1,788,750	$0		$24,844	$26.90	$24,844	$26.90	0%
15	Heat & Ventilation	$1,176,000	$1,176,000	$0	VRF. includes energy recovery, MUA system	$16,333	$17.68	$16,333	$17.68	0%
15	Air Conditioning			$0	in H&V	$0	$0.00	$0	$0.00	
15	Fire Protection	$399,000	$339,150	-$59,850	100% coverage per code. CLT elimnates heads abo	$5,542	$6	$4,710	$5	-15%
16	Electrical	$2,304,000	$2,304,000	$0	Includes fixtures and fire alarm	$32,000	$34.65	$32,000	$34.65	0%
16	Security System	$35,000	$35,000	$0	Allowance	$486	$0.53	$486	$0.53	0%
	Accessory Buildings			$0		$0	$0.00	$0	$0.00	
	Other/misc			$0		$0	$0.00	$0	$0.00	
	Subtotal Structural	$16,708,249	$17,917,016	$1,208,767		$232,059	$251.25	$248,847	$269.43	7.23%
2	Earth Work	$983,390	$983,390	$0		$13,658	$14.79	$13,658	$14.79	0%
2	Site Utilities	$229,540	$229,540	$0		$3,188	$3.45	$3,188	$3.45	0%

2	Roads & Walks	$37,049	$37,049	$0		$515	$0.56	$515	$0.56	0%
2	Site Improvement	$91,850	$91,850	$0	Fencing, walks	$1,276	$1.38	$1,276	$1.38	0%
2	Lawns & Planting	$109,900	$109,900	$0		$1,526	$1.65	$1,526	$1.65	0%
2	Environmental Remediation	$20,000	$20,000	$0		$278	$0.30	$278	$0.30	0%
2	Demolition	$80,000	$80,000	$0		$1,111	$1.20	$1,111	$1.20	0%
2	Unusual Site Cond	$486,000	$486,000	$0	SOE	$6,750	$7.31	$6,750	$7.31	0%
	Subtotal Site Work	*$2,037,729*	*$2,037,729*	$0		$28,302	$30.64	$28,302	$30.64	0%
	Total Improvements	**$18,745,979**	**$19,954,746**	$1,208,767		$260,361	$281.89	$277,149	$300.07	6.45%
1	General Conditions	$1,499,678	$1,439,678	-$60,000		$20,829	$23	$19,996	$22	-4%
	Estimate Contingency	$800,000	$800,000	$0		$11,111	$12.03	$11,111	$12.03	0%
	Subtotal	**$21,045,657**	**$22,194,424**	$1,148,767		$292,301	$316.48	$308,256	$333.75	5.46%
1	Builders Overhead-3%	$631,370	$631,370	$0		$8,769	$9.49	$8,769	$9.49	0%
1	Builders Profit-3%	$631,370	$631,370	$0		$8,769	$9.49	$8,769	$9.49	0%
	TOTAL	**$22,308,396**	**$23,457,164**	**$1,148,767**			**$335.46**	**$325,794**	**$352.74**	**5.15%**
	GC BOND, ADD	$223,084	$234,572	$11,488		$3,098	$3.35	$3,258	$3.53	5.15%
	BUILDING PERMIT FEES, ADD	$187,460	$199,547	$12,088		$2,604	$2.82	$2,771	$3.00	6.45%
				$0						
	Total Construction Cost	**$22,718,940**	**$23,891,283**	**$1,172,342**		**$315,541**	**$342**	**$331,823**	**$359**	
	Total Cost/square foot:	**$341.64**	**$359.27**	**$17.63**						
	Total Cost/dwelling unit	**$315,541**	**$331,823**	**$16,283**						

Percent Increase in cost for CLT **5.16%**

Shawmut TOD Schecule of Values Scheme 2

Reductions attributed CLT
Increases attributed CLT

Div	Trade Item	LFW	CLT	Delta	Description	LFW $/DU	LFW $/sf	CLT $/DU	CLT $/sf	% Diff
3	Concrete	$1,366,085	$1,166,085	-$200,000	Foundations and slabs/CLT 1st floor	$18,973	$21	$16,196	$18	-15%
4	Masonry	$189,000	$18,750	-$170,250	Stair and Elev Shafts CMU vs CLT.Inc 75lf of CMU in garage	$2,625	$3	$260	$0	-90%
5	Metals			$0		$0	$0.00	$0	$0.00	
	Structural Steel	$387,000	$287,000	-$100,000	Garage Steel	$5,375	$6	$3,986	$4	-26%
	Misc Metals	$20,000	$20,000	$0		$278	$0.30	$278	$0.30	0%
6	Rough Carpentry					$0	$0.00	$0	$0.00	
	Structural Frame	$1,945,440	$3,491,666	$1,546,226	**LFW-1st floor as concrete;CLT 1st floor as CLT**	$27,020	$29.25	$48,495	$52.51	79%
	Misc Rgh Carpentry	$40,000	$40,000	$0		$556	$0.60	$556	$0.60	0%
6	Finish Carpentry	$328,964	$328,964	$0	sills, install cabinets/doors/specialties	$4,569	$4.95	$4,569	$4.95	0%
7	Waterproofing	$101,081	$101,081	$0	caulking, misc	$1,404	$1.52	$1,404	$1.52	0%
7	Insulation		$0	$0		$0	$0.00	$0	$0.00	
	SPFM in Walls- 5 1/2"	$148,649	$133,784	-$14,865		$2,065	$2	$1,858	$2	-10%
	Exterior Rigid EPS 1.5" on walls	$123,874	$111,486	-$12,387		$1,720	$2	$1,548	$2	-10%
	SPFM garage ceiling	$79,772	$0	-$79,772		$1,108	$1	$0	$0	-100%
	1" Rigid Insulation on CLT over garage			$0	included in gypsum underlayment	$0	$0.00	$0	$0.00	
	Steel Fireproofing	$22,928	$16,049	-$6,878		$318	$0	$223	$0	-30%
7	Roofing	$322,695	$322,695	$0		$4,482	$4.85	$4,482	$4.85	0%
7	Sheet Metal and Flashing	$3,000	$3,000	$0	Gutters & Downspouts	$42	$0.05	$42	$0.05	0%
7	Exterior Siding	$1,002,880	$888,320	-$114,560	CLT lower bllg ht by 4'	$13,929	$15	$12,338	$13	-11%
8	Doors	$384,769	$384,769	$0	includes frames and hardware	$5,344	$5.79	$5,344	$5.79	0%
8	Windows	$379,797	$379,797	$0	Fiberglass windows	$5,275	$5.71	$5,275	$5.71	0%
8	Glass	$25,000	$25,000	$0	Storefronts and entries	$347	$0.38	$347	$0.38	0%
9	Lath & Plaster			$0		$0	$0.00	$0	$0.00	
9	Drywall	$1,869,099	$1,710,039	-$159,060	Includes metal studs, tape & finish	$25,960	$28	$23,751	$26	-9%
9	Tile Work	$301,399	$301,399	$0	Tile Bath Floors inc Water proofing @ $30/sf. Tub surround 6'high, 3x5 subway tile. Tile in Lobby/Amenity @$25/sf installed	$4,186	$4.53	$4,186	$4.53	0%
9	Acoustical Ceiling	$113,750		-$113,750	2x2 ceiling in garage	$1,580	$2	$0	$0	-100%
9	Acoustical Underlayment			$0				$0	$0.00	
	Gypsum U/L w mat at floors 2,3,4	$113,419	$201,246	$87,827				$2,795	$3.03	$1
	Gypsum U/L 1st floor over garage		$48,749	$48,749	3/4 gypcrete vs 2" plus 2" rigid at 1st floor	$1,575	$2	$677	$0.73	
9	Wood Flooring			$0		$0	$0.00	$0	$0.00	
9	Resilient Flooring	$248,120	$248,120	$0		$3,446	$3.73	$3,446	$3.73	0%
9	Carpet	$35,320	$35,320	$0	Corridors-Carpet @ $ 5.00 sf	$491	$0.53	$491	$0.53	0%
9	Paint & Decorating	$304,556	$274,402	-$30,153	All walls, ceilings, trim, exteriors	$4,230	$5	$3,811	$4	-10%
10	Specialties	$58,700	$58,700	$0	Toilet accessories, mailboxes, etc	$815	$0.88	$815	$0.88	0%
11	Special Equipment	$30,000	$30,000	$0	Trash Eq	$417	$0.45	$417	$0.45	0%
11	Cabinets	$387,200	$387,200	$0	Kitchen cabinets, vanities. Granite tops@ $40/sf	$5,378	$5.82	$5,378	$5.82	0%
11	Appliances	$320,400	$320,400	$0	Dwelling unit inc Ref, DW,Range,W/D	$4,450	$4.82	$4,450	$4.82	0%
12	Blinds & Shades	$45,045	$45,045	$0	at all residential windows	$626	$0.68	$626	$0.68	0%
13	Modular/Manufactured			$0		$0	$0.00	$0	$0.00	
13	Special Construction			$0	SOE	$0	$0.00	$0	$0.00	
14	Elevators or Conveying Syst.	$307,560	$307,560	$0		$4,272	$4.62	$4,272	$4.62	0%
15	Plumbing & Hot Water	$1,788,750	$1,788,750	$0		$24,844	$26.90	$24,844	$26.90	0%
15	Heat & Ventilation	$1,176,000	$1,176,000	$0	VRF. includes energy recovery, MUA system	$16,333	$17.68	$16,333	$17.68	0%
15	Air Conditioning			$0	in H&V	$0	$0.00	$0	$0.00	
15	Fire Protection	$399,000	$339,150	-$59,850	100% coverage per code. CLT elimnates heads abo	$5,542	$6	$4,710	$5	-15%
16	Electrical	$2,304,000	$2,304,000	$0	Includes fixtures and fire alarm	$32,000	$34.65	$32,000	$34.65	0%
16	Security System	$35,000	$35,000	$0	Allowance	$486	$0.53	$486	$0.53	0%
	Accessory Buildings			$0		$0	$0.00	$0	$0.00	
	Other/misc			$0		$0	$0.00	$0	$0.00	
	Subtotal Structural	$16,708,249	$17,329,527	$621,278		$232,059	$251.25	$240,688	$260.59	3.72%
2	Earth Work	$983,390	$983,390	$0		$13,658	$14.79	$13,658	$14.79	0%
2	Site Utilities	$229,540	$229,540	$0		$3,188	$3.45	$3,188	$3.45	0%

2	Roads & Walks	$37,049	$37,049	$0		$515	$0.56	$515	$0.56	0%
2	Site Improvement	$91,850	$91,850	$0	Fencing, walks	$1,276	$1.38	$1,276	$1.38	0%
2	Lawns & Planting	$109,900	$109,900	$0		$1,526	$1.65	$1,526	$1.65	0%
2	Environmental Remediation	$20,000	$20,000	$0		$278	$0.30	$278	$0.30	0%
2	Demolition	$80,000	$80,000	$0		$1,111	$1.20	$1,111	$1.20	0%
2	Unusual Site Cond	$486,000	$486,000	$0	SOE	$6,750	$7.31	$6,750	$7.31	0%
	Subtotal Site Work	*$2,037,729*	*$2,037,729*	$0		$28,302	$30.64	$28,302	$30.64	0%
	Total Improvements	**$18,745,979**	**$19,367,256**	$621,278		$260,361	$281.89	$268,990	$291.24	3.31%
1	General Conditions	$1,499,678	$1,439,678	-$60,000		$20,829	$23	$19,996	$22	-4%
	Estimate Contingency	$800,000	$800,000	$0		$11,111	$12.03	$11,111	$12.03	0%
	Subtotal	**$21,045,657**	**$21,606,935**	$561,278		$292,301	$316.48	$300,096	$324.92	2.67%
1	Builders Overhead-3%	$631,370	$631,370	$0		$8,769	$9.49	$8,769	$9.49	0%
1	Builders Profit-3%	$631,370	$631,370	$0		$8,769	$9.49	$8,769	$9.49	0%
	TOTAL	**$22,308,396**	**$22,869,674**	**$561,278**			**$335.46**	**$317,634**	**$343.90**	**2.52%**
	GC BOND, ADD	$223,084	$228,697	$5,613		$3,098	$3.35	$3,176	$3.44	2.52%
	BUILDING PERMIT FEES, ADD	$187,460	$193,673	$6,213		$2,604	$2.82	$2,690	$2.91	3.31%
				$0						
	Total Construction Cost	**$22,718,940**	**$23,292,043**	**$573,103**		**$315,541**	**$342**	**$323,501**	**$350**	
	Total Cost/square foot:	**$341.64**	**$350.26**	**$8.62**						
	Total Cost/dwelling unit	**$315,541**	**$323,501**	**$7,960**						

Percent Increase in cost for CLT **2.52%**

MASS TIMBER ACCELERATOR

LONGWOOD PLACE
305 BROOKLINE AVE

Mass Timber Accelerator

FINAL REPORT
JUNE 2, 2023

SKANSKA

COMMERCIAL DEVELOPMENT | USA BUILDING

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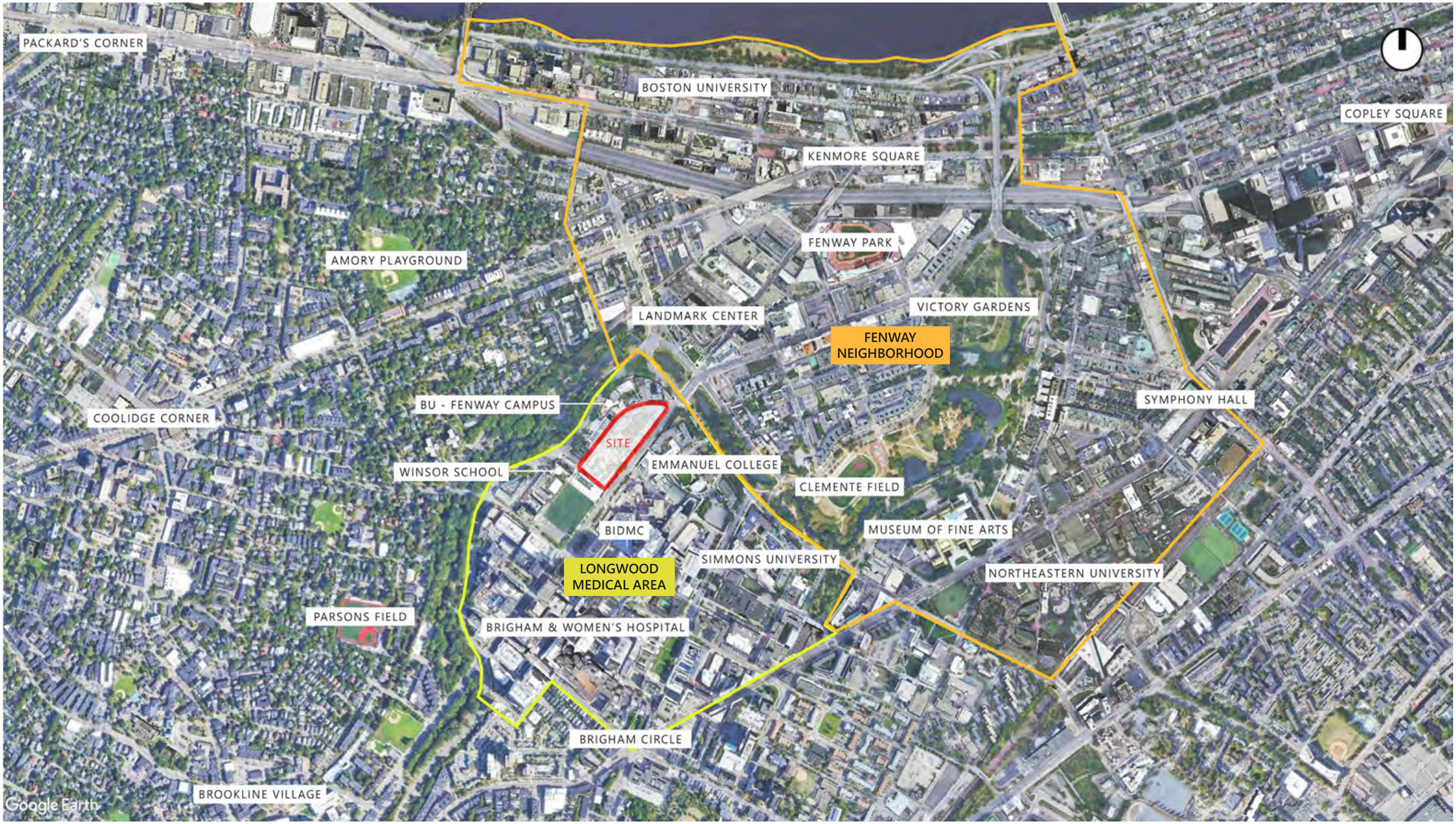
CONTENTS

A NEIGHBORHOOD OF LIFE-CHANGING ACTIVITY



The site sits within the Longwood Medical and Academic Area (LMA), which features the nation's top hospitals, world class medical research centers and academic institutions. Boston's beloved Emerald Necklace park forms the north and west boarders of the LMA. Huntington Avenue, lined with arts and cultural institutions, marks the south edge.

PROJECT OVERVIEW

The Longwood Place Project (the "Project") will create a welcoming mixed-use destination that will infuse the Fenway and Longwood Medical Area (LMA) neighborhoods with a variety of offerings for both public and private uses. The Project reimagines the 5.8-acre site (currently known as the Simmons University Residential Campus, referred to herein as the "Project Site") as a vibrant nucleus of sustainable and innovative workspaces, active community amenities, much needed housing, and an inclusive public realm for the larger neighborhood.

The Project will transform the existing Simmons Brookline Avenue parcel, delivering five new buildings and a rich public realm and urban landscape that will extend the vitality of the Fenway into the LMA. The LMA has long been home to esteemed academic and healthcare institutions but has lacked public amenities and an active public realm to support the LMA population. The Longwood Place Project embraces these opportunities and proposes buildings, new public spaces and amenities that are intended to be welcoming to all in the Fenway/LMA neighborhoods and to promote a sense of belonging for visitors from all cultures.

Beyond the expansive and inclusive public realm, Longwood Place seeks to offer a place for innovation to excel and new residents to call home. Three state-of-the-art life science buildings pair with two vital residential buildings to provide a rich offering of programs that serve the neighborhood and greater Boston. These five buildings will incorporate sustainability into the heart of their design by including measures that will increase energy efficiency and approach carbon neutrality among other goals.

All service and loading will be located below grade, thereby removing all loading activities from the ground-level, creating a public realm at grade that is safer for both people and vehicles.

PROJECT SUMMARY

The Proposed Project will include up to 1.70 million square feet of gross floor area (GFA)[1] of mixed-use development distributed over five buildings including residential, community space, retail, laboratory/office uses, and accessory and ancillary parking.

With a variety of building heights and building uses, the future development aims to bring density to the extended downtown core and life to the neighborhood beyond the normal working business hours. It is particularly noteworthy that the Proposed Project plans for approximately 2.6 acres of publicly accessible exterior open space. Ground-floor retail and community-facing programming will complement and activate the public realm.

The Project will deliver improved pedestrian and bicycle infrastructure along the Project's Brookline Avenue frontage that will improve connectivity and safety and will enhance the pedestrian experience.

MIXED USE	**LIFE SCIENCE AND RESEARCH, COMMERCIAL OFFICE, RETAIL, AND RESIDENTIAL**
OPEN SPACE	**2.6 ACRES (43% OF SITE)**
GFA	**1.7M SF** Public exterior open space
HEIGHT	**170' TO 295'** A variety of building heights across the site. Includes the mechanical penthouse.
LEVELS	**10 TO 18** Levels above grade
SERVICE + LOADING	**ENTIRELY BELOW GRADE**
PARKING	**0.3 PER 1,000 SF** Consistent with City of Boston Parking Ratio Guidelines - Sept 2021
TIMELINE	**5 TO 10 YEARS** Delivered in phases

A PUBLIC HEART
Flexible landscaped zones are designed for significant active public programming as well as passive use. A main heart within the core of the project provides ample opportunity for local activities while also creating an anchoring element with which the interior public spaces connect and engage.

AN ACTIVE LANDSCAPE
A mix of active and passive programming is a vital part of the public realm experience. Opportunities for events like farmer's markets, outdoor fitness and recreation, concerts and arts and culture activities can be supported in spaces throughout the landscape as well as those interior spaces that abut the outdoor open space.

[1]All references to gross square feet or GSF or gross floor area or GFA in this PDA have the meaning of "Floor Area, Gross" as defined in Article 2 of the Boston Zoning Code, which excludes certain areas including, but not limited to, below-grade parking, mechanicals, and areas serving the operation of a building.

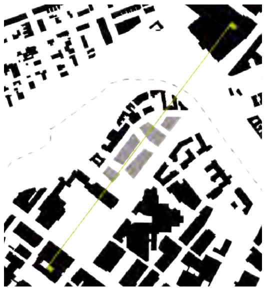
BUILDING R1
High rise residential
205,000 sf GFA
18 stories
210’ total height
(including penthouse)

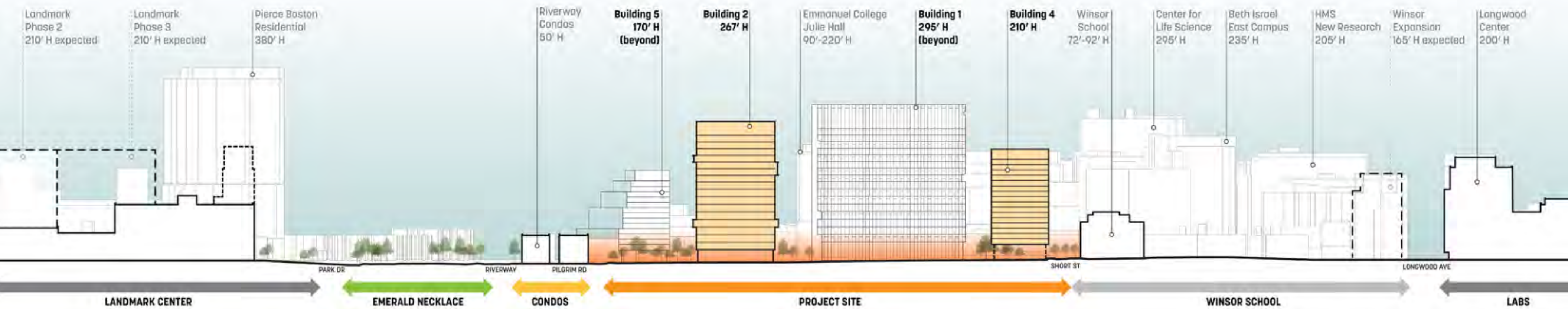
BUILDING C2
High rise commercial
340,000 sf GFA
13 stories
239’ total height
(including penthouse)

BUILDING C1
High rise commercial
550,000 sf GFA
18 stories
295’ total height
(including penthouse)

BUILDING C3
High rise commercial
460,000 sf GFA
17 stories
267’ total height
(including penthouse)

BUILDING R2
High rise residential
145,000 sf GFA
14 stories
170’ total height
(including penthouse)





THE URBAN FABRIC

With commercial and residential buildings up to 18 stories tall, the proposed massings join other tall buildings in the neighboring districts along the Brookline Avenue corridor.

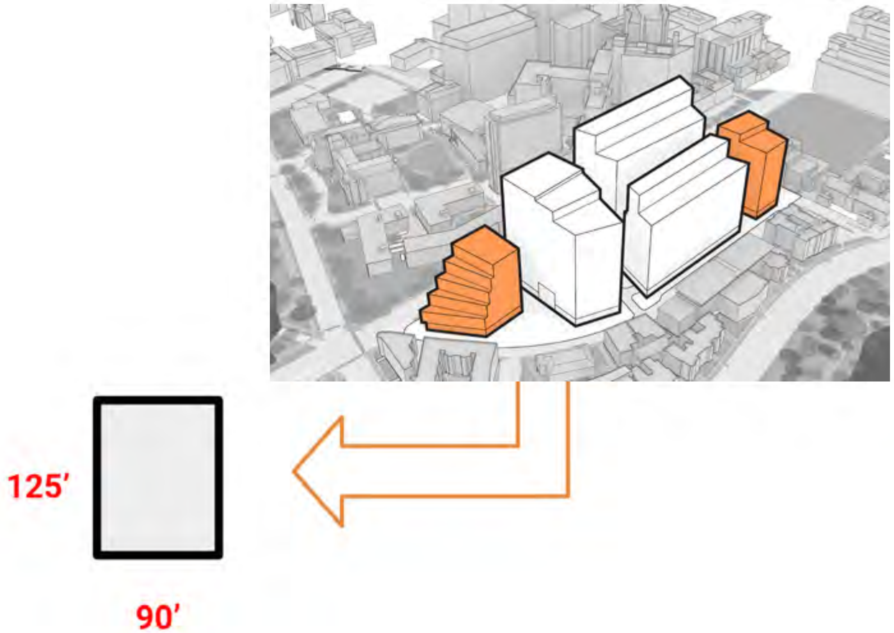
What are the advantages and disadvantages of using mass timber, or a hybrid, versus conventional steel and concrete for residential and commercial lab uses?

What advantages does using mass timber offer for Skanska's business goals of optimizing cost, schedule, leasing, and approvals?

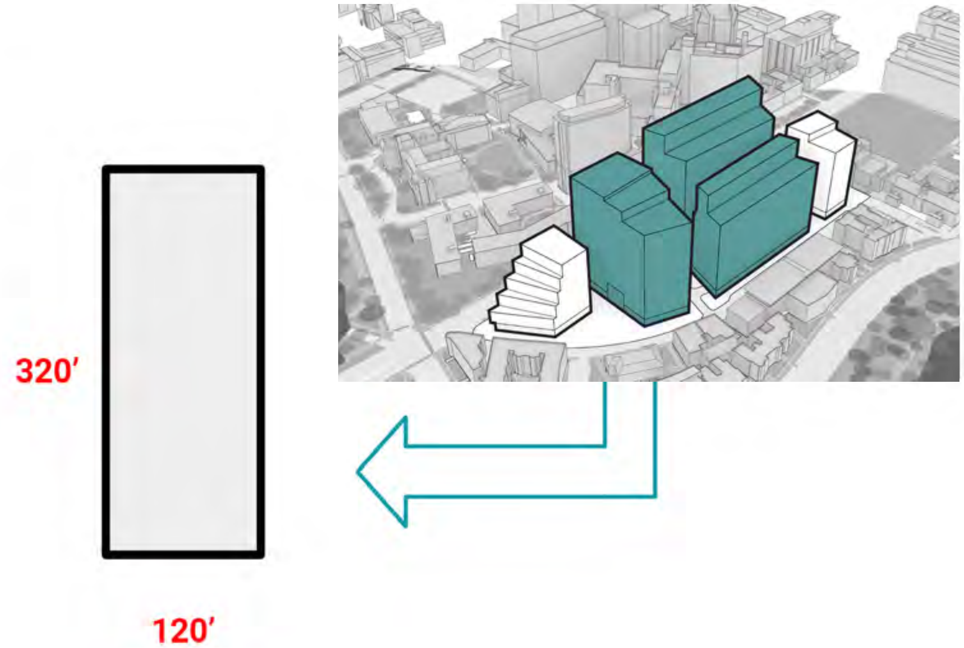
ACCELERATOR GOALS

Through the Mass Timber Accelerator, the Project team aims to challenge the status quo of how buildings are designed and constructed. Wood is a material with inherent natural beauty, and it is a renewable resource when its supply is sustainably managed. As a lower-carbon alternative to conventional materials like steel and concrete, mass timber promises to be a critical method in combating climate change. When optimized, it is also a material that has the potential to be faster and easier to work with. Advances in technology used in fabrication processes can supercharge the amount of work done off-site in a controlled environment, advancing the construction schedule before material arrives on site. Prefabrication has the potential to save significant time off a building's overall delivery timeline. This means that mass timber may offer a distinct economic benefit as well.

For these reasons, adoption of mass timber is accelerating. Successful examples include mostly low and mid-rise residential buildings. There remain limited examples of commercial mass timber buildings. . Through the Mass Timber Accelerator the team endeavors to explore how tall buildings like those proposed for the Longwood Place project can benefit even from the use of mass timber construction. The Team also seeks to understand how the advantages of Mass Timber may translate across different use types, like the residential and commercial life science uses proposed as part of this Project. We see the Accelerator as an opportunity to evaluate the potential of mass timber early before commencing the conceptual design process for individual project components.



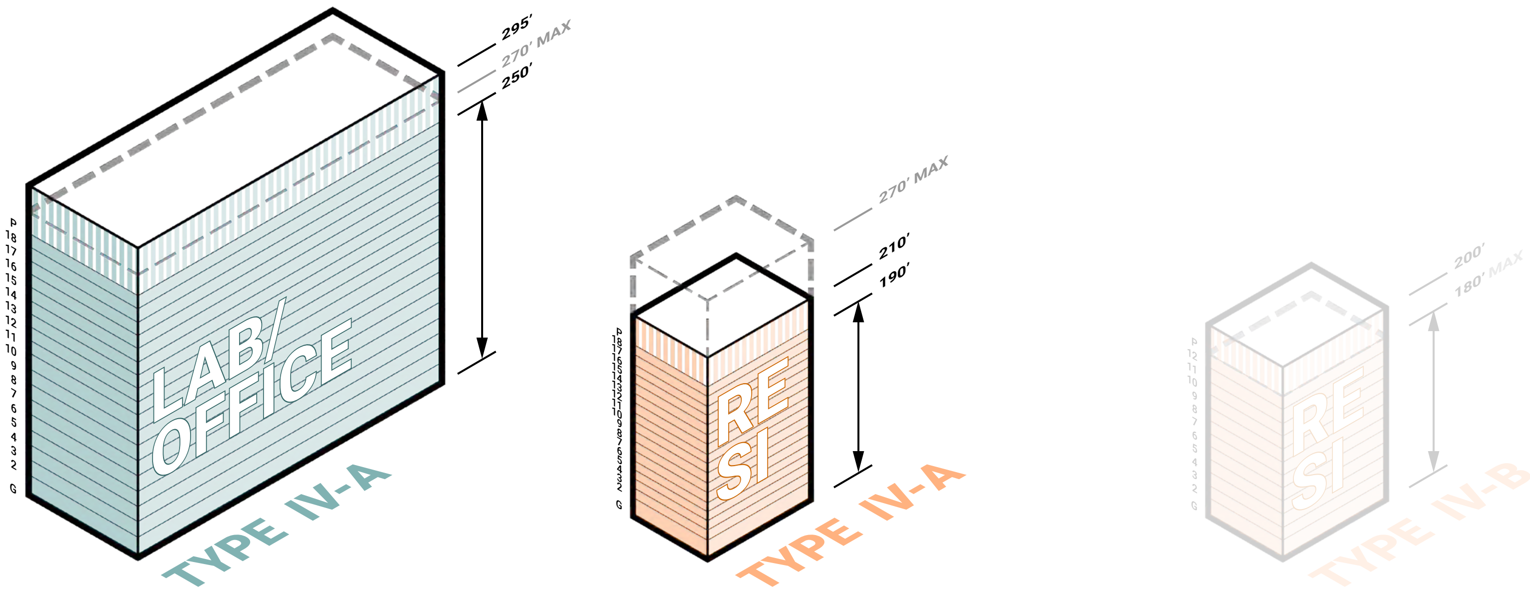
RESIDENTIAL
SIMPLIFIED FOOTPRINT



LIFE SCIENCE COMMERCIAL
SIMPLIFIED FOOTPRINT

STUDY APPROACH

For the purposes of the Mass Timber Accelerator study, the Project team will investigate one residential building and one commercial building, each in a simplified form that approximates the same floor plate size and shape of the buildings on the development site. Since the exercise is a study of contrasts with conventional construction methods, we will develop a conventionally-framed layout, a mass timber layout, and a hybrid layout that uses structural elements from each system. Each building layout will be developed differently to optimize the nature of that particular structure. Simply adapting an efficient steel layout to mass timber would not capitalize on the particularities of the material. For this study, each layout will have a unique approach that considers span, column grid, and beam direction independently. This approach will enable a side-by-side comparison of structural systems and the implications for interior planning, systems flexibility, material procurement and schedule, and ultimately cost effectiveness.



18 STORIES
250' HEIGHT TO ROOF
EXCL PENTHOUSE
730K GSF

18 STORIES
190' HEIGHT TO ROOF
EXCL PENTHOUSE
214K GSF

12 STORIES
180' HEIGHT TO ROOF
EXCL PENTHOUSE
203K GSF

BUILDING CODE

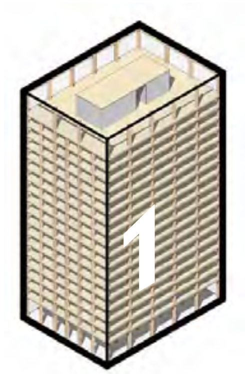
The Project proposes both the residential and commercial buildings up to 18 stories tall, but below 270 feet in height, which would qualify Type IV-A construction under IBC 2021 (expected to be adopted by Massachusetts sometime in 2023). An alternative construction, Type IV-B, allows up to 12 stories and a allows for a maximum height of 180 feet. The residential buildings are a candidate for this construction type since the roof is no higher than 180 feet. However, the limit of 12 stories under Type IV-B would mean a significant reduction from the 18 stories currently planned.

Type IV-A requires fire resistance ratings and protection of members (according to IBC base code without any potential MA amendments), which include:

- Required 3-hr rating of primary structural frame;
- Required 2-hr rating of floors and secondary structural frame;
- Combustible concealed spaces are not permitted;
- Interior exit and elevator hoistway enclosures in buildings greater than 12 stories or 180' must be constructed of noncombustible materials;
- Minimum 40 minutes noncombustible protection of outside face of exterior walls; and
- Interior faces of mass timber elements shall be protected.

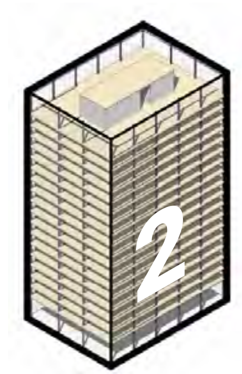
Following the 2021 IBC prescriptively means that tall buildings with the heights as proposed, constructed as Type IV-C, would require all timber columns, beams, and deck to be concealed with protective layers of gypsum board. However, the material property of mass timber has inherent fire resistance, without covering, when properly designed. Mass timber elements can be engineered to withstand 2-or-3 hours of fire exposure and retain their load-bearing capacity for the full duration of a flame exposure. This type of testing demonstrates mass timber's ability to char when exposed to fire, building an insulating layer at a predictable rate which protects the inner material from combustion. There is precedent for design teams to use advanced fire testing to demonstrate to building officials and AHJs the equivalent fire resistance of exposed mass timber, subject to AHJ approval, and appeal for a greater percentage of exposed members than allowed by the prescriptive code. Other less restrictive variations of Type IV construction already allow more exposed mass timber. If the AHJ approves a greater area of unprotected mass timber, it would result in material savings (cost and carbon) of gypsum board no longer needed to encapsulate mass timber elements. A greater degree of exposure would also reveal the structural material and warmth of the wood.

RESIDENTIAL
STRUCTURAL SCHEMES



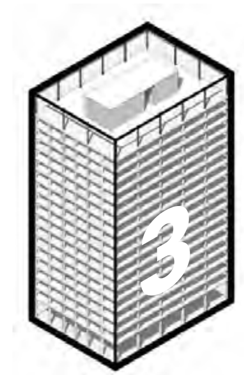
MASS TIMBER

FLOOR SLAB	**5-PLY CLT + CONC**
COLUMNS	**GLULAM**
SHEAR WALLS	**CIP CONCRETE**
BEAMS	**GLULAM**



HYBRID STEEL + TIMBER

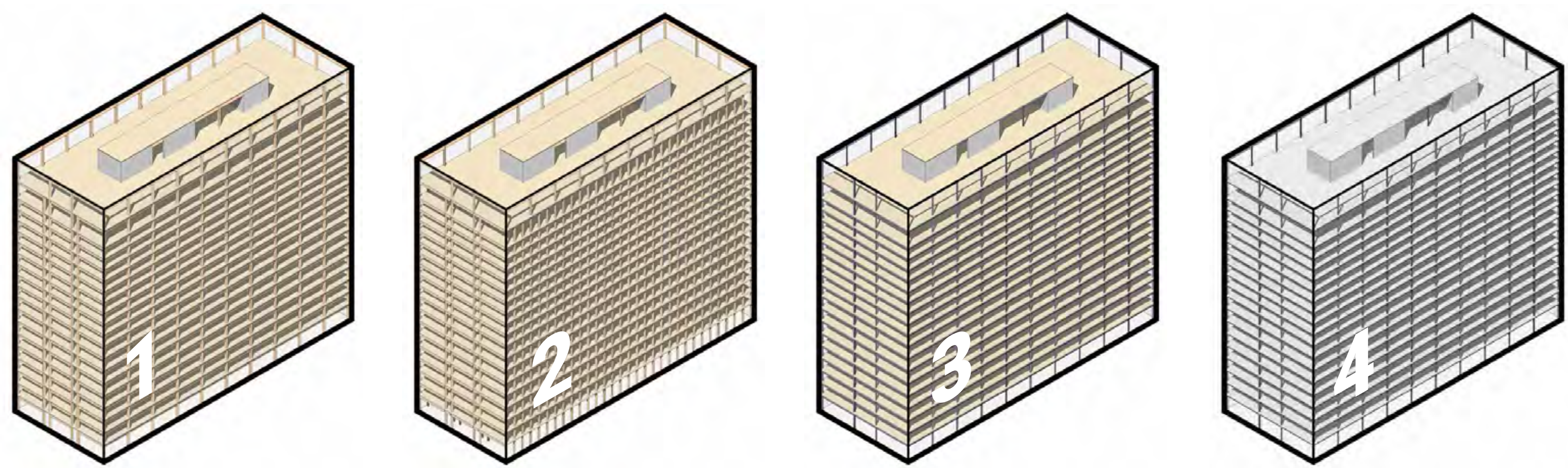
FLOOR SLAB	**5-PLY CLT + CONC**
COLUMNS	**STEEL W SECTIONS**
SHEAR WALLS	**CIP CONCRETE**
BEAMS	**STEEL W SECTIONS**



CONVENTIONAL FRAMING

FLOOR SLAB	**CONC FLAT SLAB**
COLUMNS	**CIP CONCRETE**
SHEAR WALLS	**CIP CONCRETE**
BEAMS	**N/A**

COMMERCIAL LAB/OFFICE
STRUCTURAL SCHEMES



MASS TIMBER

FLOOR SLAB **5-PLY CLT + CONC**
COLUMNS **GLULAM**
SHEAR WALLS **CIP CONCRETE**
BEAMS **GLULAM**

MASS TIMBER | DENSE GRID

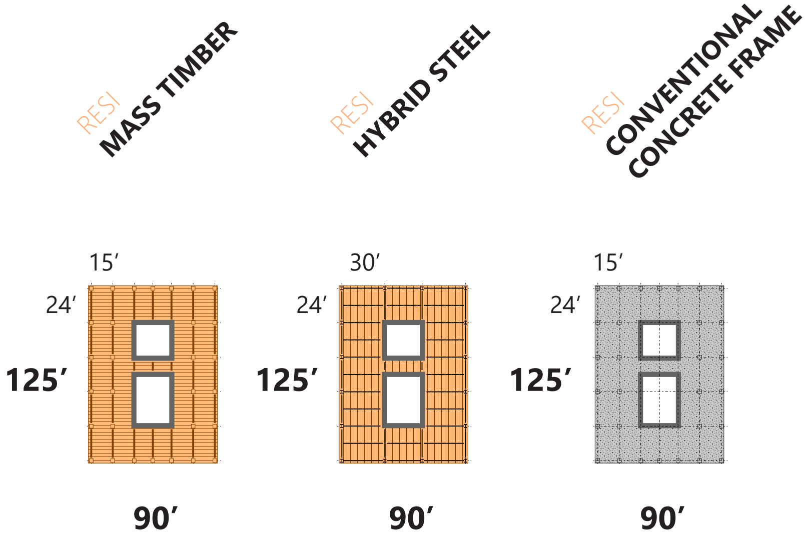
FLOOR SLAB **5-PLY CLT + CONC**
COLUMNS **GLULAM**
SHEAR WALLS **CIP CONCRETE**
BEAMS **GLULAM**

HYBRID STEEL + TIMBER

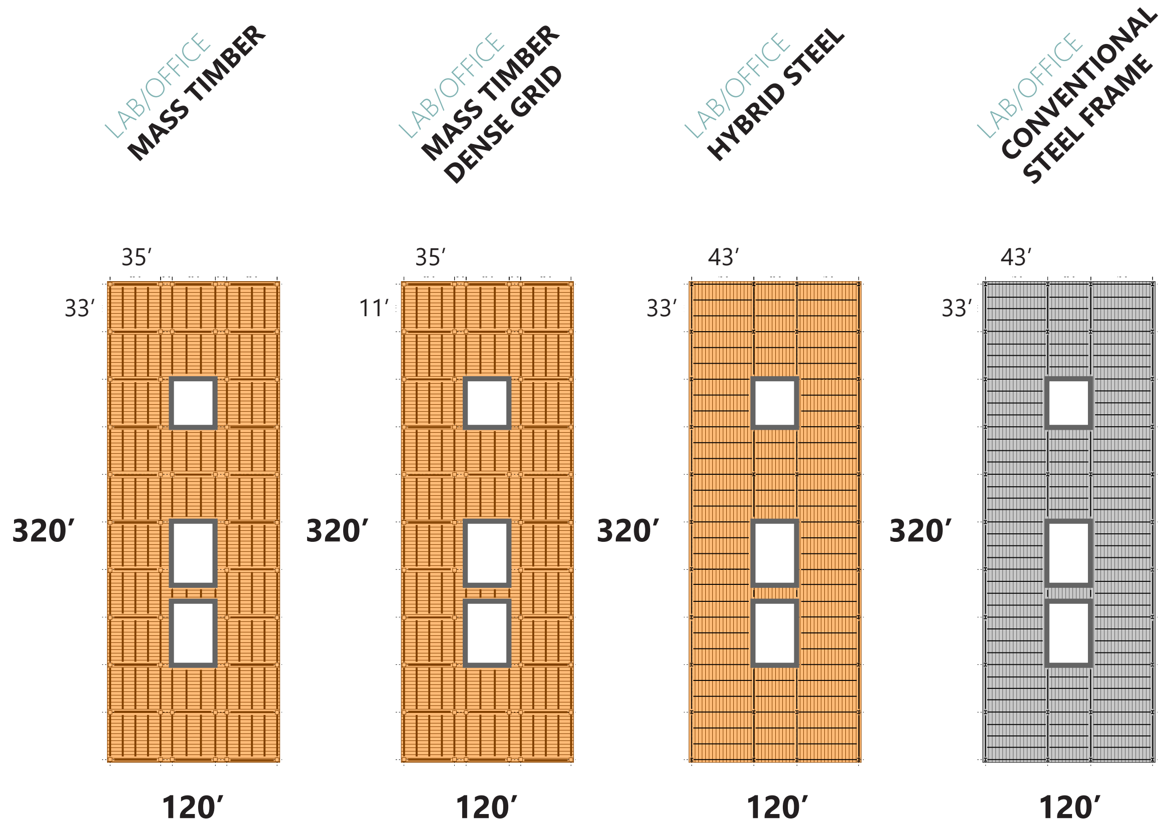
FLOOR SLAB **5-PLY CLT + CONC**
COLUMNS **STEEL W SECTIONS**
SHEAR WALLS **CIP CONCRETE**
BEAMS **STEEL W SECTIONS**

CONVENTIONAL FRAMING

FLOOR SLAB **CONC ON METAL DECK**
COLUMNS **STEEL W SECTIONS**
SHEAR WALLS **CIP CONCRETE**
BEAMS **STEEL W SECTIONS**



RESIDENTIAL
COMPARISON OF STRUCTURAL SYSTEMS



LIFE SCIENCE COMMERCIAL
COMPARISON OF STRUCTURAL SYSTEMS

DESIGN PRINCIPLES

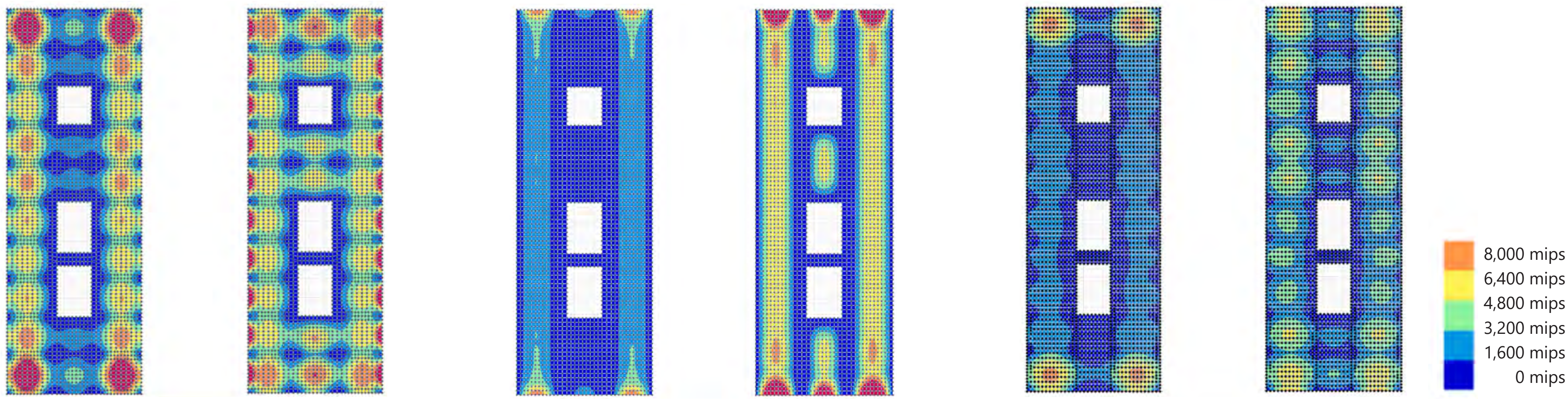
From a space planning perspective, determining a plan layout is achieved by balancing the building structure and clear floor area needs. Early space planning begins with the kind of uses that the space will accommodate. The process then evaluates and selects a structural system based on its span capabilities. Both must be matched to bring together to maximize structural efficiency and to achieve the openness and flexibility that the building uses demand.

The mass timber and hybrid structural systems were designed to meet the conceptual architectural requirements of the residential, office, and lab spaces, while also striving to achieve the most efficient use of timber as a structural material. All the floor systems utilize 5-ply CLT panels, which allow for longer floor spans and greater flexibility for MEP openings compared to 3-ply panels, while also being more cost-effective than 7-ply panels. A three-inch concrete topping provides a wearing surface with sufficient thickness to limit cracking while also improving the floor's response to vibrations due to the added weight.

The column grids in the residential options provide architectural flexibility and structural efficiency. The CLT panels span 15 feet between double glulam beams in the pure timber option, removing the need for secondary beams that are typically required for longer spans. The double beams are sized as square sections to minimize structural depth, which reduces material efficiency as compared to deeper beams. In the hybrid option, the CLT panels span between secondary steel beams that frame into primary girders. The longer spans achieved in steel allow all the columns to be located at the building perimeter, but require sections twice as deep as compared to the pure timber option.

The column grids for the speculative lab options were selected with material efficiency in mind. The pure timber options utilize a double line of columns along the building core to reduce span lengths. The first option uses a traditional framing system with secondary beams spanning between primary girders, which requires four feet of structural depth to achieve spans greater than 30 feet. The second timber option uses a denser column grid to remove the secondary beams, which proves to be a more efficient use of material while also improving the floor's vibration response. The hybrid lab option utilizes a column grid similar to that of a conventional steel and concrete building, but the long spans and light floor system amplify the vibration response and require significantly heavier beams.

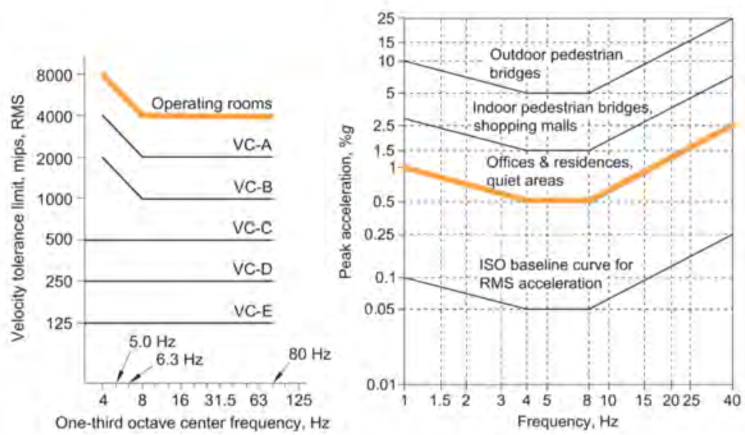
FOOTFALL VIBRATION ANALYSIS
FULL FLOOR EXCITATION



LAB MASS TIMBER

LAB MASS TIMBER DENSE GRID

LAB CONVENTIONAL STEEL



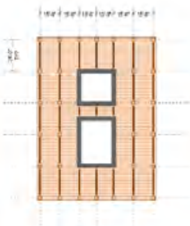
VIBRATION DESIGN

The dynamic response of a floor system is governed by its mass and stiffness. Timber's low mass can bring a floor system's natural frequency into the range of human walking frequencies. Limiting the response to footfall-induced vibrations requires increasing the floor's stiffness, which is typically achieved by a combination of reducing span lengths and increasing beam depths, in response to programmatic constraints.

In this study, typical vibration targets for human comfort (0.5%g) were used for the residential and office spaces, and the gravity sizes of the beams provided sufficient stiffness to meet these targets. Stricter vibration criteria of 8,000 micro-inches per second (mips or µin/s) were used for the speculative lab spaces, which required upsizing the beams from their gravity sizes to achieve the vibration targets.

Agreeing on a baseline standard of vibration resistance is especially important to the commercial building design since it is planned as speculative lab. The future tenants' exact criteria are not known during design, so an assumption must be made based on market trends. The goal of designing for floor vibration is to facilitate a range of potential lab tenants to provide a floor within the vibration tolerances of some sensitive lab equipment and manufacturing machinery, while not overdesigning the building's structure with excess material and unnecessary cost.

SUPPLIER OPTIMIZATION
MATERIAL AVAILABILITY



RESI MT

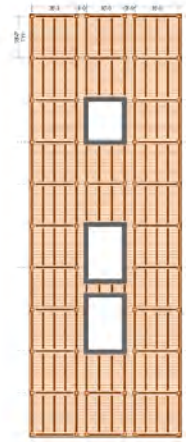
24' GRID / 3 SECTIONS =
8' CLT WIDTHS

DOUBLE SPAN =
30' CLT LENGTHS

RESI HYBRID

30' GRID / 4 SECTIONS =
7.5' WIDTHS

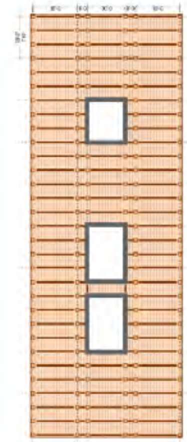
SINGLE SPAN =
24' LENGTHS



LAB MASS TIMBER

33' GRID / 4 SECTIONS =
8.25' WIDTHS

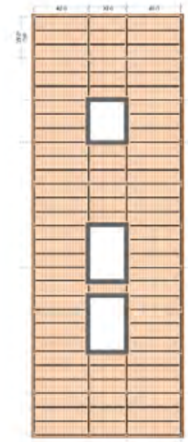
DOUBLE SPAN =
43' LENGTHS



LAB MT - DENSE GRID

35' GRID / 4 SECTIONS =
8.75' WIDTHS

SINGLE SPAN =
33' LENGTHS



LAB HYBRID

43' GRID / 5 SECTIONS =
8.6' WIDTHS

SINGLE SPAN =
33' LENGTHS

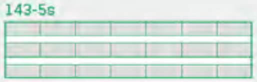
AVAILABLE 5-PLY CLT

UP TO **8.85' WIDTH**

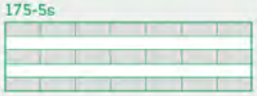
UP TO **64' LENGTH**
40' LENGTH is more typical to facilitate local transport

5 LAYERS

143-5s



175-5s



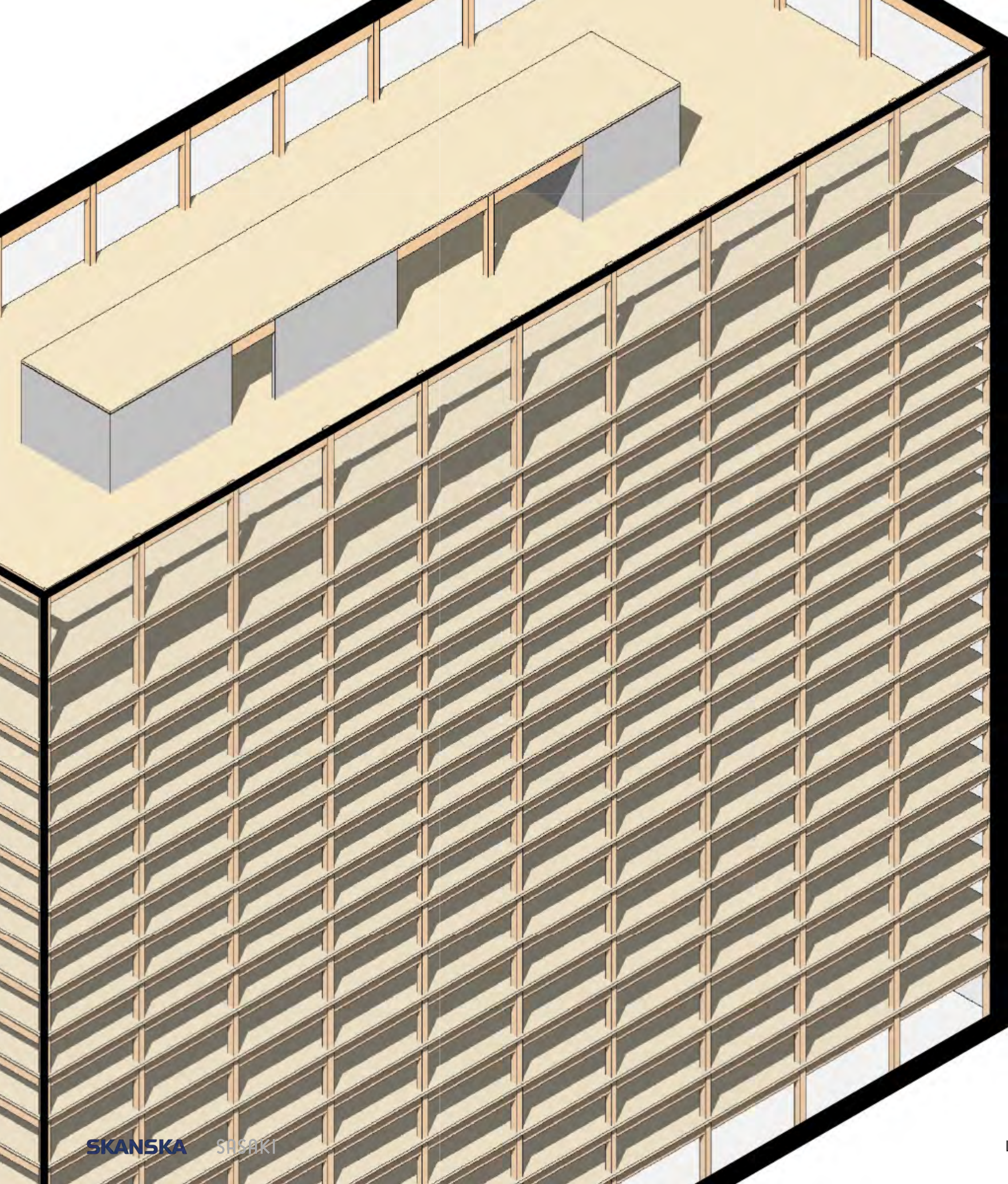
SLABS AND PANELS

Layup combinations
89-3s, 105-3s,
143-5s, 175-5s,
197-7s, 213-7l, 245-7s, 245-7l
and 267-9l

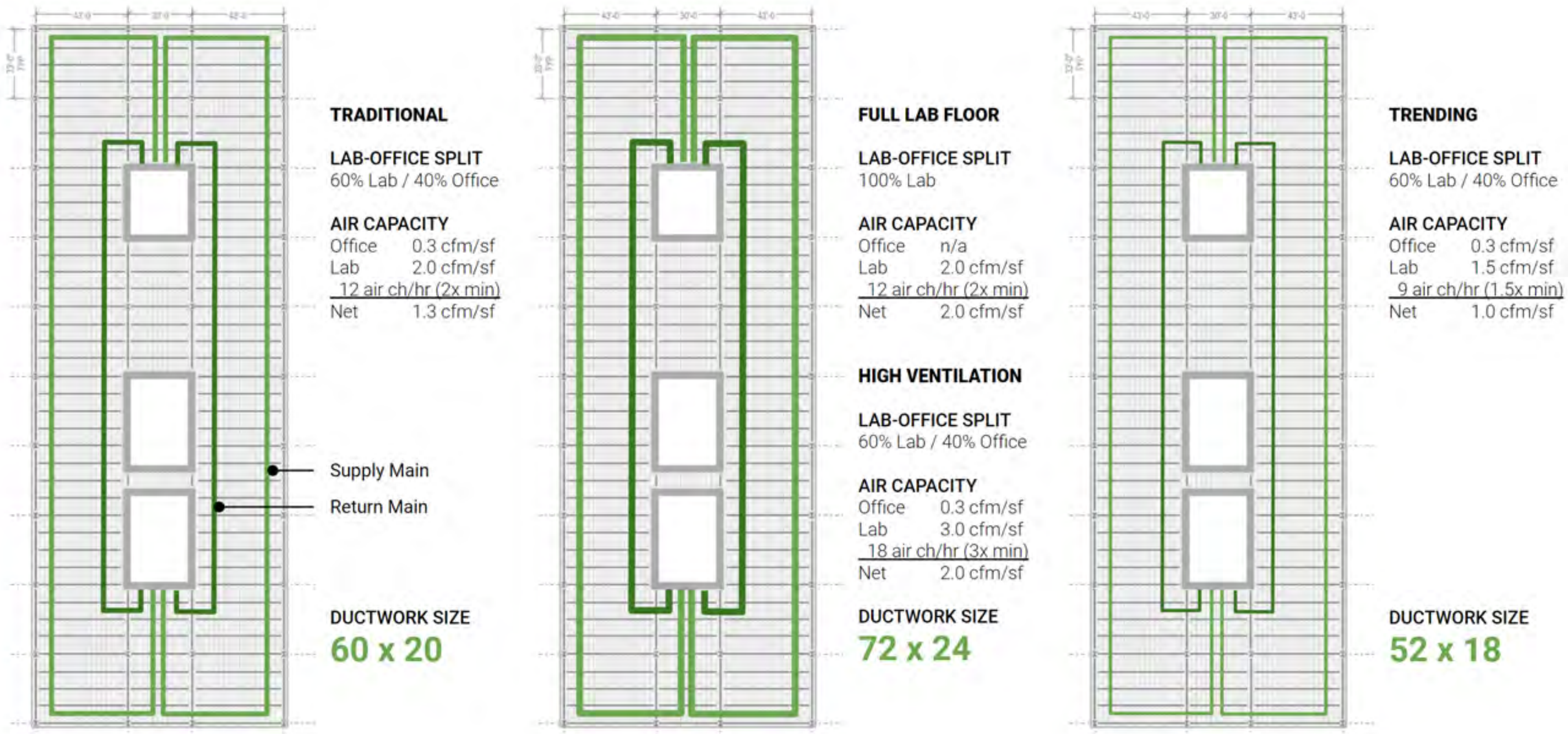
Maximum sizes
2.70 × 19.5 m (106-1/4 in. × 64 ft)

Stress grade
E1 (L 1950Fb and T No. 3/Stud)

Example from Nordic Structures



HVAC DISTRIBUTION
DUCT SIZE RANGE



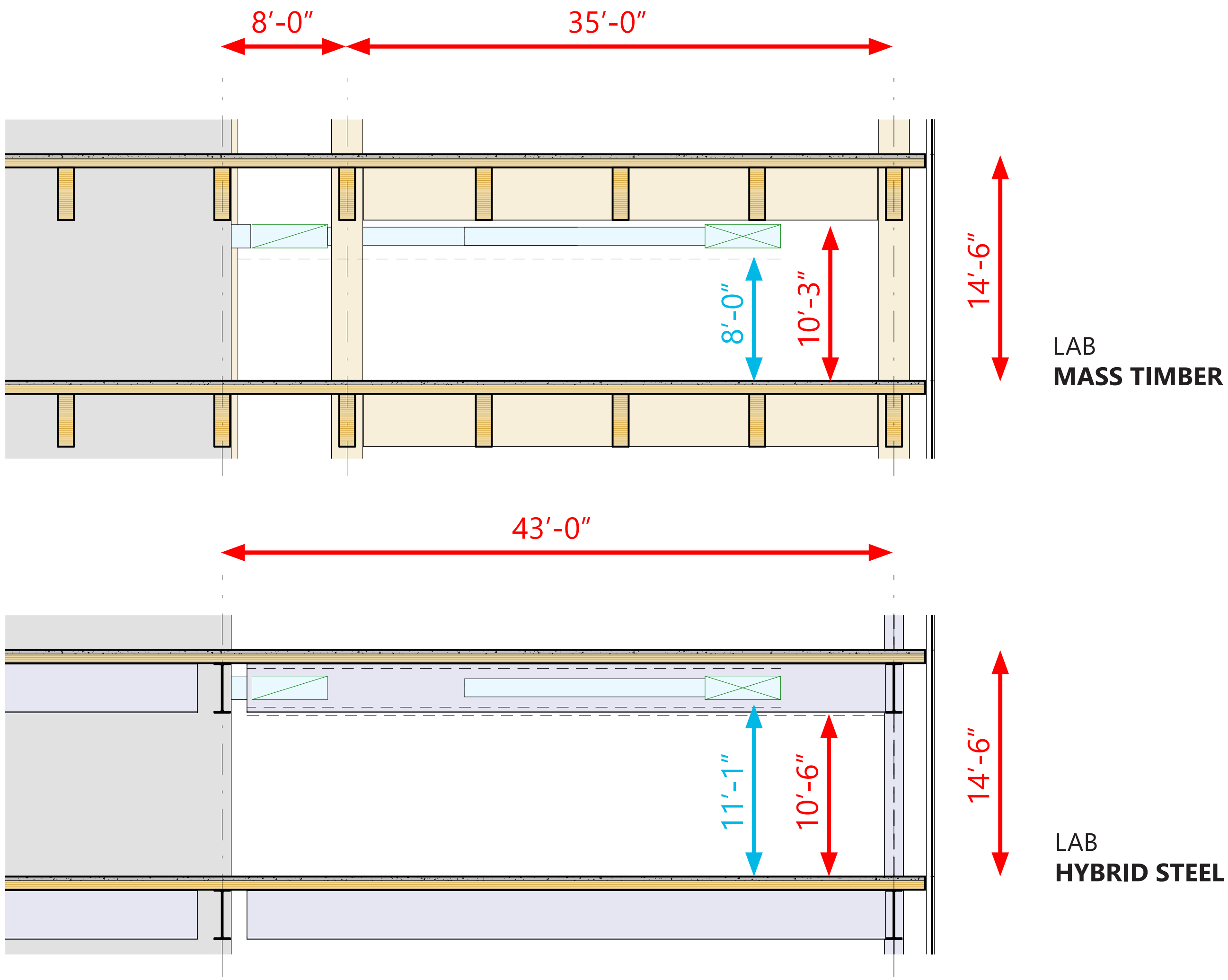
MEP INTEGRATION PRACTICES

Design principles remain the same between traditional construction and mass timber in that flexibility and spatial planning should be maintained to the greatest extent possible to allow the building program to be maximized and retain leasing objectives.

First, the core structure must be flexible enough to accommodate changes in duct sizing and openings onto each floor since individual tenant requirements may not come into focus until late in the design process. Also, the building core structure must allow access to the shafts for maintenance and future reconfigurations.

Particular attention must be paid to floor openings in CLT deck panels. Because CLT has a strong/weak axis and the floor is made up of individual panels, a penetration through CLT may need to be split across two panels, for instance, if its size removes too much material from a single panel.

The commercial buildings assume a mix of lab-ready floors and office tenant floors. The lab floors are expected to be located on lower floors in the building where chemical storage is less restricted. However, upcoming code changes are expected to allow significantly more chemicals on higher floors. As a result, we have considered that the building may need to be even more flexible to allow for more robust ventilation needs as lab uses extend up to higher floors. Future adaptability is a key factor for tenants of the com-



mercial building. For this reason, the assumed MEP zone is sized to the largest duct expected on every floor to accommodate reconfigurations. For airflows, an average 60% lab / 40% office floor can have net air capacity requirements of 1.3 cubic feet per minute (cfm) per square foot. That baseline figure can elevate up to 3 cfm/sf with the much larger ductwork required by a chemistry lab, vivarium, or a Good Manufacturing Practice (GMP) lab facility.

Since there are many factors which will be considered in the MEP design, our team has assembled a series of possible mass timber framing schemes that would support MEP pathways in a variety of ways, each with different benefits and drawbacks. Best practices in engineering need to be well thought out at the concept phase with respect to distribution of systems to maximize ceiling heights, location of system components to minimize the impact on structure where there is heavy equipment, and develop plans to support change throughout the life of the building.

Selecting a mass timber design may require a premium in either system distribution cost, planning for additional floor to floor heights to allow the additional structural depth, and detailed MEP coordination. The coordination work could determine dedicated ceiling zones for pipe and duct runs, and require extra care in planning/sizing floor openings and core walls to allow flexibility for future tenants.

FLOOR-TO-FLOOR HEIGHT

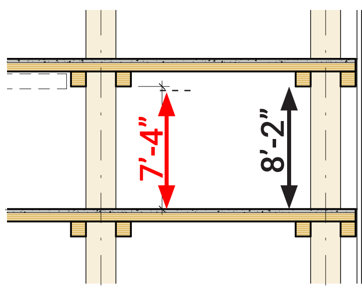
The floor-to-floor height of each option is informed by the structural member sizing and the available space to run MEP above the occupants. For the purpose of this comparison, our team has established a clear zone as a standard for each building type: a minimum 8'-0" clear height for residential and a minimum 9'-6" clear height for commercial.

Typical air distribution and piping must be considered together with the structural system and layout. For air distribution at each level, beam penetrations through conventional steel can allow duct runs and structure to exist in virtually the same plane within the ceiling plenum. Mass timber can support penetrations but at a smaller scale. Openings through glulam beams are more compatible with pipe sleeves than ducts. When proposing openings through timber, char protection from fire exposure must factor in material loss at each exposed surface, including those surfaces at beam openings. The result is that the net loss of structural material at a glulam beam can be much larger when compared to a penetration through a steel beam with spray fireproofing.

RESI | MASS TIMBER

8'-0" CLR MIN
7'-4" TO DUCT

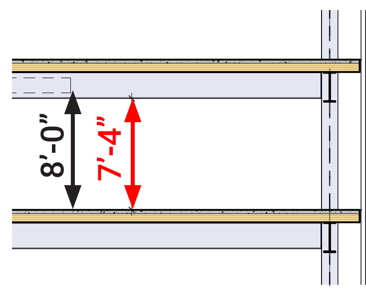
RAISE 1'-0" TO
11'-0" FTF



RESI | HYBRID STEEL

8'-0" CLR MIN
7'-4" TO BEAM

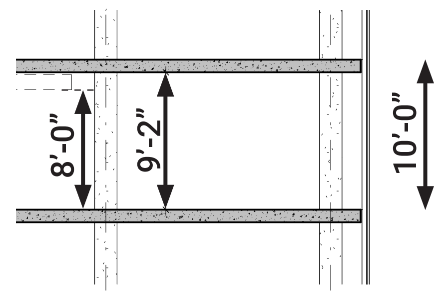
RAISE 1'-0" TO
11'-0" FTF



RESI | CONVTL CIP

8'-0" CLR
8'-0" TO DUCT

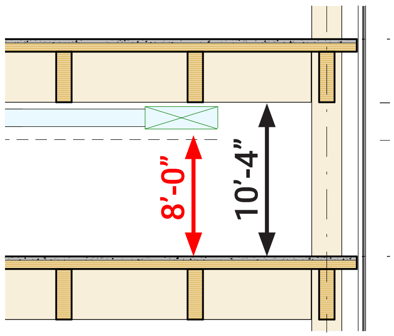
10'-0" FTF



LAB MASS TIMBER

9’-6” CLR MIN
8’-0” TO DUCT

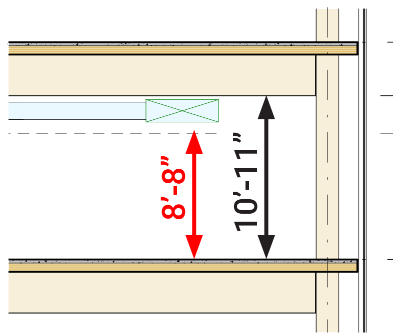
RAISE 1’-6” TO
16’-0” FTF



LAB MT DENSE GRID

9’-6” CLR MIN
8’-8” TO DUCT

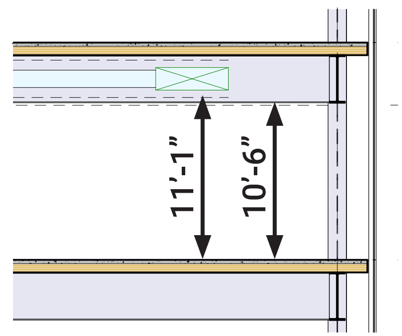
RAISE 10” TO
15’-4” FTF



LAB HYBRID STEEL

9’-6” CLR MIN
10’-6” TO BEAM

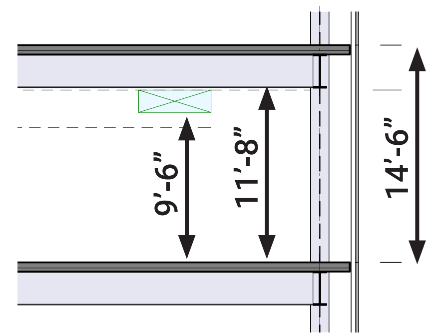
14’-6” FTF

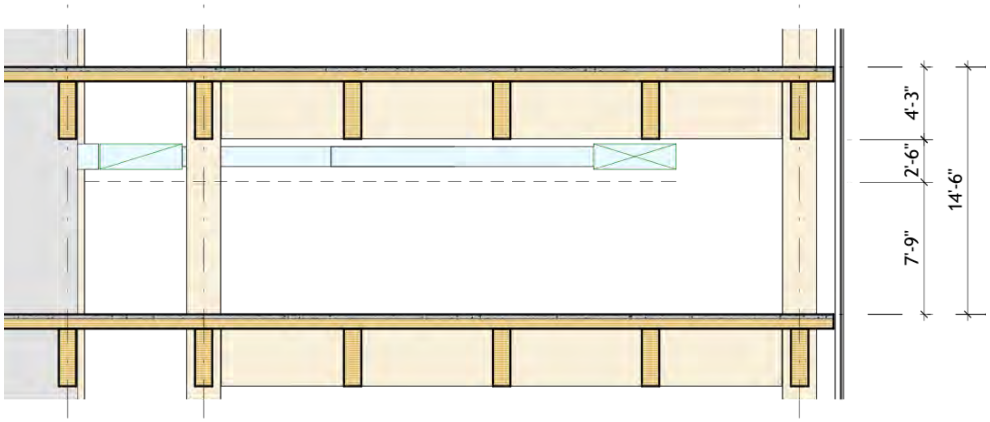


LAB CONVTL STEEL

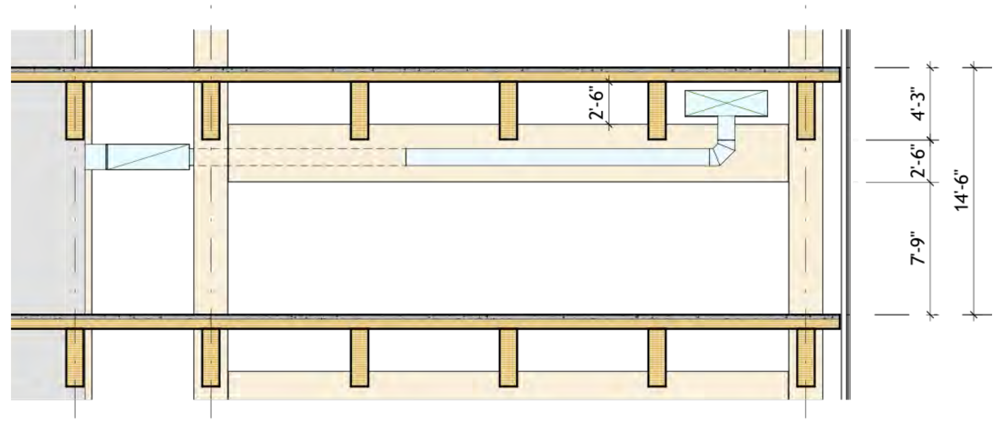
9’-6” CLR MIN
9’-6” TO DUCT

14’-6” FTF

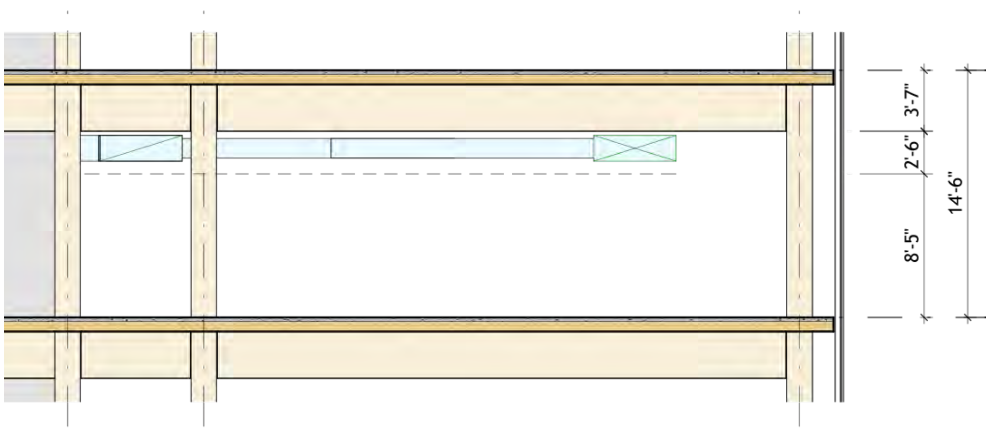




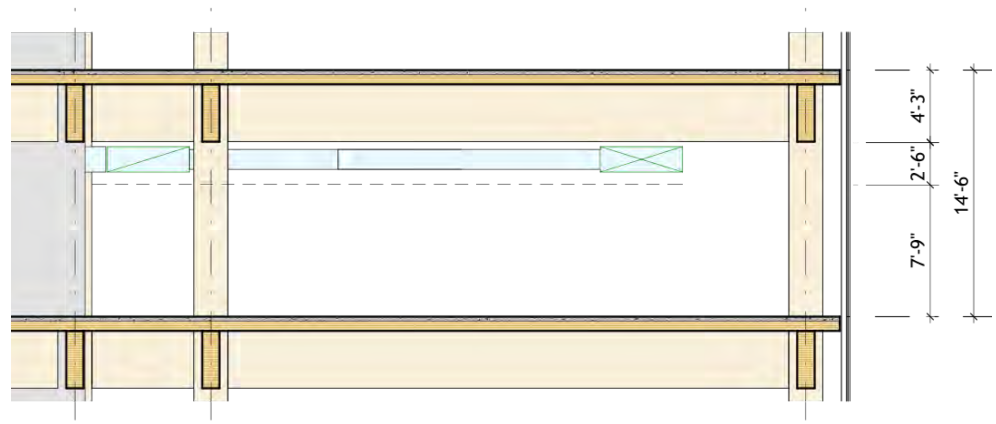
MASS TIMBER BASE
1.18 cf/sf



DROPPED BEAM
1.18 cf/sf



DENSE COLUMN GRID
1.05 cf/sf



ROTATED SPANS
1.18 cf/sf

MASS TIMBER VARIATIONS

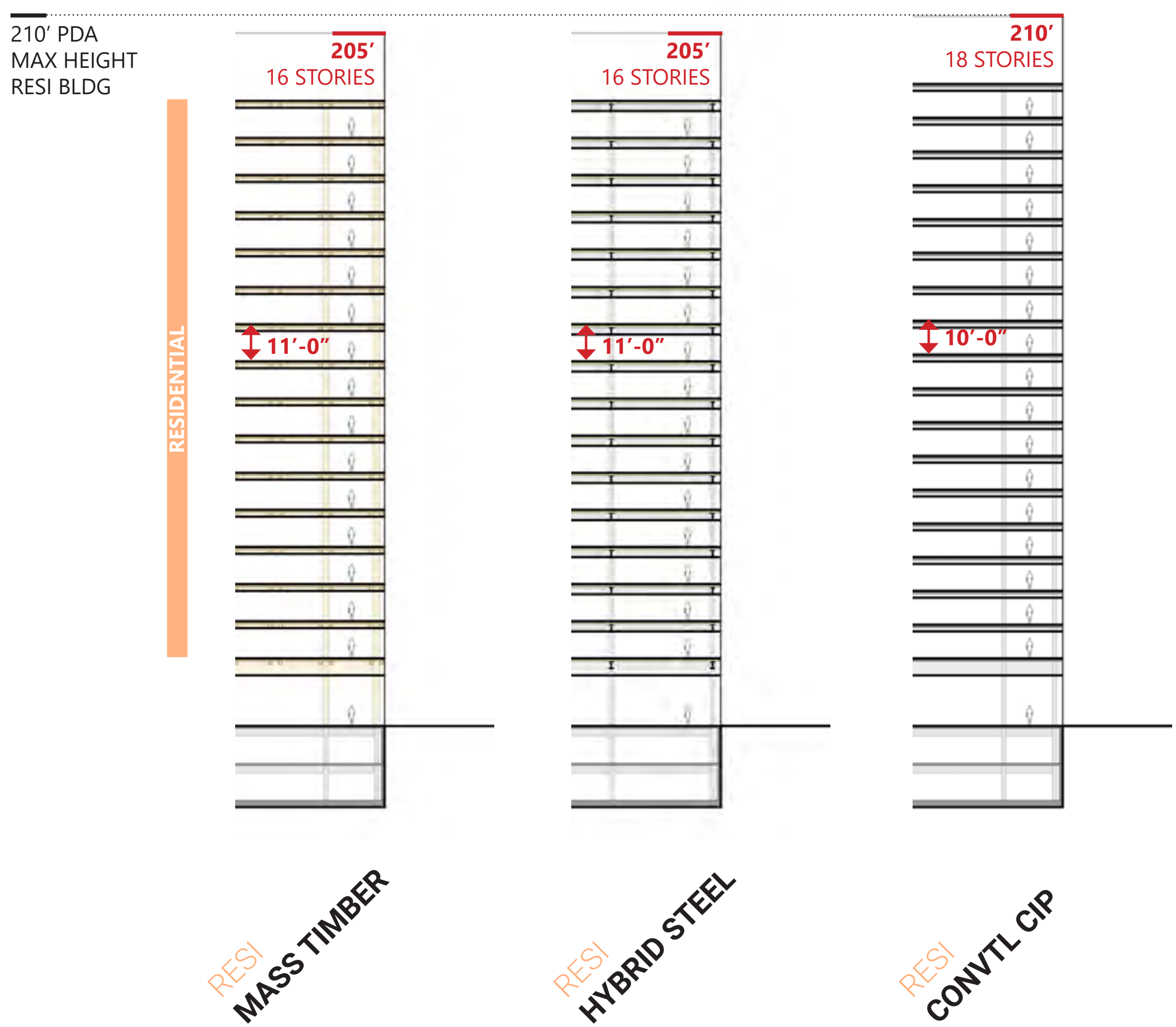
Variations of mass timber designs can have different material use rates, expressed in cubic feet of fiber per square foot, with an effect on overall material cost. Each iteration has positives and negatives for space saved in the MEP routing pathways and tenant flexibility due to the spacing and location of columns.

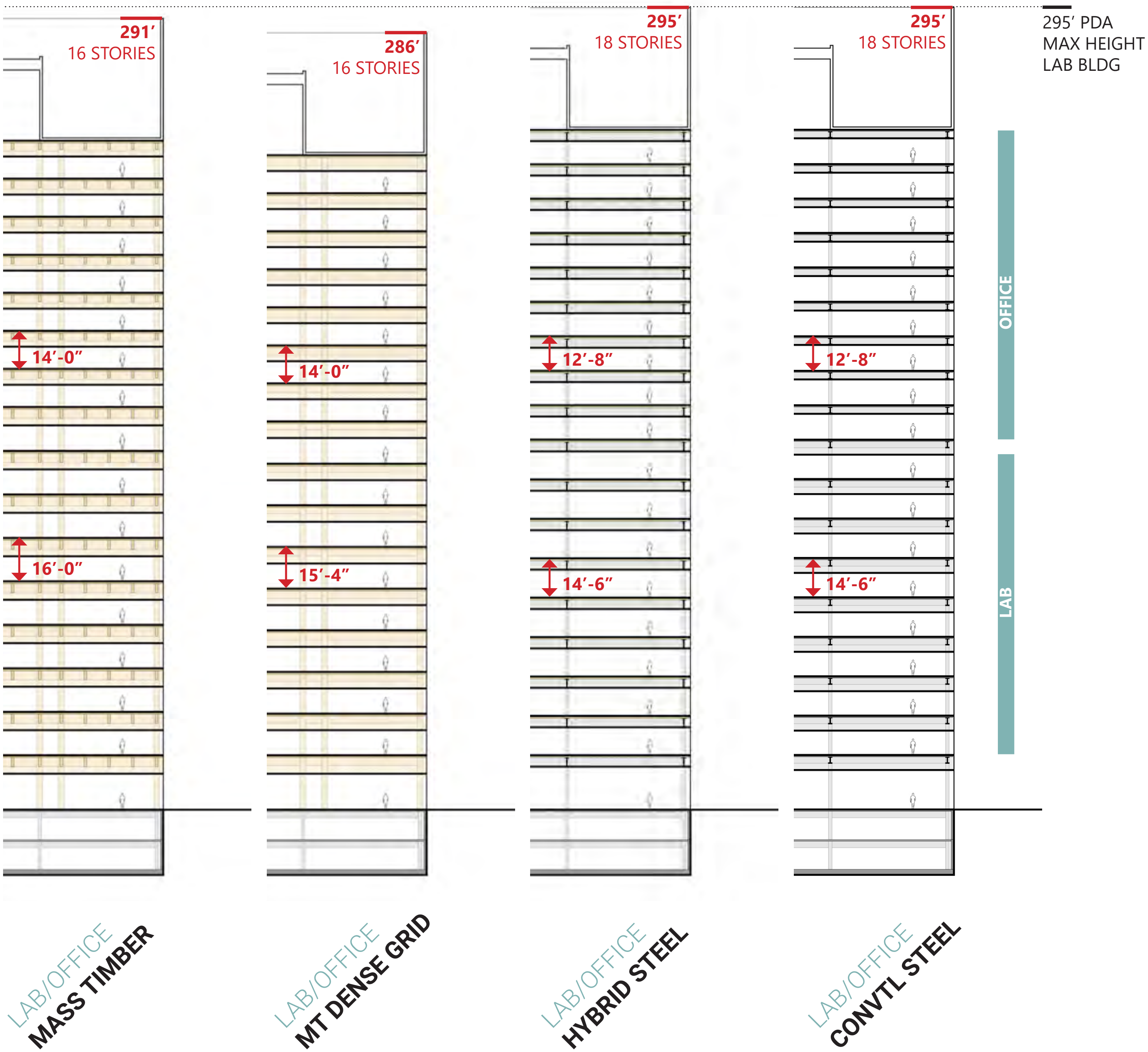
MASS TIMBER BASE
1.18 cf/sf

DROPPED BEAM
1.18 cf/sf

DENSE COLUMN GRID
1.05 cf/sf

ROTATED SPANS
1.18 cf/sf


210' PDA
MAX HEIGHT
RESI BLDG
RESIDENTIAL
205'
16 STORIES
11'-0"
205'
16 STORIES
11'-0"
210'
18 STORIES
10'-0"
RESI MASS TIMBER
RESI HYBRID STEEL
RESI CONVTL CIP



BUILDING SECTIONS

What does all this mean for overall building height? The number of stories of each building is based on an assumed floor to floor height typical for the building use and construction type. For both building types in this study, the taller floor-to-floor required by mass timber construction reduces the total number of floors that were initially planned within the zoning envelope established by the PDA.

EMBODIED CARBON

Buildings are the dominant contributor to greenhouse gas emissions. A vast amount of energy is consumed harvesting raw materials, manufacturing construction supplies, assembling these materials into a building, and operating these buildings for their entire life cycle. The energy consumed during this process is powered largely by fossil fuels. Finding ways to lower the carbon associated with each of these processes is essential to redirecting climate change. There are several initiatives within the City of Boston that aim to reduce carbon emissions related to buildings, including the Zero Net Carbon Building Zoning initiative. For this study, we will focus only on the embodied carbon within the building structure.

Wood is a renewable resource. It requires much less energy to harvest and produce as a building material. Forests also sequester carbon as they grow, capturing and storing atmospheric carbon dioxide through photosynthesis.

390
kg CO_2e/m^2

CONCRETE FRAME
CONCRETE FLAT SLAB

240
kg CO_2e/m^2

STEEL FRAME
COMPOSITE SLAB

170
kg CO_2e/m^2

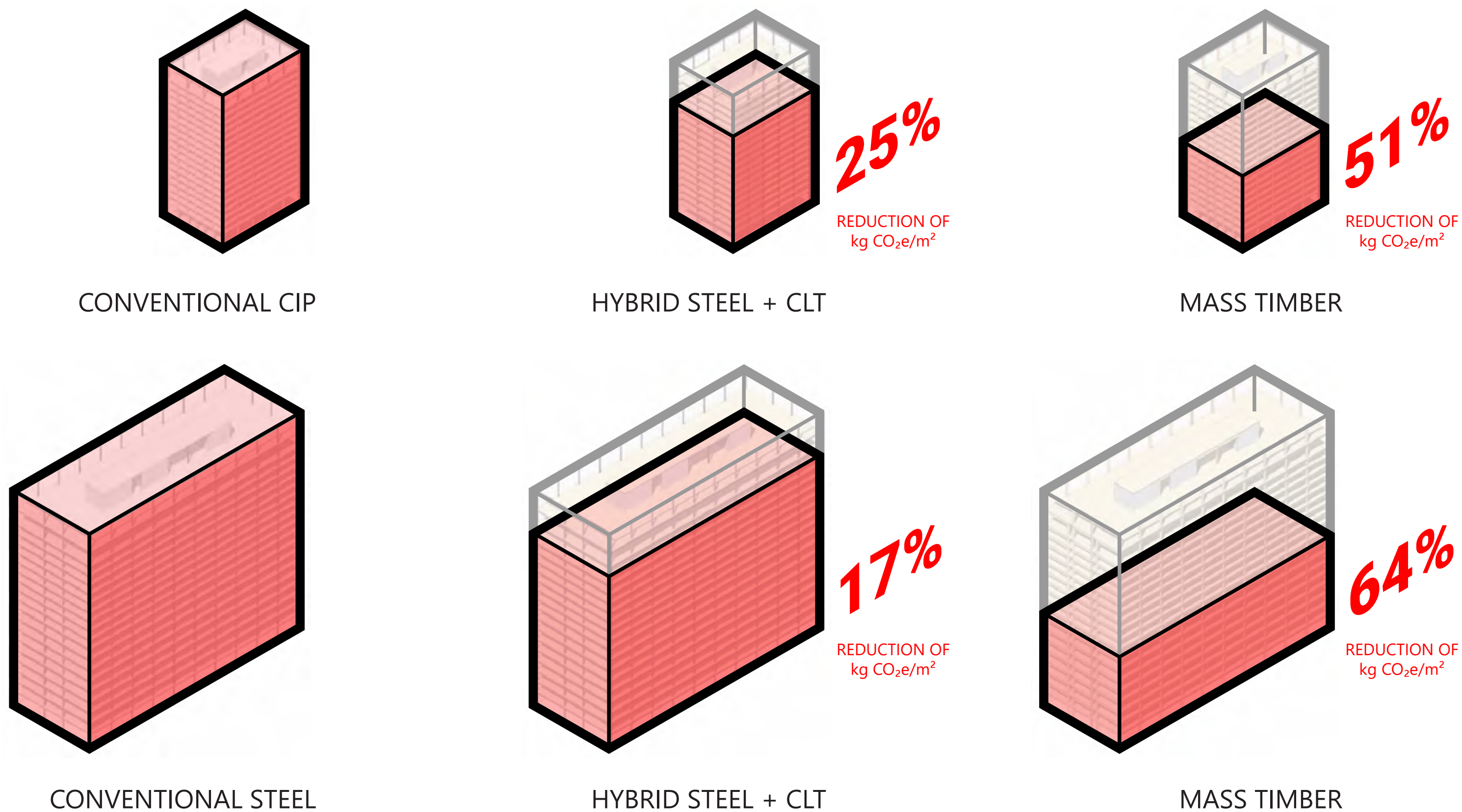
STEEL FRAME
CLT FLOOR DECK

130
kg CO_2e/m^2

GLULAM FRAME
CLT FLOOR DECK

Figures include embodied carbon from foundations and exclude facade, interiors, and other systems

Benchmark GWP data courtesy of Thornton Tomasetti

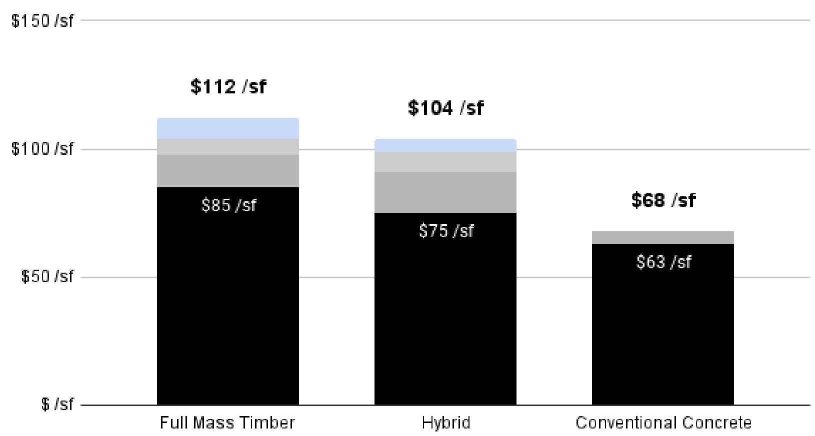


Industry benchmark data indicates that building with mass timber can be done with nearly half the carbon of a similar steel structure or nearly one-third of a similar concrete structure. Our goal was to test the potential carbon savings of the residential and commercial options for this site, using actual layouts and virtual models to run an analysis of each building element to determine the total embodied carbon of the above-grade structure. The results conclude that mass timber can save over half the carbon of a similar conventionally framed building. Hybrid structures also benefit greatly from exchanging carbon-intensive slab on metal deck for CLT planks, since the floor structure represents over half of the embodied carbon in the residential building and just under half in the commercial lab building.

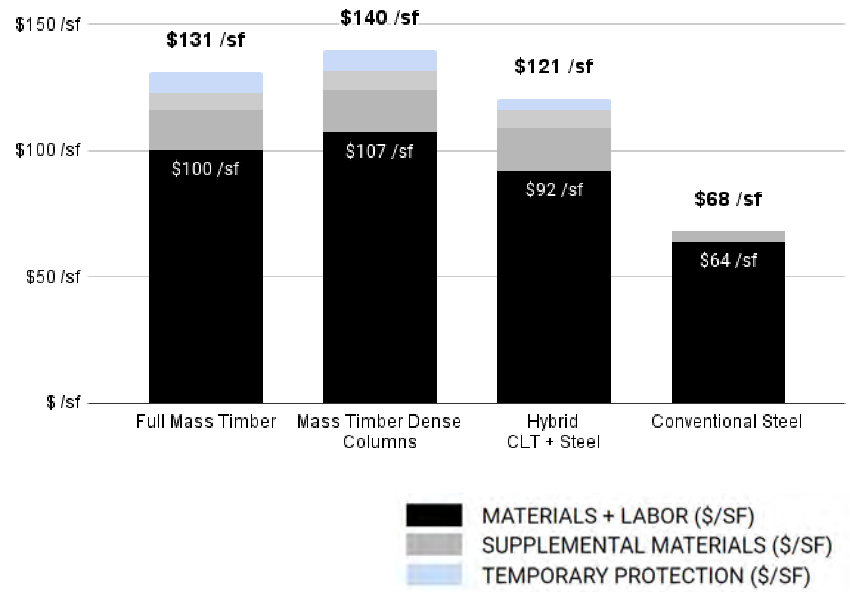
Figures include embodied carbon from foundations and exclude facade, interiors, and other systems

CONSTRUCTION COST ANALYSIS

RESIDENTIAL
MATERIALS + LABOR COSTS
$/SF OF STRUCTURAL FRAME + FLOORS

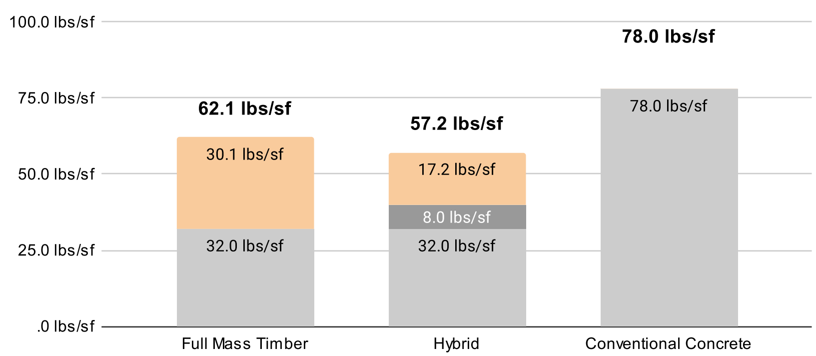


COMMERCIAL
MATERIALS + LABOR COSTS
$/SF OF STRUCTURAL FRAME + FLOORS

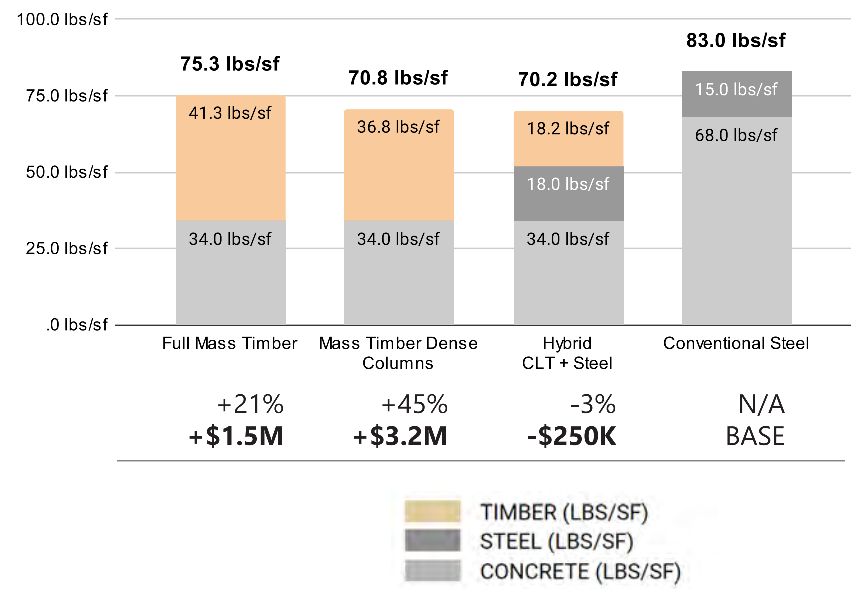


WEIGHT OF THE STRUCTURE / COLUMN LOADING

RESIDENTIAL
STRUCTURAL WEIGHT + COLUMN LOADS
LBS/SF OF STRUCTURAL FRAME + FLOORS

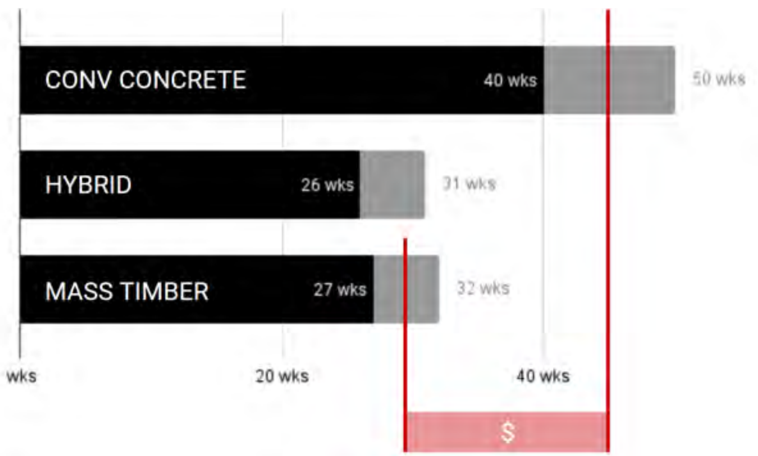


COMMERCIAL
MATERIALS + LABOR COSTS
LBS/SF OF STRUCTURAL FRAME + FLOORS



POSSIBLE FOUNDATION REDUCTION		Full Mass Timber (Res.)	Hybrid (Res.)	Conventional Concrete	Full Mass Timber (Com.)	Mass Timber Dense Columns	Hybrid CLT + Steel	Conventional Steel
	VOLUME (%)	-14%	-29%	N/A	+21%	+45%	-3%	N/A
	VALUE ($)	**-$250K**	**-$500K**	BASE	**+$1.5M**	**+$3.2M**	**-$250K**	BASE

RESIDENTIAL
ERECTION TIMELINE
NUMBER OF WEEKS



GENERAL CONDITIONS
13-18 WKS AT $90K/WEEK EST.
- $1.2M - $1.6M

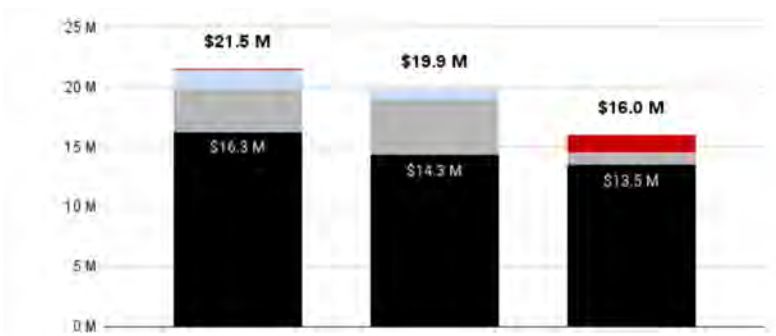
COMMERCIAL
ERECTION TIMELINE
NUMBER OF WEEKS

GENERAL CONDITIONS
7-10 WKS AT $105K/WEEK EST.
+ $750K - $1M

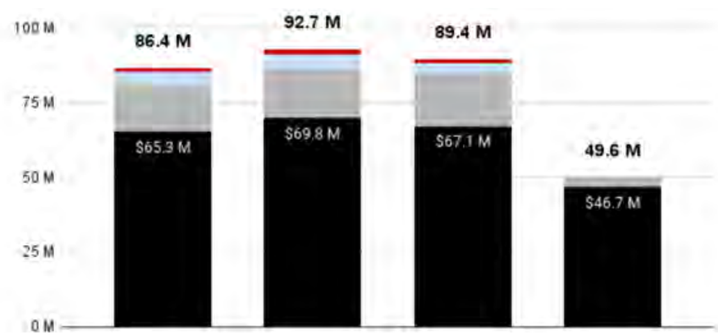
ERECTION TIMELINE, LOWER RANGE (WKS)
ERECTION TIMELINE, UPPER RANGE (WKS)

CONSTRUCTION SCHEDULE ANALYSIS

RESIDENTIAL
TOTAL CONSTRUCTION COST
$ INCLUDING PREMIUM FOR EXTENDED GENERAL CONDITIONS



COMMERCIAL
TOTAL CONSTRUCTION COST
$ INCLUDING PREMIUM FOR EXTENDED GENERAL CONDITIONS



SCHEDULE EXTENSION MONETIZED

MATERIALS + LABOR ($)
SUPPLEMENTAL MATERIALS ($)
TEMPORARY PROTECTION ($)
GENERAL CONDITIONS PREMIUM ($)

CARBON REDUCTION ANALYSIS

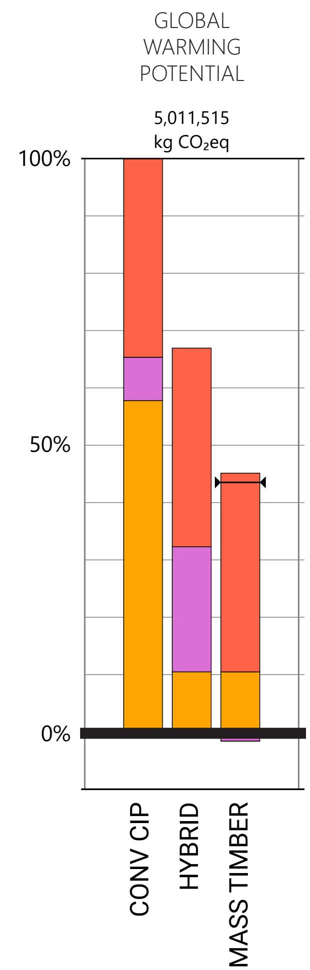
RESIDENTIAL OPTIONS

GLOBAL WARMING POTENTIAL
BY MATERIAL

LEGEND

Net value (impacts + credits)

- 03 - Concrete
- 05 - Metals
- 06 - Wood/Plastics/Composites



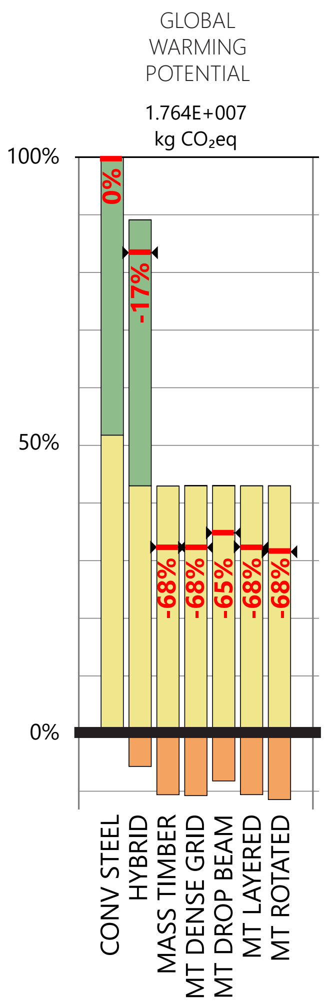
GLOBAL WARMING POTENTIAL
BY STRUCTURAL COMPONENT

LEGEND

Net value (impacts + credits)

- Floors
- Structure
- Walls

LAB OPTIONS



GLOBAL WARMING POTENTIAL
BY MATERIAL

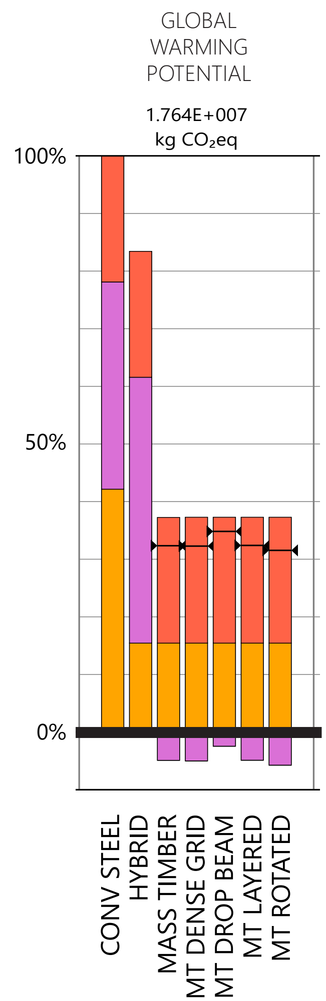
LEGEND

Net value (impacts + credits)

03 - Concrete

05 - Metals

06 - Wood/Plastics/Composites



GLOBAL WARMING POTENTIAL
BY STRUCTURAL COMPONENT

LEGEND

Net value (impacts + credits)

Floors

Structure

Walls

Figures account for above grade construction of building frame and slabs only, excluding facade, MEP, interior fit-out, etc.

RESIDENTIAL	Full Mass Timber	Hybrid CLT + Steel	Conventional Concrete
Structural System			
Total Building Height (stories)	16	16	18
Total Building Height (ft)	205.0'	205.0'	210.0'
Total Building Area (sf GSF)	191,250 sf	191,250 sf	213,750 sf
Total Building Area (as % of GFA approved in PDA)	89%	89%	100%
Structural Material: Timber Volume Efficiency (cf/sf)	0.86	0.49	n/a
Structural Material: Timber Volume Efficiency (lbs/sf)	30.1 lbs/sf	17.2 lbs/sf	n/a
Structural Material: Steel Weight Efficiency (lbs/sf)	n/a	8.0 lbs/sf	.0 lbs/sf
Structural Material: Concrete Weight Efficiency (lbs/sf)	32.0 lbs/sf	32.0 lbs/sf	78.0 lbs/sf
Structural Material: Total Matl Weight (lbs/sf)	62.1 lbs/sf	57.2 lbs/sf	78.0 lbs/sf
Ability to meet Acoustic Criteria (STC 50)	yes	yes	yes
Coordination with MEP Service Distribution (base building)			
Garage Structural Integration (is column transfer needed between tower and garage?)			
Cost & Schedule			
Design Cost			
Potential for Design Assist			
Material ($/sf of Structural Frame and Floors)	see mat'l + labor line	see mat'l + labor line	see mat'l + labor line
Material + Labor Costs ($/sf of Structural Frame and Floors)	$85 /sf	$75 /sf	$63 /sf
+ Supplemental Material ($/sf, 50% from below)	$13 /sf	$16 /sf	$5 /sf
+ Supplemental Material (added $/sf, 100% from below)	$6 /sf	$8 /sf	$ /sf
+ Supplemental Material ($/sf of fireproofing, GWB enclosures, materials to make base building code compliant)	$19/sf for 100% GWB enclosure. $13/sf for 50% Exposed MT & 50% GWB Enclosed	$24/sf for 100% GWB enclosure @ CLT Deck & SFP @ Columns & Beams. $16/sf for 50% Exposed MT & 50% GWB Enclosed & 100% SFP Columns & Beams	There is no additional cost for code related materials but most likely a $5/sf premium will be required for additional finishing of the underside of deck.
Labor Costs ($/sf)	see mat'l + labor line	see mat'l + labor line	see mat'l + labor line
Availability of Skilled Labor (list challenges)			
Temporary Protection during Construction ($/sf)	$8 /sf	$5 /sf	n/a
Construction Cost (Struct Frame, $)	$16.3 M	$14.3 M	$13.5 M
Construction Cost (Supplemental Material 100%, $)	$3.6 M	$4.6 M	$1.1 M
Construction Cost (Temp Protection, $)	$1.5 M	$1.0 M	$0.0 M
Construction Cost Premium (GCs, $)	$0.1 M	$0.0 M	$1.5 M
Foundation Volume - Footings (cf)	9,000	7,500	10,500
Foundation Volume - Footings (% savings)	-14%	-29%	n/a
Foundation Volume - Footings ($ savings)	-$250,000	-$500,000	Base Cost is $1.75M

RESIDENTIAL	Full Mass Timber	Hybrid CLT + Steel	Conventional Concrete
Supply/Manufacturer Competitiveness	Limited Local & National MT Supplier Options will lead to a less competitive bidding process. Therefore a delegated design process should be considered to achieve a more cost-competitive project.	With a hybrid approach, the scope of work will be split between the MT and Steel trades, which could affect the desire to bid on the project as the scope is not a 100% MT or 100% Steel Project.	The local concrete subcontractor market is more available then MT.
Procurement (list challenges)	Challenges: -Mass Timber CLT Deck, Gulam Beams & Columns size availability varies from supplier to supplier - Domestic Wood Species are limited (Wood species from over Seas pose logistic & quality assurance risk) -When procuring MT a delegated design should be considered to maximize the design efficiency and limit coordiation risk.	Challenges: -Mass Timber CLT Deck, Gulam Beams & Columns size availability varies from supplier to supplier - Domestic Wood Species are limited (Wood species from over Sea pose logistic & quality assurance risk) -Coordination btw MT & Steel Subcontractor can pose a risk.	Challenges: - Local Market pricing and subcontractor availability can quickly change the Cost feasibility of CIP vs. steel. Since Steel has increased in cost CIP structures are more cost feasible.
Material Availability / Lead Time (wks)	MT Lead Time TBD	14wks for WF Beams, MT Lead Times TBD	n/a
Erection Timeline (wks)	27wks-32wks	26wks-31wks	40wks-50wks
Erection Timeline (wks, low end)	27 wks	26 wks	40 wks
Erection Timeline (wks, added for high end)	5 wks	5 wks	10 wks
General Conditions/ Week	$90,000		
Schedule GC savings low end / premium high end ($)	-$1,170,000	-$1,260,000	n/a
Schedule GC savings high end / premium low end ($)	-$1,620,000	-$1,710,000	n/a
Insurance Costs (premium vs typical)			
Leasing			
Ceiling Heights (8'-0" min for ea)	8'-0"	8'-0"	8'-0"
Floor To Floor Heights	11'-0"	11'-0"	10'-0"
Flexible Planning	n/a	n/a	n/a
MEP Flexibility: Adaptability for TI	n/a	n/a	n/a
Ground Floor / Lobby Flexibility			
Unit Layout Flexibility	neutral	neutral	neutral
Marketability of Design Story	very good	good	neutral
Skanska Value			
Embodied Carbon Above Grade (total kgCO2 eq)	2.2 M	3.4 M	5.0 M
Total Building Area (m2 GSM)	17,768 m2	17,768 m2	19,858 m2
Embodied Carbon (kgCO2 eq / m2)	122.8	188.8	252.4
Embodied Carbon (% reduction)	-51%	-25%	n/a
Embodied Carbon Below Grade (total kgCO2 eq)	2.6 M	2.6 M	2.6 M
Total Garage Area (m2 GSM)	3,939 m2	3,939 m2	3,939 m2
Embodied Carbon Above+Below Grade (kgCO2 eq)	4.8 M	6.0 M	7.6 M
Embodied Carbon Above+Below Grade (kgCO2 eq / m2)	220.3	274.3	319.9
Sustainability Story	very good	good	none
City / State Approvals			
Sustainability Narrative	Positive	Positive	Neutral
Embodied Carbon	Positive	Positive	Neutral
Building Code Requirements	Neutral	Neutral	Neutral
Energy Code Requirements	Neutral	Neutral	Neutral
Carbon Neutral Operations	Neutral	Neutral	Neutral
Potential for Code Variances to allow exposed materials	Yes	Yes	N/A

POSITIVE

NEUTRAL

NEGATIVE

LAB

	Full Mass Timber	Mass Timber Dense Columns	Hybrid CLT + Steel	Conventional Steel
Structural System				
Total Building Height (stories)	16	16	18	18
Total Building Height (ft)	291.0'	285.6'	294.9'	294.9'
Total Building Area (sf GSF)	652,800 sf	652,800 sf	729,600 sf	729,600 sf
Total Building Area (as % of GFA approved in PDA)	89%	89%	100%	100%
Structural Material: Timber Volume Efficiency (cf/sf)	1.18	1.05	0.52	n/a
Structural Material: Timber Volume Efficiency (lbs/sf)	41.3 lbs/sf	36.8 lbs/sf	18.2 lbs/sf	n/a
Structural Material: Steel Weight Efficiency (lbs/sf)	n/a	n/a	18.0 lbs/sf	15.0 lbs/sf
Structural Material: Concrete Weight Efficiency (lbs/sf)	34.0 lbs/sf	34.0 lbs/sf	34.0 lbs/sf	68.0 lbs/sf
Structural Material: Total Matl Weight (lbs)	75.3 lbs/sf	70.8 lbs/sf	70.2 lbs/sf	83.0 lbs/sf
Ability to meet Vibration Criteria (Market Standard @ 8,000 mps)	yes	yes	yes	yes
Coordination with MEP Service Distribution (base building)				
Garage Structural Integration (is column transfer needed between tower and garage?)				
Cost & Schedule				
Design Cost				
Potential for Design Assist				
Material ($/sf of Structural Frame and Floors)	see mat'l + labor line	see mat'l + labor line	see mat'l + labor line	see mat'l + labor line
Material + Labor Costs ($/sf of Structural Frame and Floors)	$100 /sf	$107 /sf	$92 /sf	$64 /sf
+ Supplemental Material ($/sf, 50% from below)	$16 /sf	$17 /sf	$17 /sf	$4 /sf
+ Supplemental Material ($/sf, 100% from below)	$7 /sf	$8 /sf	$7 /sf	
+ Supplemental Material ($/sf of fireproofing, GWB enclosures, materials to make base building code compliant)	$23/sf for 100% GWB enclosure. $16/sf for 50% Exposed MT & 50% GWB Enclosed	$25/sf for 100% GWB enclosure. $17/sf for 50% Exposed MT & 50% GWB Enclosed	$24/sf for 100% GWB enclosure @ CLT Deck & SFP @ Columns & Beams. $17/sf for 50% Exposed MT & 50% GWB Enclosed & 100% SFP Columns & Beams	$4/sf for SFP Columns and Beams.
Labor Costs ($/sf)	see mat'l + labor line	see mat'l + labor line	see mat'l + labor line	see mat'l + labor line
Availability of Skilled Labor (list challenges)	Challenges: -Limited Local Labor Forces, -Limited erectors experienced w/ teaming up with MT Suppliers -Limited CM Experience w/ MT Process	Challenges: -Limited Local Labor Forces, -Limited erectors experienced w/ teaming up with MT Suppliers -Limited CM Experience w/ MT Process	Challenges: -Limited Local Labor Forces	There is a large skilled steel labor force to pull from. The only labor force challenge is the large backlog of projects subcontractors have to will reduce the availability of the skilled labor force.
Temporary Protection during Construction ($/sf)	$8 /sf	$8 /sf	$5 /sf	n/a
Construction Cost (Struct Frame, $)	$65.3 M	$69.8 M	$67.1 M	$46.7 M
Construction Cost (Supplemental Material 100%, $)	$15.0 M	$16.3 M	$17.5 M	$2.9 M
Construction Cost (Temp Protection, $)	$5.2 M	$5.2 M	$3.6 M	$0.0 M
Construction Cost Premium (GCs, $)	$0.9 M	$1.3 M	$1.2 M	$0.0 M
Foundation Volume - Footings (cf)	52,500	63,000	42,000	43,500
Foundation + Excavation (% savings)	21%	45%	-3%	n/a
Foundation Volume - Footings ($ savings)	$1,500,000	$3,250,000	-$250,000	Base Cost is $7.25M

POSITIVE
NEUTRAL
NEGATIVE

LAB

	Full Mass Timber	Mass Timber Dense Columns	Hybrid CLT + Steel	Conventional Steel
Supply/Manufacturer Competitiveness	Limited Local & National MT Supplier Options will lead to a less competitive bidding process. Therefore a delegated design process should be considered to achieve a more cost-competitive project	Limited Local & National MT Supplier Options will lead to a less competitive bidding process. Therefore a delegated design process should be considered to achieve a more cost-competitive project	With a hybrid approach, the scope of work will be split between the MT and Steel trades, which could affect the desire to bid on the project as the scope is not a 100% MT or 100% Steel Project.	The Local Steel subcontractor market is very competitive. The only variable that effects this is the subcontractors backlogs
Procurement (list challenges)	Challenges: -Mass Timber CLT Deck, Gulam Beams & Columns size availability varies from supplier to supplier - Demostic Wood Species are limited (Wood species from over Seas pose logistic & quality assurance risk) -When procuring MT a deligated design should be considered to maximize the design efficiency and limit coordiation risk.	Challenges: -Mass Timber CLT Deck, Gulam Beams & Columns size availability varies from supplier to supplier - Demostic Wood Species are limited (Wood species from over Seas pose logistic & quality assurance risk) -When procuring MT a deligated design should be considered to maximize the design efficiency and limit coordiation risk.	Challenges: -Mass Timber CLT Deck, Gulam Beams & Columns size availability varies from supplier to supplier - Demostic Wood Species are limited (Wood species from over Sea pose logistic & quality assurance risk) -Coordination btw MT & Steel Subcontractor can pose a risk	Challenges: - Lead Times can be affected by custom shapes and sizes - Project Backlog can affect cost completitveness
Material Availability / Lead Time (wks)	MT Lead Time TBD	MT Lead Time TBD	14wks for WF Beams, MT Lead Times TBD	14wks for WF Beams & 20 Wks for Metal Deck
Erection Timeline (wks)	45wks- 52wks	50-55wks	47-55wks	35-45wks
Erection Timeline (wks, low end)	45 wks	50 wks	47 wks	35 wks
Erection Timeline (wks, added for high end)	7 wks	5 wks	8 wks	10 wks
General Conditions/ Week	$105,000			
Schedule GC savings low end / premium high end ($)	$1,050,000	$1,575,000	$1,260,000	$0
Schedule GC savings high end / premium low end ($)	$735,000	$1,050,000	$1,050,000	$0
Insurance Costs (premium vs typical)				
Leasing				
Ceiling Heights (9'-6" min for ea)	9'-6"	9'-6"	9'-6"	9'-6"
Floor To Floor Heights	16'-0"	15'-4"	14'-6"	14'-6"
Flexible Planning	neutral	less	good	good
MEP Flexibility: Adaptability for TI	less	less	less	neutral
Ground Floor / Lobby Flexibility				
Tenant Fit Out Flexibility	good	less	good	very good
Marketability of Design Story	very good	very good	good	neutral
Skanska Value				
Embodied Carbon (total kgCO2 eq)	5.7 M	5.7 M	14.7 M	17.6 M
Total Building Area (m2 GSM)	60,647 m2	60,647 m2	67,781 m2	67,781 m2
Embodied Carbon (kgCO2 eq / sf)	94.1	93.9	217.1	260.2
Embodied Carbon (% reduction)	-64%	-64%	-17%	n/a
Embodied Carbon Below Grade (total kgCO2 eq)	6.0 M	6.0 M	6.0 M	6.0 M
Total Garage Area (m2 GSM)	10,498 m2	10,498 m2	10,498 m2	10,498 m2
Embodied Carbon Above+Below Grade (kgCO2 eq)	11.7 M	11.7 M	20.7 M	23.6 M
Embodied Carbon Above+Below Grade (kgCO2 eq / m2)	164.5	164.4	264.6	302.0
Sustainability Story	very good	very good	good	none
City / State Approvals				
Sustainability Narrative	Positive	Positive	Positive	Neutral
Embodied Carbon	Positive	Positive	Positive	Neutral
Building Code Requirements	Neutral	Neutral	Neutral	Neutral
Energy Code Requirements	Neutral	Neutral	Neutral	Neutral
Carbon Neutral Operations	Neutral	Neutral	Neutral	Neutral
Potential for Code Variances to allow exposed materials	Yes	Yes	Yes	N/A

NEXT STEPS + TAKEAWAYS

The intent of this study was to understand, at a very early stage in the planning process, what opportunities and challenges Mass Timber construction could present for the Longwood Place Project. With (5) buildings being developed over 10 or more years, Skanska has the opportunity to explore different design and construction methodologies, and evaluate if and when they may make sense for a future phase of this Project. There are some significant findings that have come out of this conceptual study that will influence the thinking and planning as the design process advances.

1| There are significant benefits to incorporating Mass Timber in residential design and construction – reducing the building's carbon footprint, lowering the weight of the building in order to downsize foundations, and shortening the schedule for construction. The cost is still higher for Mass Timber at this time, but there are many other benefits that should be considered when weighing the options for the superstructure. As the Mass Timber market matures on the east coast it is possible that it may become more competitive to conventional construction methodologies.

2| Vibration criteria and HVAC distribution are two major elements in lab design that are more challenging to achieve in lab buildings with Mass Timber. Deeper steel beams with penetrations allow for an integrated structure and MEPFP zone that allows for tighter floor to floor heights. Mass timber requires taller floor to floor dimensions where MEPFP and structure run in stacked layers separate from one another. This was a surprise and resulted in the Mass Timber schemes achieving fewer stories within the maximum heights allowed by the Project's zoning.

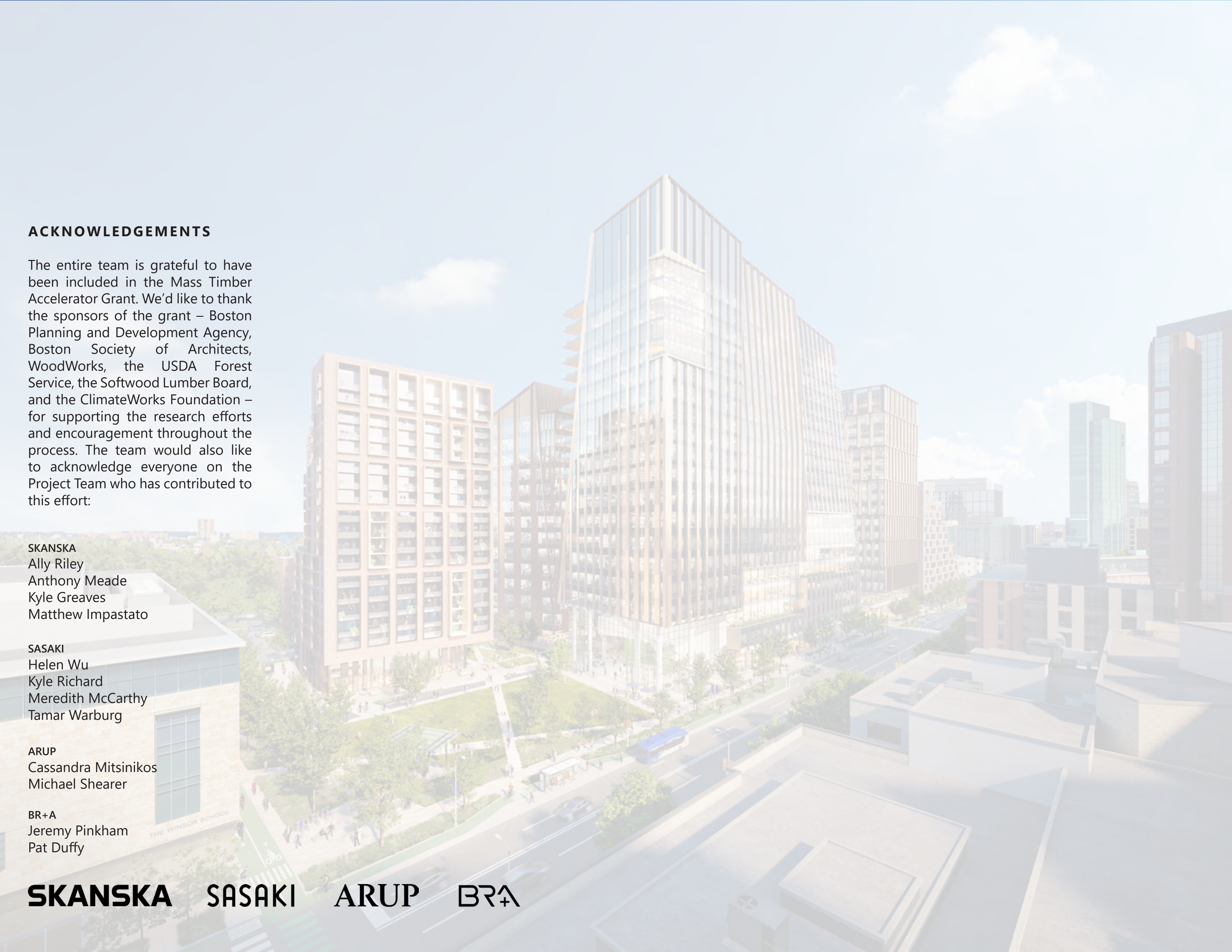
3| Mass Timber in residential construction has many newly completed projects paving the way for those in process and those still in planning. There is an established pipeline of material suppliers, fabricators, and installers. This should make Mass Timber in residential projects more and more feasible as time goes on. Commercial lab buildings will follow suit, but currently it is perceived as a newer construction system less familiar to those who operate in this space. It will take more time and implementation to get the costs and schedule to be financially viable for those projects, especially at a high-rise scale of 18 stories.

4| The reduction in construction schedule for Mass Timber identified in the residential case study is not realized in the commercial lab. The schedule is either the same length or sometimes longer than conventional steel and concrete. Since lab buildings typically utilize longer spans with plans less restricted by columns, there are more individual members in a mass timber lab than a comparable steel building. Due to the higher number of crane picks to hoist the comparatively higher number of Mass Timber pieces, this analysis identified that the schedule becomes lengthier than conventional construction. The extended schedule, on top of the added materials for code required fire protection, makes Mass Timber a higher first cost option for lab buildings. At the moment, there are also no precedents in this market to confirm whether the higher first costs of a Mass Timber lab building enhance leasability or increase potential rents and building valuations to make the economics work.

PROGRAM EVALUATION + IMPACT

Without this grant, the Project team would likely not have had the opportunity to evaluate Mass Timber at this level of detail this early in the planning process, and it is likely the discussion would have been focused mainly on cost. Prior to advancing the conceptual design for Phase 1 of the Longwood Place Project, the program has been instrumental in helping the design team to evaluate many options simultaneously when it comes to proposed structural systems for the future buildings. The interim and final presentations were well timed to allow us an opportunity to understand how the other project teams were approaching Mass Timber and provided valuable lessons about how they were navigating real challenges they faced on their projects.

The Accelerator program also fostered connections and relationships across project teams that will hopefully support a continued inter-project dialogue that will help Mass Timber grow in adoption across the City over time.



ACKNOWLEDGEMENTS

The entire team is grateful to have been included in the Mass Timber Accelerator Grant. We'd like to thank the sponsors of the grant – Boston Planning and Development Agency, Boston Society of Architects, WoodWorks, the USDA Forest Service, the Softwood Lumber Board, and the ClimateWorks Foundation – for supporting the research efforts and encouragement throughout the process. The team would also like to acknowledge everyone on the Project Team who has contributed to this effort:

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Boston Mass Timber Accelerator Program

FINAL REPORT / August 31, 2023

RISE

SODEN SUSTAINABILITY cbt CODE RED CONSULTANTS odeh engineers VANDERWEIL

INTRODUCTION

RISE and the 18 Spice Street team are proud to have been selected for the second round of the BPDA's Mass Timber Accelerator Program. The resources and access provided by the program and its partners enabled our project team to study the application of mass timber construction in a high-rise residential tower in Boston. RISE partnered with CBT, Odeh Engineers, Binderholz, Code Red, and Soden Sustainability to explore 18 Spice Street, a proposed project in Charlestown, as a candidate for mass timber construction.

The 18 Spice Street Site is located along the Cambridge Street connection between Charlestown and Somerville. The project closely abuts the Sullivan Square area allowing for quick access to public transit. The project, along with the surrounding developments, will help to invigorate the currently industrial area to provide public space, retail and housing for the area. The project is proposed at 24 stories (267') and consists of 365 residential units.

Our ultimate goal was study how we could design 18 Spice to be a healthier and more sustainable building. By taking guidance precedent from other high rise MT projects across the country, the team identified critical design measures that optimized carbon efficiency, constructability, and likelihood of code compliance. This report will summarize team's work over the course of the program and their key findings on the project's feasibility.

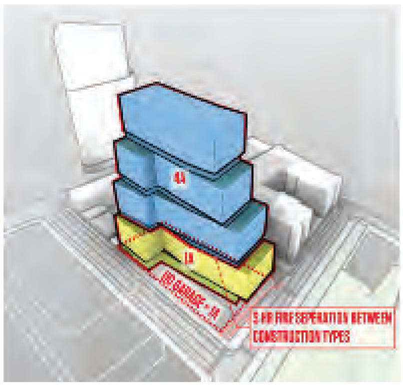
PROJECT PLANNING

Programming on the ground level was driven by the need for multiple retail opportunities and a significant public realm and exterior space for residents and retail consumers. The ground level also needed to accommodate a large bike storage room, loading dock, and an entry to the below grade parking garage. On the upper floors it was important to include a diverse mix of unit types, ranging from Studios to 3 Bedroom units. Two large amenity spaces with outdoor terraces were placed on Levels 7 and 13 to serve the needs of the building's residents.

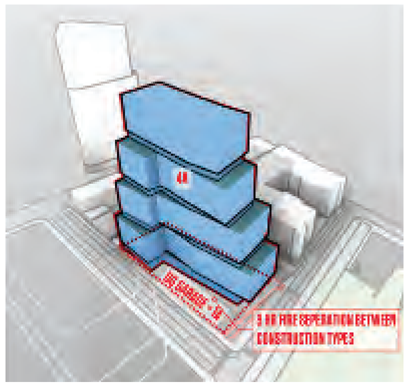
CODE PATH

The main project drivers for Mass Timber were overall material efficiency, height and number of floors, building shaping and cantilevers, and clear heights within the building. Using an existing design as a baseline, the project team established 3 primary code compliance pathways to provide a framework for the study. Each pathway had similarities, but with their own unique major considerations:

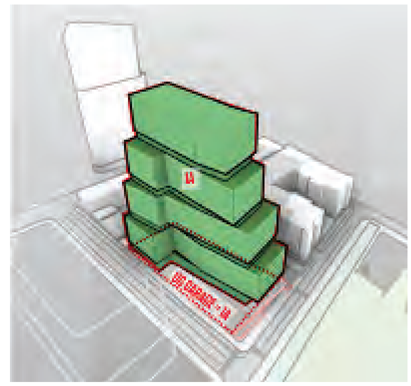
OPTION 1/1A
MT Tower over Podium



OPTION 2/2A
All MT Tower



OPTION 3
Hybrid Steel + MT



APPROACH	CONSTRUCTION TYPE	MAJOR CONSIDERATIONS
OPTION 1	Type IV-A over 1A (Podium)	18-story Type IV-A building above a 6-story non-combustible podium This is an as-of-right approach, assuming: • Maximum aggregate area of Type IV-A portion is 553,500 sf • Maximum total building height is 270 ft • All mass timber is concealed by wallboard - Option 1A assumes a code variance to expose 50% of MT ceilings, further coordination with AHJ is required.
OPTION 2	Type IV-A (All MT)	24 stories of mass timber Variance required given that, relative to Type IV-A parameters, the design exceeds allowable number of stories (18), and allowable aggregate area (553,500 sf). No local precedence for such an approval.
OPTION 3	Type 1A (Hybrid MT+Steel)	Variance required to allow combustible structural elements in IA construction. While there is local precedence for this approach under a previous variance, it is unclear whether the approach would be granted current day, given the specificity of the 10th edition relative to prescriptive approaches for tall mass timber.

STRUCTURAL SYSTEM SELECTION & COORDINATION

The team's selection of structural systems was driven by the building height, the building's floor plan layouts, floor-to-floor heights, and the project goals to utilize the efficiencies in mass timber construction while maintaining the code compliance pathway.

Floor panels were selected to be 5-ply 2-hour rated CLT panels throughout. Options for 5-ply 180mm panels with protected underside and 5-ply 200 mm panels with exposed underside to meet fire ratings were given. Final floor panel type to be selected based on code compliance options with accompanying to be determined acceptable variances for percentage of exposed mass timber.

Glulam beams and columns were selected for the typical floor framing with sizing varying by floor, spans, and structural load. These member sizes were governed by structural loading / deflection requirements. They were not governed by fire-rating and work as both exposed and protected. An option to use steel beams and steel columns in lieu of glulam members was given for the hybrid code compliance option.

The glulam beam and column layout was selected to maximize the CLT span capacity to allow for maximum open floor area to minimize impacts of columns on unit layouts. The beam sizes were suitable to cantilever over columns to support the building overhangs. Due to potential beam depth issues with the building floor-to floor heights it was documented that double glulam beams could be a solution to reduce beam depths.

The beam and column layout was also selected to simplify MEP coordination to minimize the number of beams spanning parallel with the corridor. This layout does however require beams to cross over the corridor so options were given to upturn the crossing beams with steel beams in lieu of glulam beams to simplify MEP coordination and to allow for maximum space in the ceiling cavity for MEP requirements.

For the lateral force resisting system the team explored using mass timber shear walls and timber braces, but due to the building height it was determined this was not a feasible solution therefore a combination of ordinary concrete shear wall cores and steel plate blade walls were selected.

COST ANALYSIS

For the cost analysis, we analyzed code compliance path 1 in comparison to our baseline design scenario that used steel framing with composite decks. In compliance path 1 we used the same construction method for everything below grade as the baseline, which consisted of 3 levels of slurry wall and a 5' mat slab. We also used the same construction method as the baseline for the podium Levels 1-6, and kept the structural core systems consistent with the baseline as well.

RISE worked with Binderholz and Turnkey Lumber to generate conceptual estimates for compliance path 1 and 1A, with 1A assuming a variance for 50% exposure of Mass Timber ceilings.

The results of our cost analysis showed that the premium for switching to Mass Timber construction is approximately 6% of the project's hard costs. The largest cost drivers were the building's superstructure and façade system. One major takeaway was that switching to Mass Timber saved approximately 3 months in the overall project schedule. This led to savings both in the construction budget and the overall carry costs for the project. Another major takeaway from our analysis was that by assuming a code variance to expose 50% of the Mass Timber ceilings, our project could save an additional $1.7 million in drywall costs.

Our team believes that as we advance the Mass Timber design for the project, we will be able to reduce this premium to between 2% and 3%. Our team will be deeply focused on the façade system design as that was the most significant cost driver found as part of this study. After discussions with other Mass Timber developers across the country, we will work towards a more cost efficient window wall system to use as a basis of design for this project.

CARBON AND LCA

RISE partnered with Soden Sustainability and CBT to perform an embodied carbon analysis for each code compliance pathway and our baseline scenario. To perform this analysis, the team used OneClick LCA software to conduct 60-year lifecycle assessments for each pathway's structure and enclosure.

The results showed carbon reductions for each code compliance pathway below:

- Option 1 (Steel Podium): 29.2% reduction in embodied carbon from baseline
- Option 2 (All Mass Timber): 43.2% reduction in embodied carbon from baseline
- Option 3 (Steel Columns w/ CLT Decking): 7.3% reduction in embodied carbon from baseline

If we include Biogenic CO2 storage (carbon absorbed by the trees that produced wood used for construction) we see even further carbon reductions:

- Option 1 (Steel Podium): 125.3% reduction in embodied carbon from baseline
- Option 2 (All Mass Timber): 189.3% reduction in embodied carbon from baseline
- Option 3 (Steel Columns w/ CLT Decking): 101.7% reduction in embodied carbon from baseline

When compared to the baseline steel building, these results equate to:

- Option 1 (Steel Podium): eliminating carbon emissions from 1372 cars for a year, or eliminating carbon emissions from powering 685 homes for a year
- Option 2 (All Mass Timber): eliminating carbon emissions from 2072 cars for a year, or eliminating carbon emissions from powering 1035 homes for a year
- Option 3 (Steel w CLT Decking): eliminating carbon emissions from 1113 cars for a year, or eliminating carbon emissions from powering 556 homes for a year

In conclusion, our key takeaways included:

- The fully mass timber option resulted in the greatest reductions in embodied carbon
- Replacing steel decking with CLT resulted in a small embodied carbon reduction relative to the other options, indicating that reducing the amount of steel beams and columns is a more effective intervention
- Despite being slightly more carbon-intensive during the construction process, all the options saw the majority of their carbon reductions achieved in the A1-A3 (material extraction, transport, and production) phases. Mass timber is less carbon-intensive to extract and produce when compared to steel and concrete

NEXT STEPS

The project team determined next steps to advance the Mass Timber design for 18 Spice Street as follows:

- Further Investigation into Code Complexities and refinement of Cost Analysis
- Whole Building LCA: Focus on other bigger contributors to global warming like Concrete.
- Investigate building facade: Looking at lightweight/pre-panelized facades with low GWP and how they relate to Mass Timber spandrel design
- Review acoustic options: Plytec is a potential option that is 90% recycled materials and is able to achieve a better than 50 STC rating

- Wood Species considerations: Not all Mass Timber products have the same structural capacity or Global Warming Potential (GWP)
- Refinements to MT Embodied Carbon Analysis: What are the impacts to the carbon story when looking at the transportation of the materials to the site? How green is the grid being used to manufacturer CLT?

PROGRAM FEEDBACK

Overall, RISE was very happy with the resources and guidance provided by the program partners and its funders. There are two points of feedback we would like to provide

1. Provide more guidance on Mass Timber vendors and suppliers and invite local trade representatives to be part of the conversation. Including these parties will provide more consistent results across all project participating in the program. It could also make sense for the MTA program to designate a specific vendor of choice for all projects to work with through the course of the program.
2. Explore additional and alternate grant funding sources. This could increase the amount of resources and funds available to the project teams, allowing for a more detailed and in depth analysis of Mass Timber feasibility for each project participating in the program.

We look forward to continuing conversations with the BPDA and the MTA program partners as we continue to explore options for Mass Timber construction at 18 Spice Street and advance the project design.

BOSTON MASS TIMBER ACCELERATOR

Suffolk Downs Building B16

Contents

I. Executive Summary: Overview

1. Summary Report

For this project, Elkus Manfredi teamed up with HYM Investment Group, Moriarty, and Thorton Tomasetti to prepare a direct comparison of mass timber versus steel structural systems in a eight-story residential building at Suffolk Downs. The study included an evaluation of design and embodied-carbon benefits along with an evaluation of the construction-cost differential between the two options.

The approved master plan for Suffolk Downs anticipates the creation of approximately 10.5 million square feet of built area, 7.3 million of which will be residential. This includes over 7,000 residential units.

Our goal in choosing a site at Suffolk Downs was to perform an early-stage conceptual analysis that could be replicated at other sites within the master plan area and at other project sites around Boston.

Parcel B-16 was chosen for study because it is relatively typical of the residential building sites planned at Suffolk Downs. It is part of the future Phase 1B and has been planned for a +/- 200,000 SF eight-story residential building. The master plan includes basic building-massing and zoning requirements for the site and we worked within these parameters. This includes a two-story above-grade parking podium wrapped by residential uses, six stories of residential space in a U-shaped building above the podium, and a 100’ overall height limit. Located in the middle of the U-shaped upper stories is a central courtyard space on the third floor.

To facilitate the study, schematic floor plans and structural framing plans were developed for both the steel- and mass-timber-framed building options. The unit count, floor-to-floor heights and basic layout is the same between the options.

The team embraced a comprehensive mission statement:

> ***“To evaluate the value of mass timber for residential block B-16 and future development at Suffolk Downs.”***

This resulted in an evaluation of mass timber in three categories:

1. Environmental

The team demonstrated a **40% reduction in embodied carbon** using mass timber when compared to a steel structural system. If also accounting for the biogenic storage potential of wood, we demonstrated that the mass timber structure would be **net carbon negative**.

2. Efficiency

Cost: We first identified the variables between the two options that would affect cost, described further on page 13. These variables were estimated to be 9% more expensive in the mass-timber-framed building, but the **cost premium for mass timber was estimated to be only 1.3% when considering the total construction cost of the building.**

Schedule: The team discussed additional efficiencies that could potentially be gained from reduced erection time and overall schedule savings, but **a detailed analysis of construction schedule was not within the scope of our evaluation.**

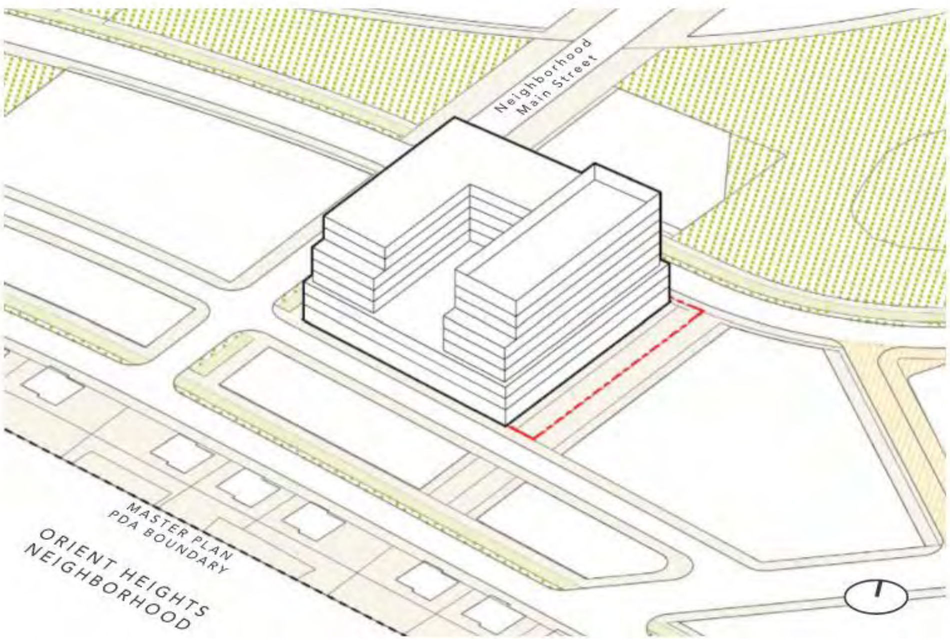
3. Differentiation

Exposed mass timber in residential units creates the opportunity for a **unique biophilic aesthetic that can differentiate a mass timber building**. Our multidisciplinary team explored the interior design opportunities with mass timber through the creation of the renderings included on page 9 and 10.

2. Design Illustrations & Drawings

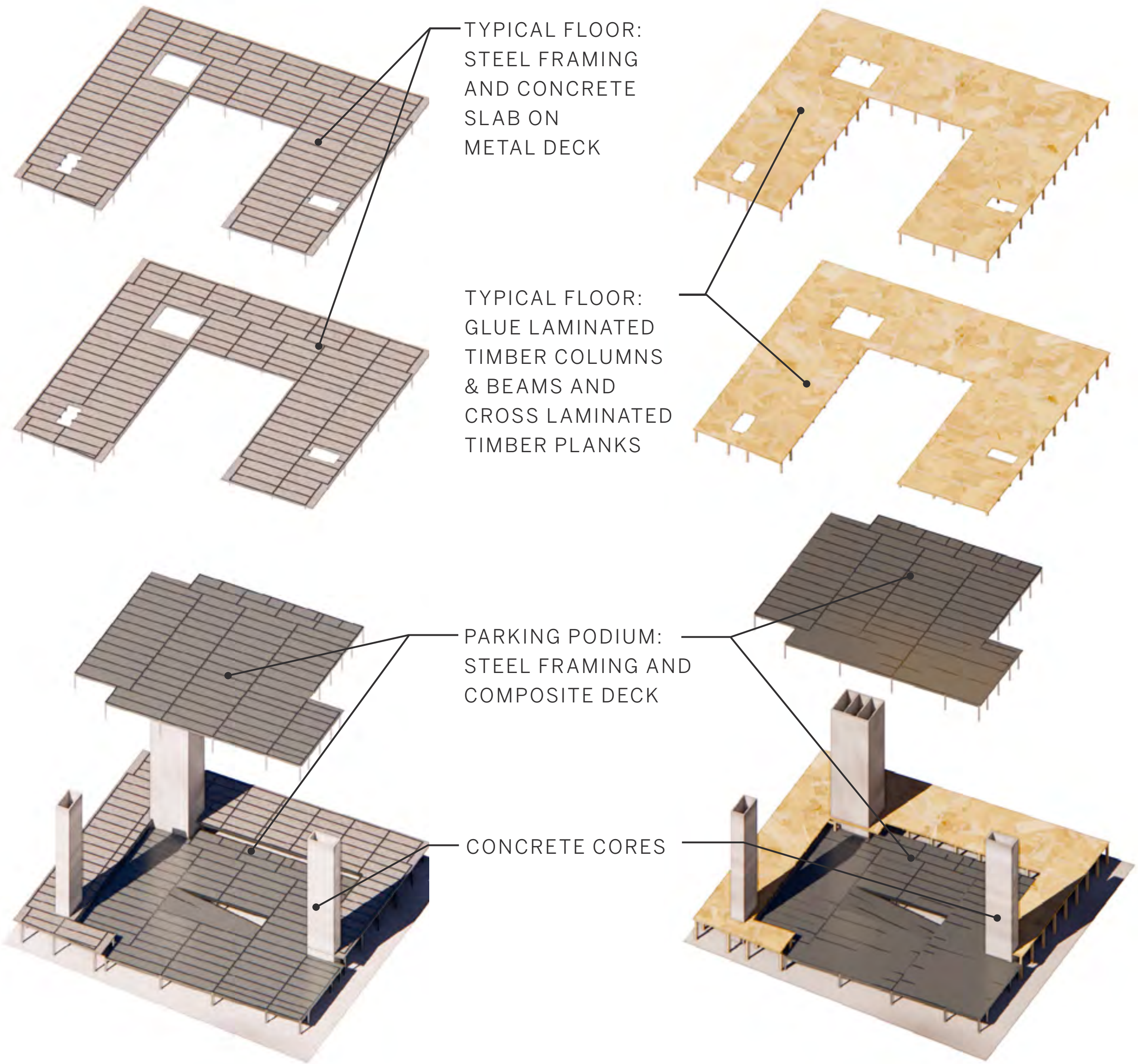
SITE B16 LOCATION

Image: CBT Architects



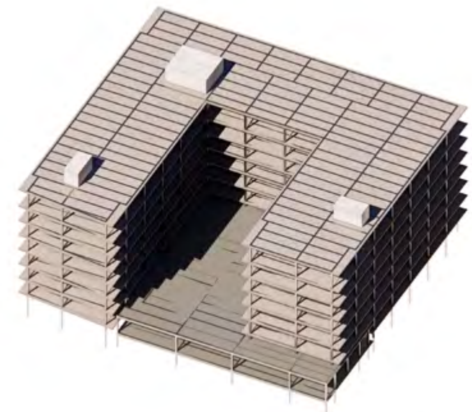
ZONING VOLUME: SITE B16 BUILDING MASSING FROM MASTER PLAN

Sample Building Massing Plan



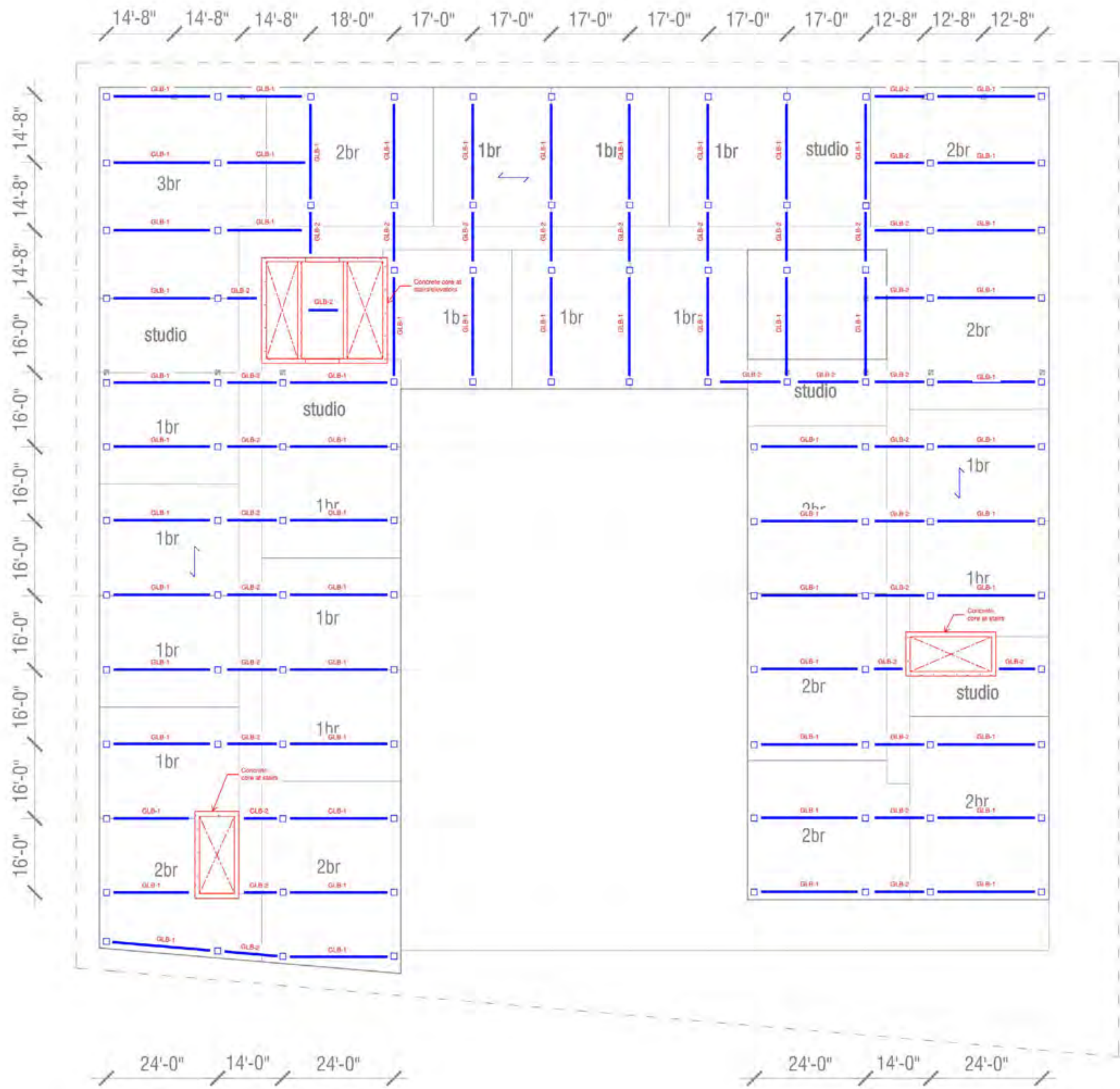
STEEL STRUCTURE

MASS TIMBER STRUCTURE

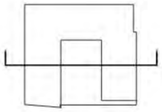


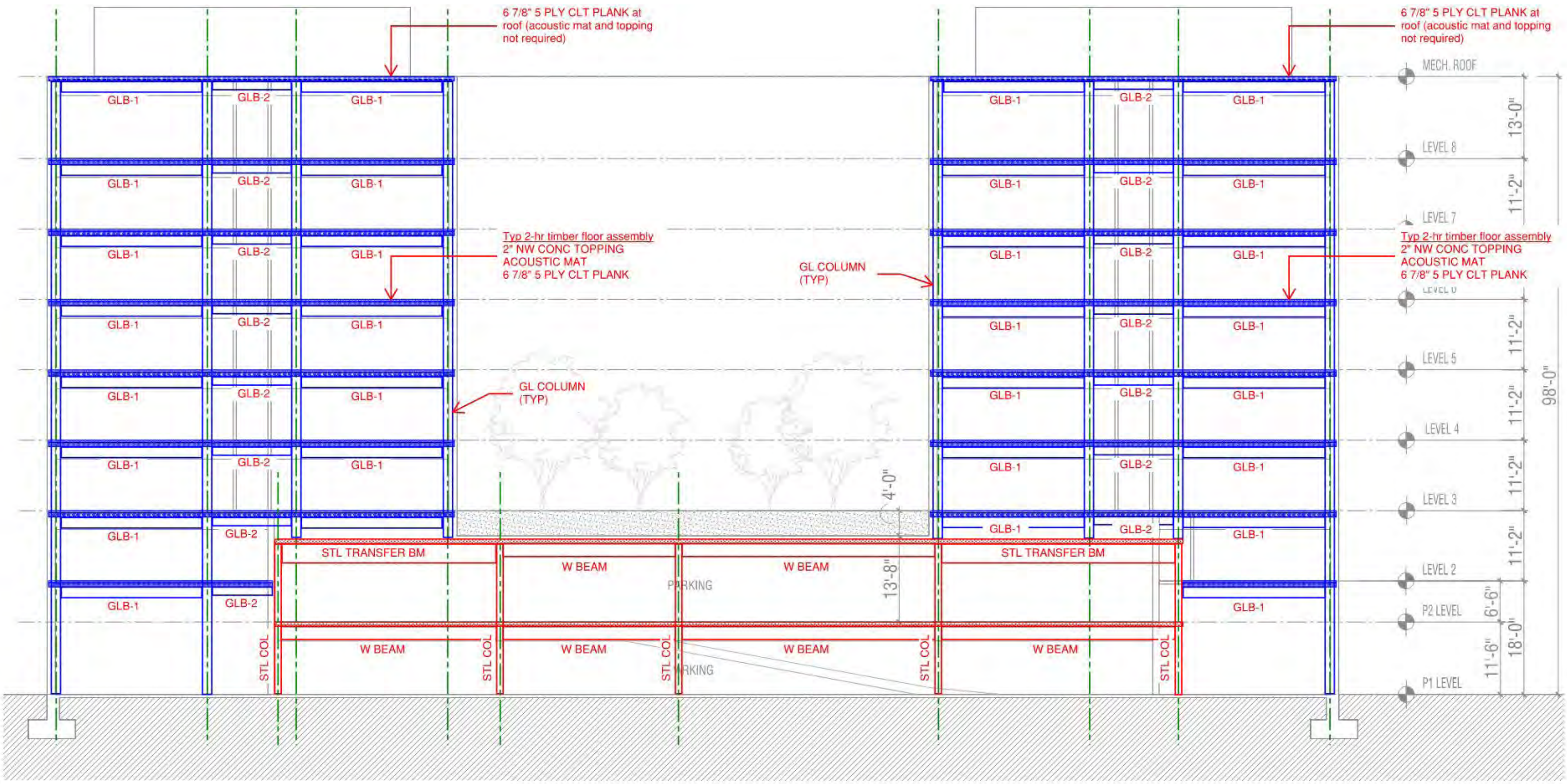
STEEL STRUCTURE

MASS TIMBER STRUCTURE



MASS TIMBER — UPPER FLOOR FRAMING PLAN





MASS TIMBER — STRUCTURAL SECTION

GLULAM BEAM

STEEL BEAM

MIDDLE UNIT — STEEL FRAME BUILDING

MIDDLE UNIT — MASS TIMBER FRAME BUILDING

CORNER UNIT — STEEL FRAME BUILDING

CORNER UNIT — MASS TIMBER FRAME BUILDING

II. Benefits & Outcomes

1. Building Practices

The Suffolk Downs Building B16 project is unique in that it is a hypothetical project not actively in design. The multi-family program and location of the project are planned for a future phase of development at the Suffolk Downs redevelopment site. The estimated construction start date is sometime in 2025–2026 and by then the opportunity to use mass timber is likely.

Design and Construction Strategies

In order to truly evaluate mass timber, the team's approach was to compare the same program—an eight-story multifamily structure—as both a steel-framed building and as a mass-timber-framed building.

Both schemes include a two-levels-above-grade parking podium framed with structural steel and slab-on-deck construction and include concrete cores. Both options also contain the same residential unit mix, and all floors are designed with an 11'-2" typical floor-to-floor height. The team also discussed whether mass timber would allow for lower floor-to-floor heights and potentially allow the addition of another floor within the height limit for this site. It was determined that the study would be most beneficial if comparing buildings with the same overall area and floor-to-floor heights, but the potential for reduced floor-to-floor heights and the opportunity to add an additional floor merits further study on a project-specific basis.

Building Code Strategies

A mass timber building of this height will be considered Type IV B construction. This is a new type in the 10th edition of IBC 2021. The 10th edition limits the amount of mass timber that can be exposed in Type IV B, but due to the estimated start of this project being sometime in 2025–2026, the project anticipates the future adoption of the 11th edition of the building code based on IBC 2024. Based on input provided by WoodWorks and Code Red as part of the accelerator program, we understand the 11th edition is anticipated to allow the exposure of > 25% of the mass timber surface area in Type IV B.

2. Analysis

Structural Analysis

The structural analysis considered two systems. The first of these was a mass timber superstructure for the residential and retail spaces, with a steel-and-concrete-framed structure for the parking areas. The second option considered an all-steel-and-concrete option. Both options include concrete cores and the foundations for both systems are assumed to be concrete. At this time, little information is known about the soil characteristics beneath this site, but the analysis included an estimate of the quantity of foundation concrete based on an analysis of column loads. This showed that the overall quantity of concrete used in foundations could be reduced by as much as 20% in the timber-framed option.

SUPERSTRUCTURE — TIMBER-FRAMED OPTION

- The floor structure for the towers in this option will be 5-ply, 6 7/8"-thick cross-laminated timber (CLT) planks spanning to glue-laminated timber (GL) beams and columns. The CLT planks will be exposed at the underside and become the finished ceiling in living and bedroom spaces for the majority of the units. The CLT will be topped with 2" of normal-weight concrete overlaying an isolation mat to improve acoustics and vibration performance.

- CLT floor planks are required to be fabricated to provide a minimum two-span continuous condition across the entire footprint.
- The CLT planks, GL beams and all associated connections will be designed to achieve a 2-hour fire-resistance rating without additional fire protection or coverings. The fire resistance is provided, in accordance with NDS Chapter 16, by removing the effective char depth to each exposed face from the member. The member is then designed to carry the design loads, with appropriate strength increase factors applied per NDS, after the loss of section has occurred.
- The GL columns and all associated connections are designed to achieve a 2-hour fire-resistance rating without additional fire protection or coverings.
- For GL beam-to-column connections, all beams with be hung from the face of the columns with concealed hangers. Typical details used on similar projects were provided to assist with cost estimating.
- The timber column grid generally does not align with the parking column grid at the bottom two stories. Transfer beams are required to support the timber columns above the parking levels.
- The lateral-force-resisting system for the building will be reinforced concrete cores. The walls of the cores are 16" thick.
- The exterior facade system is assumed to be metal panel, glazed curtain wall, or other siding materials of similar weight. A facade weight allowance of 20 psf has been carried in the design.
- Structural materials:
    a. Concrete (normal-weight):

1) CLT topping:	f'c = 3,000 psi
2) Slab on deck:	f'c = 4,000 psi
3) Core walls:	f'c = 6,000 psi

    b. Slab on deck: 4.5" concrete on 2.0 composite deck (6.5" total thickness). See plans for reinforcement.

    c. Steel framing:

1) Beams & Columns	Wide flange, ASTM A992
2) All other steel	ASTM A36
3) Headed Studs	3/4"Øx5" (minimum)

    d. Timber framing:

1) CLT floor planks:	Grade E1
2) GL beams:	24F-1.8E (or better)
3) GL columns:	Fc = 2,000 psi (minimum)

SUPERSTRUCTURE — STEEL-FRAMED OPTION

- The floor structure for the towers in this option will be a composite slab consisting of 2" deck with 4-1/2" normal weight topping.
- Slabs are supported by wide-flange steel beams between 14 and 18 inches deep. Steel columns will also be W14.
- The residential column grid generally does not align with the parking column grid at the bottom two stories. Transfer beams are required to support the columns above the parking levels
- The lateral-force-resisting system for the building will be reinforced concrete cores. The walls of the cores are 16" thick.
- The exterior facade system is assumed to be metal panel, glazed curtain wall, or other siding materials of similar weight. A facade weight allowance of 20 psf has been carried in the design.

- Structural materials:
    a. Concrete (normal-weight):
        1) Slab on deck: f'c = 4,000 psi
        2) Core walls: f'c = 6,000 psi
    b. Steel framing:
        1) Beams & Columns Wide flange, ASTM A992
        2) All other steel ASTM A36
        3) Headed Studs 3/4"Øx5" (minimum)

Cost Analysis

We first identified the primary variables between the two structural systems that would affect cost. These include:

- Structural framing
- Interior framing, drywall, and interior finish, including an estimate of reduction by leaving a portion of mass timber surfaces exposed.
- Spray-applied fireproofing
- Concrete, including estimated foundation quantities.

In total, these variables were estimated to be 9% more expensive in a mass-timber-framed building when compared to a steel-framed building. However, this cost premium was estimated to be only 1.3% when considering the total construction cost of the building. This worked out to a premium of +/- $8,700 per unit in this 196-unit building.

The team discussed additional efficiencies that could potentially be gained from reduced erection time and overall schedule savings, but a detailed construction schedule analysis was not within the scope of our evaluation.

Environmental Considerations & Context

We found the following to be the main environmental impacts of using mass timber:

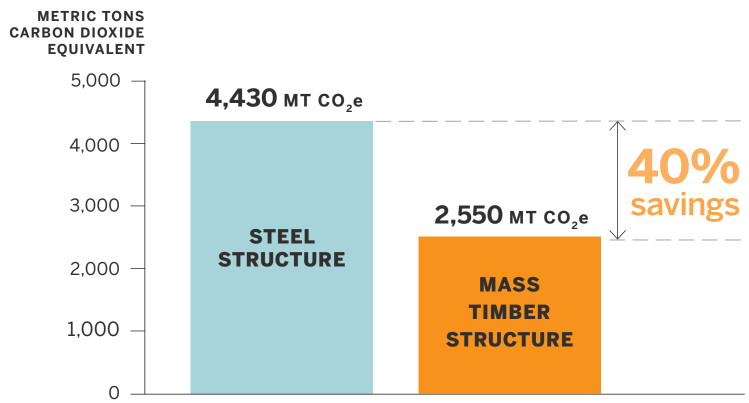
- Embodied-carbon savings from using wood, which is a regenerative building material that requires less energy to be turned into a structural material compared to steel or concrete.
- Mass timber beams and planks are suitable to be left exposed as a finish material, therefore embodied energy is saved by using fewer finish materials such as metal framing and drywall.
- The natural wood finish provides a biophilic connection for occupants, which supports health and wellness.
- The simple and efficient pre-fabrication process and installation saves energy and reduces waste in the process.

There are two ways to consider the embodied carbon of timber. One is to consider the starting point as the moment you cut down the tree, in which case all the carbon emitted is additive (transportation, fabrication, etc), much like any other material. This is illustrated in the chart on the next page titled "Steel vs Timber, not including Biogenic Storage Potential." The other perspective is to take credit for all the CO2 stored in the tree throughout its life, which is greater than the energy it takes to harvest and process the wood into something useful; it's essentially negative embodied carbon. This is reflected in the "including Biogenic Storage Potential" chart on the next page.

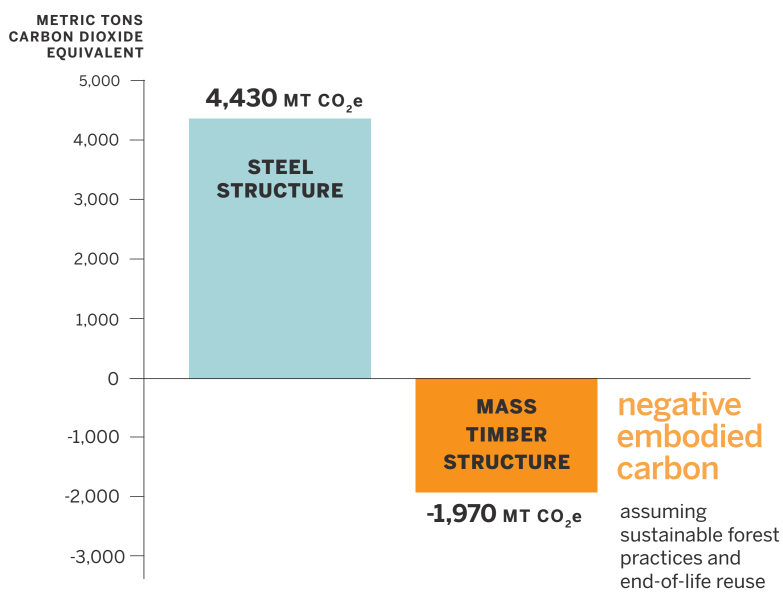
In both scenarios there is real value in terms of carbon reduction. Even with the more conservative approach of not considering biogenic storage potential, the timber option vs. steel yields a 40% reduction in embodied carbon. The emissions avoided in this scenario is equal to the carbon sequestered by 2,225 acres of U.S. forests in one year. That acreage is roughly equivalent to the size of the Middlesex Fells Reservation. If the structure is considered for its biogenic storage potential, it has become a net carbon sink.

STEEL VS. TIMBER: EMBODIED CARBON COMPARISON WITH AND WITHOUT BIOGENIC STORAGE POTENTIAL

Steel vs Timber, not including Biogenic Storage Potential



Steel vs Timber, including Biogenic Storage Potential



3. Opportunities Realized & Lessons Learned

Value of Mass Timber

We began this project with the goal of evaluating the value of mass timber. As we worked through our design process, it became apparent that this value was not limited to economic or sustainability considerations. The use of mass timber provides additional design opportunities that include the creation of a unique biophilic aesthetic that differentiates a multi-family residential building and enhances occupant comfort. The decision about a building's structural system is typically made early in the design process, and this study has demonstrated the importance of including a broad range of value considerations in this decision-making process.

Challenges

Evaluating mass timber as part of an early-stage feasibility study for a project requires an upfront commitment to advancing design to a level that allows the many variables that can be impacted by mass timber to be evaluated. This requires commitment by an owner and all members of the design team in order to allow both challenges and opportunities to be identified.

Because mass timber is relatively new, upfront input from a construction manager is essential. In our project, feedback from JMA about sequencing and constructibility was essential to informing early design decisions.

It is also challenging that currently there is no local CLT manufacturer in New England. Local production will help adoption of mass timber by making it more accessible, more supportive of the regional economy, and reduced perception of risk from supply and transit concerns.

III. Program Impact

1. Program Evaluation & Impact

The Mass Timber Accelerator Grant was a productive process in which we were able to explore mass timber for a typical project type that Elkus Manfredi Architects has a lot of experience with: mid-high-rise multi-family residential and mixed-used projects. Thornton Tomasetti brought their expertise with mass timber structural design to the team and we worked through an iterative process together to find the appropriate structural grid dimensions and framing concept that also allowed for a useful layout of the residential units. Doing this through the grant process allowed us the time to consider details such as the impact on mechanical system layouts, and explore balancing that functionality with where we would want to see the mass timber structure exposed.

The structure and goals also allowed for productive conversations with the developer and contractor on logistics of design and construction and how to determine the value of this construction type.

Weekly Roundtable and Educational Sessions

The weekly roundtable Zoom calls—where we could all join and ask questions or work through issues we were stuck on, with WoodWorks providing advice or sharing what they were observing on current construction projects—were efficient and useful.

Midterm Structure

The charrette structure, in which teams presented their progress in a roundtable format, was especially helpful. Getting feedback from peers in the architecture profession is not something we normally get to engage in through our typical work process. The open and casual environment that the BPDA and BSA hosted allowed the teams to share their challenges or lessons learned and ask for feedback or offer advice. This is invaluable in that the more we share, the quicker we all progress to using more sustainable strategies to build.

2. Feedback on Overall Program

In summary, the timeline and structure was useful and productive in exposing project teams to mass timber in a way that was meaningful. The end results of the studies are useful to all participants and the takeaways can be readily incorporated into the future work of each team.

Another important aspect was that the teams were not comprised of just the designers and structural engineers but also involved the owners, developers, and construction partners. It was helpful for all to learn from the other projects, but also key to more holistically understanding the nuances of working with mass timber in order to make more accurate value judgments for future projects.