Substituting Mass Timber for Post Tensioned Concrete in the Design of a Multi-Story Educational Building: A study of the Implications for Structural Design and Integration of Mechanical Systems

Research + Terminal Project

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Master of Science
Mass Timber Design Focus
2021-2022

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01 Introduction

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TOPIC:

Substituting Mass Timber for Post Tensioned Concrete in the Design of a Multi-Story Educational Building: A study of the Implications for Structural Design and Integration of Mechanical Systems

Master of Science
Research + Terminal Project
By: Aaryn Gray
2021 - 2022

Committee: Judith Sheine (Chair), Mikhail Gershfeld, & John Rowell

FIGURE 1 I Oregon State University, Peavy Hall Atrium. Corvallis, OR. (Josh Partee, 2020)

ABSTRACT:

The utilization of and advances in mass timber over the last decade have changed our perceptions of construction materials and building today. As mass timber buildings are rising in interest to the architectural design profession, the building Industry as a whole is taking the initiative to further understand and develop new and more efficient solutions for designing with mass timber. A major driver of the increased interest in the employment of mass timber is that in comparison to concrete and steel, timber systems can be more sustainable. Building and construction accounts for 39% of the worlds CO2 Emissions (UNEP, 2019), and the use of timber instead of concrete and steel can reduce these emissions by 69% (Himes and Busby, 2020). Because of this, the utilization of mass timber is a path for reducing global warming potential.

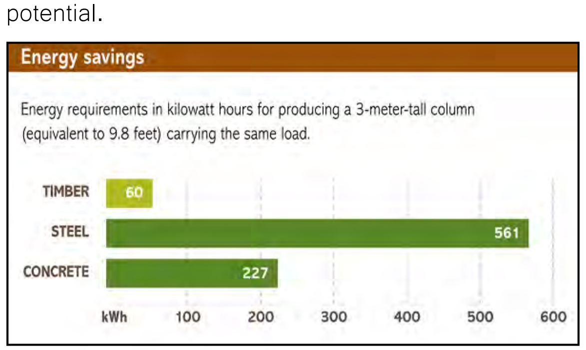

FIGURE 2 I Reducing Carbon Emissions With Wood. (OFRI. 2018)

While understanding the advantages and implications of the mass timber structure is critical for both sustainability and cost control, it is also important to understand that the structure can also inform or inhibit the way we as designers accommodate for efficient system integration. Accommodation for system integration, which includes a buildings systems for mechanical, electrical, and plumbing (MEP) as well as for heating, ventilation, and air conditioning (HVAC), plays a crucial role in how the building performs, whether for meeting an architectural aesthetic, or overall efficiency in construction and cost. Focusing on mass timber structural system types, research, analysis, and design was performed to determine the advantages and implications of substituting mass timber in a building that had originally been designed with a post-tensioned concrete structure, and how the structure needed to change in order to achieve both an optimal structural system and efficient service integration in an educational building.

INFORM

FIGURE 3 I Timber T-Rib Composite Panels. Catalyst in Spokane, WA. (Benjamin Benschneider, 2020.)

INHIBIT

FIGURE 4 I Glulam Post and Beam with Ducting. Radiator Building, Portland, OR. (Josh Partee, 2017.)

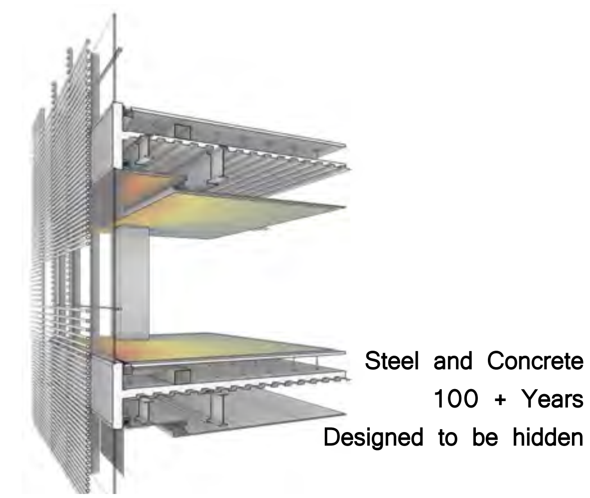

FIGURE 5 I Structure Designed for Drop Ceilings. (Alexander Ayres, Date Unknown)

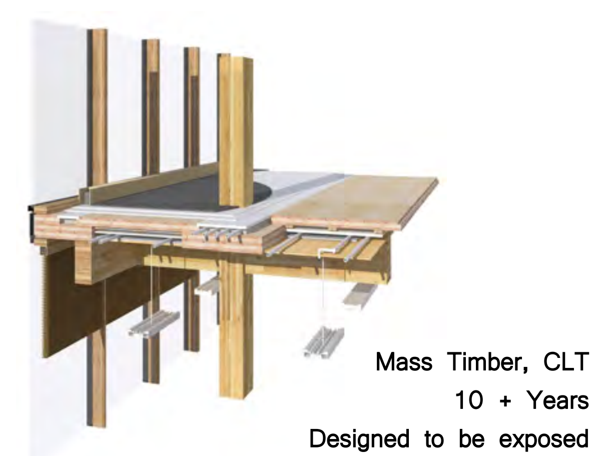

FIGURE 6 I Structure Designed for Exposure. (MGA, 2018)

With mass timber products such as cross-laminated timber (CLT) being relatively new in the United States, there is no "typical" way to design mass timber structures or to integrate services. Every project offers its own requirements and limitations, and these can implicate changes to the mass timber structure itself. This research explored a series of North American mass timber case studies to analyze the advantages and disadvantages of their structural, service, and integration solutions. Following this study, the lessons learned were applied to an existing, recently completed university building with a steel and concrete structural system, by substituting its structure with a mass timber one. Using the existing structural system and new mass timber alternatives, comparisons were made for both structural and system integration approaches to see if sustainability and efficiency goals could be achieved with a mass timber system. Through this applied research method, we can begin to understand how the mass timber structure can be both optimized and designed for better and more efficient system integration in educational buildings.

Keywords: Mass Timber, Structure, Integration, System, Services, Optimization, Efficiency.

FIGURE 7 I Logging Timber
(Nico N., 2010)

PROJECT IMPORTANCE:

Unlike more conventional building materials such as concrete and steel that have been employed in the U.S. for more than a century, mass timber is relatively new to the building industry. In many educational buildings with steel or concrete as the major structural system, services are often designed to be hidden, which also often hides the structure. With mass timber there is a desire to expose the structural material for its aesthetic and biophilic properties (Green and Taggart, 2017) and this poses some special questions about service integration. Understanding the material as well as its structural capabilities including the most efficient structural grid, floor-to-floor heights, vertical load paths, etc. is essential in creating efficient outcomes for designs that allow for construction efficiency, sustainability, and aesthetics. This research explored the various design decisions made for a building, and how these decisions can impact the mass timber structure.

PRIMARY RESEARCH QUESTIONS:

- What are the advantages and implications of employing a mass timber structure in comparison to concrete and steel?

- How can the mass timber structure be optimized for both structural performance and for integrating systems?

FIGURE 8 I CLT Panel Spacing in the WIDC, Canada.
(Ema Peter, 2014)

BACKGROUND:

Designing with mass timber provides copious advantages for sustainability and innovation (UNEP, 2019), but there are challenges in accommodating MEP and HVAC systems, especially if the end goal is to expose the maximum about of timber. While there is significant research and publication on steel and concrete structural design for BIM (typical) system modeling, where the systems and structure are frequently hidden, with mass timber so new to the industry, these types of resources are not yet prevalent. This research project begins to fill these gaps by addressing the advantages and implications of utilizing a mass timber structure in comparison to concrete and steel, and how efficiently integrated structure and system design can inform better educational spaces.

SCOPE:

The project will be performed in three primary parts.

1 - Case Study Research
2 - Substituting Post Tensioned Concrete With Mass Timber at Tykeson Hall
3- Life Cycle Assessment

SEPTEMBER 2021
(FALL)

Topic Choice.

Topic Development and Terminal Project Planning.

JANUARY 2022
(WINTER)

Case study Analysis and Research.

MARCH 2022
(SPRING)

Substituting Tykeson Hall's Structure with Mass Timber for Structural and Service Efficeincy.

Running Life Cycle Assesment on Exising and New Models.

JUNE 2022

FIGURE 9 | Mass Timber Structure at District Office, Portland OR. (Structure Magazine, 2020)

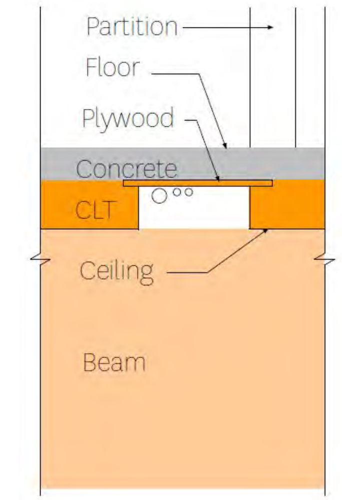

FIGURE 10 | District Office Timber-Composite Floor System. (Hacker Architects, 2022)

1 - Case Study Research

While there is no "typical" method of integrating HVAC and MEP with mass timber structures, there are a number of constructed buildings that approached this design challenge in a variety of ways. In this section eight case studies of completed mass timber buildings were examined to assess their design approaches to structural and system integration. Within these case studies two differing mass timber structural systems were examined: all wood structural systems and wood hybrid structural systems (with wood gravity and either a steel or concrete lateral system). Analyzing these case studies informed a greater understanding of various design approaches to efficient integration of mass timber structures and MEP/HVAC systems. These approaches include but are not limited to utilizing composite floor assemblies, panel spacing to allow chases between floor panels, uni-directional beam structures, long spanning, or short spanning structural grids, etc.

List of Case Studies:

All Wood Systems:
- Catalyst
  Michael Green Architecture & Katerra | Spokan, Washington | 2020
- OSU Peavy Hall
  Michael Green Architecture | Corvallis, Oregon | 2018
- Wood Innovation and Design Center
  Michael Green Architecture | British Columbia, Canada | 2014
- John W. Olver Design Building
  Leerz Weinzapfel Associates / Amherst,

Wood Gravity Systems - with steel or concrete lateral systems
- District Office
  Hacker Architects | Portland, Oregon | 2020
- Bullitt Center
  Miller Hull Partnership | Seattle, Washington | 2013
- Brock Commons
  Acton Ostry Architects / Vancouver, British Columbia / 2016
- OSU Cascades
  SRG Partnership / Bend, Oregon / 2021

FIGURE 11 | Interior View Of Tykeson Hall
(Architect Magazine, 2019)

2 - Substituting Post Tensioned Concrete With Mass Timber at Tykeson Hall

Tykeson Hall is a recently completed educational building at the University of Oregon, in Eugene, Oregon that offers a variety of spaces to accommodate structurally and service efficiently. Academic classrooms, offices, and common rooms in Tykeson Hall all require differing MEP and HVAC systems. This project analyzed how the structural system needed to accommodate to these existing conditions. This project also outlines how the existing HVAC distribution units of the building were changed/ re-routed to expose the mass timber ceiling in many of these spaces.

This scope of study seeks to optimize both the mass timber structural system and the service integration efficiency through the conceptual exploration of a mass timber system. To allow for greater focus within the project scope, one of the two structural systems explored through case studies was chosen for substituting the post-tensioned concrete and steel structure in Tykeson Hall with mass timber: the mass timber gravity system. With the existing lateral system of concrete walls remaining a constant, this allowed more focus on the specifics of the mass timber gravity system and the exploration of the integration of the MEP systems. Other variables of the existing project that were not within this projects scope are the buildings enclosure, cost, and construction timeline. The final design of Tykeson Hall was studied and explored to outline the advantages and implications when employing a mass timber structure in an education building.

Existing Project Title:
Willie and Don Tykeson Hall
Office 52 Architecture & Rowell Brokaw Architects / Eugene, Oregon / 2019

FIGURE 12 | Exterior View Of Tykeson Hall
(Architect Magazine, 2019)

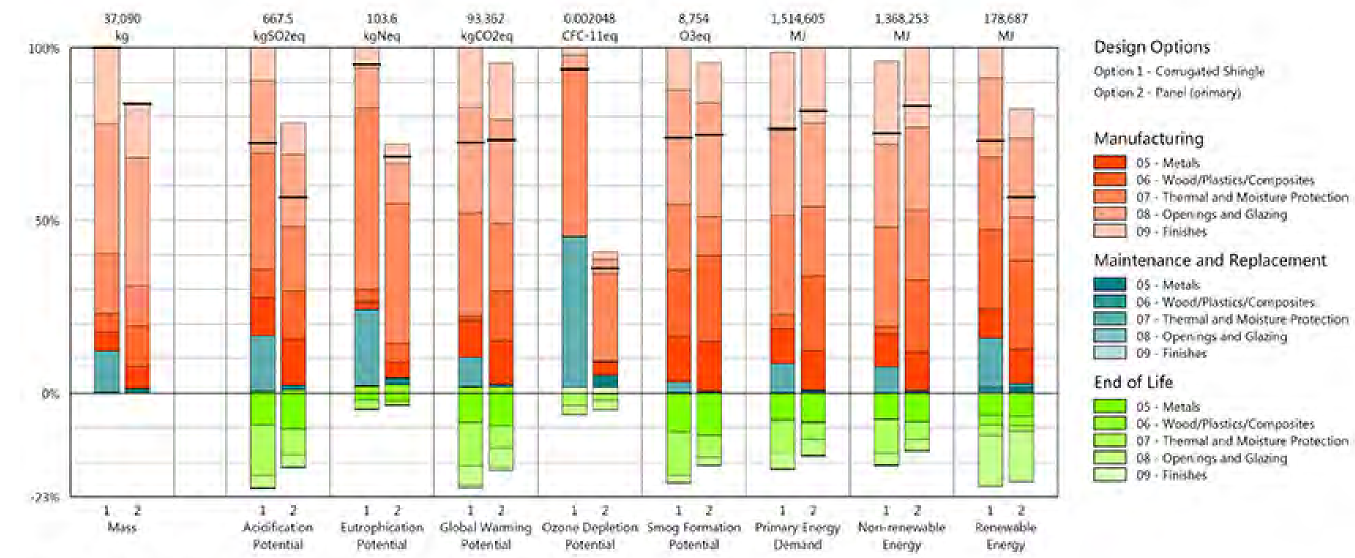

FIGURE 13 | Example of Comparison LCA.
(KT Innovations, 2021)

3 - Life Cycle Assessment

Once the conceptual structural design of Tykeson Hall utilizing mass timber was completed, research and analysis for Life Cycle Assessment (LCA) of the two building models and their respective floor assemblies was performed. By comparing the alternative mass timber structure with the existing steel and concrete structure, the environmental advantages of utilizing mass timber vs. concrete and steel was demonstrated.

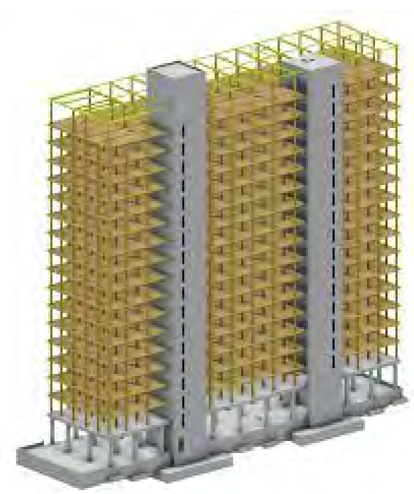

FIGURE 14 I UBC Brock Commons Building Structure. (Acton Ostry Architects, 2017)

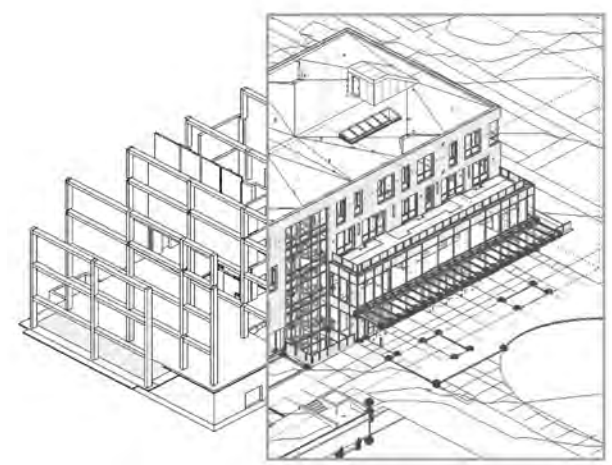

FIGURE 15 I X-Ray Image of Tykeson Hall's Mass Timber Structure. (Aaryn Gray, 2022)

METHODOLOGY:

1 - Case Study Research

Case studies were performed using material in online articles and in print literature of the published projects. Each project was documented in the following sub-groups: Project Overview, Architectural Design, Structural Design, Integrative Design for the accommodation of systems, and summary of structure and system integration. Each project was catalogued in chapter 2 of this book.

Programs used: Microsoft Word, Adobe Illustrator, Adobe InDesign

2 - Substituting Post Tensioned Concrete With Mass Timber at Tykeson Hall

The mass timber structural design for Tykeson Hall utilizing mass timber started by evaluating and studying the existing steel and concrete building through the existing Revit Model and As Built architectural plans. By studying the existing models and plans, I was then able to design iterations for a new mass timber structural system for Tykeson Hall. By collaborating with architectural, engineering, and system expertise I was able to design one mass timber model that was both structurally efficient and effectively integrated HVAC/MEP services. The final Revit model contains the buildings new mass timber structure, new HVAC systems, and reduced foundations, with other elements of the building design and model remaining the same. This stage of research and design was performed using computerized Revit model iterations and plan drawings, with periodic reviews for approval and changes with my advisors and consultants via in person or on Zoom meetings.

Programs used: Revit, Adobe InDesign, Adobe Illustrator, Microsoft Suite, Zoom

FIGURE 16 I Logo for Software Tally. (BIM Chapters, 2020)

3 - Life Cycle Assessment

Post completion of the mass timber models, the two Revit models (one mass timber, one steel and concrete) were employed for Life Cycle Assessment using Tally, a computerized Revit plug-in that evaluates a projects Revit model for its embodied energy and sustainable performance factors. Through these calculations comparisons were made for Global Warming Potential (GWP) between the new mass timber design and the existing steel and concrete one.

Programs used: Revit to Tally, Microsoft Word, Microsoft Sheets, Adobe InDesign, Adobe Illustrator

FIGURE 17 I University of Oregon Logo.
(Study Architecture, 2016)

FIGURE 18 I Rowell Brokaw Logo.
(Rowell Brokaw, Date Unknown)

COLLABORATION:

University of Oregon

At the University of Oregon, I worked closely with my committee chair Judith Sheine for reviews on both architectural and project deliverables. I also worked with University of Oregon professor John Rowell for additional research and design guidance. John Rowell is also one of the founders of Rowell Brokaw Architects, architect of record for Tykeson Hall.

Rowell Brokaw Architects

From Rowell Brokaw Architects, professor and architect John Rowell and architect Chris Andrejko provided the Revit model and associated drawings for the existing project of Tykeson Hall. Both John and Chris advised with additional design consultation and provided me the needed information for Tykeson Hall to complete this conceptual conversion.

FIGURE 19 I Cal Poly Pomona Logo.
(Cal Poly Pomona, Date Unknown)

FIGURE 20 I Systems West Logo.
(Systems West Engineers, Date Unknown)

Cal Poly Pomona

For structural advising and review I worked closely with Cal Poly Pomona Professor of Civil Engineering Mikhail Gershfeld to achieve an efficient structural design for the new mass timber structure. It is important to note that the mass timber structural design for Tykeson Hall is a conceptual project, and all design decisions were made in approval with Professor Gershfeld, but not fully calculated for these structural assumptions. In addition to this structural advising, I referenced existing structural analysis tools from the Fast + Epp website (Fast + Epp, 2020).

Systems West Engineers

For the conceptual design planning of the mass timber buildings new HVAC distribution units, I consulted with Greg Langdon and Paul Fooks of Systems West Engineers, the consultants for the Tykeson Hall project. Because one of the primary design goals was to expose the mass timber ceiling in Tykeson Hall, new systems were chosen for the project in order to meet the desired design criteria while still meeting the buildings required heating and cooling loads. Greg Langdon and Paul Fooks aided in making this new design.

02 Case Studies

Contents: All Wood Systems
Wood Gravity Systems
Advantages and Implications
Overview

Case studies and their structural systems inform a greater understanding of the various structural design approaches when utilizing mass timber and how they address efficient integration of MEP and HVAC systems. They also inform a greater understanding of the structural implications of these design moves.

List of Case Studies:

All Wood Systems:

Catalyst
Michael Green Architecture & Katerra I Spokane, Washington I 2020

OSU Peavy Hall
Michael Green Architecture I Corvallis, Oregon I 2018

Wood Innovation and Design Center
Michael Green Architecture I British Columbia, Canada I 2014

John W. Olver Design Building
Leerz Weinzapfel Associates / Amherst, Massachusets I 2017

Wood Gravity Systems - with steel or concrete lateral systems

District Office
Hacker Architects I Portland, Oregon I 2020

Bullitt Center
Miller Hull Partnership I Seattle, Washington I 2013

Brock Commons
Acton Ostry Architects / Vancouver, British Columbia / 2016

OSU Cascades
SRG Partnership / Bend, Oregon / 2021

ALL WOOD SYSTEMS:

List of Case Studies in This Section:

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Michael Green Architecture I Corvallis, Oregon I 2018

Wood Innovation and Design Center
Michael Green Architecture I British Columbia, Canada I 2014

John W. Olver Design Building
Leerz Weinzapfel Associates / Amherst, Massachusetts I 2017

All Wood Systems - Overview:

ALL WOOD STRUCTURES	 Catalyst Michael Green Architecture & Katerra / Spokane, Washington / 2020	 OSU Peavy Hall Michael Green Architecture / Corvallis, Oregon / 2018	 Wood Innovation and Design Center Michael Green Architecture / British Columbia, Canada / 2014	 John W. Olver Design Building Leerz Weinzapfel Associates / Amherst, Massachusetts / 2017
STRUCTURE	- Gravity : Post and Beam - Lateral: 7 Ply CLT Walls - Grid: 30 x 30 - Mass Timber Utilized: 5 Ply & 7Ply CLT and Glulam	- Gravity : Post and Beam - Lateral: 7 Ply CLT Rocking Walls - Grid: varies - Mass Timber Utilized: 5 Ply CLT and Glulam	- Gravity : Post and Beam - Lateral: 5 Ply & 7 Ply CLT Walls - Grid: 30 x 30 - Mass Timber Utilized: 5 Ply & 7Ply CLT and Glulam	- Gravity : Post and Beam, Timber -Conc. Composite Floors - Lateral: Timber Brace Frames - Grid: not uniform (meant to be steel) - Mass Timber Utilized: 5 Ply CLT and Glulam
MEP & HVAC INTEGRATION	- Integrated & Exposed : Systems run within Timber - Timber ribbed panels. - Concealed: Wooden Drop Ceilings are utilized in service heavy spaces and corridors.	- Integrated & Concealed : Systems run within chases in floo r, then concealed with finish gypsum of wood. - Concealed: Wooden Drop Ceilings are utilized in service heavy spaces.	- Integrated & Concealed : Systems run within chases in floor r, then concealed with finish gypsum or wooden screening.	- Exposed : Systems run under beams, all are exposed and labeled for educational purpose. - Concealed: Wooden Drop Ceilings are utilized in service heavy spaces.

FIGURE 21 I (MGA, 2020)
FIGURE 22 I (MGA, 2021)
FIGURE 23 I (MGA, 2014)
FIGURE 24 I (Leerz Weinzapfel Associates, 2015)

FIGURE 25 | Exterior View of Catalyst, Spokane WA.
(Michael Green Architecture, 2020)

Catalyst

Architect: Katerra + Michael Green Architecture
Location: Spokane, Washington
Year Completed: 2020
Size: 164,000 Sq. Ft
Type: Office Building

Overview: Catalyst is one of the first office buildings in the United States constructed utilizing cross laminated timber (CLT). The building is currently pursuing Zero Energy and Zero Carbon certification by the International Living Future Institute, if given, Catalyst will be one of the largest buildings in North America to meet both sustainability standards. The buildings program is made to be a fully integrated living laboratory for new sustainability technologies, materials, construction techniques, operational practices, and design. This building is a place where industry and academia can come together to innovate and collaborate, and the building showcased flexible spaces for both of these multi-functional uses.

FIGURE 26 | Interior View of Catalyst, Spokane WA.
(Michael Green Architecture, 2020)

Architectural Design: The design team at MGA created a multi-functional space made for both office and academic purposes. All spaced in the building requiring different programmatic elements so the design team came up with a linear building space that accommodates for these various programmatic uses including offices and labs. From the start of the design process, the primary driver of the project was to design and construct a mass timber building that could exceed the performance of a steel and concrete building. By employing timber in this design the team showcased the benefits of mass timber, and more specifically CLT, for its aesthetics, building efficiency, and sustainable efficiency standards.

FIGURE 27 | Section Perspective
(Michael Green Architecture, 2021)

FIGURE 28 | Section Perspective Detail
(Michael Green Architecture, 2021)

Structural Design - Gravity Framing System: The gravity framing of the building utilizes glulam beams and columns constructed as a post-and-beam structural frame. The beams are either 14 or 16 inches wide, and up to 40 inches deep. Structural engineers, Katerra, also utilized an innovative timber-timber composite rib floor panel to achieve composite action at the floor. To do this, crews glued and screwed two glulam beams to the underside of each 10x30 foot CLT floor panel at the factory, making the panel fit perfectly within Catalyst's 30x30 foot grid.

FIGURE 29 | Section Perspective Detail
(Michael Green Architecture, 2021)

Structural Design - Timber-Concrete Composite Floor System: The floor system of Catalyst utilized Cross Laminated Timber (CLT) in composite with a lightweight concrete topping. Here, floor plates were designed to be simple in section, while also meeting the long spans of the building (30'). This was also necessary to meeting the program requirements. The use of CLT panel type varied throughout the structure: 3-ply was used for exterior walls and 5-ply was used for floors and roofs. Even with the added lightweight concrete topping, the panel weighed just 41 psf.

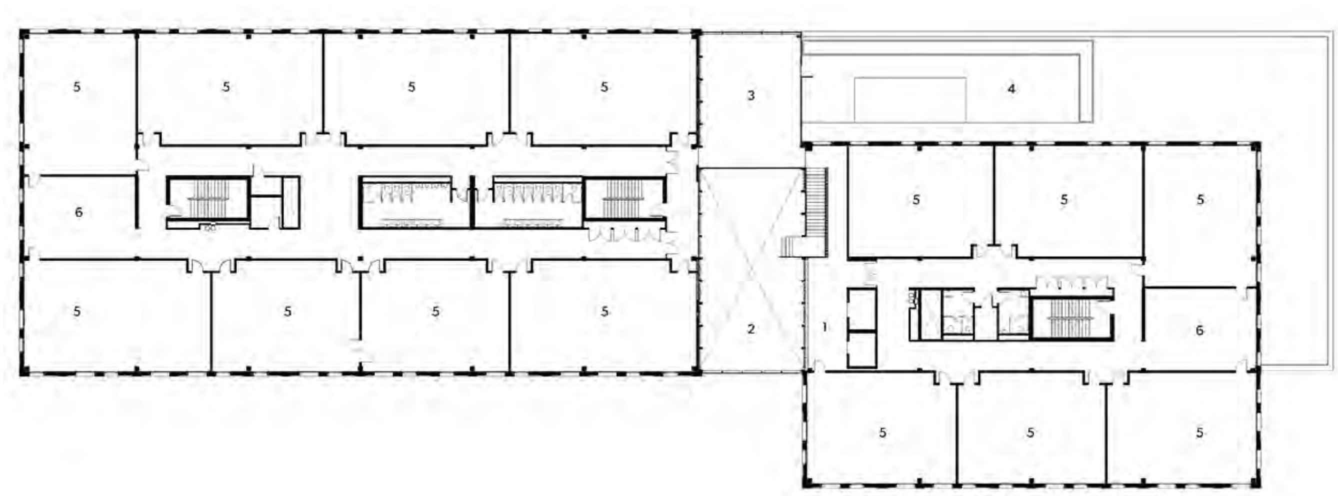


FIGURE 30 I Floor Plan of Catalyst
(Michael Green Architecture, 2021)

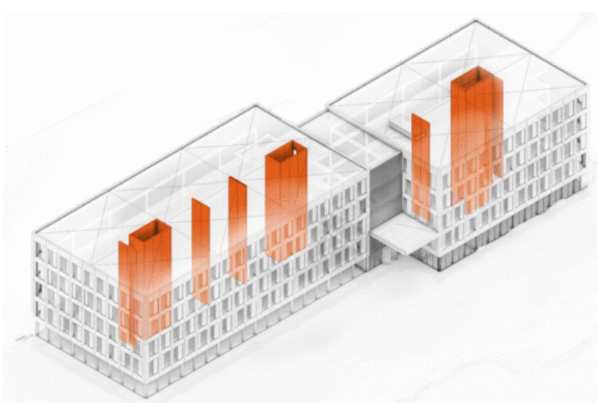


FIGURE 31 I Structural CLT Cores and Walls of Catalyst
(Katerra, 2021)

Structural Design - Lateral Framing System: The lateral system for Catalyst utilized 7-ply CLT for its shear walls. The buildings shear walls was built on top of a conventional concrete slab on grade foundation. A balloon-frame shear wall design was used for the wood lateral system at the building's core. CLT shear panels were stacked and spliced together with a glued-in rod connection to achieve this structural design.

FIGURE 32 I T-Rib CLT Floor Panels
(Michael Green Architecture, 2021)

Integrative Design - Timber-Timber Composite Rib Floor Panels: Catalyst utilizes a double T-rib timber on timber rib floor panel to better integrate the buildings HVAC and MEP systems. This structural configuration allowed for a shallow span-to-depth ratio of 15.5 feet. Even with the concrete topping, the floor to ceiling height was beneficial to the office program spaces, as well as for accommodating to HVAC and MEP conditions in exposed ceiling spaces. This rib configuration was also a great fit for office use for this ability to integrate services within the ribbed spaces. This is one of the first projects in North America able to achieve a long span using true wood-to-wood composite in these rib panels instead of concrete composite.

FIGURE 33 I Rendered Section Perspective Detail
(Michael Green Architecture, 2021)

FIGURE 34 I Wooden Drop Ceilings In Entry Area
(Michael Green Architecture, 2021)

Integrative Design - Wooden Drop Ceilings: While the majority of the Catalyst building celebrates the exposed CLT ceiling, in the buildings more public and open programmatic areas the use of wooden drop ceilings with spacing for lighting and sprinklers were employed. This allowed efficient MEP and HVAC concealment and integration in these spaces.

FIGURE 35 | Exterior View of Peavy Hall at OSU, Corvallis OR.
(Michael Green Architecture, 2018)

OSU Peavy Hall

Architect: Michael Green Architecture
Location: Corvallis, Oregon
Year Completed: 2018
Size: 83,000 Sq. ft.
Type: Educational Building

Overview: The Oregon State University building was created for the University's College of Forestry. Peavy Hall in the Forest Sciences Complex allows students, faculty, and staff to experience first hand the structural potential and beauty of wood through mass timber design. By utilizing a mass timber design constructed of cross laminated timber (CLT), the building truly embodies wood science and acts as an educational tool for the students, faculty, and overall users of the building. By designing indoor and outdoor spaces for education, the building not only offers innovative classrooms, laboratories, meeting spaces and offices, but also outdoor habitable spaces and classrooms, too.

FIGURE 36 | Interior View of Peavy Hall at OSU, Corvallis OR.
(Michael Green Architecture, 2018)

Architectural Design: Peavy Hall is connected to its forested context through its design. The building is designed as two intersecting bars, connecting to the existing Richardson Hall. The academic bar features 20 classrooms, computer rooms, and laboratories. Classroom and lab spaces range from small to large and interior to exterior. The design team emphasized facilitating a range of teaching styles through its innovative and biophillic design. At the heart of Peavy Hall is the Roseburg Forest Products Atrium. The Atrium is directly connected to the Peavy Arboretum, an outdoor classroom created for the building and campus people showcasing a collection of local plant species. The edge between the building and the adjacent arboretum is "blurred" to remind students and faculty of their unique and critical role as environmental stewards.

FIGURE 37 | Interior View of Atrium.
(Michael Green Architecture, 2018)

FIGURE 38 | Rendered Section Perspective Detail
(Equilibrium, 2020)

Structural Design - Gravity Framing System: The gravity framing system of Peavy Hall utilizes glulam beams and columns in a post-and-beam structural frame. In this structure, MGA employs a double post-and-beam approach where the beams are placed flat to allow for greater integration and structural efficiency. By doubling the beams structural depth was preserved, and therefore aided in the integration of all mechanical systems.

FIGURE 39 | Rendered Section Perspective Detail
(Equilibrium, 2020)

Structural Design - Timber-Concrete Composite Floor System: The floor system at Peavy Hall utilizes a timber-concrete composite composed of 5-ply CLT panels and a concrete topping slab. The system minimized sound travel and vibration from floor-to-floor through the use of acoustic insulation between the timber and concrete layers. The concrete deck also allowed for concealment of panel spacing/chases between CLT panels.

FIGURE 40 | Rendered Section Perspective Detail
(Equilibrium, 2020)

FIGURE 41 | Interior View of CLT Rocking Shear Walls (Josh Partee, 2020)

Structural Design - Lateral Framing System: For lateral stability, Peavy Hall uses a CLT rocking wall system, the first of its kind in North America, with shear walls composed of separate sections connected vertically by a post-tension system. This allows the walls to move and self-center during a seismic event. This design also allows for components to be selectively replaced on an as-needed basis. Because the building is used as a teacher concept and a first of its kind, the shear structure is closely monitored by over 200 sensors to gather data on vertical and horizontal structural movement as well as moisture levels. These shear walls also are exposed in the buildings stairwell and class room spaces.

FIGURE 42 | Axonometric Diagram of CLT Rocking Shear Walls (Equilibrium, 2018)

FIGURE 43 | Chases for Mechanical and HVAC (Sarah Giglio, 2020)

Integrative Design - CLT Spacing/ Chases: The CLT floor panels in Peavy Hall is spaced to allow for MEP and HVAC chases as well as to reduce the amount of fiber used in the building. There is also spacing between the beams for additional chasing. This spacing is effective in concealing and integrating the buildings mechanical systems. These chases are concealed using standard Gypsum board or wooden slatting.

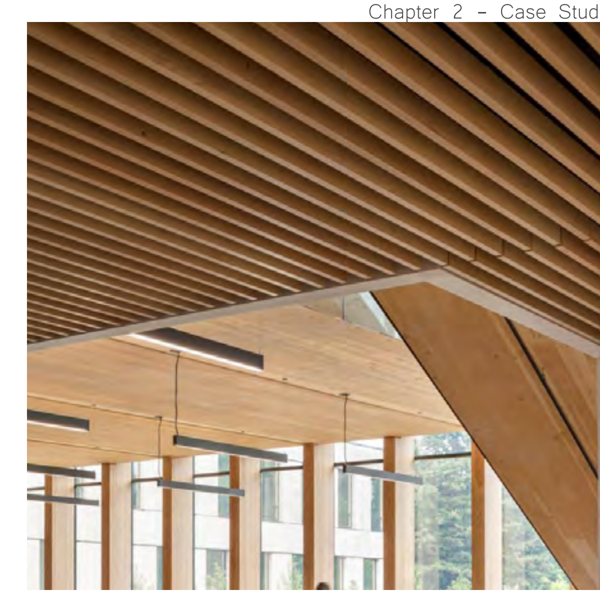


FIGURE 44 | Wooden Drop Ceilings (Josh Partee, 2020)

Integrative Design - Wooden Drop Ceilings: Wooden drop ceilings are also utilized for more MEP heavy spaces such as larger labs and classrooms. Exposing as much wood as possible was important to this all-wood project, and for the areas where the structure is not exposed, wood finishes are used.

FIGURE 45 | Exterior View of the WIDC.
(Michael Green Architecture, 2015)

Wood Innovation and Design Center

Architect: Michael Green Architecture
Location: British Columbia, Canada
Year Completed: 2014
Size: 4820 m. Sq.
Type: Office & Education Building

Overview: The Wood Innovation Design Center (WIDC) is a office and educational building made for researchers, academics, and design professionals. Made to be a innovative and collaborative space, the building is used for generating ideas for innovative uses of wood. The WIDC was one of the tallest modern wood structures in the world at 29.5 meters high, a precedent to now taller mass timber structures. Being a innovative mass timber building, the WIDC pioneered and introduced new methods of working with mass timber panels, more specifically cross-laminated timber (CLT).

FIGURE 46 | Interior View of the WIDC.
(Michael Green Architecture, 2015)

Architectural Design: The WIDC's lower floors of the building provide facilities dedicated to education of wood design. Upper floors provide office space for government and wood industry-related organizations. The design being for a center focusing on wood innovation, the CLT structure is highlighted and Exposed providing a biophilic response of the use and capability of wood. Instead of focusing solely on a showpiece structure, the team at MGA instead created a building that is easily replicated for educational purpose, and the use of CLT lended a hand to this.

FIGURE 47 | Section Perspective of the WIDC.
(Michael Green Architecture, 2015)

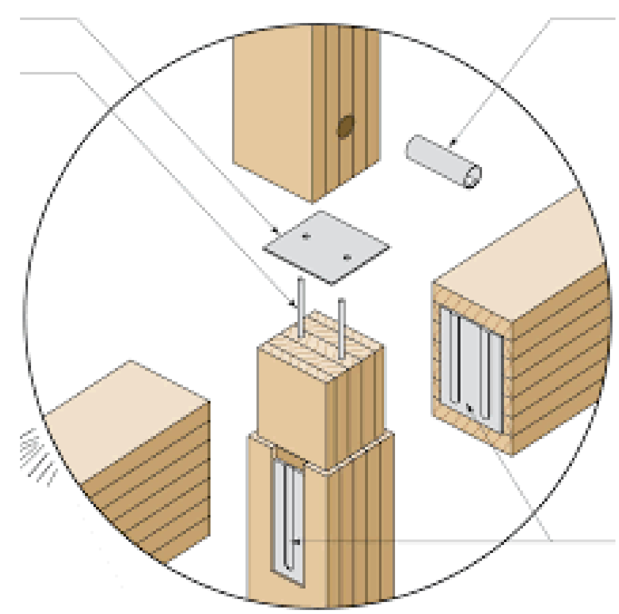


FIGURE 48 | Post and Beam Framing System Detail.
(Building Innovations, 2018)

Structural Design: The WIDC was created to showcase the potential for building mid- and high-rise structures using engineered mass timber products, such as CLT, there is no concrete used above the ground floor slab. The design incorporates a simple, 'dry' structure of systems integrated CLT floor panels, Glulam columns and beams, and mass timber walls.

FIGURE 49 | Structural System of the WIDC.
(Michael Green Architecture, 2015)

Structural Design - Gravity Framing System: The designs gravity framing system consists of Glulam columns and beams. The building's structural simplicity is easily replicated many times through the building for faster construction and easy installation. Glulam beams, which vary in size based on their location, are 14x14½ inches on the ground floor and 12x11½ inches on the upper floors. The beam-to-column connection is made using a proprietary, pre-engineered aluminum dove-tail connector.

FIGURE 50 | Interior View of Mass Timber Structure.
(Michael Green Architecture, 2015)

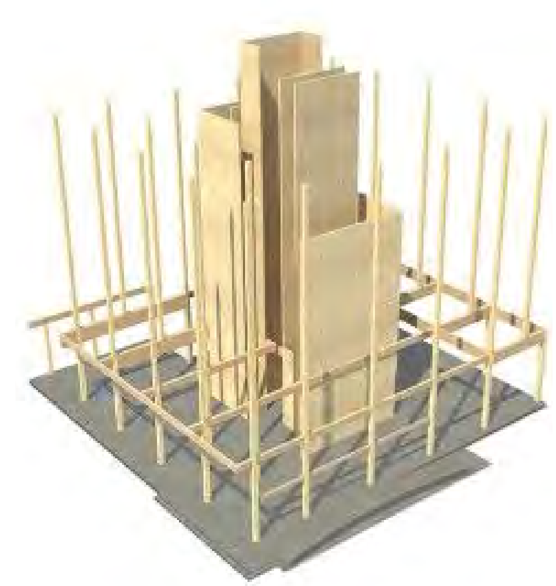


FIGURE 51 | Structural System of the WIDC.
(Michael Green Architecture, 2015)

FIGURE 52 | Rendered Section Detail.
(Michael Green Architecture, 2015)

Structural Design - Lateral Framing System: The lateral design of WIDC utilizes 5-ply and 7-ply CLT panels for the buildings shear walls, located at the stairs and elevator core. The CLT lateral system transfers the buildings seismic loads to the ground through these walls and cores and are spliced together to span between floors.

Structural Design - Timber Floor System: The floor system of the building utilizes a dry construction technique of not using concrete in the entirety of the design other than at its ground floor slab and foundations. Instead, the design employs both 5-ply and 7-ply CLT Panels spaced and stacked on one another creating a staggered design, with standard plywood and carpet finish. This spacing of the CLT panels allows for chases within the floor and aids in reducing the fiber and weight of the finished floor assembly.

FIGURE 53 | Wooden Screening Between CLT Chases.
(Michael Green Architecture, 2015)

Integrative Design - CLT Spacing/ Chases: The buildings MEP and HVAC systems are primarily integrated through chases in the floor assembly. The customized staggered design in the floor and ceiling allowed for efficient concealment and shelter to most of the buildings services.

Integrative Design - Wooden Screening: In between the chases and spaces of the floor assembly are wood screens which are used to conceal the buildings mechanical systems within these spaces. This concealment method is used throughout most of the building, and was used to meet an architectural standard of aesthetic when integrating mechanical systems.

FIGURE 54 | Exterior View of UM Design Building.
(Leers Weinzapfel Associates, 2015)

John W. Olver Design Building

Architect: Leers Weinzapfel Associates
Location: Amherst, Massachusetts
Year Completed: 2017
Size: 87,400 Sq. Ft.
Type: Education Building

Overview: The John W. Olver building is a architecture, engineering, and design building at University of Massachusetts in Amherst that is used as a academic building where students and faculty gather for both classes, organized activity, and informal gathering. For students using the design spaces, the building itself acts as a learning environment and a teaching tool. The building effectively demonstrates the simplicity, power, and beauty of a design that expressively integrates structure, landscape, and architecture. The building is one of the largest cross-laminated timber (CLT) academic buildings in the United States. This building showcases the beauty of mass timber design and the sustainable benefits of its uses.

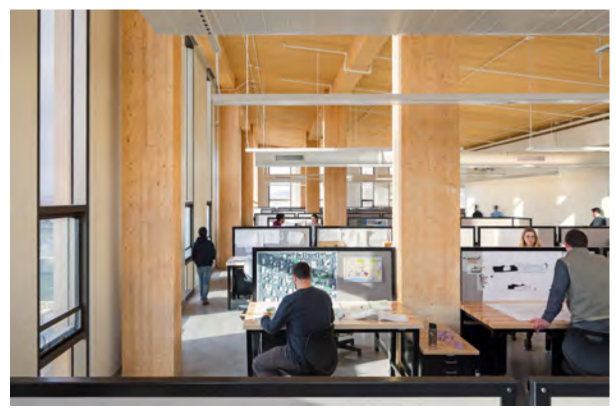


FIGURE 55 | Interior View of UM Design Building.
(Leers Weinzapfel Associates, 2015)

Architectural Design: To create a academic space for collaboration, the building was designed with a coiling and rising band of studios, faculty offices and classrooms that surrounds a sky lit commons for gathering and presentations. The building also has a green roof terrace made to be shared by the studios and faculty. The green roof terrace also acts as a experimental and educational space for the landscape department of UMass.

FIGURE 56 | Section Perspective of UM Design Building.
(Artist Unknown, 2019)

FIGURE 57 | Post and Beam Structure.
(Leers Weinzapfel Associates, 2017)

Structural Design: In the beginning stages of design, the building was originally designed utilizing steel, but after Life Cycle Assessment (LCA) on a mass timber system as compared to the existing steel design, the design team moved forward utilizing a mass timber structure for its clear sustainability benefits, as well as aesthetic.

Structural Design - Gravity Framing System: The structural gravity framing system includes glulam beams and columns, in a post-and-beam structure. Glulam floor beam sizes are 14 x 15 inches or 14 x 16 inches. Columns are 14 x 22 inches or 14 x 25 inches. Glulam members were sealed with standard factory clear-coat finishes.

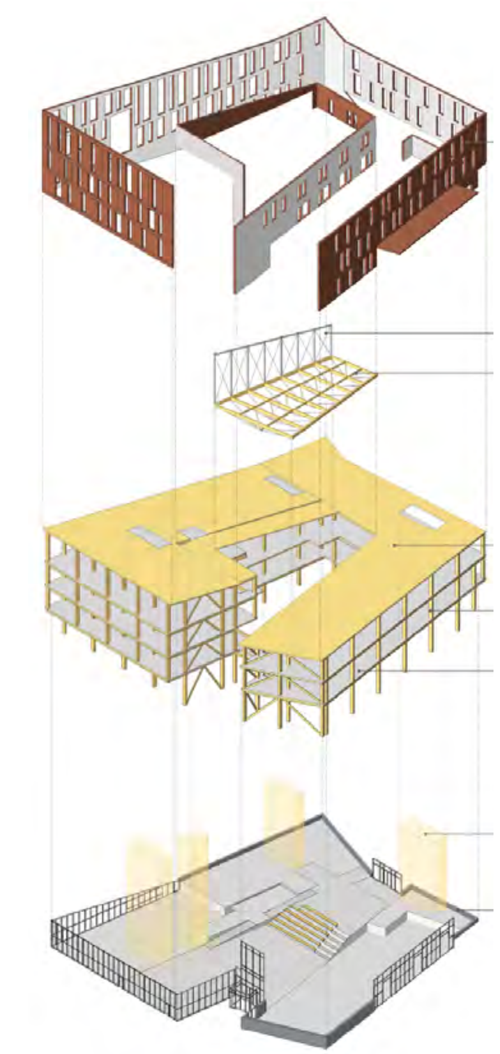


FIGURE 58 | Exploded Axonometric.
(Leers Weinzapfel Associates, 2017)

FIGURE 59 | Interior View of UM Design Building.
(Leers Weinzapfel Associates, 2015)

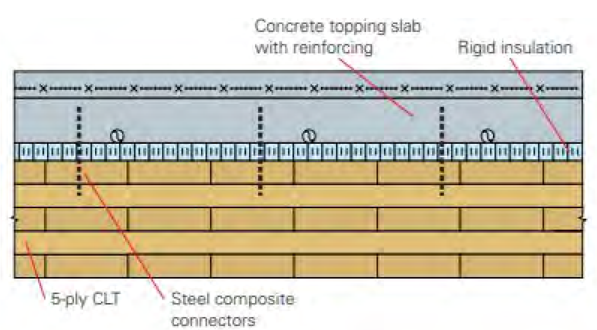


FIGURE 60 | Timber-Concrete Composite Detail.
(Woodworks, 2018)

Structural Design - Timber-Concrete Composite Floor System: With the building having spans that varied from 20 to 26 feet, a timber-concrete composite floor system was used. The team used 5-ply CLT panels with 1 inch of rigid insulation on top of the CLT (for acoustics) followed by 4 inches of reinforced concrete. The CLT ceilings are left exposed in most areas of the building. On top of the CLT, perforated metal plates are glued into notches routed into the CLT floor panels and concrete is poured on top. The main benefit is composite action. By connecting the two materials, they act in unison.

FIGURE 61 | Zipper Truss System.
(Leers Weinzapfel Associates, 2015)

Structural Design - Composite Zipper Truss System: The buildings Zipper truss system is a steel and wood truss system that allow multiple structural members to converge to a single point. This resolved the buildings structural challenge of spanning a long distance, as well as support the landscaped space above. The system also had to accommodate skylights and heavy loads both from the working rooftop garden, and the region's snowfall. There was also a desire to minimize structural depth. The zipper truss solved this

FIGURE 62 | Lateral Bracing System.
(Woodworks, 2018)

Structural Design - Lateral Framing System: The lateral-resisting system incorporates a combination of CLT shear walls and glulam bracing. Systems are designed for the locations seismic and wind forces, primarily wind forces.

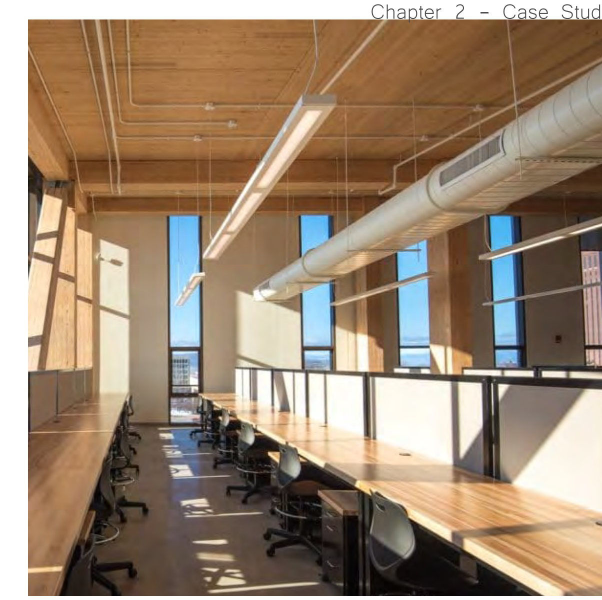


FIGURE 63 | Exposed Systems in Studio Classrooms.
(Leers Weinzapfel Associates, 2015)

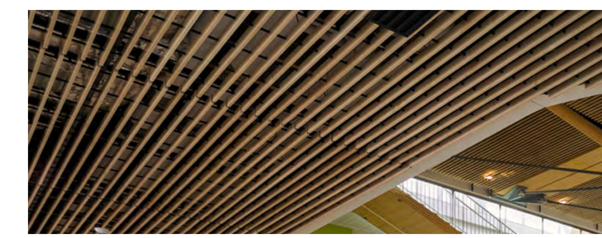
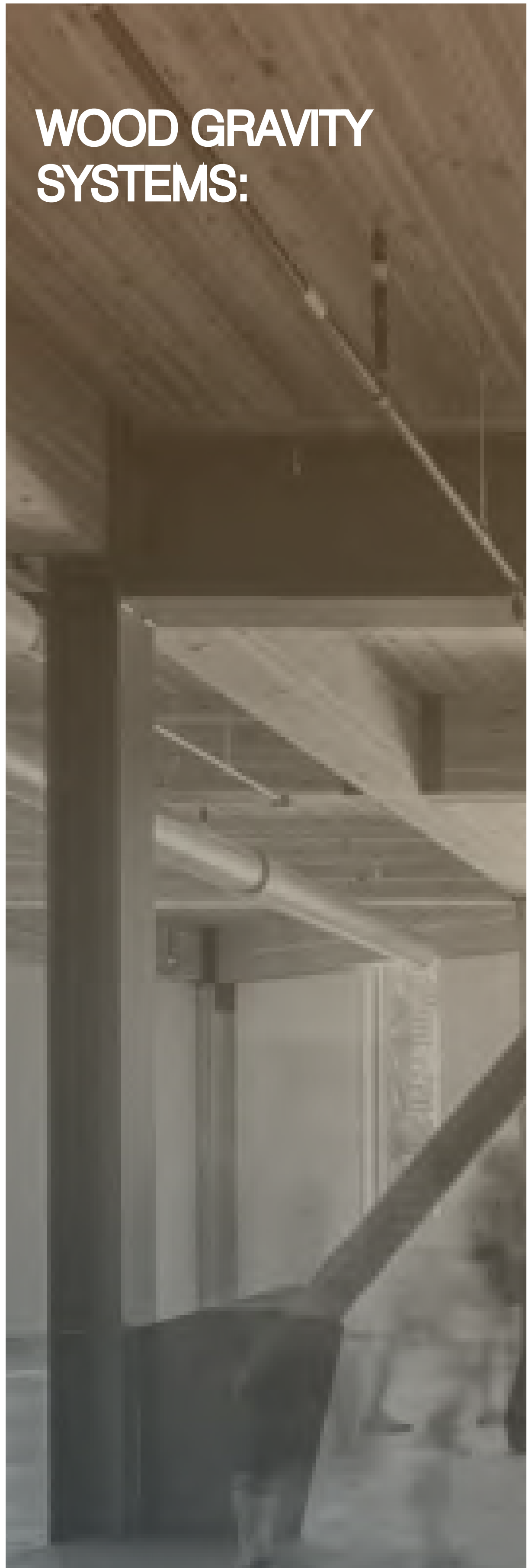


FIGURE 64 | Wooden Ceiling Screening in Atrium.
(Leers Weinzapfel Associates, 2015)

Integrative Design - Exposing MEP/HVAC: The building being a design and educational tool for the students who use the spaces, most of the buildings HVAC and MEP is intentionally exposed and labeled as a design tool. Because wood was the driver for this design, keeping most of it exposed was important, and this was the result of that design decision.

Integrative Design - Wooden Drop Screening: In the buildings common space and entry lounges HVAC and MEP are concealed behind wooden screening.



List of Case Studies in This Section:

Wood Gravity Systems - with steel or concrete lateral systems

District Office
Hacker Architects I Portland, Oregon I 2020

Bullitt Center
Miller Hull Partnership I Seattle, Washington I 2013

Brock Commons
Acton Ostry Architects / Vancouver, British Columbia / 2016

OSU Cascades
SRG Partnership / Bend, Oregon / 2021

Wood Gravity Systems - Overview:

WOOD W/ CONCRETE OR STEEL LATERAL	 District Office Hacker Architects / Portland, Oregon / 2020	 Bullitt Center Miller Hull Partnership / Seattle, Washington / 2013	 Brock Commons Acton Ostry Architects / Vancouver, British Columbia / 2016	 OSU Cascades SRG Partnership / Bend, Oregon / 2021
STRUCTURE	- Gravity : Glulam Post and Beam - Lateral: Concrete Cores - Grid: 10 x 30 (varies) - Mass Timber Utilized: 3 Ply CLT & Glulam	- Gravity : Glulam Post and Beam - Lateral: Steel Crossed Brace Frames - Grid: 20 x 30 - Mass Timber Utilized: NLT & Glulam	- Gravity : Post and Deck (No Beams) - Lateral: Concrete Cores - Grid: 9 x 13 - Mass Timber Utilized: 5 Ply CLT and Glulam	- Gravity : Post and Beam, Timber -Conc. Composite Floors - Lateral: Concrete Cores and Walls - Grid: 10 x 32 (one way) - Mass Timber Utilized: 5 Ply CLT and Glulam
MEP & HVAC INTEGRATION	- Integrated & Exposed : Systems run along one directional structure from main (MEP)	- Exposed : All Systems in the building are exposed, placed below beams. - Wet walls and shaft walls along core	- Concealed : Wood and Gypsum Finishes and Drop Ceilings. - Wet walls and shaft walls along core	- Integrated & Exposed : Systems run along one directional structure from main (MEP) corridor. - Heating and Cooling in exterior walls (JAGA)

FIGURE 65 I (Hacker Architects , 2020)
FIGURE 66 I (Miller Hull , 2014)
FIGURE 67 I (Acton Ostry Architects , 2016)
FIGURE 68 I (SRG Partnership, 2021)

FIGURE 69 | Exterior View Of District Office in Portland, OR.
(Hacker Architects, 2020)

District Office

Architect: Hacker Architects
Location: Portland, Oregon
Year Completed: 2020
Size: 106,000 Sq. ft
Type: Office Building

Overview: District Office is a commercial office building located in East Portland, Oregon. The building highlights the structural capability and appealing aesthetic of mass timber in its design - displayed inside and out. Utilizing Cross Laminated Timber (CLT), district office offers open floor plans with flexible spaces for all office type uses. One of the primary architectural goals of this project was to fully expose the wood structure as much as possible, and this required designs that were aesthetically thoughtful as well as structurally effective. District Office showcases this innovation in its exposed mass timber structure.

FIGURE 70 | Interior View Of District Office in Portland, OR.
(Hacker Architects, 2020)

Architectural Design: The design of District Office prioritizes access to natural daylight and views. With its connection to its context, District office emphasized sustainable design through its mass timber structure. At six stories tall, the building includes five floors of flexible office space with ground-floor retail and restaurant space. The buildings facade utilizes oversized sliding glass panels, made to open for outdoor connections. The office floors also offer double-height spaces which allow tenants to create more dynamic and intimate office layouts rather than a typical office layout without these customizations.

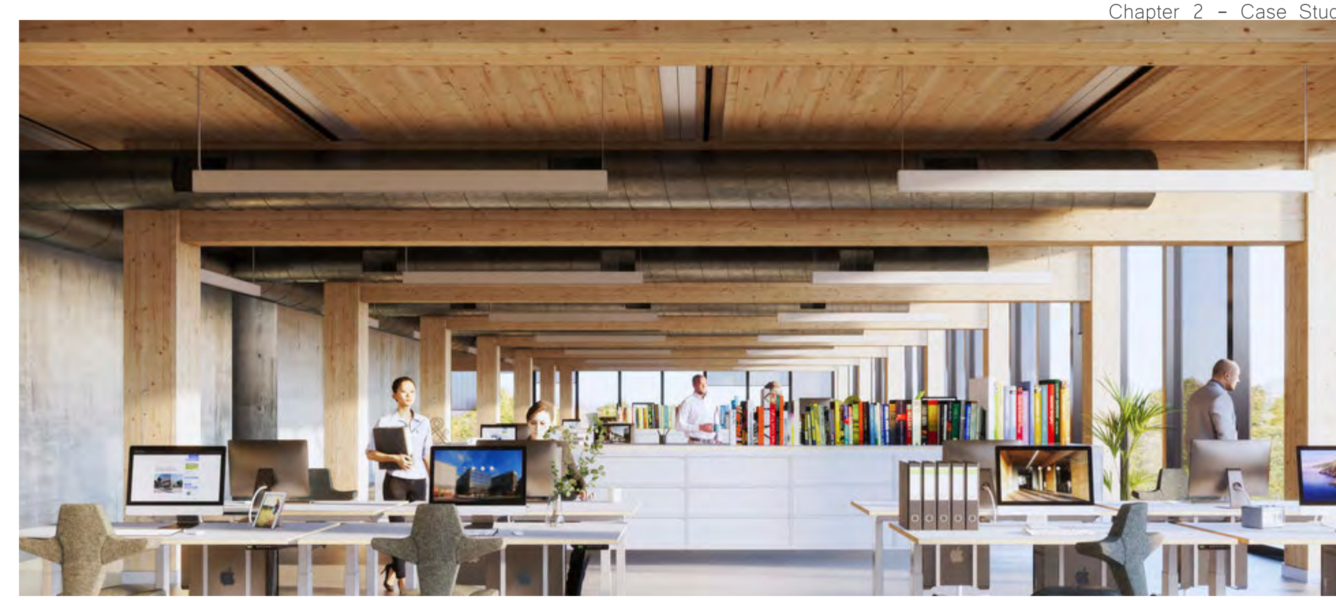


FIGURE 71 | Interior View Of District Office in Portland, OR.
(Hacker Architects, 2020)

FIGURE 72 | Post and Beam Structure with Concrete Cores.
(Structure Magazine, 2020)

Structural Design: To the design team, optimization of the structure was important in achieving the long spans with a one directional structure. The 30x10' structural grid allowed the space to be open and flexible for its tenants. To adhere to these open floor plans a central colonnade over the length of the building was employed for services and access to circulatory routes. By eliminating perimeter beams, the buildings structure allowed for more natural light with floor-to-ceiling windows. Because perimeter beams were eliminated where possible, a composite timber-concrete floor system was also used for additional support of the structural system.

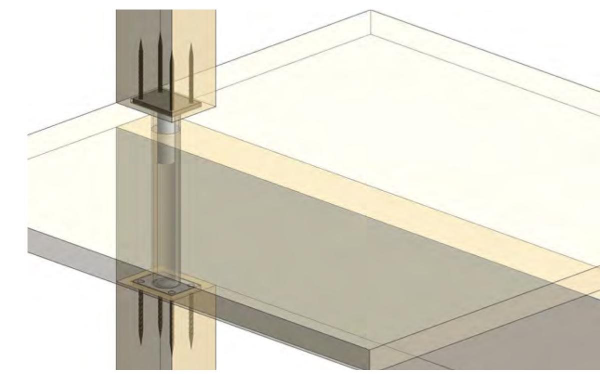


FIGURE 73 | Column Connection Detail.
(Structure Magazine, 2020)

Structural Design - Gravity Framing System: The gravity framing system utilizes a glulam post and beam design, with the structures beams being one directional. In this beam configuration, each column has a single beam framing into it. Due to individual connection complexity, the repetition of custom connections became prominent to the designs constructibility. The primary beam-to-column connection had only four variations that were used in over 350 locations. This connection consists of a single pipe extending through the beam and CLT panel to the column above, which was possible as there is only one beam framing into each column.

FIGURE 74 I Section Perspective.
(Hacker Architects, 2020)

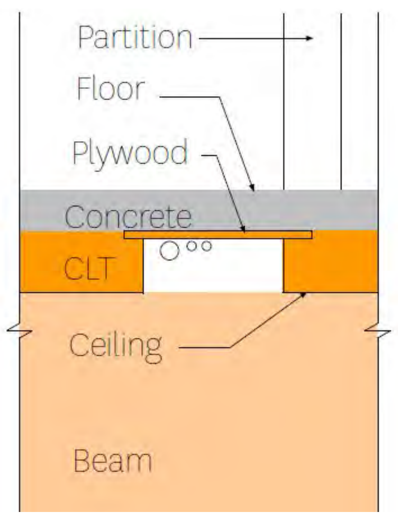


FIGURE 75 I Timber-Concrete Composite Floor.
(Hacker Architects, 2020)

Structural Design - Timber-Concrete Composite Floor System: The floor system of District Office utilizes a composite concrete-timber design. This floor assembly consists of a 3-inch concrete topping slab over 3-ply CLT panels. The composite action between the two materials allowed for greater structural advantage and aided in acoustic insulation and fireproofing benefit.

FIGURE 76 I Plan of Concrete Cores.
(Hacker Architects, 2020)

Structural Design - Lateral Framing System: For its lateral system, District offices employs two primary concrete cores. Concrete was utilized in this design over other lateral systems for fireproofing of the stairwell cores, cost reduction, as well as for an ease in construction timelines as the floors were already employing a “wet” method of construction.

FIGURE 77 I One Direction Beam Structure and CLT Chases.
(Structure Magazine, 2020)

Integrative Design - One-Directional Beam Orientation and Chases - The design team prioritized coordination of the mechanical systems to effectively expose the structure. Because these spaces are made to be open and flexible with exposed timber ceilings, organization of the buildings systems was essential. Two solutions arose and drove the framing layout: a central colonnade open to all bays and continuous chases above the beams. The central colonnade provided a path for the main mechanical runs to reach the north and south ends of the building. To further integrate the MEP, gaps between CLT panels were provided, creating mechanical chases. Small lines, such as sprinklers, can distribute to any location in the building without penetrating beams while minimizing visual impact.

FIGURE 78 | Exterior View of the Bullitt Center in Seattle WA.
(DCI Engineers, 2013)

Bullitt Center

Architect: Miller Hull Partnership
Location: Seattle, Washington
Year Completed: 2013
Size: 52,000 Sq. ft
Type: Office Building

Overview: Bullitt Center is a six-story, 52,000 sf. building. Notably, the building produces all its own energy, water, and waste needs, and is the largest and first commercial building to achieve Living Building certification. Designed to be a leaseable office building, the center also serves as a living laboratory of environmental awareness that highlights the importance of sustainable design in the architectural field. Bullitt Center emphasizes this through its minimal energy use and production, material sourcing, and other environmental control systems employed.

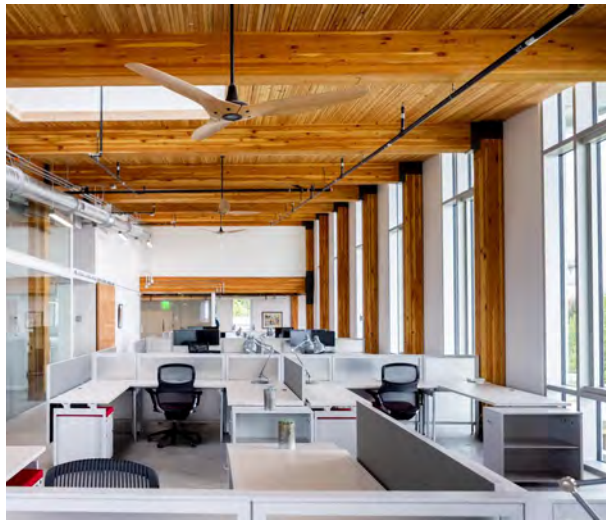


FIGURE 79 | Interior View of the Bullitt Center in Seattle WA.
(Miller Hull, 2013)

Architectural Design: Currently a leader in innovative building spaces, Bullitt Centers impressive building technology and structure are designed as separate components that can easily be updated to meet needs of the next generation of users. The buildings plan has open concept with operable floor-to-ceiling windows that maximize daylight and natural ventilation. The building also uses heavy-timber framing, light efficient windows, fully automated exterior blinds, and most visibly, the overhanging photo voltaic panel array on the roof which provides all power for the building.

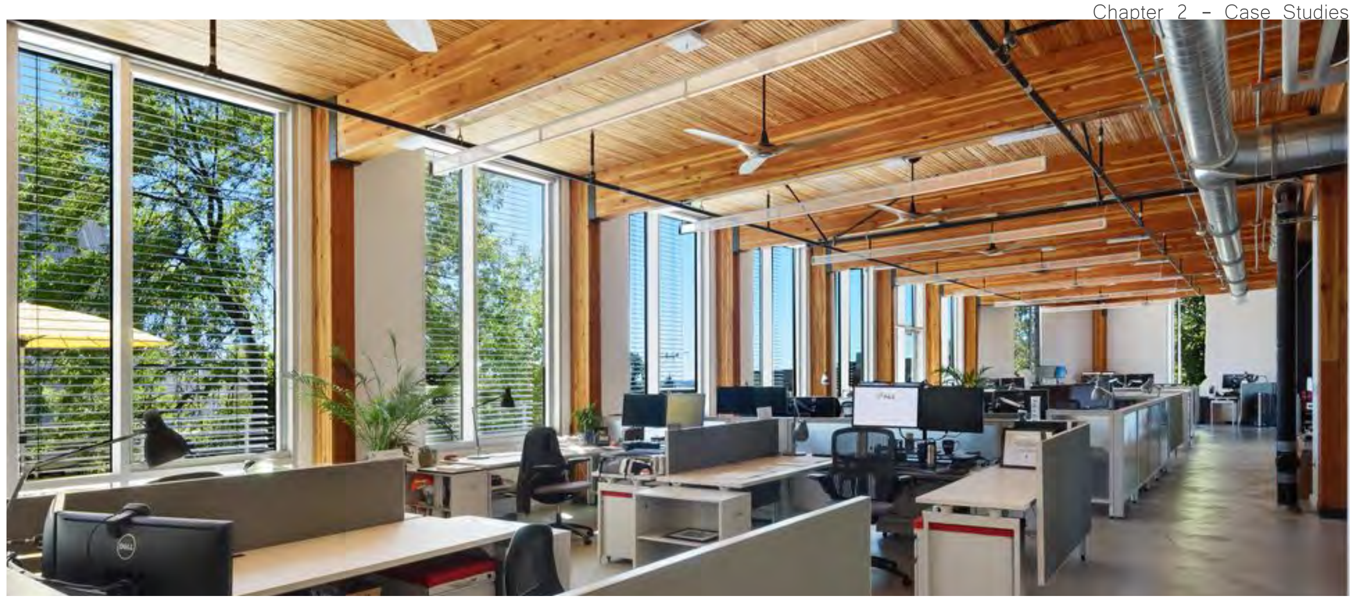


FIGURE 80 | Interior View of the Bullitt Center in Seattle WA.
(Miller Hull, 2013)

FIGURE 81 | Bullitt Center in Construction.
(Bullitt Center Staff, 2013)

Structural Design: The structure of the Bullitt Center are comprised of wood, concrete, and steel. Nail Laminated Timber (NLT) was used for the primary timber frame that sat on a concrete first floor. Concrete was employed at its first floor to carry the heavier structural loads nearest to ground. A steel core with cross-tension members was also utilized to help the center bring horizontal loading to the ground.

FIGURE 82 | Steel Resisting System in Mass Timber Building.
(Miller Hull, 2013)

Structural Design - Lateral Framing System: The lateral resisting system utilizes a steel brace system which spans all floors, including the concrete first floor. This steel BRB system was chosen due to Seattle's seismic requirements, as well as its benefit to reducing the fiber and cost of the overall building.

FIGURE 83 | Building Section.
(Bullitt Center, 2013)

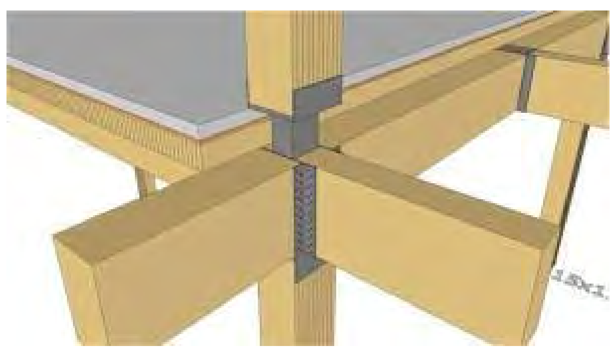


FIGURE 84 | Post and Beam Connection Detail.
(DCI Engineers, 2013)

Structural Design - Gravity Framing System: The gravity framing system of the building utilizes a glulam post-and-beam design with steel connections to create the efficient structural system.

FIGURE 85 | Polished Concrete Floors.
(Miller Hull, 2013)

Structural Design - Timber-Concrete Composite Floor System: The composite floor is comprised of a layer of concrete over the NLT floors. The use of concrete floor topping allows for greater structural stiffness and exposed timber ceilings, important to the timber design and aesthetic.

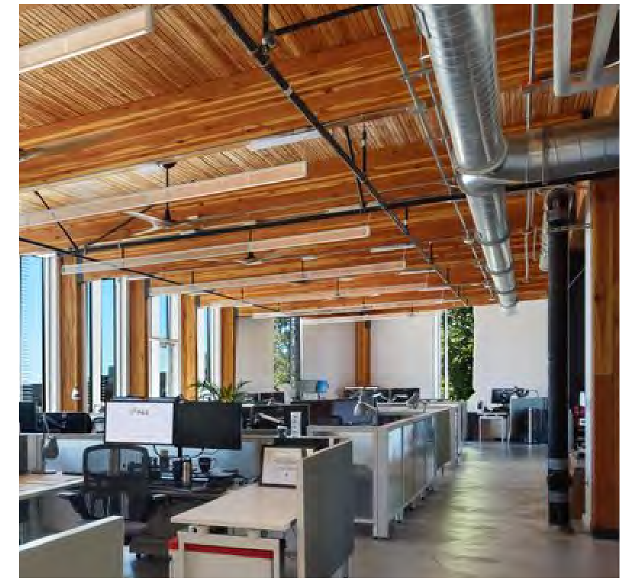


FIGURE 86 | HVAC and MEP on Timber Ceiling.
(Miller Hull, 2013)

Integrative Design - The Bullitt center utilizes a composite timber-concrete floor system that allows for exposed NLT in the ceilings. HVAC and MEP systems are organized to be exposed in this buildings design. In the exposed timber ceilings, sprinkler systems connect to each beam and are visible. Other non-hidden MEP is from lighting units. Geo-thermal systems are concealed within the concrete pour.

FIGURE 87 I Exterior View Of Brock Commons in Vancouver, BC.
(Phoenix Glass, 2016)

Brock Commons

Architect: Acton Ostry Architects
Location: Vancouver, British Columbia
Year Completed: 2016
Size: 2,233 Sq. M
Type: Residential Building

Overview: The Brock Commons Tallwood House is a student residence building at the University of British Columbia (UBC) in Vancouver, Canada. Currently the building is the tallest building with a timber structure in the world, standing at a height of 53 meters tall. The building houses 404 students and is made with a mix of one-bedroom and studio units, study and social spaces, and a student lounge on the topmost floor. The buildings innovation in design now acts as a precedent to future mass timber structures.

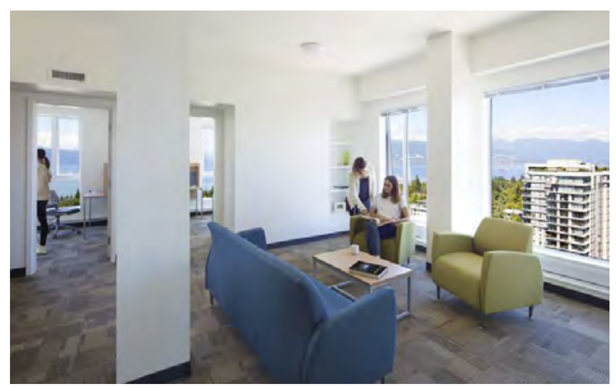


FIGURE 88 I Interior View Of Brock Commons in Vancouver, BC.
(The University of British Columbia, 2017)

Architectural Design: Brock commons highlights the importance student life and residency through its design. The building offers dormitory spaces and accommodations for the 404 residents of the building including common spaces, lounges, laundry, and office space. With sustainability and cost reduction as a primary goal for this building, the design team utilized a timber structure which adhered to this sustainability goal as well as was a method for faster and more efficient construction times. Although timber is the primary structural material, the interior does little to reveal it. The structure is concealed behind drywall and concrete topping, mainly to comply with the cities fire codes.

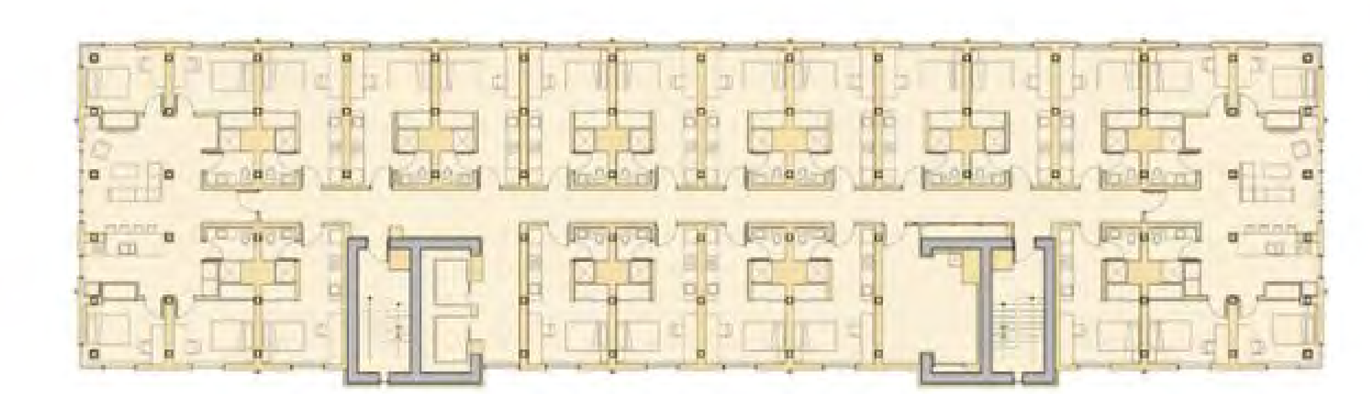


FIGURE 89 I Brock Commons Floor Plan.
(Acton Ostry Architects, 2017)

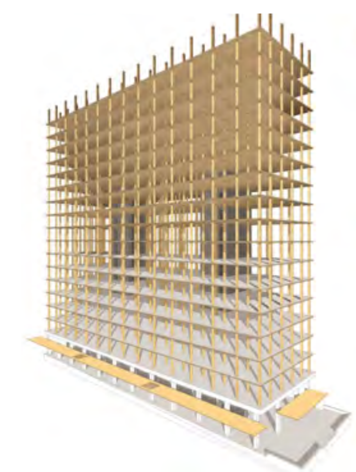


FIGURE 90 I Brock Commons Structure.
(Acton Ostry Architects, 2017)

Structural Design: The decision to utilize timber was to keep the structure simple and to essentially develop a prefabricated “kit-of-parts” that could be installed quickly and easily, with minimal labor on site. Due to the structural efficiency, Brock Commons was completed within a mere 70 days after the prefabricated components were ready for assembly on site. This is considerably shorter than the amount of time it would have taken to complete a concrete building of the same size.

Structural Design - Lateral Framing System: Two full-height concrete cores provide the lateral stability for the structure. These cores also hold the circulatory systems.

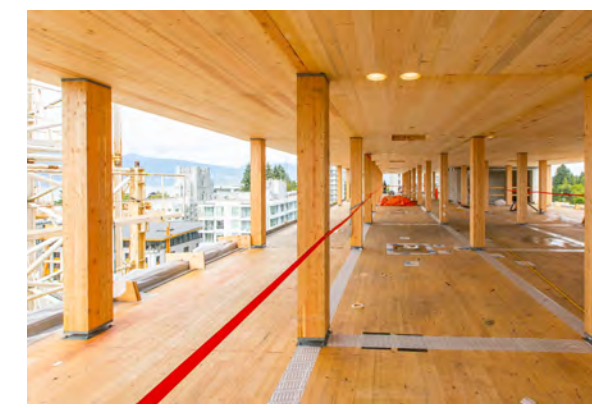


FIGURE 91 I Brock Commons Structure in Construction.
(ThinkWood, 2016)

Structural Design - Gravity Framing System: The gravity system of the building utilizes a CLT panel design that are point supported on glulam columns on a 9.35 x 13.1 foot grid. By utilizing CLT’s ability to span in both directions, the design team was able to eliminate all beams, reducing the overall structural depth of the floor to ceiling space.

FIGURE 92 | Section Perspective.
(Architect Magazine, 2017)

FIGURE 93 | Column Connection Detail.
(Architect Magazine, 2017)

Structural Design - Timber Floor System: The structure is comprised of 17 stories of five-ply cross-laminated timber (CLT) floor panels, a concrete transfer slab on the second floor, and a steel framed roof.

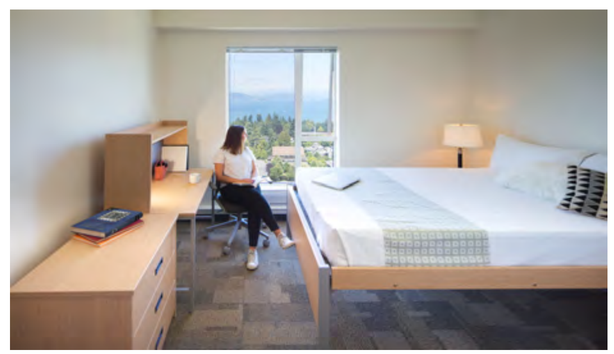


FIGURE 94 | Interior View Of Brock Commons in Vancouver, BC.
(The University of British Columbia, 2017)

Integrative Design - Concealed in Finish: With the structure being completely concealed behind drywall gypsum, the buildings MEP and HVAC easily integrated within the structure and the drop ceiling/floors.

FIGURE 95 | Interior View Of Brock Commons in Vancouver, BC.
(The University of British Columbia, 2017)

FIGURE 96 | Interior View Of Brock Commons in Vancouver, BC.
(The University of British Columbia, 2017)

Integrative Design - Wooden Drop Ceilings: In the buildings common rooms, wooden screening is utilized to conceal MEP and HVAC systems.

FIGURE 97 I Exterior View Of OSU Cascades in Bend, OR.
(SRG Partnership, 2017)

OSU Cascades

Architect: SRG Partnership
Location: Bend, Oregon
Year Completed: 2021
Size: 2,233 Sq. ft.
Type: Educational Building

Overview: The Oregon State University Cascades project was the first building to be built on a 46-acre reclaimed pumice mine acquired by the University for future campus expansion in Bend, Oregon. The academic building is placed on a steep eastern rim with panoramic views across the to be west campus and to the mountains beyond. The building and its adjacent outdoor spaces are designed to step with the topography and to create a gateway between the existing upper campus and the future development on the transformed mine. OSU showcases their commitment to sustainability through the buildings use of a mass timber structure and design.

FIGURE 98 I Interior View Of OSU Cascades in Bend, OR.
(SRG Partnership, 2017)

Architectural Design: The academic building highlights the natural beauty of timber through its exposed timber structure throughout the building's interior. By exposing the timber as much as possible the building offers a warm and inviting environment for students and faculty. The use of wood in this project also visually connects its user to the broad and expansive regional landscape. Primary facades feature tall windows with vertical shading devices tuned to their solar orientation to maximize daylighting and mitigate glare and summer heat gain. A overreaching horizontal roof plane floats above the building form and is designed to accommodate an array of photovoltaics to provide on-site renewable energy for the project. Interior academic spaces are organized on a modular grid, which will allow for future program adaptation, a primary goal of the project.

FIGURE 99 I Section Perspective.
(SRG Partnership, 2017)

FIGURE 100 I Interior View Of OSU Cascades in Bend, OR.
(SRG Partnership, 2017)

Structural Design - Gravity Framing System: The buildings gravity system utilizes a one directional glulam post and beam frame and cross-laminated timber (CLT) floors and roof system. The typical grid for the CLT and GLT structure is 10'x32'.

FIGURE 101 I Concrete Shear Walls in OSU Cascades.
(SRG Partnership, 2020)

Structural Design - Lateral Framing System: The lateral system for the building utilizes concrete cores and walls to transfer loads to ground. The buildings major circulatory systems are placed within these cores.

FIGURE 102 | Section Perspective.
(SRG Partnership, 2017)

FIGURE 103 | Concrete Floors in OSU Cascades.
(SRG Partnership, 2017)

Structural Design - Timber-Concrete Composite Floor System: The floor system is composite floor is comprised of a layer of concrete over the 5-ply CLT floors. The use of concrete and timber allows for exposed timber ceilings, important to the timber design and overall aesthetic.

FIGURE 104 | HVAC Units in Exterior Wall.
(SRG Partnership, 2017)

Integrative Design - One Directional Beam Structure & Built-in Wall HVAC Units: The building utilizes a composite timber-concrete floor system that allows for exposed CLT in the ceilings. The structural design of the building creates a central colonnade where HVAC and MEP systems are organized. In this design these systems are to be exposed and celebrated. In the exposed timber ceilings, sprinkler systems connect to each beam and are visible. Other non-hidden MEP is from lighting units. The use of a JAGA in wall HVAC unit allows for greater concealment of air circulation systems and was essential to the exposed timber design.

ADVANTAGES AND IMPLICATIONS OVERVIEW-

To Summarize

All Wood Systems:
Catalyst
Michael Green Architecture & Katerra I Spokane, Washington I 2020

OSU Peavy Hall
Michael Green Architecture I Corvallis, Oregon I 2018

Wood Innovation and Design Center
Michael Green Architecture I British Columbia, Canada I 2014

John W. Olver Design Building
Leerz Weinzapfel Associates / Amherst, Massachusetts I 2017

Wood Gravity Systems - with steel or concrete lateral systems

District Office
Hacker Architects I Portland, Oregon I 2020

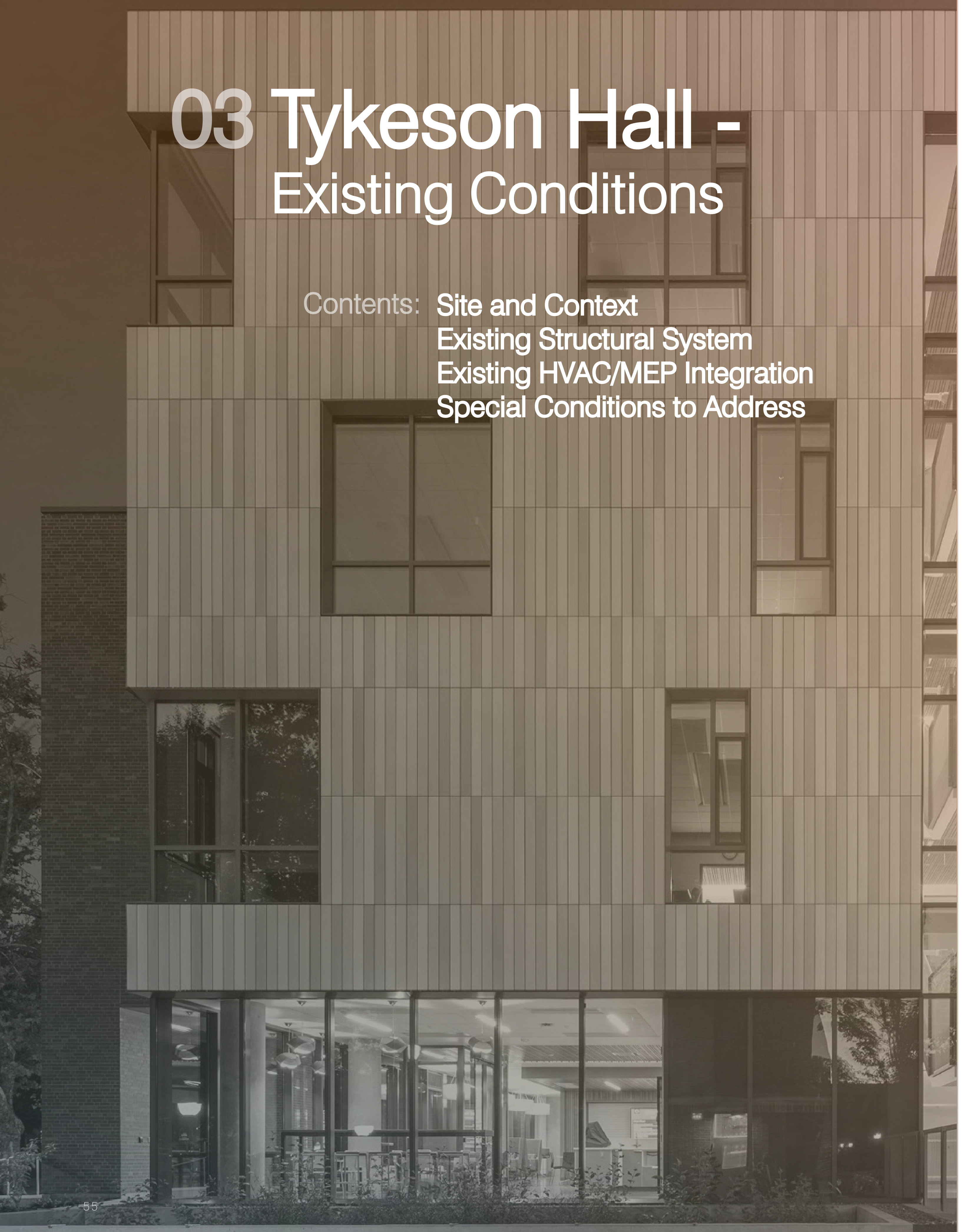
Bullitt Center
Miller Hull Partnership I Seattle, Washington I 2013

Brock Commons
Acton Ostry Architects / Vancouver, British Columbia / 2016

OSU Cascades
SRG Partnership / Bend, Oregon / 2021

Advantages and Implications Observed from Case Studies

Application to Structure		Advantages for Integration		(+/-) Implications to Whole
CLT Spacing / Chases	→	Ability to run and conceal services within.	→	Dependent on floor construction type. Will need additional framing.
Timber on Timber Composite Floor Panels	→	Ability to run MEP/HVAC between ribs.	→	(+) Composite Action (-) Dependent on panel sizing and structural grid.
Timber-concrete Composite Floor Systems	→	Ability to run radiant system within slab.	→	(+) Composite Action (-) Dependent on project timeline (wet vs. dry construction)
One/Uni-Directional Beam Orientation	→	Ability to run systems without interruption of beams.	→	Will likely need additional reinforcment (composite in floors, etc.)
Flat Use Beams	→	Ability to minimize structural depth.	→	Dependent on span. Will need more dimention than if upright.
Point Supported CLT	→	Ability to run systems freely (no beams).	→	Dependent on span/ floor to floor height.



03 Tykeson Hall - Existing Conditions

Contents: Site and Context
Existing Structural System
Existing HVAC/MEP Integration
Special Conditions to Address

FIGURE 105 I Tykeson Hall Section Perspective.
(Office 52 Architecture, 2018)

Why Tykeson Hall:

I chose Tykeson Hall to explore the advantages and implications of utilizing mass timber because it is a recently completed educational building constructed of post tensioned concrete and steel. Located on the University of Oregon campus, Tykeson hall offers a variety of spaces to accommodate both structurally and service efficiently, making it the ideal project for a conceptual conversion and study such as this.

SITE & CONTEXT

Project Details:

Name: Willie and Donald Tykeson Hall
Architects: Office 52 Architecture and Rowell Brokaw Architects
Building Type: Education
Size: 64,000 Sq.Ft,
Location: 1030 East 13th Avenue, University of Oregon, Eugene OR.
Year Completed: 2019
Certifications: LEED Gold

Project Description:

Tykeson Hall is a recently completed educational building at the University of Oregon in Eugene, Oregon. Situated at the heart of campus, the building serves the university's College of Arts and Sciences (CAS). CAS is home to 800 faculty, 42 fields of study, and over 11,000 students (CAS, 2018) . Because CAS, with office and classrooms in a variety of locations on campus, did not have a central building as of 2017, Office 52 Architecture and Rowell Brokaw Architects teamed up to create a building for CAS that serves as a multifunctional home base for the college. Even with building on a constrained campus site with a small building footprint of 64,000 sq.ft., the architects of Tykeson Hall created an efficient gateway for learning and career development. Also situated on the L-shaped site is a quad space filled with vibrant oak trees, seating, and art instillations. Named the Memorial Quad, the spacious lawn acts as a community space for all campus users.

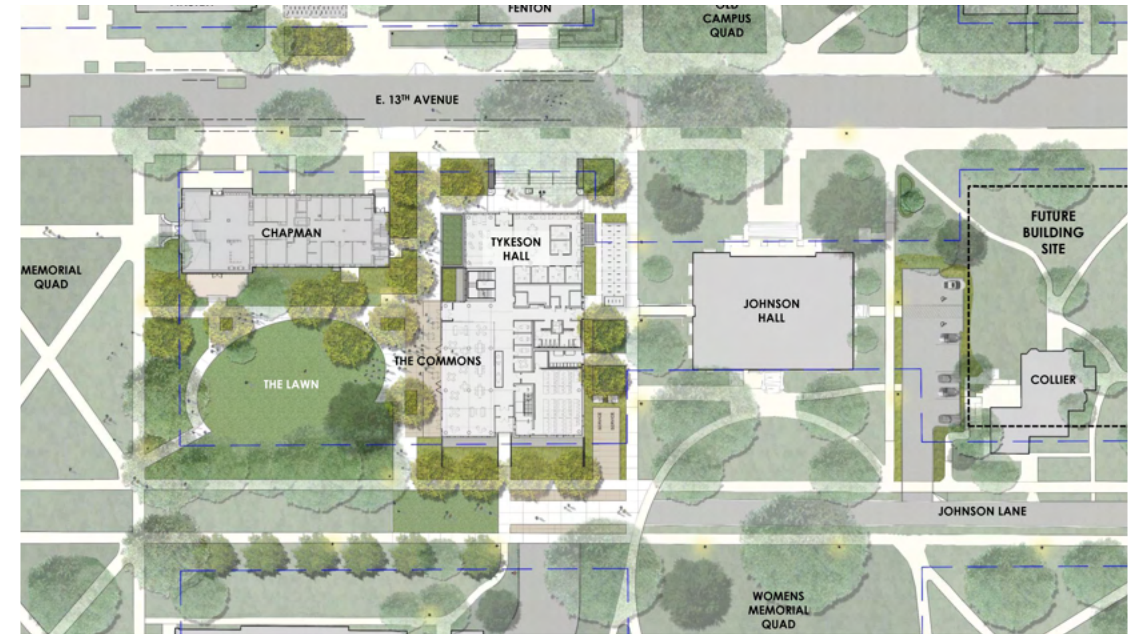


FIGURE 106 I Site Map of Tykeson Hall. (Office 52 Architecture, 2017)

FIGURE 107 I Map of Eugene OR, and Tykeson Hall. (Wikimedia Commons, 2018)

FIGURE 108 I Map of University of Oregon and Tykeson Hall. (Office 52 Architecture, 2017)

EXISTING STRUCTURAL SYSTEM:

Overview:

The existing structural design of Tykeson Hall utilizes a post tensioned (P/T) concrete slab and reinforced concrete columns. There are no beams in this structure other than in its top floor, which is structurally supported by steel elements, unlike the concrete floors below. This change in structural material between floors 1-3 and 4 was made for the differing structural load requirements from floor to floor. On the 4th floor steel HSS columns and I-Joists were employed, this system did not follow the existing column grid below. Radiant heating and cooling tubes are embedded directly into the P/T slab on each floor.

Photos of Existing Structure:

FIGURE 109 | Tykeson Hall Concrete Structure in Construction. (Josh Partee, 2018)

FIGURE 110 | Tykeson Hall Concrete Column and Walls. (Josh Partee, 2018)

FIGURE 111 | Interior View of Tykeson Hall. (Aaryn Gray, 2022)

FIGURE 112 | Interior View of Tykeson Hall. (Aaryn Gray, 2022)

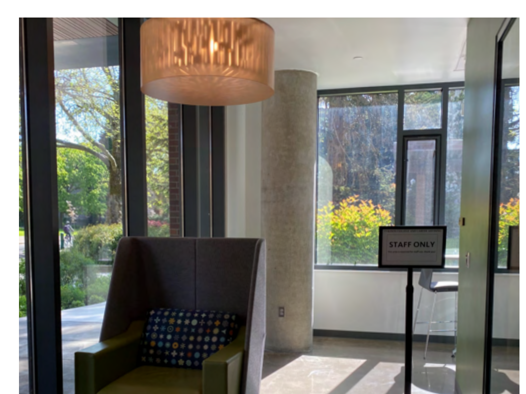


FIGURE 113 | Interior View of Tykeson Hall. (Aaryn Gray, 2022)

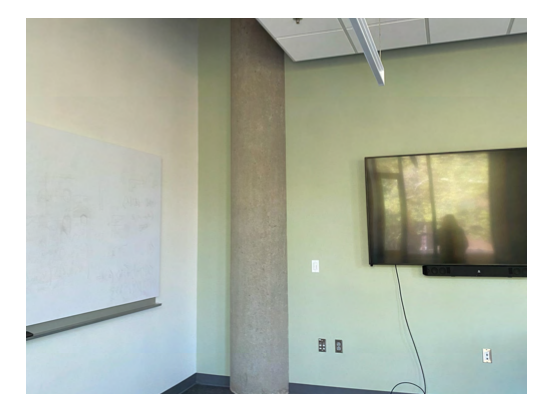
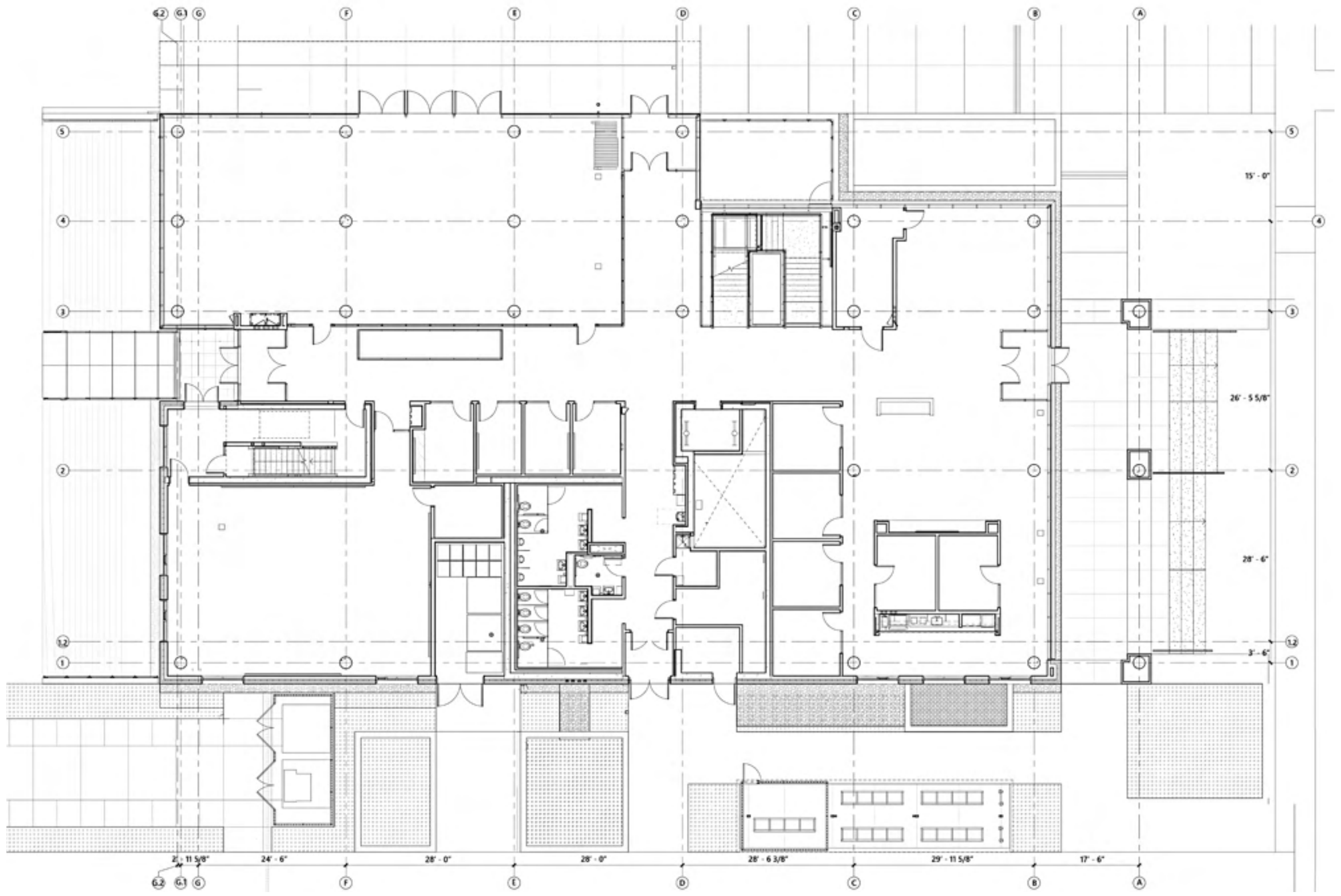
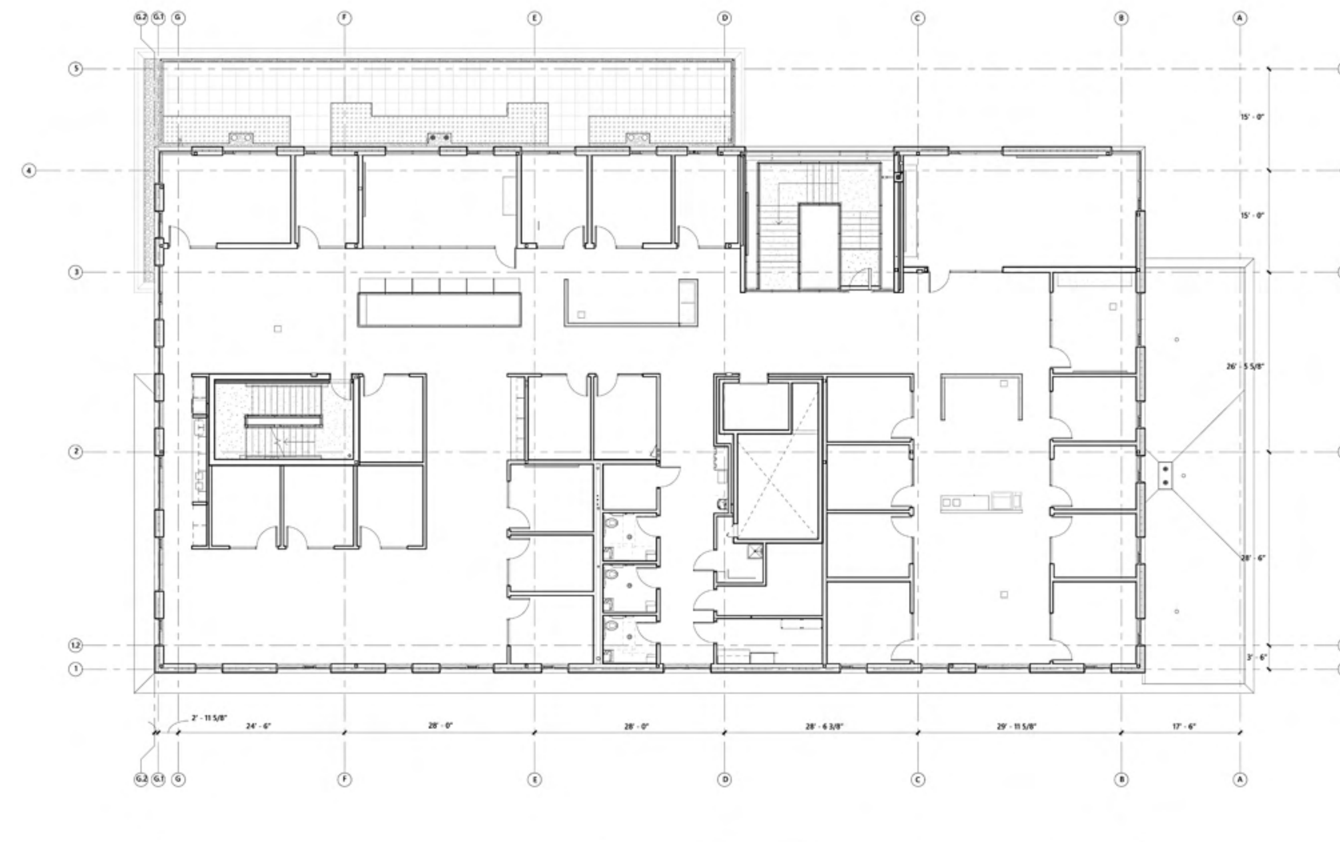


FIGURE 114 | Interior View of Tykeson Hall. (Aaryn Gray, 2022)

Plans of Existing Structure:

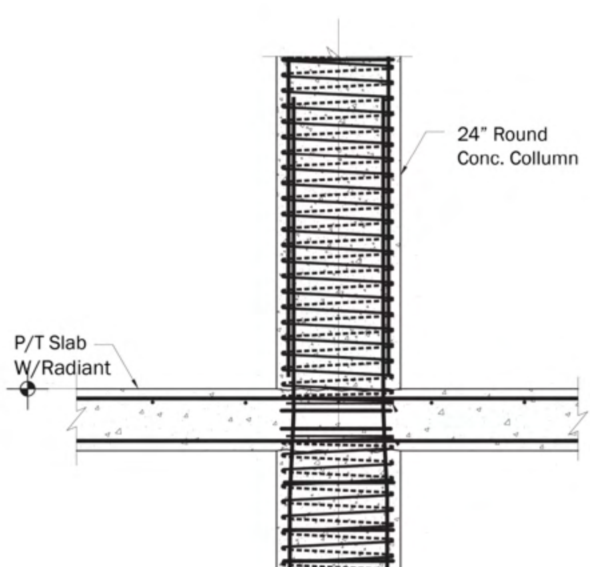


First Floor Plan
NTS



Fourth Floor Plan
NTS

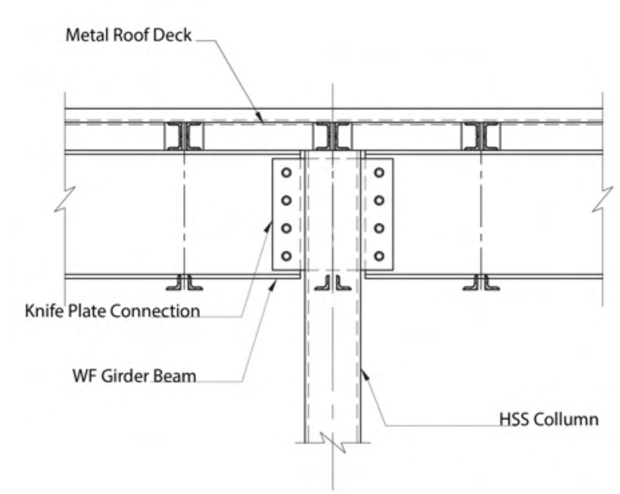
Details of Existing Structure:



Existing Floor to Column Detail
NTS

EXISTING FLOORS 0-3 (TYP.) –
Post Tension Concrete Slab & Column

The existing structural design of Tykeson Hall utilizes a 12" Post Tension (P/T) concrete slab and 24" reinforced concrete columns. There are no beams in this structure (other than at top steel floor). Radiant heating and cooling tubes are embedded directly into the P/T slab.



Existing Column to Beam Detail
NTS

EXISTING FLOOR 4 –
I-Joist, Steel Deck, & HSS Column

The existing structural design of Tykeson Hall in floor four changes to a steel design utilizing HSS Tube Steel columns, I joist beams, and a con-ventional metal deck. The HSS steel columns do not follow the existing column grid of floors 0-3.

EXISTING MEP/ HVAC INTEGRATION:

Overview:

To showcase the structural implications of system integration in a mass timber building the existing HVAC system of Tykeson Hall was redesigned for the design goals of exposing the mass timber ceiling as well as meeting an architectural standard of aesthetic. In this section I describe the existing HVAC distribution units utilized in the concrete and steel building and how these would need to be redesigned to meet the desired design goals as well as operate efficiently to meet the heating and cooling loads of the building.

Photos of Existing HVAC/MEP:

FIGURE 115 I HVAC/MEP of Tykeson Hall. (Aaryn Gray, 2022)

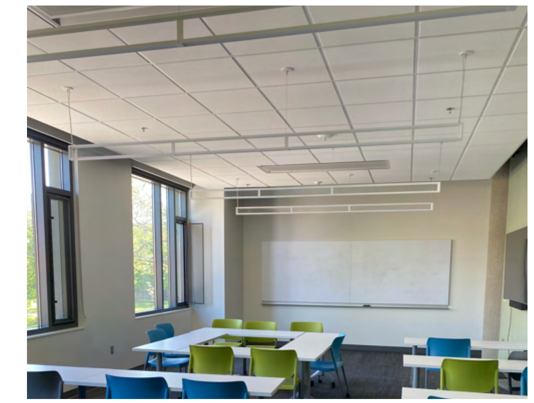


FIGURE 116 I HVAC/MEP of Tykeson Hall. (Aaryn Gray, 2022)

FIGURE 117 I HVAC/MEP of Tykeson Hall. (Aaryn Gray, 2022)

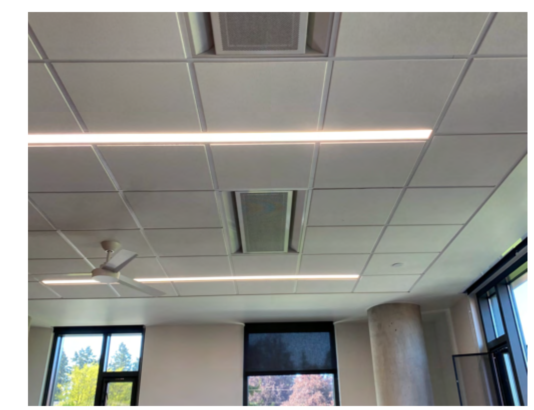


FIGURE 118 I HVAC/MEP of Tykeson Hall. (Aaryn Gray, 2022)

FIGURE 119 I HVAC/MEP of Tykeson Hall. (Aaryn Gray, 2022)

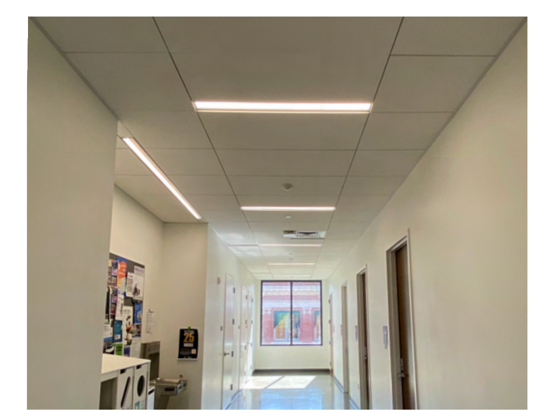
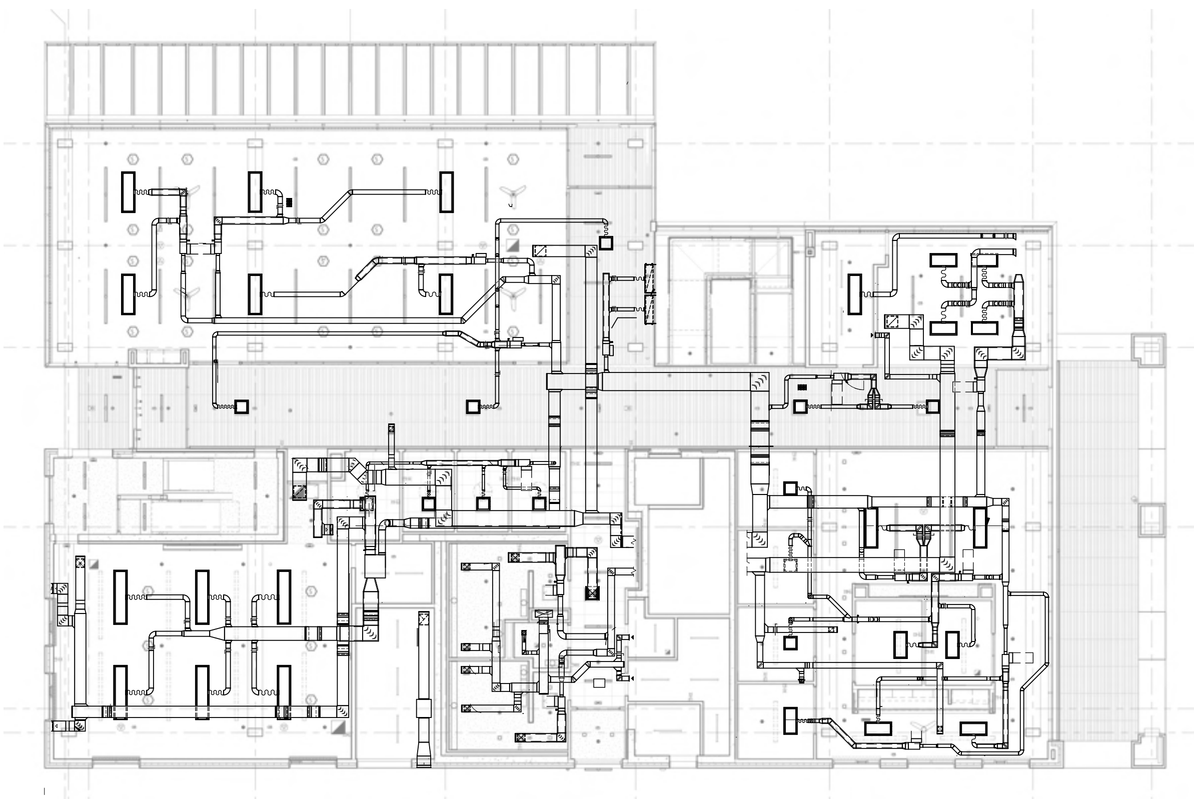


FIGURE 120 I HVAC/MEP of Tykeson Hall. (Aaryn Gray, 2022)

Existing HVAC Systems:



▬ = EXISTING HVAC

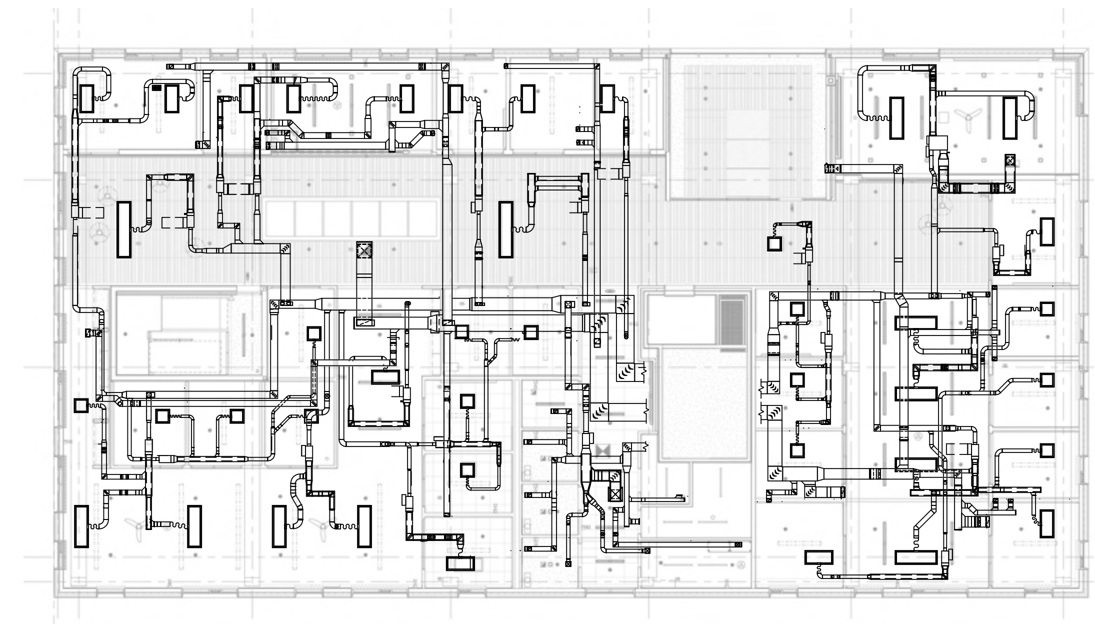
1st Floor (Typ.) Reflected Ceiling Plan
With Existing HVAC
NTS

The existing HVAC systems of Tykeson Hall are primarily reliant on Pacific Chilled Beams for meeting heating and cooling loads. These systems, while highly efficient, are conventionally located above drop ceilings due to their size and need for additional ducting. Because the existing Tykeson Hall utilizes drop ceilings in the entirety of the building, these systems are integrated seamlessly into the ceilings design. All ducting of Tykeson Halls systems also runs beneath these drop ceilings, concealing the ceiling structure.

EXISTING - TYP. for Concrete and Steel
PACIFIC - CHILLED BEAM UNIT

Unit -

FIGURE 121 | Pacific Chilled Beam.
(Swaegon, Date Unknown)



▬ = EXISTING HVAC

4th Floor Reflected Ceiling Plan
With Existing HVAC
NTS

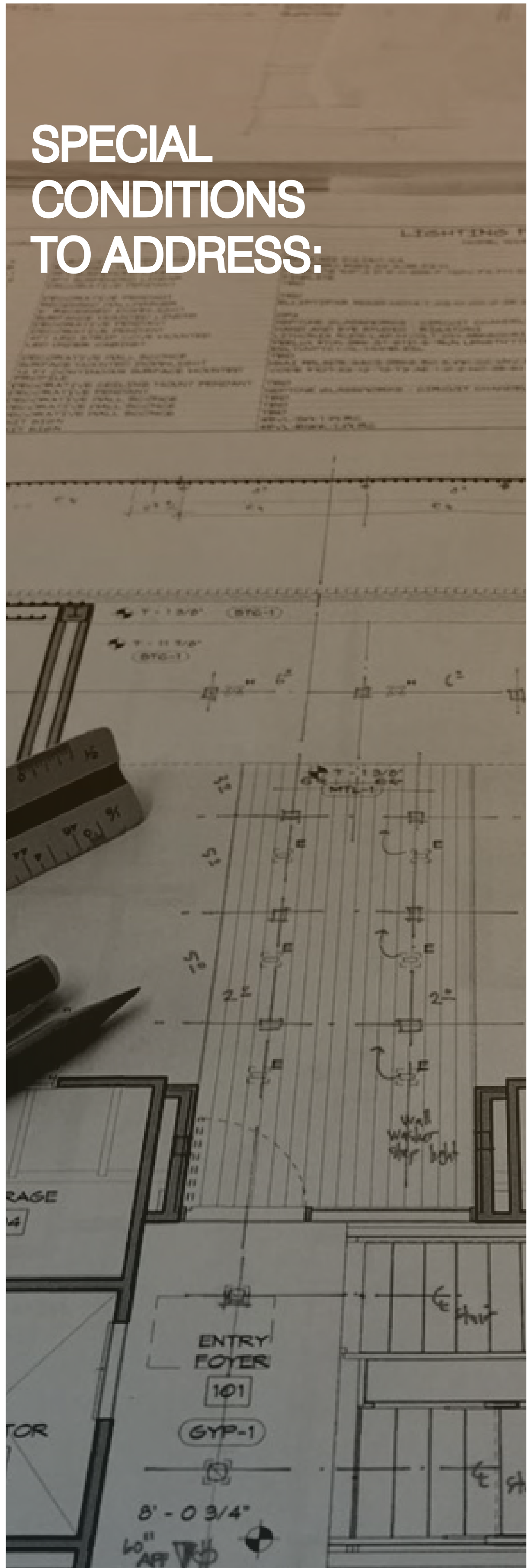
EXISTING - TYP. for Concrete and Steel
Integrated Unit - Into Ceiling

FIGURE 122, 123 | Pacific Chilled Beam, Installed.
(Swaegon, Date Unknown)

EXISTING - TYP. for Concrete and Steel
Spec. Information -

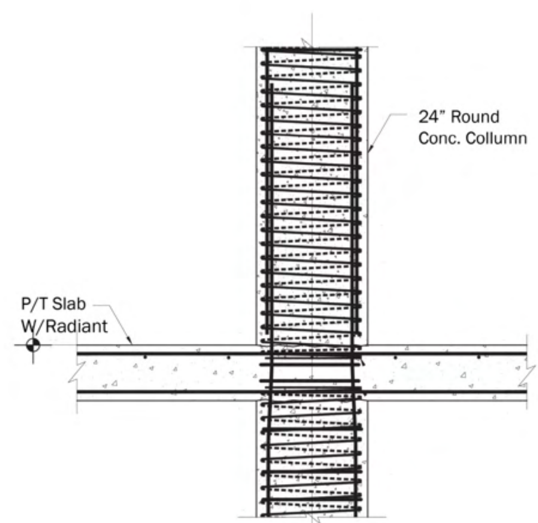
Positioning: Ceiling, Built-in
Heating capacity: Up to 12707 BTU/hr
Cooling capacity: Up to 13977 BTU/hr
Airflow: Up to 315 CFM
Depth: 10.6"

SPECIAL CONDITIONS TO ADDRESS:



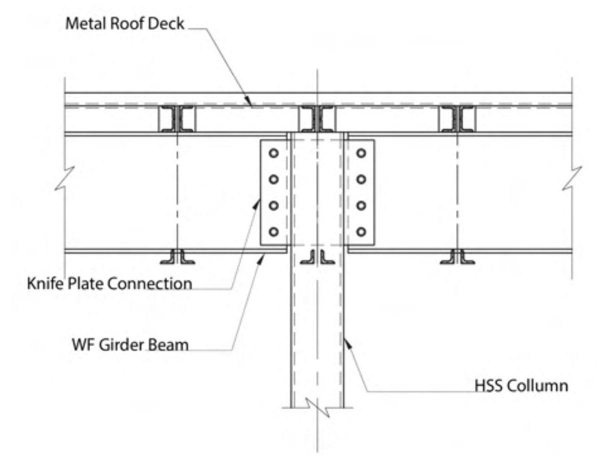
No Beams:

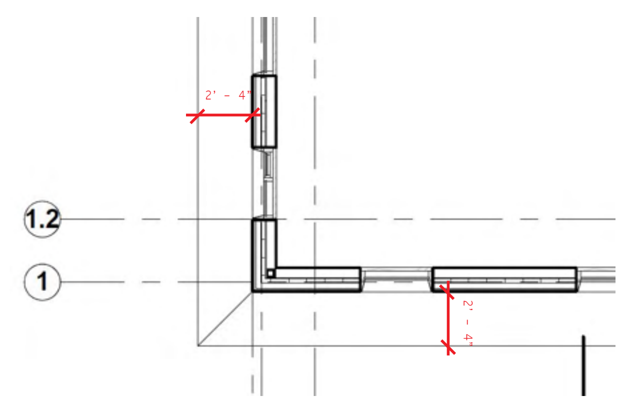
The existing structure of Tykeson Hall has no beams other than on the fourth floor where I-Joist beams are employed in the roof. A mass timber design with the spans required to accommodate the various programmatic areas in Tykeson Hall needs beams for structural viability, and therefore needs to be addressed for both structural efficiency and integrating systems within a reasonable structural depth.



4th Floor in Steel + 4th Floor Facade Steps Back:

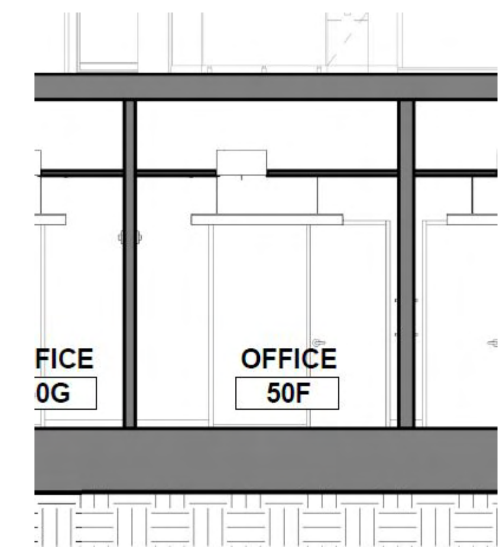
Because the fourth-floor bears less weight than the floors below it, steel was utilized as the primary structural material. This steel floor does not follow the structural grid and its façade stepped back from the columns of the floors below it. Because the mass timber design was more efficient if it followed the structural column grid through all floors, changes to the existing structural grid were necessary.





Structure is Hidden Behind Drop Ceiling:

As the major existing structure of Tykeson Hall was concrete, there was no desire to expose the structural material in the ceiling. This was advantageous for concealing all HVAC and MEP systems within drop ceilings. In the mass timber design, there is a desire to expose the structural material, and this implicated changes to both the structural system and service design of Tykeson Hall.



04 Tykeson Hall - Mass Timber Design

Contents:
Design Criteria
Mass Timber Material
Mass Timber Structural System
Structural Weight and Sizing
HVAC/MEP Integration
Final Rendered Perspectives

FIGURE 124 | Interior View of Tykeson Hall in Mass Timber (Aaryn Gray, 2022)

Tykeson Hall offers a variety of spaces to accommodate structurally and service efficiently. In this study a mass timber system was substituted for the concrete and steel structural system in the existing building and needed to accommodate for academic classrooms, offices, and common rooms which all have differing structural spans and HVAC requirements. Through Revit model iterations and plans that went through consistent review with my advisors and consultants, a mass timber structural system was conceptually designed for both structural and service efficiency.

DESIGN CRITERIA:

Efficiency:

Efficiency of Structural Design:

- Employ a mass timber system with minimal change to the existing structural spans and spaces within them.
- Minimize fiber through the exploration of construction assemblies, primarily the floor assembly.
- Minimize waste when sizing structural members through employing structural analysis tools and review from engineering professionals.
- Minimize waste through prefabrication and off-site construction methods.

Efficiency of HVAC/MEP System Design:

- Employ a mass timber system with minimal structural beam depths to achieve more space for HVAC and MEP runs.
- Employ HVAC systems that are organized and easily accessible for maintenance and control.
- Minimize energy waste through employing appropriate types of systems in the building, and in the optimal locations.

Sustainable Efficiency:

- Employ a mass timber structure that minimizes the use of concrete and steel in order to reduce environmental impact.
- Reduce the fiber of the buildings structure to reduce environmental impact.

Aesthetics:

Mass Timber Standards:

- Promote the effects of biophilia such as higher levels of focus and comfort (Green and Taggart, 2017) by exposing the wooden structural material where possible.
- Promote the use of mass timber in educational spaces through its natural beauty and biophilic effect on its users.
- Minimize HVAC and MEP in exposed CLT areas for cleaner designs and more exposure of the timber structure.
- Protect the mass timber structure by employment of polished concrete floors, which is a University of Oregon standard.

MASS TIMBER MATERIAL:

Product Sourcing:

FIGURE 125 I DR Johnson to Tykeson Hall on the Map (Google Maps, 2022)

For this project, all CLT and Glulam products were chosen from those manufactured by DR Johnson Wood Innovations in Riddle, Oregon - only 91 miles to the site of Tykeson Hall. DR Johnson is a respected and experienced mass timber manufacturer in the Pacific Northwest as of 1951 and was the first producer of APA certified CLT in the United States. Because of the availability, variety, and quality of the materials in conjunction with the location of this site (GWP is reduced by sourcing materials locally through cutting down on emissions generated by transportation), DR Johnson was the primary choice for the manufacturing of the buildings CLT panels, Glulam columns, and Glulam Beams.

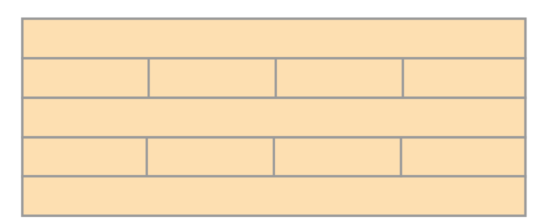
Table 2. ASD Reference Design Values[a] for DRJ CLT (for Use in the U.S.)

CLT Grade[b]	Layup ID[c]	Thickness, t_p (in.)	Lamination Thickness (in.) in CLT Layup: =	⊥	=	⊥	=	⊥	=	Major Strength Direction: $(F_bS)_{eff,f,0}$ (lbf-ft/ft)	$(EI)_{eff,f,0}$ (10^6 lbf-in.²/ft)	$(GA)_{eff,f,0}$ (10^6 lbf/ft)	$V_{s,0}$ (lbf/ft)	Minor Strength Direction: $(F_bS)_{eff,f,90}$ (lbf-ft/ft)	$(EI)_{eff,f,90}$ (10^6 lbf-in.²/ft)	$(GA)_{eff,f,90}$ (10^6 lbf/ft)	$V_{s,90}$ (lbf/ft)
E2	3	4 1/8	1 3/8	1 3/8	1 3/8					3,825	102	0.53	1,980	165	3.6	0.56	660
	5	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			8,825	389	1.1	3,300	1,440	95	1.1	1,980
	7	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	15,600	963	1.6	4,625	3,300	364	1.7	3,300

FIGURE 126 I DR Johnson CLT Structural Values and Dimensions (DR Johnson, 2022)

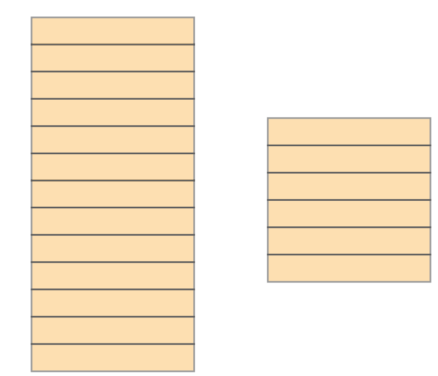
Cross Laminated Timber (CLT):

CLT was employed in this project for its spanning capabilities in a multi-story building. In the structural analysis of Tykeson Hall both 7-ply and 5-ply CLT panels was considered. Through iterations of the structural systems with my advisor board, 5-ply was the structural and sustainable choice for the employment of mass timber in Tykeson Hall.



Glue Laminated Timber (Glulam):

For the gravity system of Tykeson Hall, Glulam was utilized for the building's columns and beams. Glulam was chosen over other structural materials for its compatibility with CLT and its variability through its sizing to meet the structural demands of Tykeson Hall.

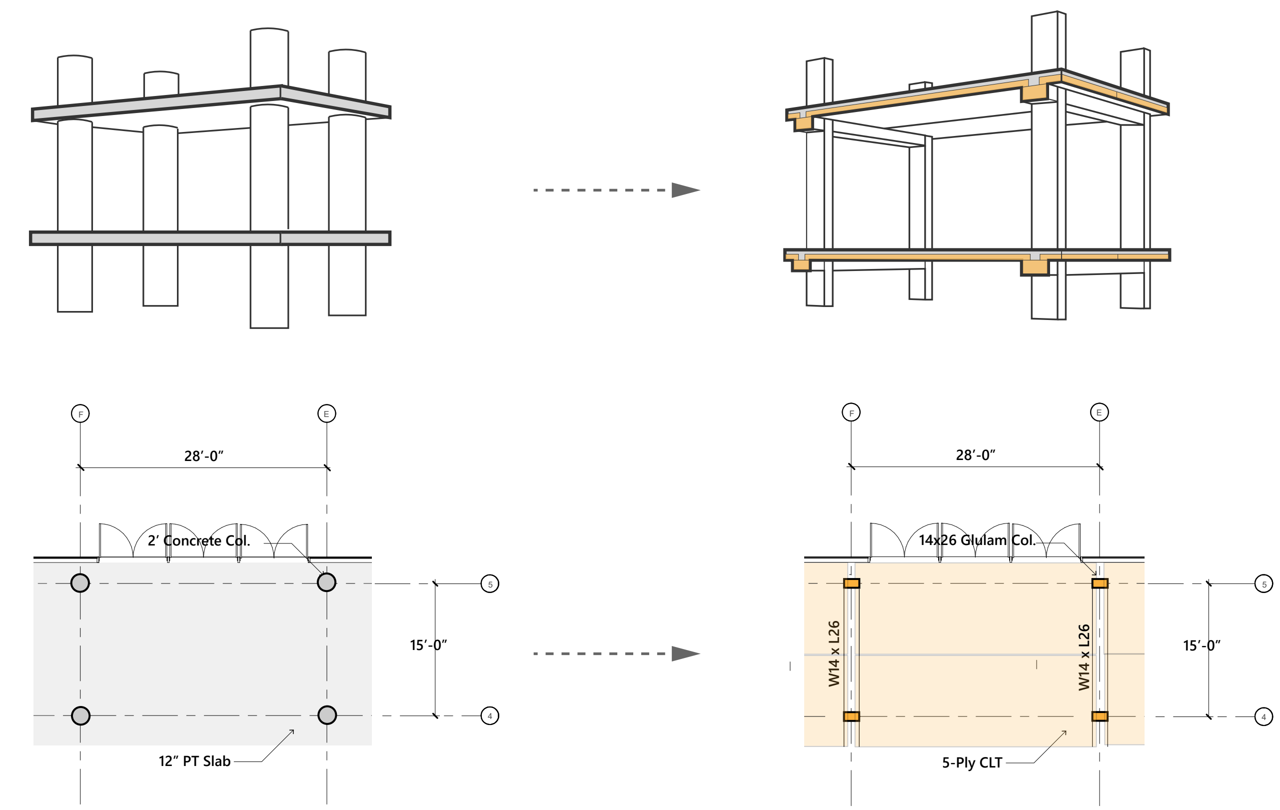


MASS TIMBER STRUCTURAL SYSTEM:

Overview:

To allow for greater specificity within the project scope the advantages and implications of utilizing mass timber were explored by substituting the existing post tensioned concrete and steel structure of Tykeson Hall with a mass timber one. In this section I describe the mass timber structural system and how iterations needed to be made to meet design criteria and goals.

Substituting a Post Tensioned Concrete Structure into A Mass Timber One:



Mass Timber Structure In Plan -

First Floor Plan
NTS

Fourth Floor Plan
NTS

Structure Description:

NEW FLOORS 1-4 –

The mass timber system of Tykeson Hall utilizes 14x26 Glulam columns and beams for the gravity system. This supports a timber-concrete composite floor assembled with 5-Ply CLT panels and 4" of reinforced concrete. HBV connectors are used for composite action between the timber and concrete and to improve vibration performance of the floor system.

FLOOR 0 - Basement

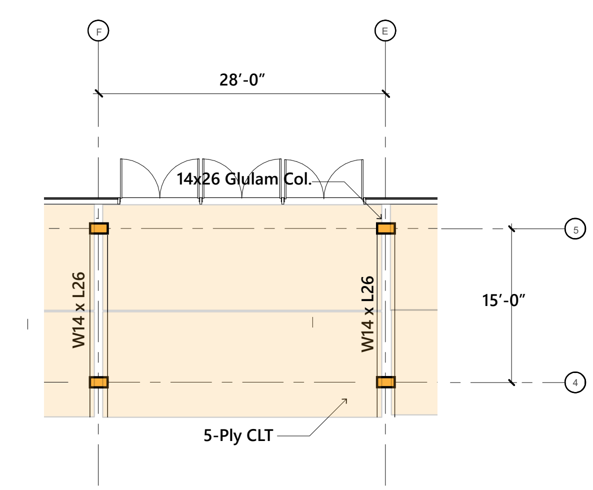
The basement level of the mass timber design will remin concrete.

Structural Components:

- **Glulam Post and Beam**
  W14 X L26 Columns
  W14 X L26 Beams

- **CLT-Concrete Composite**
  5-Ply CLT, 10' x Span (varies)
  4" Reinforced Concrete
  HBV Strips

- **Shear**
  12" Concrete Walls



Bay Study - CLT Layout
NTS

Uni-Directional Beam Structure:

A uni-direction beam structure was employed to reduce the buildings fiber use as well as to simplify the MEP and HVAC system integration. By eliminating beams in one direction, HVAC and MEP systems are able to run with minimal obstruction from a central corridor or core. In addition to this, by eliminating perimeter beams on the North and South façade the design can take advantage of daylighting and views. By removing the West to South beams from the structure, the building needed additional support through the timber-concrete composite floor.

Mass Timber Structure In Section -

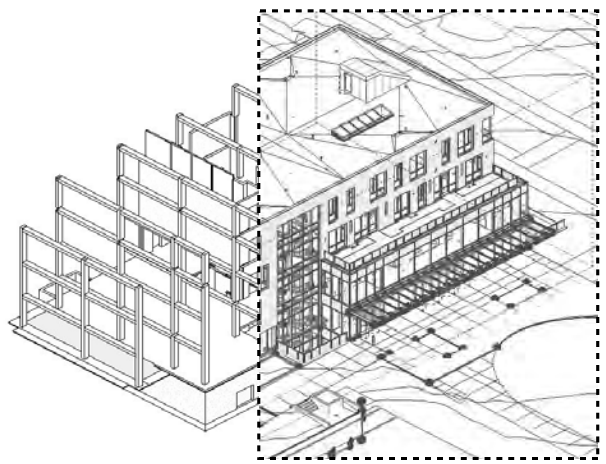
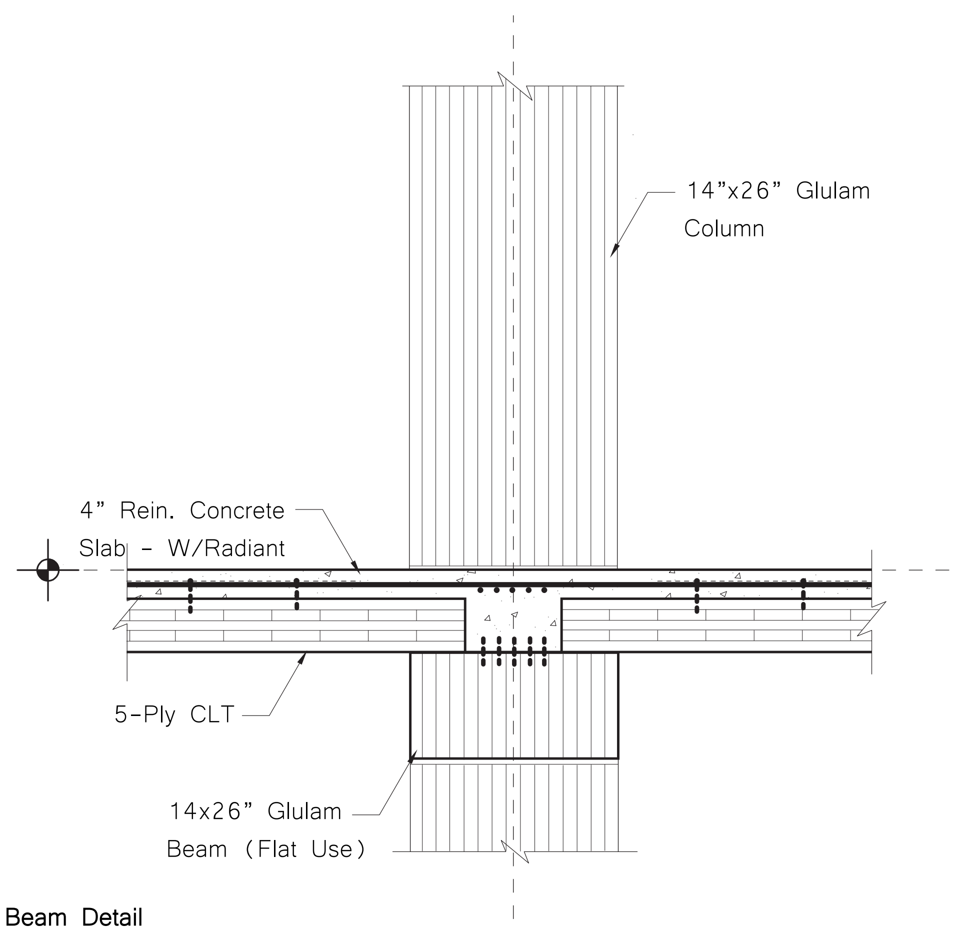


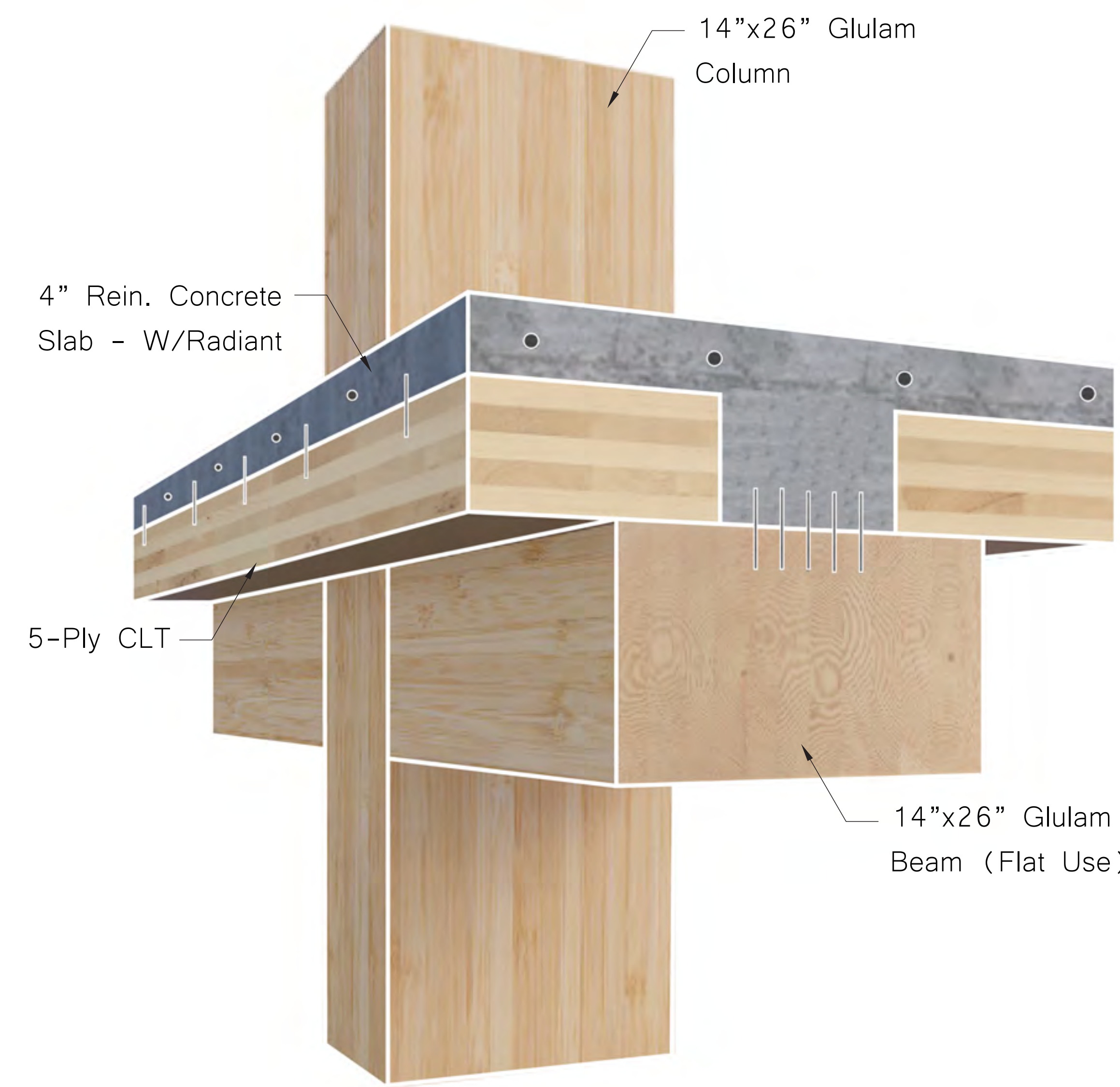
FIGURE 127 I X-Ray View Into Tykeson Hall Mass Timber Model (Aaryn Gray, 2022)

Timber-Concrete Composite Beams (Flat Use):

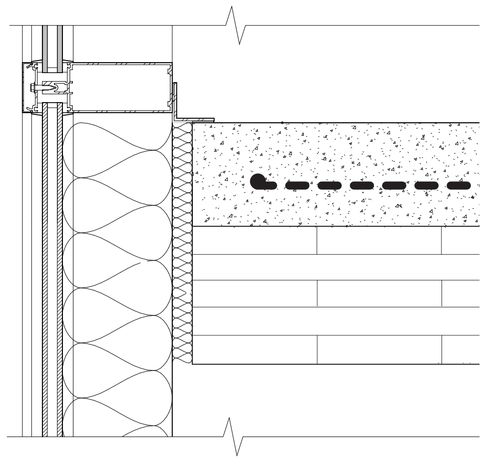
In this structural design the Glulam beams are installed flat, depth dimension in the horizontal instead of the vertical position. This composite action flat beam is connected through HBV connectors to the concrete slab above (see detail) and provides the needed composite support for Tykeson Hall's gravity system. Utilizing this system was advantageous for meeting both the structural and system design goals; the composite flat-use beam reduced structural depth allowing HVAC and MEP runs to take up less ceiling dimension. With a floor-to-floor height of 14', this was important to the overall design of the building.



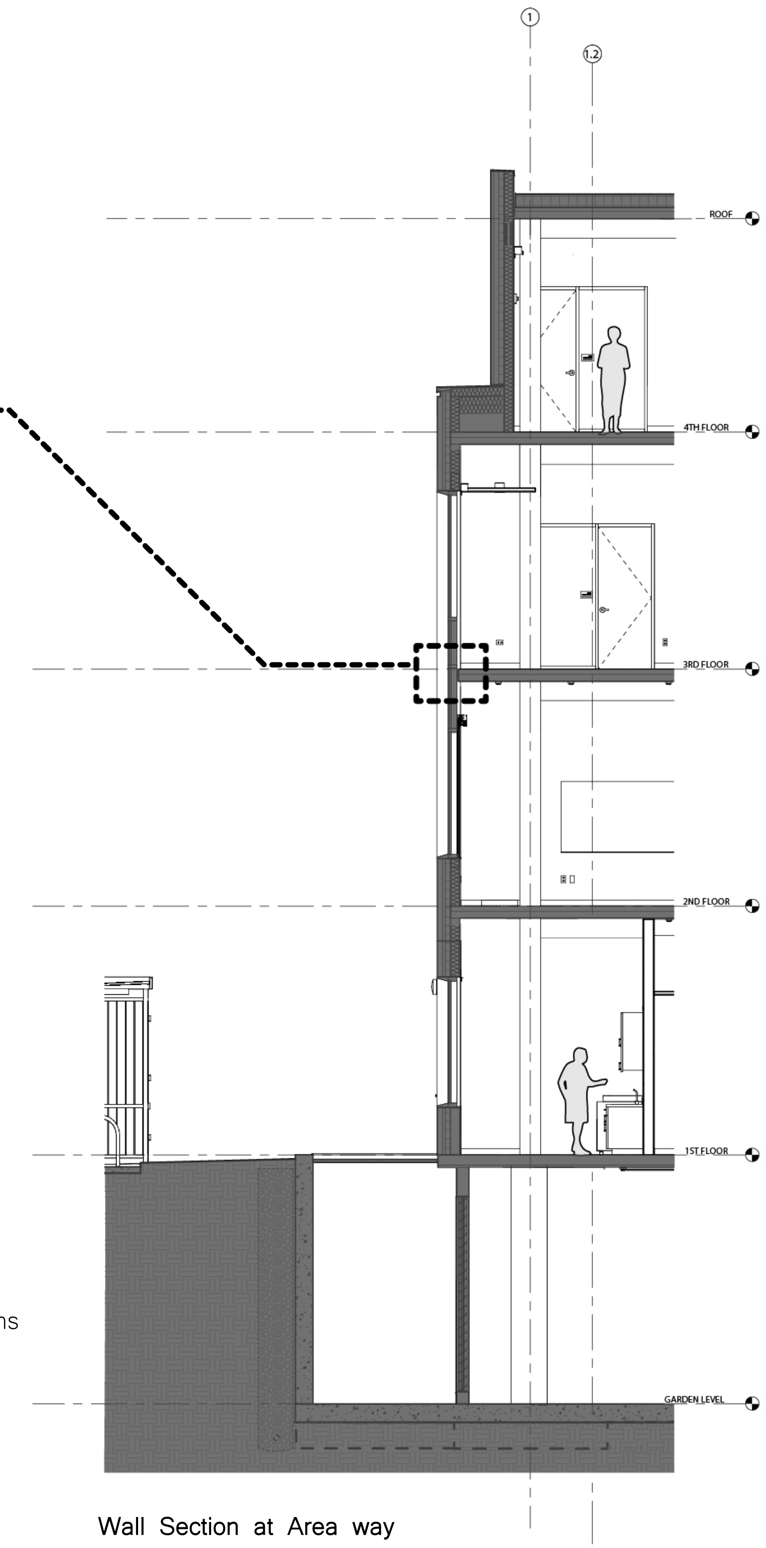
New Floor to Beam Detail
NTS



Rendered Section Detail



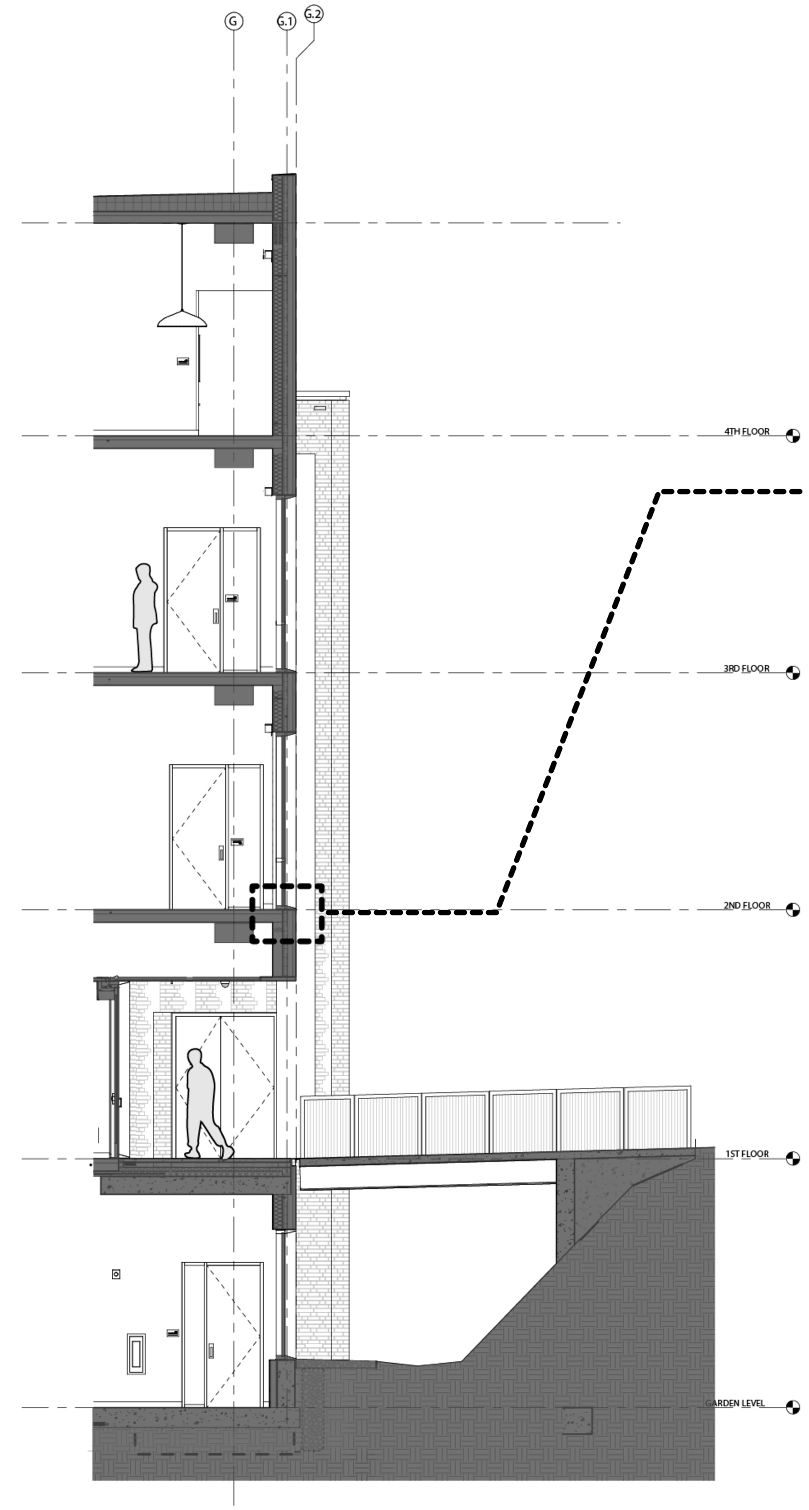
Floor to Exterior Curtain Wall Detail
NTS



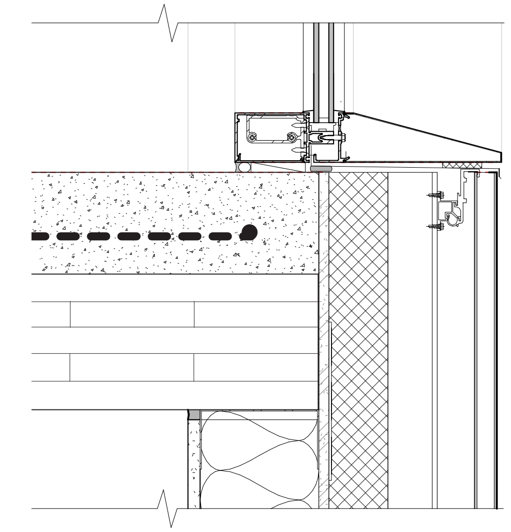
Wall Section at Area way
NTS

Realignment of Column Grid:

In order to accommodate the 4th floor, which stepped back from floors 1-3, the glulam columns were moved inboard of the original concrete column locations, with the composite timber-concrete floor system cantilevering past the columns, as shown in the section drawing.



Wall Section at Bridge
NTS



Floor to Exterior Terra Cotta Wall Detail
NTS

Rendered Section Perspective Detail

Rendered Section Perspective Detail

Rendered Section Perspective

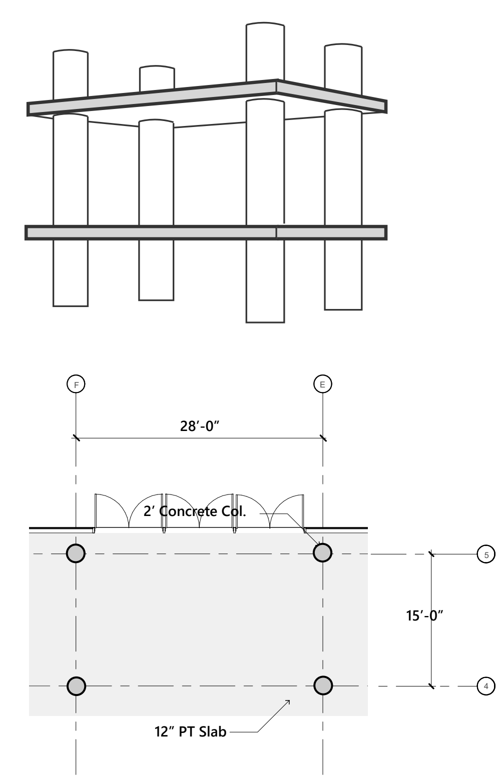
STRUCTURAL WEIGHT AND SIZING:

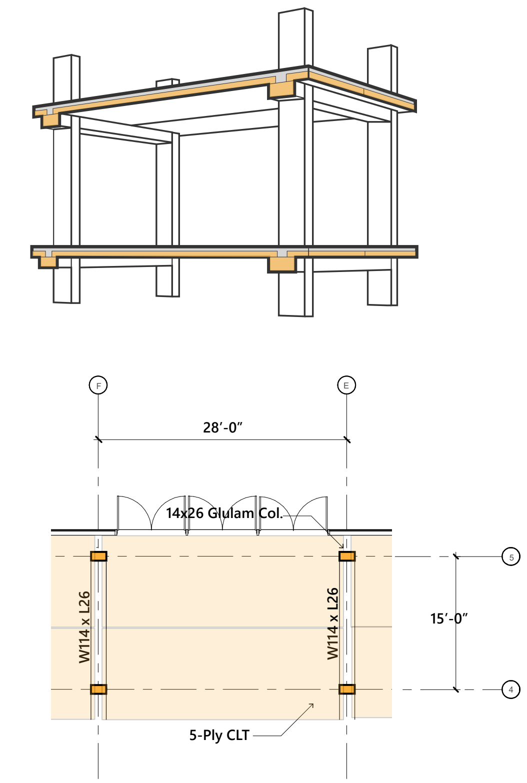
Overview:

In this section I identify areas where the structure of the building was changed due to the different building loads and weight between a concrete and steel structure to a mass timber one. In collaboration with my advisor, engineer and professor Mikhail Gershfeld, structural design decisions were made regarding the conceptual sizing of the gravity system, lateral system, and foundations. This structural sizing plays a crucial role not only in the structural design, but in the environmental performance of the building which was analyzed in the Life Cycle Assessment in chapter 5.

Note: Structural sizing was determined through assumption-based explorations and decisions which were periodically reviewed by engineer and professor Mikhail Gershfeld. No calculations were made other than the utilization of the Fast+Epp timber bay design tool.

Weight and Load Comparison:





EXISTING -

	LBS/CF	CF TOTAL	WEIGHT TOTAL
FLOOR (Concrete)	150 LBS/CF	~ 43,281 CF	~6,492,150 LBS
BEAMS (Steel on 4th)	489 LBS/CF	~ 212 CF	~103,668 LBS
COLUMNS (Concrete)	150 LBS/CF	~ 3,318 CF	~497,700 LBS
EST. TOTAL			**~7,093,518 LBS**

NEW -

	LBS/CF	CF TOTAL	WEIGHT TOTAL
FLOOR (Timber-Concrete)	77 LBS/CF	~ 43,281 CF	~3,349,395 LBS
BEAMS (Timber)	36 LBS/CF	~ 3,560 CF	~128,160 LBS
COLUMNS (Timber)	36 LBS/CF	~ 3,605 CF	~129,780 LBS
EST. TOTAL			**~3,607,335 LBS**

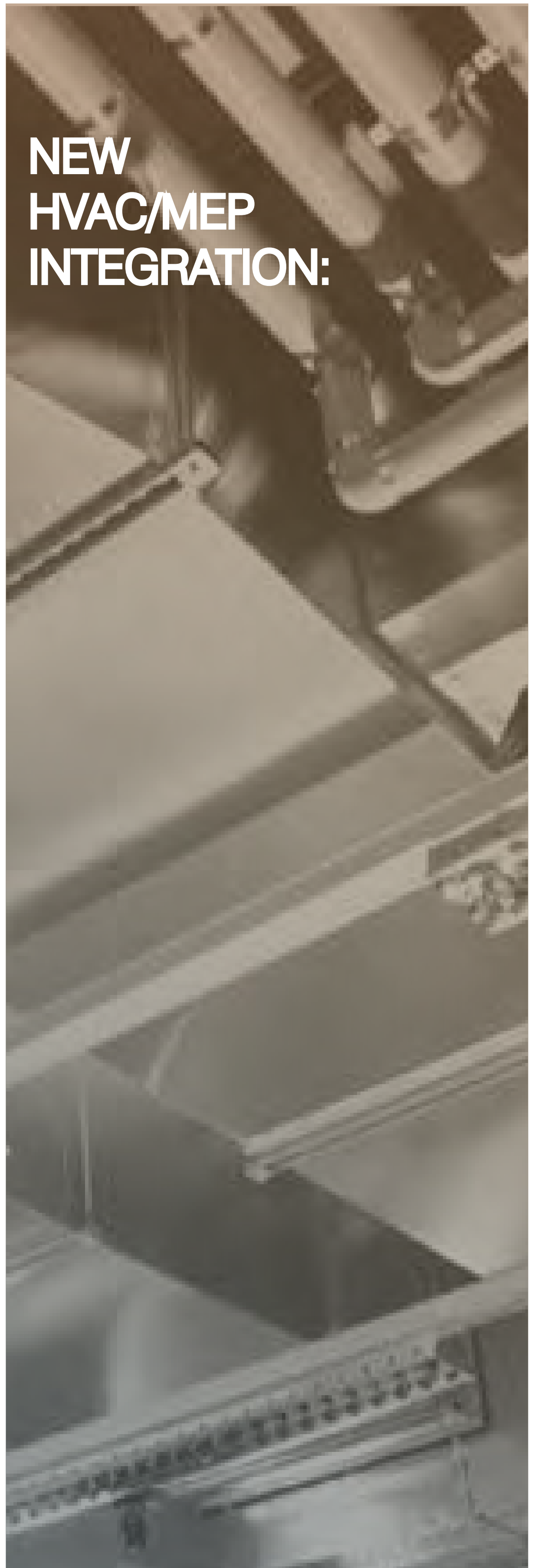
~ 49% Lighter

NOTE:
These calculations only account for the stated structural elements. It does not account for other loads such as walls, furniture, and finishes.

Main Areas Considered:	Changes Made:
• **Reducing the Structures Weight** Thinking about environmental impact of the mass timber design, reducing fiber wherever possible is critical to the building's structural and environmental efficiency.	Gravity System: The structural gravity system of Tyeskon Hall was reduced in weight by approximately 50% from the existing P/T concrete design to the mass timber one due to the reduction in material weight of the roof and floor construction assemblies (partial substitution of concrete for wood).
• **Reducing the Amount or Size of Shear Walls** With mass timber weighing considerably less than concrete, it is assumed that the lateral system, in this case of reinforced concrete shear walls, will resist less lateral load and therefore can use less concrete and less reinforcement in mass timber structures than in concrete and steel ones.	Shear System: While it is likely that with structural calculations performed for the new mass timber system, the concrete shear wall system could be reduced, for this conceptual study it was assumed that they stayed as they were in the original design.
• **Reducing Foundation Sizes** Because mass timber is lighter in weight, when utilizing mass timber structures foundations will support less load and can be considerably reduced.	Foundations: Because the structural gravity systems weight was reduced by approximately 50%, it was assumed that the foundations of this gravity system (not lateral) can also be reduced by 50% in volume. In the existing design of Tykeson Hal mat slabs are utilized for the building's foundation. As the new structure is considerably lighter, the volume of the existing foundations can be reduced by half. It is likely that the mat system may no longer be required.

As stated, these structural assumptions are made in consultation with advisor Mikhail Gershfeld. This reduction in foundation sizes is critical for the Life Cycle Assessment tracking of the environmental impact of the mass timber building in comparison to the existing concrete and steel design.

NEW HVAC/MEP INTEGRATION:

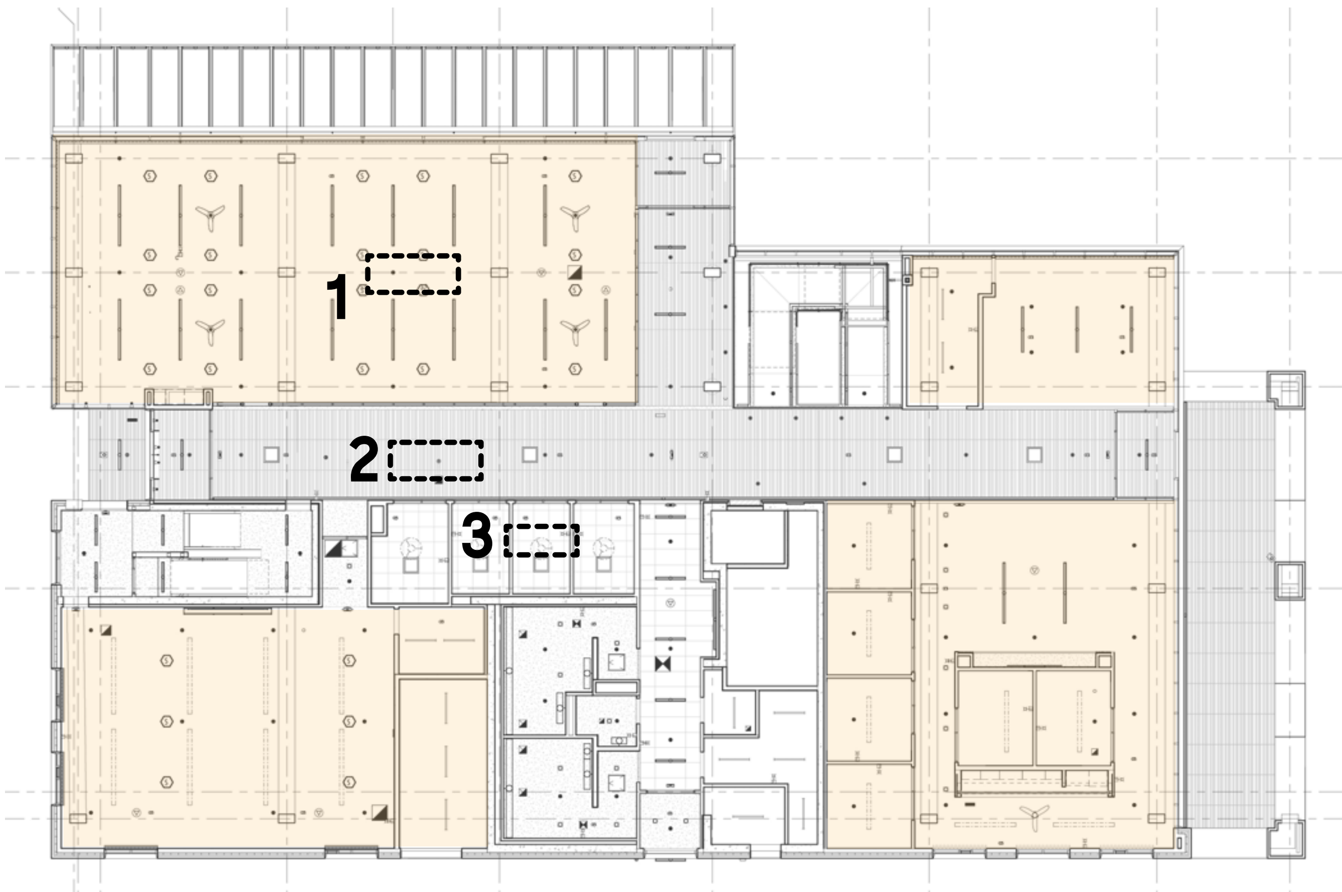


Overview:

The existing design of Tykeson Hall utilizes drop ceilings to completely conceal all systems, which also conceals the concrete and steel structure. With mass timber there is a desire to expose the material for biophilic and aesthetic reasons. This required the re-design of the buildings existing HVAC distribution units with different systems that allowed for exposing the mass timber ceiling, as well as meeting all heating and cooling loads of the building.

FIGURE 128 I Interior View of Tykeson Hall in Mass Timber (Aaryn Gray, 2022)

Exposing the Mass Timber Structure:



= EXPOSED CLT

1st Floor (Typ.) Reflected Ceiling Plan
NTS

In the mass timber design of Tykeson Hall I prioritize timber exposure in the ceilings by locating services in the central corridors and core of the building where drop ceilings would remain to conceal these mechanical and HVAC systems. By doing this, approximately 60% of the structural material is exposed, and 40% concealed.

1 Exposed CLT

FIGURE 129 I Exposed Timber Ceiling
(Aaryn Gray, 2022)

= EXPOSED CLT

4th Floor Reflected Ceiling Plan
NTS

2 Wooden Drop Ceilings

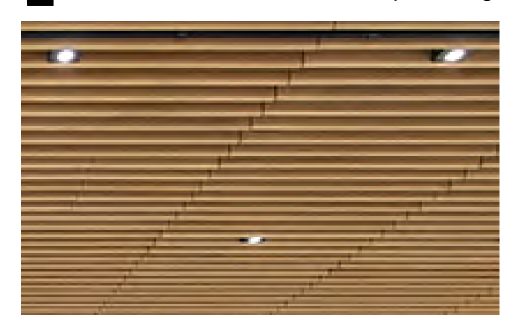


FIGURE 130 I Wooden Drop Ceiling
(Derako, Date Unknown)

3 Acoustic Tile Drop Ceilings

FIGURE 131 I Acoustic Tile Drop Ceiling
(Bob Vila, Date Unknown)

Substituting HVAC Units:

PRICE - ACBC Active Chilled Beam Displacement Cabinet

Unit -

Integrated Unit - **Onto Wall**

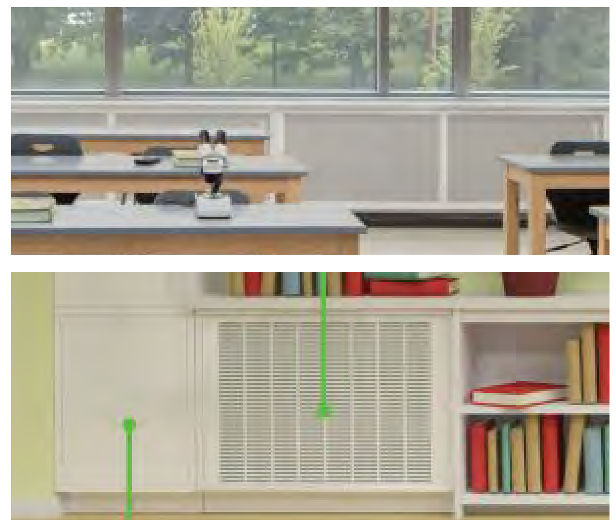
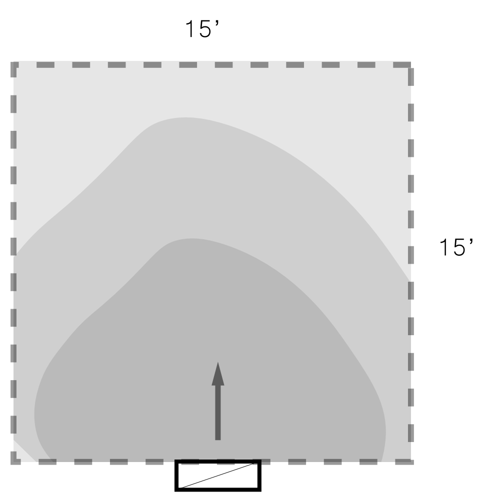


FIGURE 132, 133, 134 I ACBC Units
(Price Industries, Date Unknown)



Spec. Information -

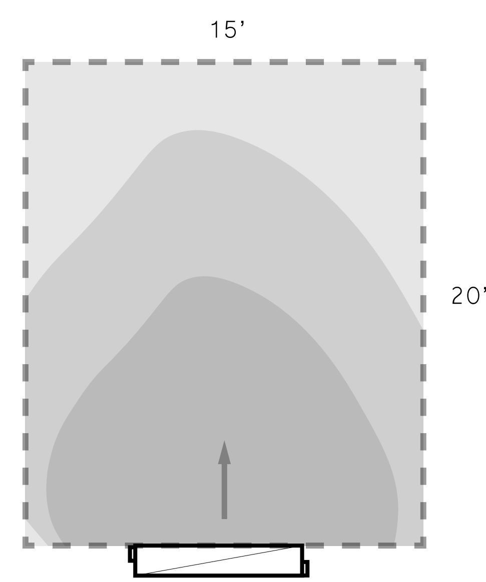
Positioning: Built-in, Freestanding on Floor
Heating capacity: Up to 2812 BTUH
Cooling capacity: Up to 3676 BTUH
Airflow: Up to 350 CFM
Depth: 9 1/4"
Coverage: 15' x 15' (approx.)

PRICE - ACBR Active Chilled Beam Recessed

Unit -

Integrated Unit - **Into Drop Soffit/Ceiling**

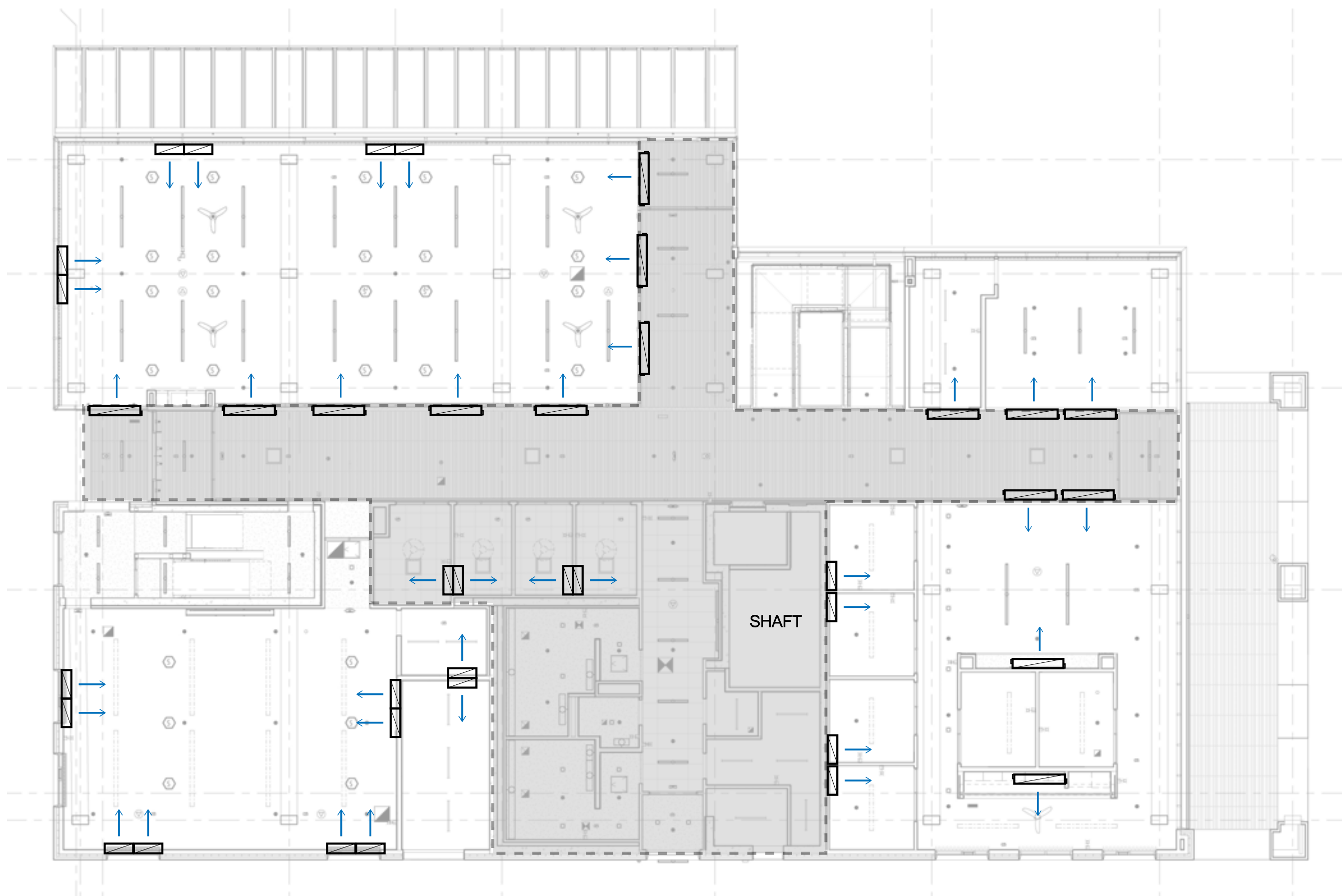
FIGURE 135, 136, 137 I ACBR Units
(Price Industries, Date Unknown)



Spec. Information -

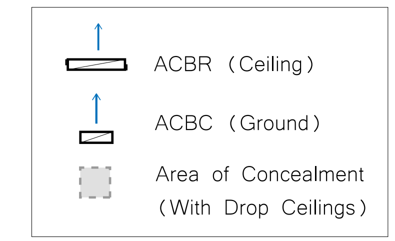
Positioning: Soffit Ceiling, Built-in, Hanging
Heating capacity: Up to 1190 BTUH
Cooling capacity: Up to 1860 BTUH
Airflow: Up to 190 CFM
Depth: 9"
Coverage: 15' x 20' (approx.)

Planning for Substiituted HVAC Units



1st Floor RCP With Substituted HVAC (Units Only)
NTS

KEY:



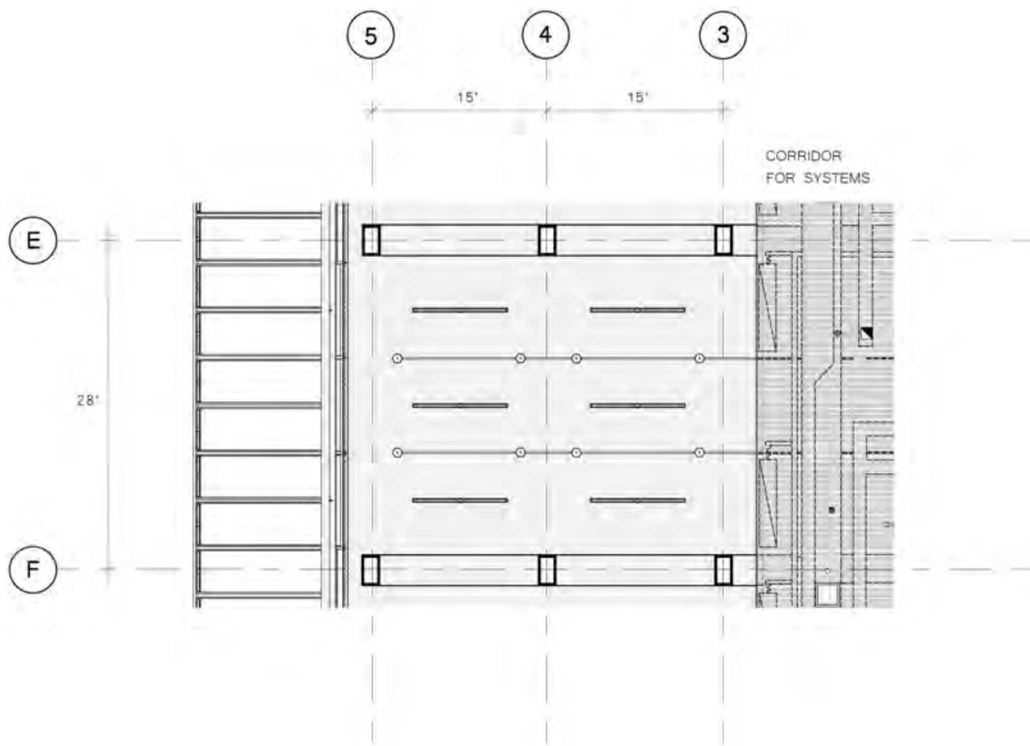
4th Floor RCP With Substituted HVAC (Units Only)
NTS

To meet the design goal of exposing the mass timber ceiling a change in the HVAC distribution units were necessary. The substituted HVAC units utilized in Tykeson Hall are the Price Industries ACBC Chilled Beam Displacement Cabinet unit and ACBR Active Chilled Beam Recessed unit. The ACBC unit is installed into the wall and can be built into the interior's cabinetry. The ACBR is a ceiling mounted unit that can discharge heating and cooling loads both vertically and horizontally into a space, depending on how the system is installed. These systems are built into a soffit wall or drop ceiling. With consultation from Systems West engineers, these systems were chosen for their ability to be installed outside of the ceiling area - which was essential for meeting the design criteria of exposing the mass timber ceiling with minimal interruption of HVAC and MEP systems. With that being said, while the distribution unit was changed the mechanical system of utilizing radiant heating and cooling stayed constant. The substituted units were advantageous to this design as it operates from the same source as the existing units and therefore was chosen for this exploration.

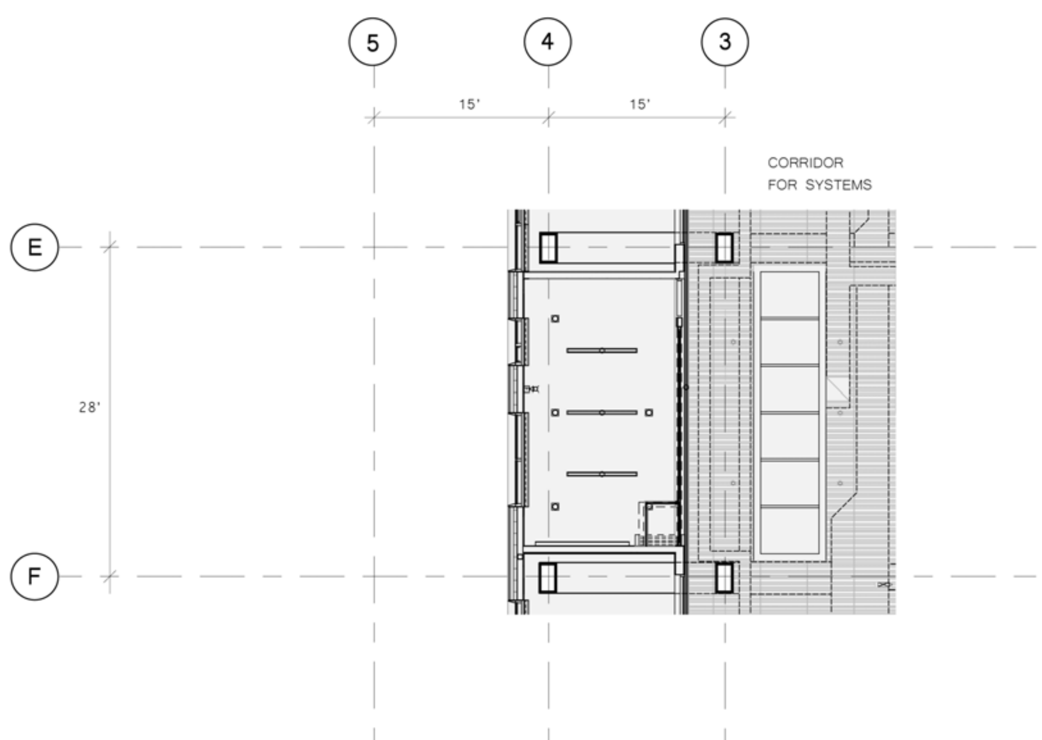
Structural Depth and Mechanical Clearances:

The structural depth of the Glulam beams acted as an obstacle to the conceptually re-routed HVAC units and ducting of the building. In collaboration with Systems West Engineers, a duct clearance of 18" was given under the beams to the designed drop ceiling. In the alternate direction where beams are not present, 32" of depth was given. This allowed for the majority of the buildings systems to be concealed withing the central service corridor which is designed to be concealed with drop ceilings, important to meeting design criteria and goals.

HVAC Systems Integrated:



1st Floor Reflected Ceiling Plan
With Substituted HVAC - Singular Bay
NTS



4th Floor Reflected Ceiling Plan
With Substituted HVAC - Singular Bay
NTS

Acoustic and Vibration Implication when Exposing the CLT Ceiling:

While the goal of exposing the mass timber ceiling was met by making these intentional design moves of substituting the HVAC distribution units and allowing for the ceilings to be free of mechanical units to display the ceiling for aesthetic and biophilic purposes. It is important to address the need for additional sound insulation in these areas due to the absence of acoustic ceiling tiles. In addition to this, vibration between structural members of the building can also create noise, along with the existing airborne and impact borne sound. With the mass timber structure being wood, which expands and contracts naturally, vibration/-structure borne sound, to need to be addressed in a mass timber design. Acoustic barriers such as incorporating acoustic mats, carpet, and/or rigid insulation beneath the concrete floor can aid in the acoustic performance of the mass timber building.

HVAC Systems Integrated:

FIGURE 138 | Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

PRICE –
ACBR Active Chilled Beam Recessed

FIGURE 139 | Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

FIGURE 140 | Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

PRICE –
ACBC Active Chilled Beam Displacement Cabinet

FIGURE 141 | Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

FINAL RENDERED PERSPECTIVES:

FIGURE 142 | Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

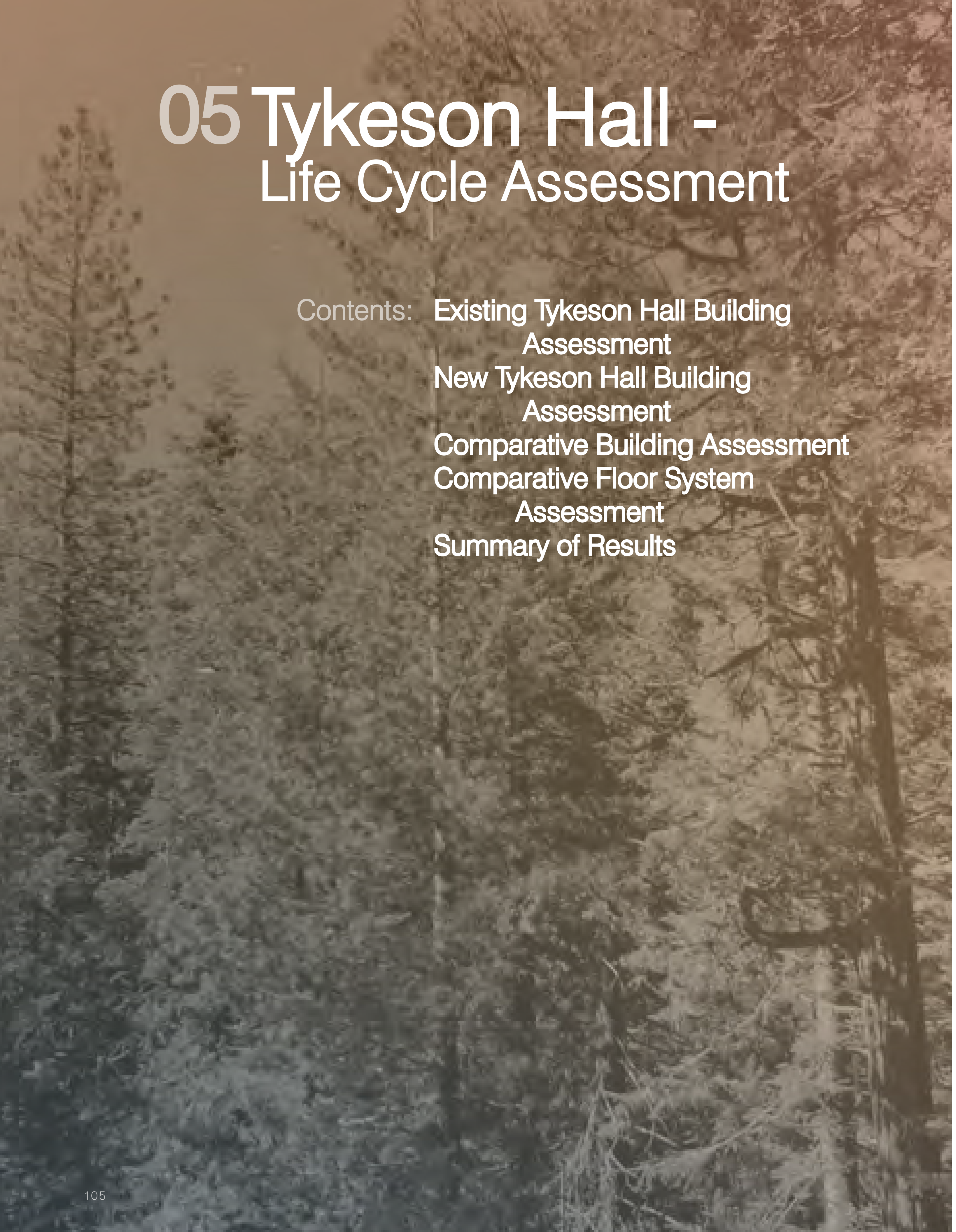
FIGURE 143 | Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

FIGURE 144 I Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

FIGURE 145 I Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

FIGURE 146 I Interior View of Tykeson Hall in Mass Timber
(Aaryn Gray, 2022)

FIGURE 147 I Section Perspective of Tykeson Hall
(Aaryn Gray, 2022)



05 Tykeson Hall - Life Cycle Assessment

Contents:

Existing Tykeson Hall Building Assessment
New Tykeson Hall Building Assessment
Comparative Building Assessment
Comparative Floor System Assessment
Summary of Results

Overview:

Life Cycle Assesment (LCA) is a tool to quantify a building's or building assemblies enviormential impact. In this study, the Revit plug-in Tally was emplyed to asses the enviormental impacts of the existing post-tensioned concrete building of Tykeson Hall and compared with the proposed mass timber design. Through this asement of the existing and new building models, we can begin to understand the enviormental implications of building materials in comparion to one another. In this chaperter I review the results of these assesments.

EXISTING TYKESON HALL BUILDING ASSESSMENT

Description:

The existing structural design of Tykeson Hall utilizes a 12" post-tensioned (P/T) Slab and 24" reinforced concrete columns. There are no beams in this structure, other than at the 4th floor. The existing structural design of Tykeson Hall on floor four changes to a steel design utilizing HSS Tube Steel columns, I-joist beams, and a con-ventional metal deck. The foundation of the existing building utilizes a 2'6" Mat Slab. The exterior enclosure of the structure utilized both brick and terra cotta siding elements with window and curtain wall glazing.

In this study the existing building will be refereed to as Building A.

Report Summary

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Goal and Scope of Assessment
Asses Existing Building

tally

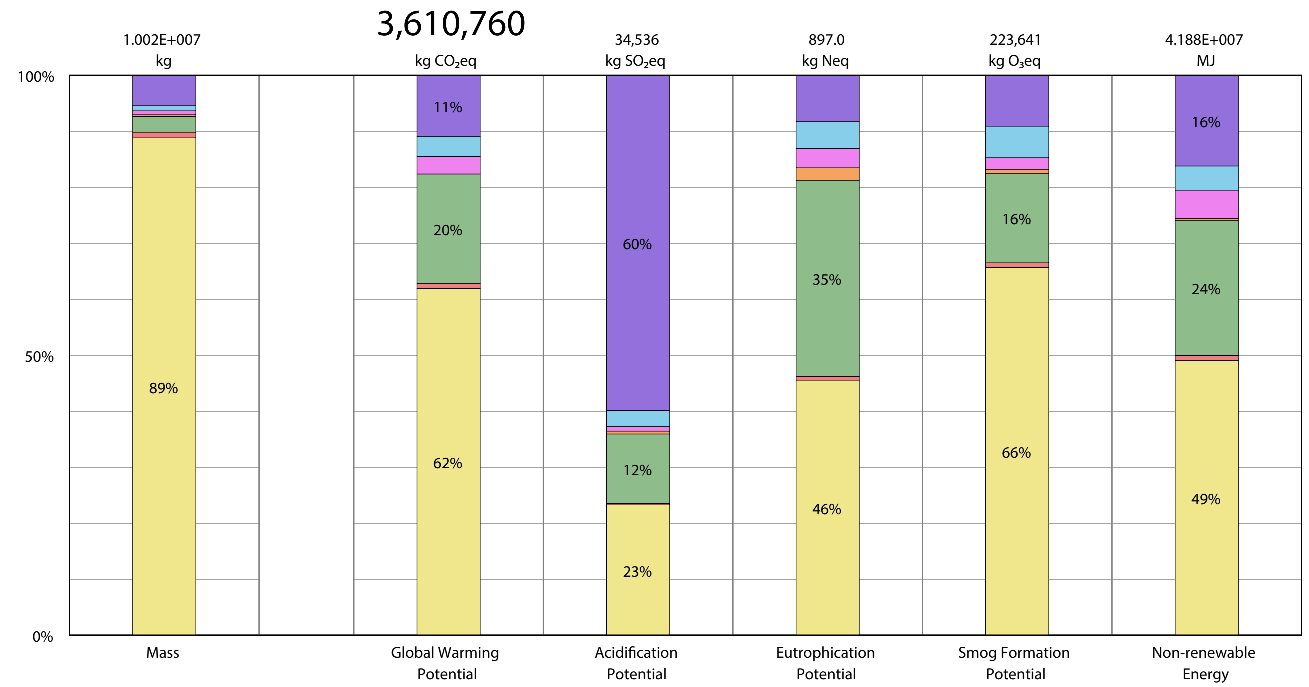
Author	aaryngGW5G3
Company	Uoregon
Date	5/20/2022
Project	TYKESON HALL
Location	1030 E. 13th AVE - EUGENE OREGON
Gross Area	62600 ft^2
Building Life	60 years
Boundaries	Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO_2eq)	3,322,133	40,822	432,016	386,199	-577,772
Acidification (kg SO_2eq)	18,596	189.2	16,995	947.5	-2,192
Eutrophication (kg Neq)	685.9	15.40	197.6	62.88	-64.8
Smog Formation (kg O_3eq)	194,090	6,250	28,677	17,810	-23,186
Ozone Depletion (kg CFC-11eq)	0.009043	1.398E-009	0.00466	3.527E-008	0.00202
Primary Energy (MJ)	4.061E+007	593,631	7,801,571	3,280,610	-6,396,003
Non-renewable Energy (MJ)	3.711E+007	579,426	7,084,134	3,067,634	-5,956,050
Renewable Energy (MJ)	3,520,338	14,355	720,189	216,617	-445,228

Environmental Impacts / Area	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO_2eq/m^2)	571.2	7.019	74.28	66.41	-99
Acidification (kg SO_2eq/m^2)	3.197	0.03252	2.922	0.1629	-0.3769
Eutrophication (kg Neq/m^2)	0.1179	0.002648	0.03398	0.01081	-0.01114
Smog Formation (kg O_3eq/m^2)	33.37	1.075	4.931	3.062	-3.99
Ozone Depletion (kg CFC-11eq/m^2)	1.555E-006	2.404E-013	8.013E-007	6.064E-012	3.474E-007
Primary Energy (MJ/m^2)	6,984	102.1	1,341	564.1	-1,100
Non-renewable Energy (MJ/m^2)	6,380	99.63	1,218	527.5	-1,024
Renewable Energy (MJ/m^2)	605.3	2.468	123.8	37.25	-76.6

Building A - LCA Results:

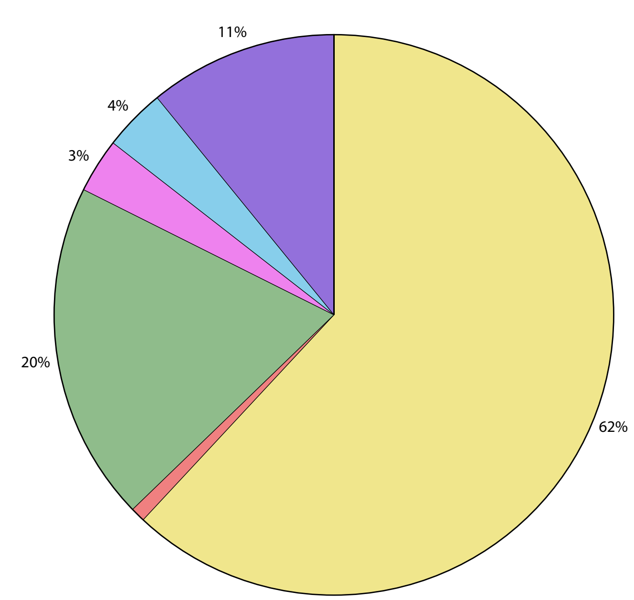
Results per Division



Legend

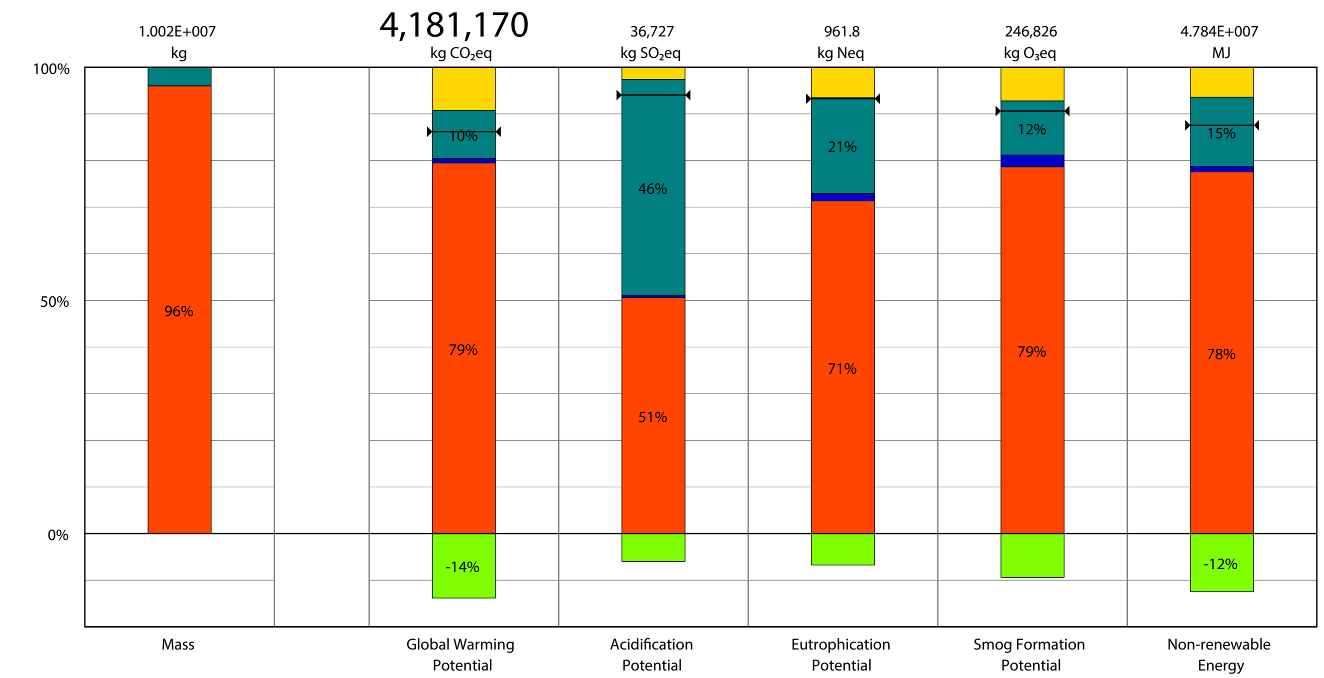
Divisions

- 03 - Concrete
- 04 - Masonry
- 05 - Metals
- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes



Global Warming Potential

Results per Life Cycle Stage

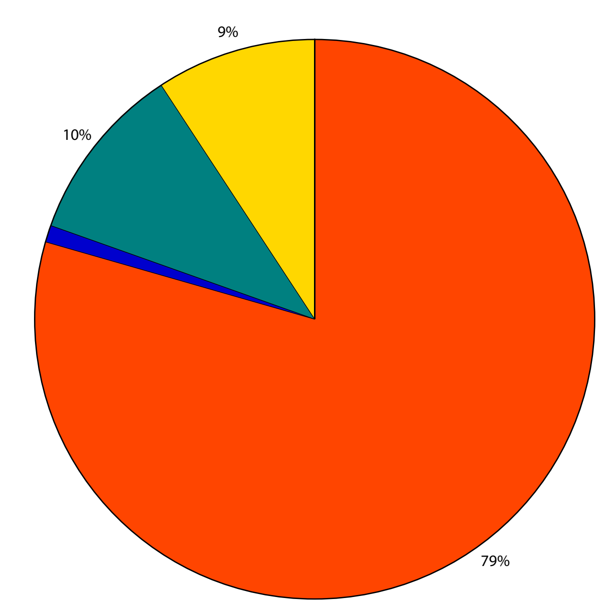


Legend

Net value (impacts + credits)

Life Cycle Stages

- Product [A1-A3]
- Transportation [A4]
- Maintenance and Replacement [B2-B5]
- End of Life [C2-C4]
- Module D [D]



Global Warming Potential

NEW TYKESON HALL BUILDING ASSESSMENT

Description:

The mass timber iteration of Tykeson Hall utilizes a 14x24 column and 14x26 beam glulam structure with 5-Ply CLT floors in composite with 4" of reinforced concrete. Radiant heating and colling coils are embedded in the slab. All columns follow the column grid to the roof. With the buildings loads being considerably reduced, the foundation of the mass timber structural design was reduced by 50% of its volume. The exterior enclosure of the structure utilized both brick and terra cotta siding elements with window and curtain wall glazing (unchanged from existing).

In this study the mass timber building will be refereed to as Building B.

Report Summary

Created with Tally
Non-commercial Version 2022.04.08.01

Author	aaryngGW5G3
Company	uoregon
Date	5/20/2022
Project	TYKESON HALL
Location	1030 E. 13th AVE - EUGENE OREGON
Gross Area	62600 ft²
Building Life	60 years
Boundaries	Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

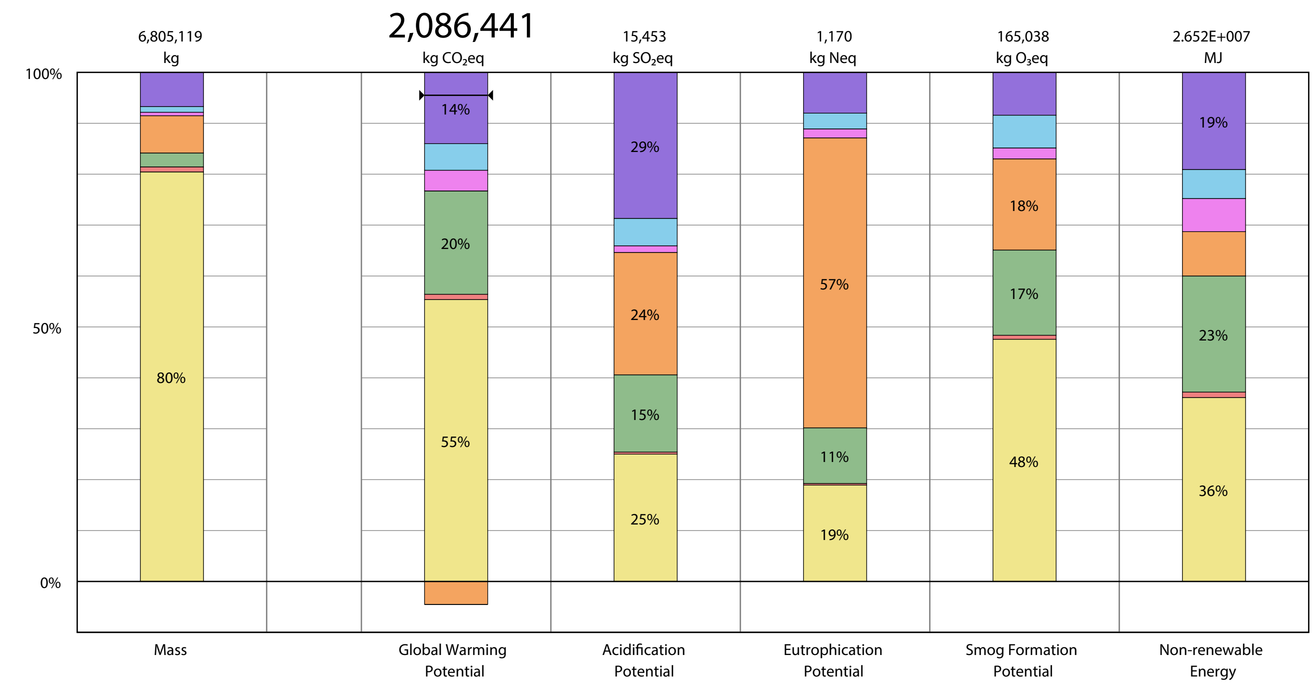
Goal and Scope of Assessment
Asses new building.

tally®

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO_2eq)	1,323,503	37,176	283,461	792,127	-443,704
Acidification (kg SO_2eq)	11,328	172.3	4,065	2,706	-2,818
Eutrophication (kg Neq)	496.6	14.03	134.8	588.3	-63.3
Smog Formation (kg O_3eq)	147,493	5,692	18,276	18,414	-24,837
Ozone Depletion (kg CFC-11eq)	0.0354	1.273E-009	0.003834	3.088E-008	9.113E-004
Primary Energy (MJ)	3.386E+007	540,619	5,512,279	2,392,561	-8,686,794
Non-renewable Energy (MJ)	2.477E+007	527,682	5,017,801	2,238,785	-6,033,069
Renewable Energy (MJ)	9,060,075	13,073	496,390	156,013	-2,661,149
Environmental Impacts / Area					
Global Warming (kg CO_2eq/m²)	227.6	6.392	48.74	136.2	-76.3
Acidification (kg SO_2eq/m²)	1.948	0.02962	0.699	0.4653	-0.4846
Eutrophication (kg Neq/m²)	0.08538	0.002412	0.02317	0.1012	-0.01088
Smog Formation (kg O_3eq/m²)	25.36	0.9788	3.142	3.166	-4.27
Ozone Depletion (kg CFC-11eq/m²)	6.088E-006	2.189E-013	6.593E-007	5.311E-012	1.567E-007
Primary Energy (MJ/m²)	5,822	92.96	947.8	411.4	-1,494
Non-renewable Energy (MJ/m²)	4,259	90.73	862.8	385.0	-1,037
Renewable Energy (MJ/m²)	1,558	2.248	85.35	26.83	-458

Building B - LCA Results:

Results per Division

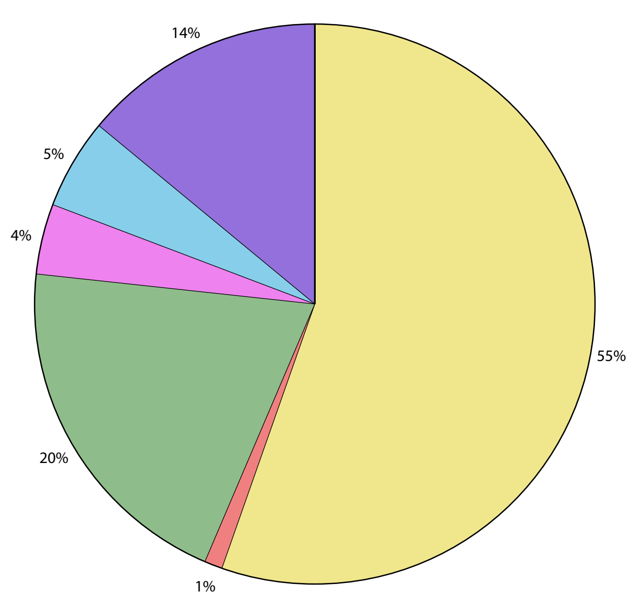


Legend

Net value (impacts + credits)

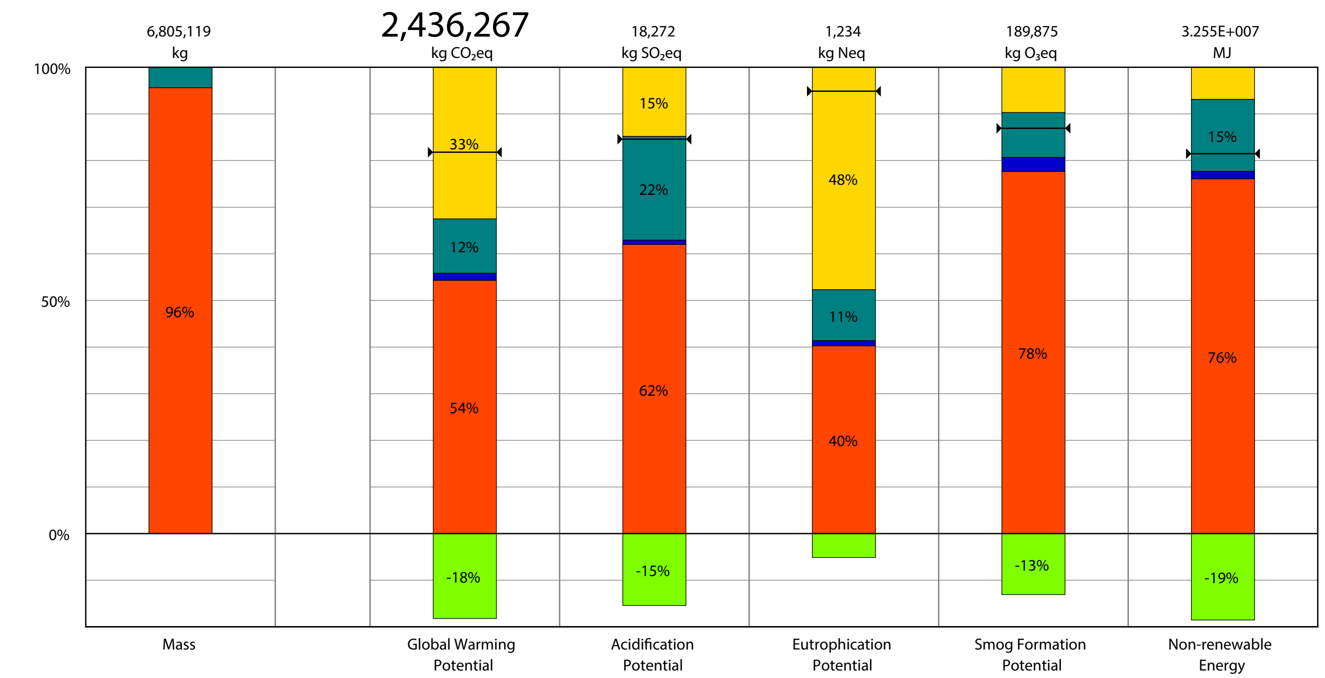
Divisions

- 03 - Concrete
- 04 - Masonry
- 05 - Metals
- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes



Global Warming Potential

Results per Life Cycle Stage

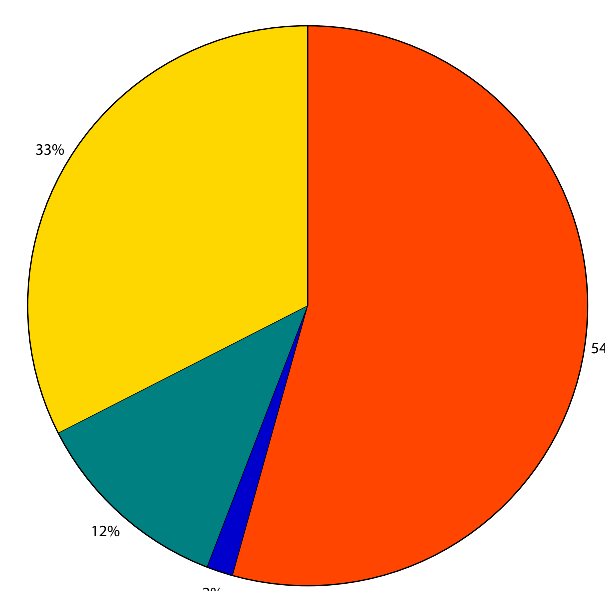


Legend

Net value (impacts + credits)

Life Cycle Stages

- Product [A1-A3]
- Transportation [A4]
- Maintenance and Replacement [B2-B5]
- End of Life [C2-C4]
- Module D [D]



Global Warming Potential

Description:

In this section I compare the results of Building Study A to Building study B. The results show a lower GWP for the mass timber building (B) through all life cycle stages.

Legend

Divisions

- 03 - Concrete
- 04 - Masonry
- 05 - Metals
- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes

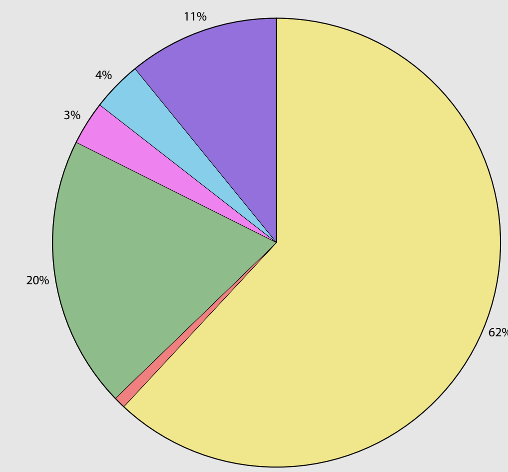
Life Cycle Stages

- Product [A1-A3]
- Transportation [A4]
- Maintenance and Replacement [B2-B5]
- End of Life [C2-C4]
- Module D [D]

Building A:

Results per Division

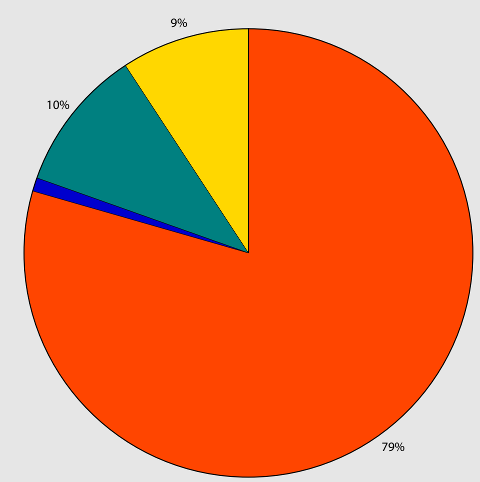
3,610,760
kg CO_2eq



Global Warming Potential

Results per Life Cycle Stage

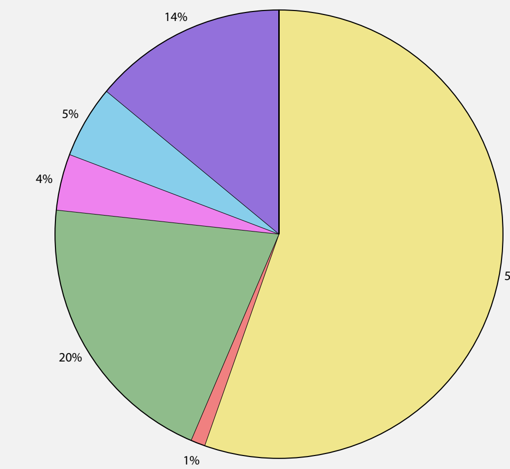
4,181,170
kg CO_2eq



Global Warming Potential

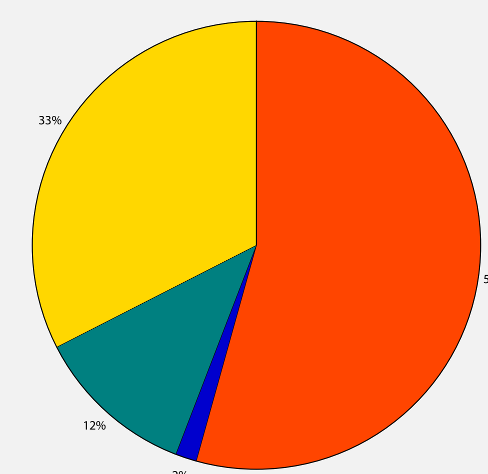
Building B:

2,086,441
kg CO_2eq



Global Warming Potential

2,436,267
kg CO_2eq

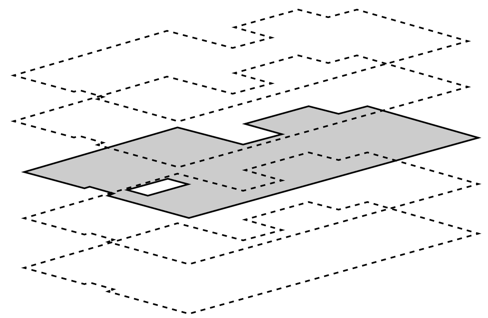


Global Warming Potential

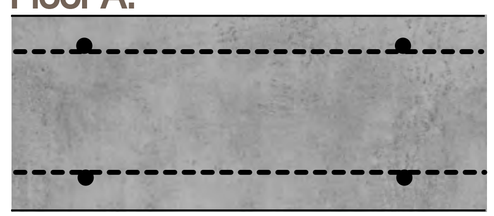
COMPARATIVE FLOOR SYSTEM ASSESSMENT

Description:

In this comparative LCA, Assembly A and Assembly B are compared for their differing environmental impacts. For this analysis one full floor system was run for analysis.



Floor A:



Floor B:

Legend

Net value (impacts + credits)

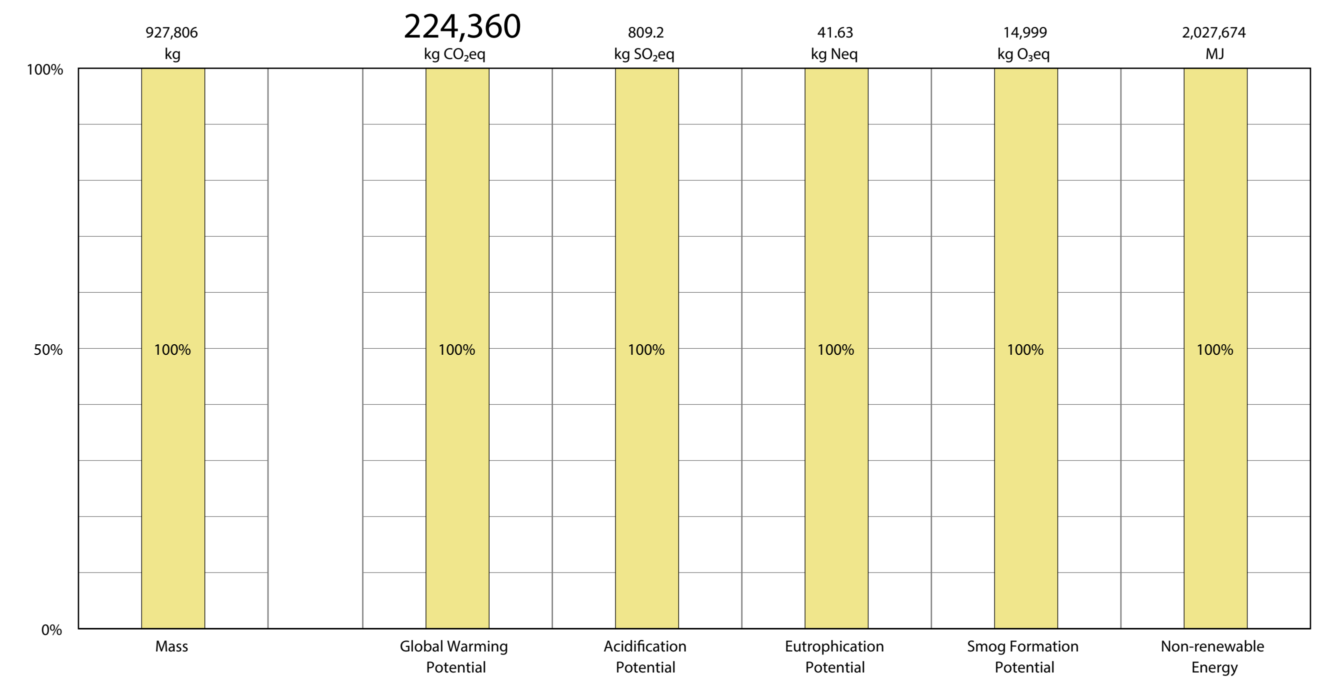
Divisions

03 - Concrete

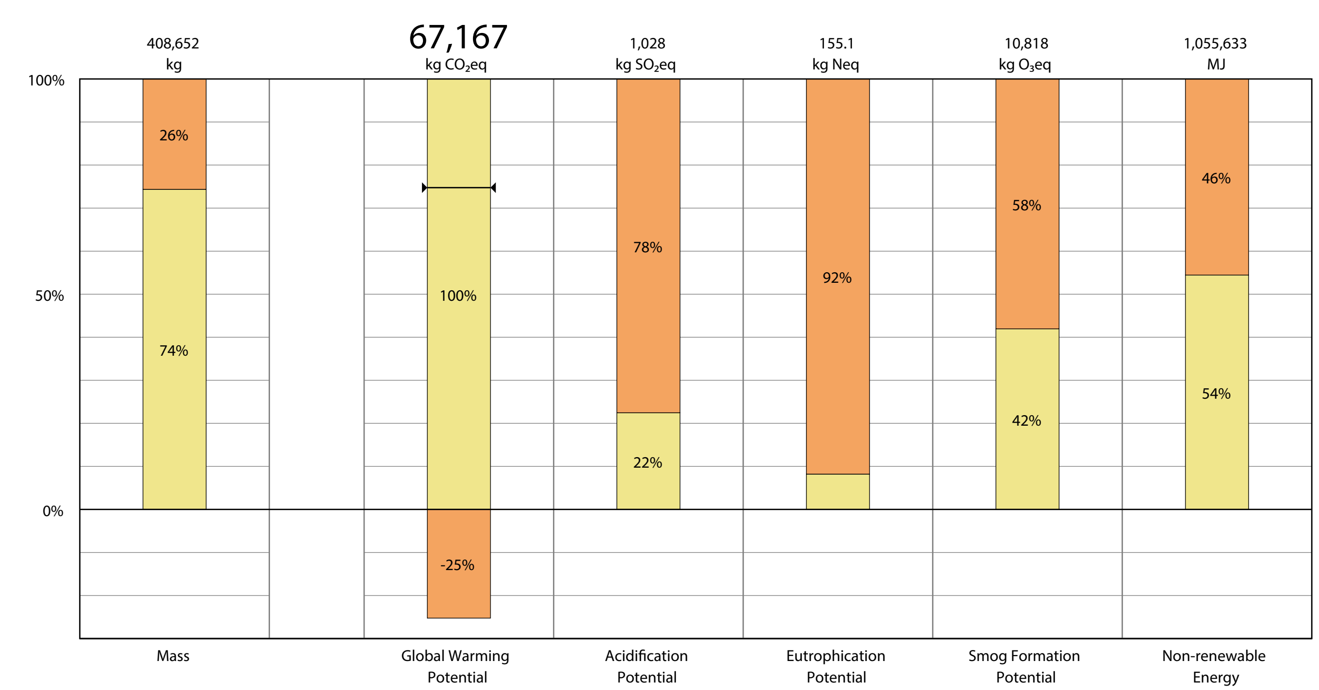
06 - Wood (CLT)

Results per Division

Floor A:



Floor B:



SUMMARY OF RESULTS

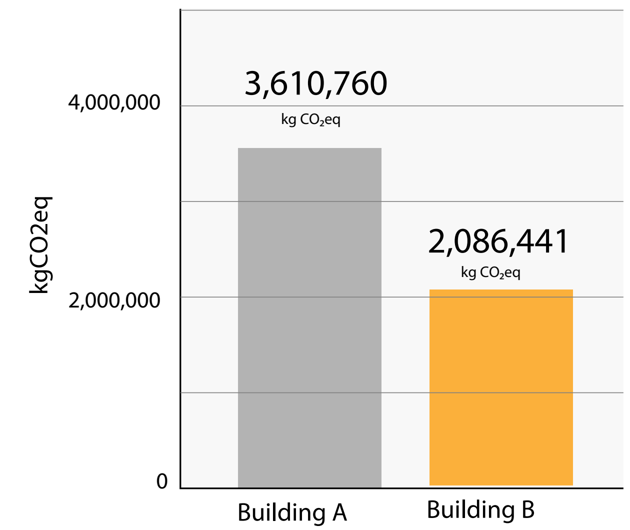
Global Warming Potential for Whole Builidng and Assembly

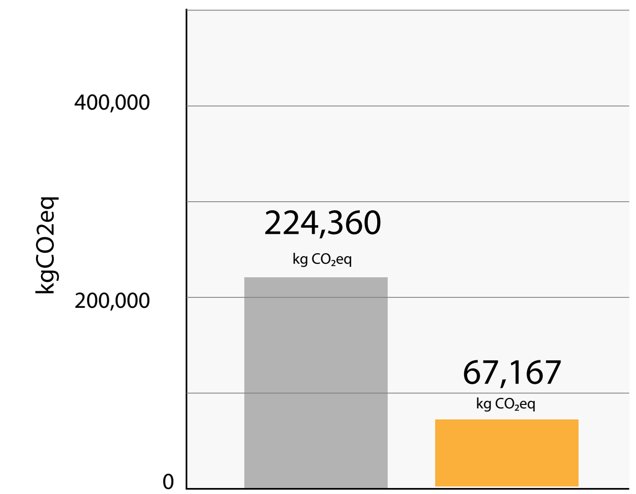
The results of the Life Cycle Analysis show a 1/3 reduction in GWP for both the building and assemblies between the existing strucutre and the conceptual mass timber one. This analysis is shown for both the material divisions and life cycle stages.

Legend:

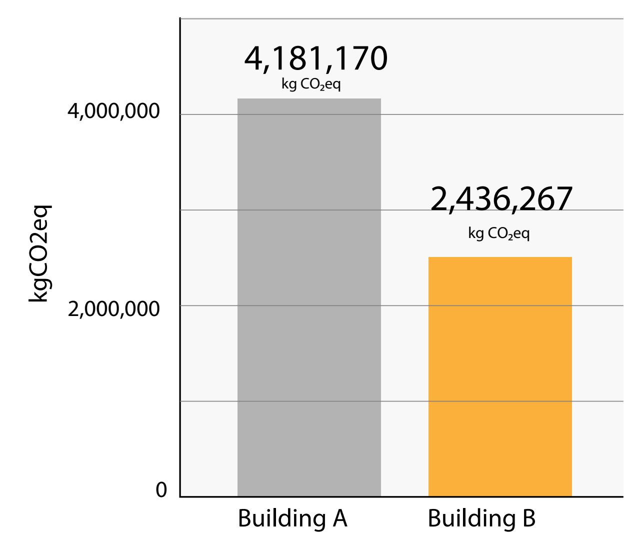
- Building A: Existing Tykeson Hall
- Building B: Mass Timber Tykeson Hall

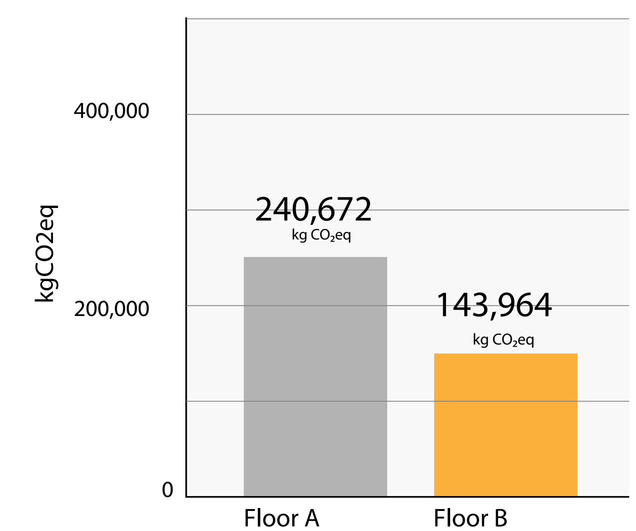
Results per Division

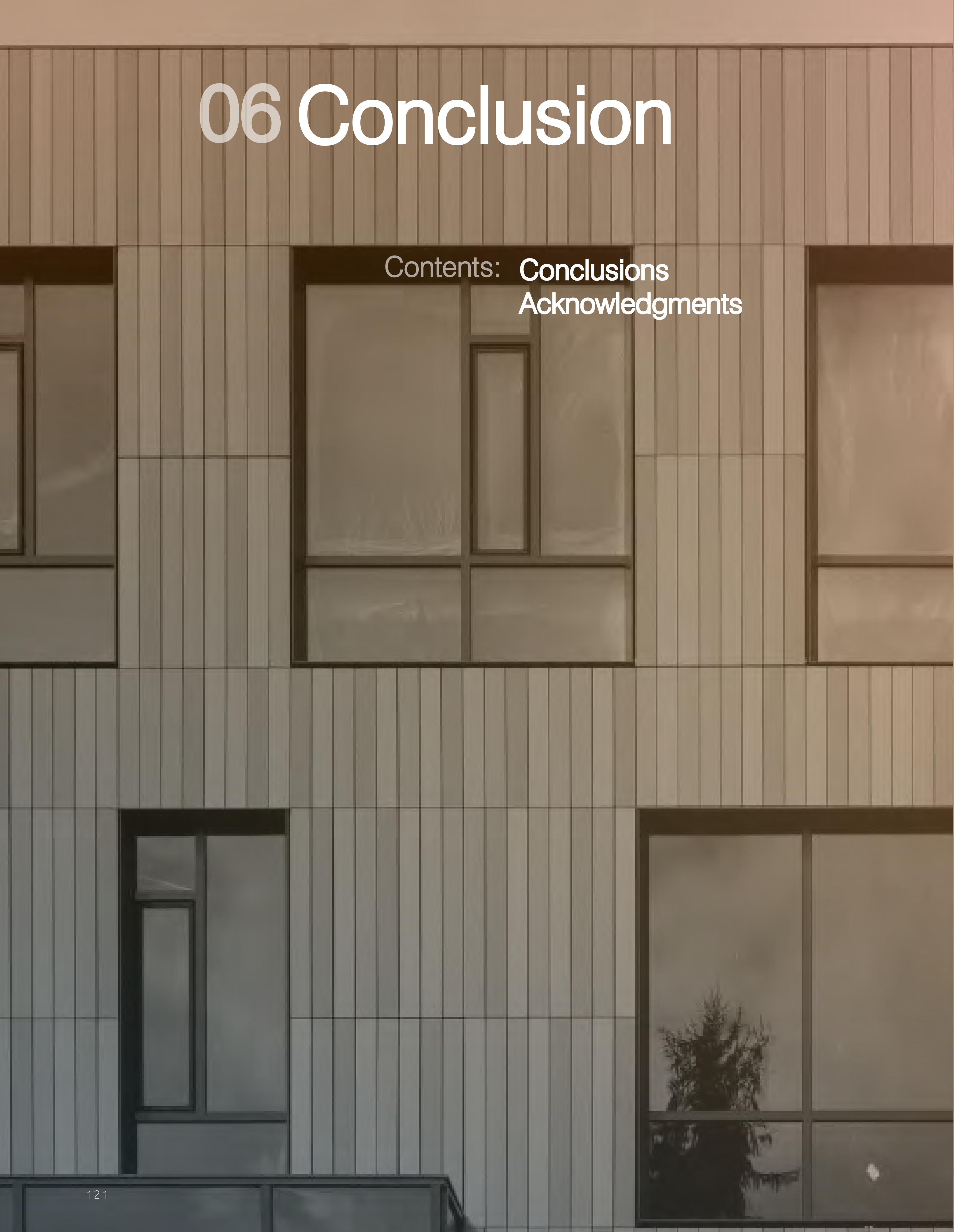




Results per Life Cycle Stage







06 Conclusion

Contents: Conclusions
Acknowledgments

Case Study Conclusion:

The goal of the case studies was to analyze existing mass timber buildings for their structural and system integration designs to understand how the mass timber structure can inform or inhibit efficient system integration. By analyzing both all wood structural systems and wood gravity structural systems I was able to catalog many of the ways previous projects approached efficient system integration - and how the structure can be optimized to inform a buildings integrated system approach. Through this research I applied some of the lessons learned to the design process of substituting the post tensioned concrete structure of Tykeson Hall into a mass timber one. The case studies show the starting point of this terminal project and were instrumental for reference and precedent for Tykeson Hall and could be useful for any other mass timber projects in the future.

Advantages and Implications Observed from Case Studies

Application to Structure	Advantages for Integration	(+/-) Implications to Whole
CLT Spacing / Chases →	Ability to run and conceal services within. →	Dependent on floor construction type. Will need additional framing.
Timber T-Rib Composite Floor Panels →	Ability to run MEP/HVAC between ribs. →	(+) Composite Action (-) Dependent on panel sizing and structural grid.
Timber-concrete Composite Floor Systems →	Ability to run radiant system within slab. →	(+) Composite Action (-) Dependent on project timeline (wet vs. dry construction)
Uni-Directional Beam Orientation →	Ability to run systems without interruption of beams. →	Will likely need additional reinforcment (composite in floors, etc.)
Flat Use Beams →	Ability to minimize structural depth. →	Dependent on span. Will need more dimention than if upright.
Point Supported CLT →	Ability to run systems freely (no beams). →	Dependent on span/ floor to floor height.

Tykeson Hall Conclusion:

The goal of substituting Tykeson Hall, an existing concrete and steel structure, into a mass timber building was to study firsthand through a real-life project the advantages and implications of employing mass timber in an educational building. Through this terminal project I explored ways to optimize the mass timber structure while still following the existing parameters including the buildings existing layout and complex programmatic spaces, university standards etc. while still meeting the design criteria I set from the beginning of this project. Through this substitution design iterations were performed for the mass timber structure and building systems to fit these parameters, including employing a composite CLT floor system, adjusting the column grid of the structure, employing flat beams, reducing foundations, and redesigning for new HVAC systems. Through this conversion the advantages and implications were made clear, and the final mass timber design showcased a structure and design that informs better and more efficient system integration for mass timber buildings.

Advantages and Implications Learned from Tykeson Hall's Mass Timber Design

Application to Structure		(+) Advantages for Integration		(+/-) Implications to Whole
Timber-Concrete Composite Floor Systems	→	(+)Ability to run radiant heating and cooling system within slab.	→	(+) Composite Action (-) Wet Construction (-) Higher Carbon Footprint (-) Will Need Acoustic Intervention when exposing mass timber ceiling
Timber-Concrete Composite Beams	→	N/A	→	(+) Composite Action (-) Wet Construction (-) Higher Carbon Footprint
Flat Use Beams	→	(+) Ability to minimize structural depth Allowng for more system clearances	→	(+) Shorter Structural Depths (-) needed more dimention than if placed upright.
Uni-Directional Beam Orientation	→	(+) Ability to run systems without interruption of beams in one direction	→	(+) Ease of system planning (-) Will likely need additional reinforcment (composite in floors, etc.)
Exposing Mass Timber Structure in Ceiling	→	(+) Minimal exposed mechanical and ducting when planned to be concealed	→	(+) Aesthetic and biophillic effects (-) Need for additional acoustic and vibration insulation

Life Cycle Assessment Conclusion:

The goal of running Life Cycle Analysis (LCA) through Tally was to show the environmental impact or Global Warming Potential (GWP) that different materials have on our planet. By running LCA for the existing concrete and steel building and comparing it with the proposed mass timer one, the results show utilizing mass timber is more sustainable, reducing GWP by 1/3! This showcases that mass timber is a viable option to be employed not only for its innovation in design and its aesthetic and biophilic propertied, but also for its ability to lower CO2 emissions in our atmosphere. Mass timber is beneficial for the future of building sustainably, and this LCA showcased that.

Future Research:

While this project followed the advantages and implications for structural and mechanical system efficiency, future topics that could be covered in a project such as this are:

- The **acoustic and vibration implications** of substituting mass timber for post tensioned concrete in the design of a multi-story educational building.
- The **construction timeline** when substituting mass timber for post tensioned concrete in the design of a multi-story educational building.
- The **cost** of substituting mass timber for post tensioned concrete in the design of a multi-story educational building.

FIGURE 148 | Master of Science Class of 2022 with Advisor Judith Sheine in District Office
(Simone Ohalloran, 2022)

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