WORLD CONFERENCE ON TIMBER ENGINEERING 2025
BRISBANE, AUSTRALIA

Advancing Timber for the Future Built Environment

FOREST TO FAÇADE: USING MASS TIMBER PANELS TO RETROFIT LOW-RISE COMMERCIAL BUILDINGS TO IMPROVE RESILIENCE

Mark Fretz[1], Gustavo Fernando Orozco Orozco[2], Andrew Loia[3], Ethan Bloom[4], Jason Stenson[5], Dale Northcutt[6], William Silva[7], Jon Smith[8], Edward Running[9], Alen Mahić[10], Siobhan Rockcastle[11], Judith Sheine[12], Andre R. Barbosa[13]

ABSTRACT: Buildings are significant contributors to anthropogenic emissions of greenhouse gases through their construction and operations. Commercial low-rise office buildings represent a substantial subset of buildings in the United States and the majority were constructed before more stringent energy and seismic codes were adopted on the U.S. West Coast. Thus, the University of Oregon Department of Architecture and Oregon State University College of Engineering collaborated with industry partners Swinerton, Timberlab, and FFA Architecture and Interiors through the TallWood Design Institute to develop a low-carbon bio-based façade retrofit solution that simultaneously upgrades building resilience (i.e., energy efficiency, daylighting, passive ventilation), building aesthetics, and seismic restraint. The system was developed using a four-story steel frame case study building and employs a post-tensioned "rocking wall" mass timber lateral force resisting system (LFRS) on the building façade.

KEYWORDS: Seismic Resilience, Energy Upgrades, Retrofits, Mass Timber

1 – INTRODUCTION

In the United States (U.S.), buildings contribute about 35% of carbon dioxide equivalent emissions to the atmosphere each year [1], thus are significant contributors to anthropogenic climate change. Of the 5.9 million U.S. commercial buildings, office buildings represent approximately 16% of this subset [2]. Office buildings built between 1960 and 1999 accounted for more than 50% of the building stock, while those built before 1960 accounted for 21% with the median year of construction in 1982 – all long before the urgency of responding to climate change challenges was reflected in building energy codes that target net zero energy use, and before more stringent

[1] Mark Fretz, Department of Architecture, University of Oregon, Portland, OR, U.S., mfretz@uoregon.edu

[2] Gustavo Fernando Orozco Orozco, Senior Project Engineer, Thornton Tomasetti, Washington, DC., U.S., GOrozco@thorntontomasetti.com

[3] Andrew Loia, FFA Architecture & Interiors, Portland, OR, U.S., aloia@ffadesign.com

[4] Ethan Bloom, FFA Architecture & Interiors, Portland, OR, U.S., ebloom@ffadesign.com

[5] Jason Stenson, College of Design, University of Oregon, Portland, OR, U.S., jstenson@uoregon.edu

[6] Dale Northcutt, College of Design, University of Oregon, Eugene, OR, U.S., tdnorth@uoregon.edu

[7] William Silva, Swinerton, Portland, OR, U.S., WSilva@swinerton.com

[8] Jon Smith, Swinerton, Portland, OR, U.S., jon.smith@swinerton.com

[9] Edward Running, FFA Architecture & Interiors, Portland, OR, U.S., erunning@ffadesign.com

[10] Alen Mahić, College of Design, University of Oregon, Eugene, OR, U.S., alen@uoregon.edu

[11] Siobhan Rockcastle, Department of Architecture, University of Oregon, Eugene, OR, U.S., srockcas@uoregon.edu

[12] Judith Sheine, Department of Architecture, University of Oregon, Eugene, OR, U.S., jesheine@uoregon.edu

[13] Andre R. Barbosa, School of Civil & Construction Engineering, Oregon State University, Corvallis, OR, U.S., andre.barbosa@oregonstate.edu

https://doi.org/10.52202/080513-0295

seismic code requirements were adopted in the Pacific Northwest [2,3].

One of the best ways to reduce carbon associated with the built environment is to maintain existing buildings by improving their aesthetics, operational energy efficiency, and resilience. Many existing buildings have already made the easy energy efficiency upgrades, such as electric lighting or MEP improvements, but improved building facade performance is critical to meeting a host of whole building targets aimed at significant reductions in overall energy use. In 1928, the Milam building in San Antonio was the first multi-story building to employ mechanical climate control in the United States and by 1948, the Equitable building in Portland, Oregon captured the twentieth-century zeitgeist of indoor mechanical climate control by displaying a hermetically sealed glass façade. This trend continued unabated through the twentieth century and most existing office buildings constructed during this period do not have operable windows intended for passive ventilation and thermal control [4]. Moreover, glazing in the predominant vintage of existing commercial office buildings (median year of construction in the U.S. is 1982) often employed metallic or colored tints intended to reduce solar gain, glare, and increase comfort. Today, architects designing office spaces are interested in specifying clear glazing to support circadian health for improved worker wellbeing and productivity, using opaque façade elements to reduce solar gain, and using daylight and operable windows to reduce energy use, connect occupants to nature, and create resilient buildings during periods of power disruptions, pandemics, or seismic events.

In the Pacific Northwest, the recognition of the potential impact of the Cascadia Subduction Zone has further created an incentive to upgrade existing buildings for seismic resilience, as the building code has evolved since the 1970s to correspond to improved understanding of seismic risks and increased base shear forces [5]. Unfortunately, many existing buildings constructed before the most recent updates in the 1990s do not meet current seismic code requirements [6]. Thus, some owners of buildings in the Pacific Northwest are making voluntary seismic upgrades to protect occupants and business assets after a seismic event. These seismic retrofits can be invasive, disruptive, and costly, and carry a substantial environmental impact. Steel and concrete feature prominently in most commercial seismic upgrades and reinforcement measures are typically applied on a building's interior. Since seismic preparedness is needed across the region for most older buildings, and not just those constructed of unreinforced masonry, developing a low-carbon bio-based façade retrofit solution that simultaneously reduces existing building operational carbon emissions while adapting them to be more resilient to future climate and catastrophic natural events can have multiple synergistic benefits.

2 – PROJECT DESCRIPTION

The University of Oregon Department of Architecture collaborated with Oregon State University College of Engineering and industry partners: Swinerton (expertise in seismic retrofit and mass timber construction), Timberlab (expertise in mass timber fabrication), and FFA

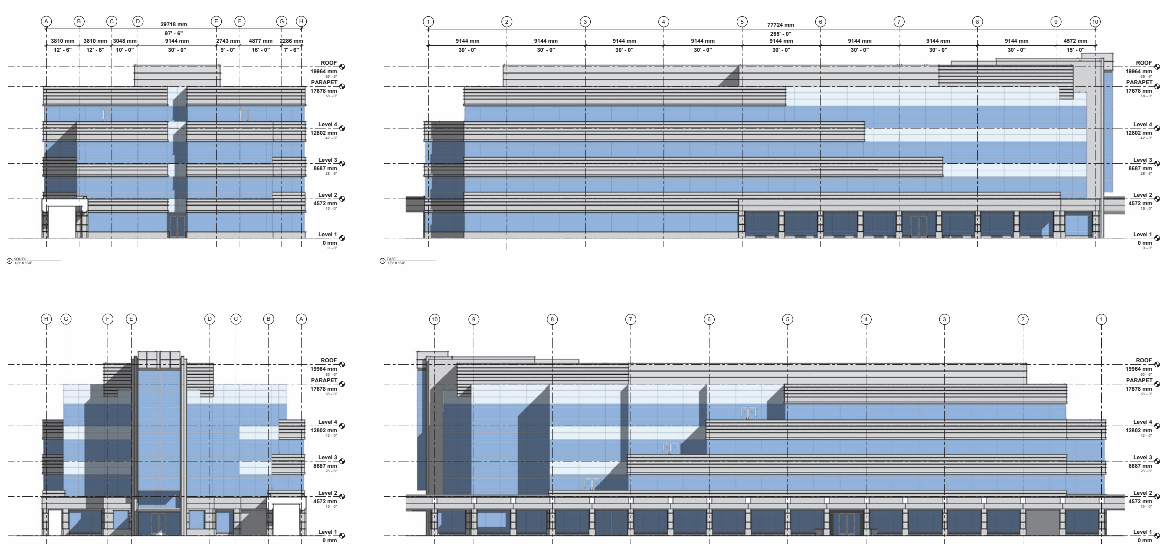

Figure 1. Existing case study building.

https://doi.org/10.52202/080513-0295

Architecture and Interiors through the TallWood Design Institute to develop a low-rise commercial facade retrofit solution to upgrade existing building seismic resistance and energy efficiency, and resilience, which includes having redundant systems (e.g., daylighting, passive ventilation) to expand the potential for continued occupancy and operation during an unplanned disruption (e.g., seismic event, power grid failure, extreme weather, pandemic). The mass timber panel (MTP) façade solution is a post-tensioned "rocking wall" lateral force resisting system (LFRS) that integrates improved building performance through enhanced thermal resistance, daylighting and passive ventilation.

The research team identified a four-story, 8041 m^2 (86, 553 ft^2) steel framed office building constructed in 1988 in the Pacific Northwest that recently completed a seismic retrofit using buckling-restrained braces (BRB). The project team obtained access to original construction documents and recent seismic retrofit documents, including cost data for the steel seismic upgrade. Therefore, this project uses the existing office building (Fig. 1) as a case study to design a conceptual MTP system for a similar seismic performance in which the façade is used for seismic restraint, simultaneously upgrading aesthetics, energy performance and resilience. The case study develops conceptual MTP façade enclosure and structural connection details, analyzes their thermal and moisture performance, and compares the MTP façade retrofit with a steel BRB retrofit baseline (Fig. 2) for first cost.

3 – DESIGN PROCESS

The existing case study building has a four-story steel frame with rectilinear shape and regular structural grid employing precast concrete wall panels and ribbon windows with a head height of 2553 mm (100.5"), a linear core with perimeter open offices and acoustic tile suspended ceiling with an elevation of 3048 mm (120") above finish floor. Unique aspects of the design include a glazed atrium at one end, exterior outdoor terraced spaces on two sides of the building that step back on each floor, and loggias partially extending along two sides.

Structural design considerations

To use the façade as a LFRS, we determined early in the design process that vertical mass timber panels spanning four floors would be required to transfer floor diaphragm loads to an upgraded foundation. Thus, the design team initially placed vertical MTP elements centered at all gridlines around the perimeter and extended panels to the parapet height, where possible to maintain a similar

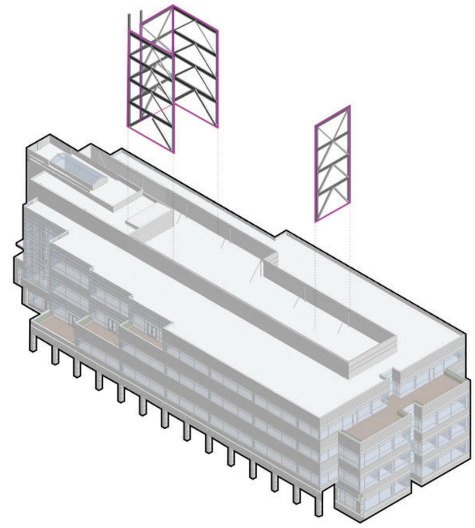

Figure 2: Existing building with BRB baseline retrofit.

building form. We decided to use veneer-based Mass Ply panels, developed by Freres Engineered Wood in Lyons, Oregon, due to its maximum available size, which spans 3607 mm (11 ft.-10 in.) wide by 14630 mm (48 ft.) long in thicknesses ranging from 51 mm (2 in.) to 305 mm (12 in.) in 25 mm (1 in.) increments. At each gridline location, a 3607 mm (11 ft.-10 in.) wide panel 178 mm (7 in.) thick was used and proportions of openings created using thinner and non-structural 76 mm (3 in.) infill MPP panels. Due to the stepping back of the façade to create outdoor terrace areas on two sides of the building, it was not possible to have continuous panels from foundation to parapet at each gridline location. The retrofit mechanism, therefore, consisted in a coupled system with exterior retrofit with continuous panels, and internal retrofit with platform MTP (Fig. 3). Non-continuous panels at gridlines were not included in the LFRS; however, these were maintained at similar proportions to the LFRS panels as part of a cohesive façade expression. The exterior retrofit walls consisted of rocking walls with U-shaped plates for energy dissipation at the first floor (Fig. 3), and four 44 mm (1.75 in.) diameter post-tensioned steel rods, a pair on each side of the panels, that extend from the foundation to 1219 mm (48 in.) above the fourth-floor slab. This system allows panels to rock during a seismic event, with a target drift ratio set at 2.4% for the Maximum Considered Earthquake (MCE_r), ensuring deformation compatibility

https://doi.org/10.52202/080513-0295

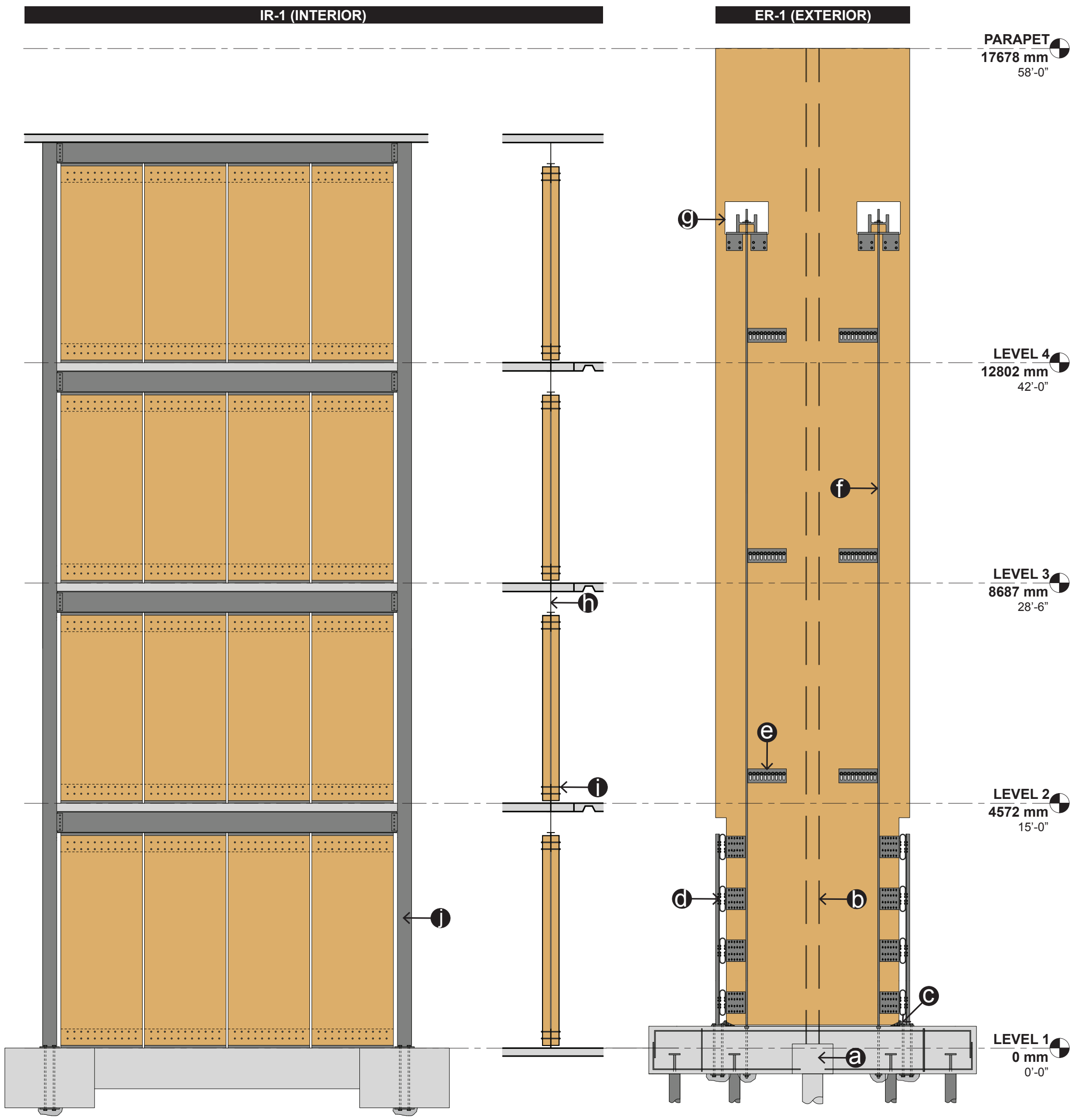

Figure 3. Lateral force-resisting system façade (ER) and core (IR) rocking wall panels. a. existing pile cap, b. existing steel column, c. MTP shoe, d. u-shaped flexural plates e. slotted slab connection, f. post-tensioned steel rod, g. post-tensioning MTP port, h. existing steel beam, i. through-bolted connection, j. existing steel columns

with the gravity systems. Additional structural engineering design details can be found in [7].

Architectural Design Considerations

The LFRS integrated into the façade requires panels that span four floors, significantly altering the existing horizontal architectural expression to vertical in the new concept. Existing ribbon windows, ubiquitous in this vintage of office building construction, are interrupted by vertical structural elements, requiring a different approach to fenestration. We elected to remove the existing suspended acoustical ceilings, painting the mechanical system and under slab white, which permitted higher window head heights of 3429 mm (135 in.), which, when coupled with light shelves and clearer glazing with higher visible light transmission of 70%, drive daylight deeper into the space. Mass timber interior façade surfaces and any associated structural connections were left exposed as an intentional design expression. The glazed atrium space would ideally be treated with new glazing to match the new window glazing; otherwise, the configuration of this

https://doi.org/10.52202/080513-0295

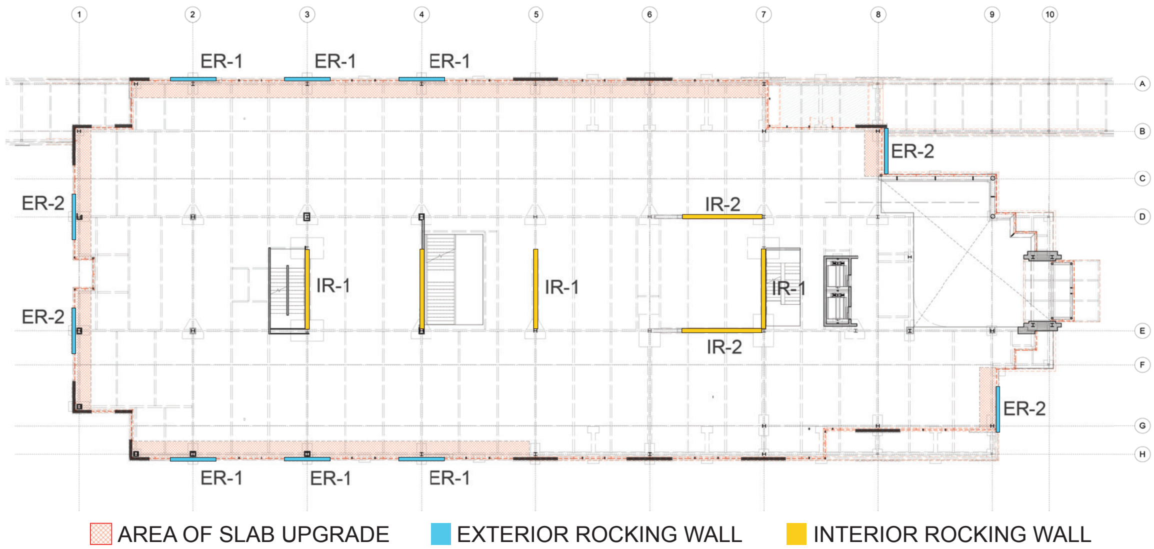

Figure 4. Typical floor plan depicting areas of seismic upgrade interventions

façade element is left largely untreated and not included in the cost estimation scope.

During the entirety of this project, the research team worked with industry collaborators Swinerton and Timberlab to develop a MTP system that would be cost-competitive with a steel BRB approach and transferrable from the case study to other commercial buildings. Therefore, we considered simplicity and constructability in the connections and details. Slab edge upgrades in areas of exterior rocking panels (Fig. 4) were required to transfer the lateral forces into the diaphragm and the team employed an out-of-plane steel plate embedded into the new slab edge with anchor rods (Fig. 5) that permitted through bolted connections at floor levels to the exterior resisting panels (ER-1 and ER-2). Interior resisting panels (IR-1 and IR-2) applied to core upgrades employ a knife plate connection detail welded to existing wide flange beams, centered in the MTP and through bolted for final connection (Fig. 3).

Typical architectural details include a wall assembly exposing MTP on the interior, vapor open water-resistant barrier, outboard mineral fiber insulation, fiberglass clips supporting galvanized steel furring hat channels, and cedar exterior cladding. Thinner infill non-structural MTP assemblies are fitted between rocking wall structural panel assemblies with 25 mm (1 in.) spacing to allow for a peak drift ratio of 4%, which is beyond the requirements set by ASCE 7-22. Window frames are detailed with 203 mm (8 in.) seismic joints adjacent to exterior rocking wall panels (Fig. 6) to remain in service after a seismic event. Exterior rocking wall panels (Fig. 3) are fitted with 45 mm (1.75 in.) post-tensioned steel rods spaced equidistant on both sides of the panel and made accessible for post-tensioning 1219 mm (48 in.) above the finish floor of the top story using a 610 mm (24 in.) MTP plug that can be removed and reinstalled.

Thermal upgrades to the façade were based on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Net Zero Energy commercial building standards. With the thickness of the mass timber panel itself contributing to thermal resistance – RSI 0.22 per 25 mm (R 1.25 per inch) – the additional mineral wool insulation required (RSI 0.70 per 25 mm or R4 per 1 in.) was 51 mm – 76 mm (2 in. – 3 in.) for the exterior rocking walls with 7 in. MTP and 76 mm – 102 mm (3 in. - 4 in.) for the 3 in. non-structural MTP infill panels in the mild Pacific Northwest climate. The total RSI value achieved was 2.55 (R14.49), which represented a 103% increase over the base case RSI of 1.26 (R7.14). A substantial advantage of the MTP backer wall over traditional light gauge steel framing is that the wood provides a thermal break to the field of fasteners required to support outboard insulation and cladding. In addition, we chose to use a fiberglass clip with stainless steel fasteners to support the galvanized light gauge steel channel on which the cladding is applied to further reduce thermal conductivity. Finally, the window system was a fiberglass frame system with higher performing insulated glass units compared to the 1988 base case, which increased the thermal performance of the façade. Based on simulated solar patterns, fixed exterior shading was designed and applied to the south and west facades to

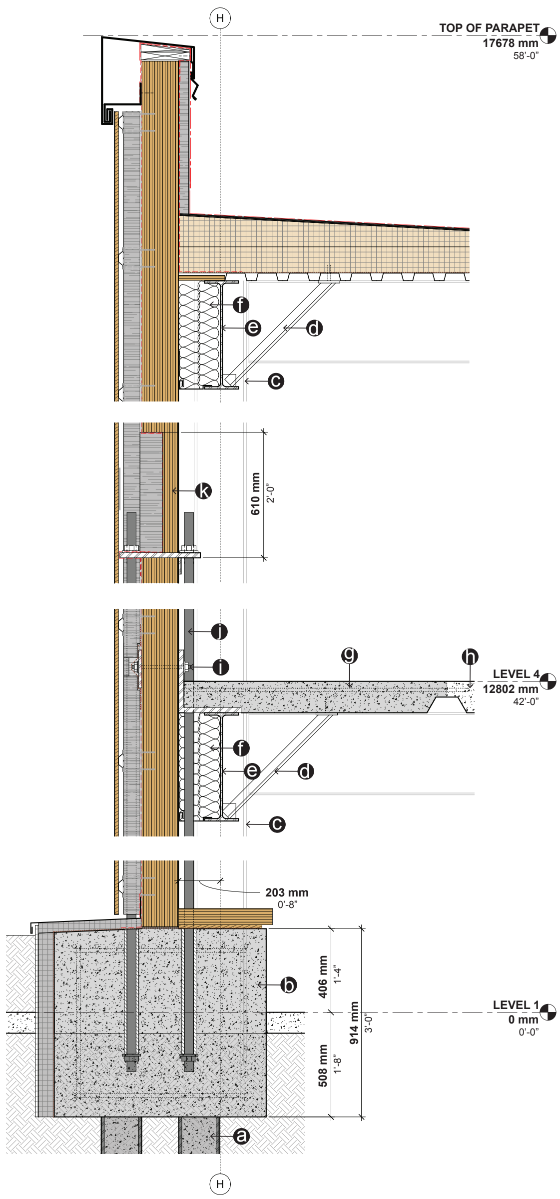

Figure 5. Façade rocking wall panel foundation and slab connection details: a. new steel micropile, b. new concrete pier cap, c. existing steel column, d. new steel strut, e. existing perimeter beam, f. firestopping and trim, g. new reinforced slab upgrade, h. existing slab, i. MTP connection, j. post-tensioned steel rod, k. 78 mm MTP plug

reduce solar gain where appropriate, another efficiency opportunity provided by the façade upgrade.

While façade insulation levels improve energy efficiency, the daylighting updates made possible with a renewed façade are a significant contributor to overall energy efficiency and resilience. As noted above, the design team reinforced the new vertical expression of the façade

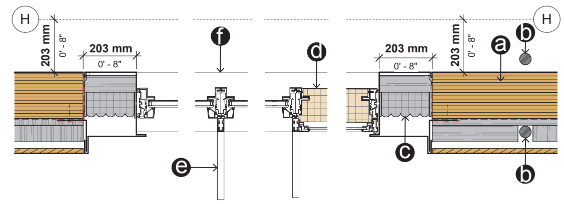

Figure 6. Typical window detail with seismic joints. a. MPP panel, b. post-tensioned steel rod, c. foam vertical expansion joint with silicone face, d. fiberglass insulated window wall bypass panel, e. vertical fin, f. infill panel below.

created by the exterior rocking wall panels by extending the window head height to the underside of the wide flange perimeter beam, adding exterior shading where required to mitigate solar gain, and interior light shelves for improved indirect distribution of illumination, separating windows into a lower view portion and upper daylighting and ventilation portion. Floor plate illumination levels were simulated using Radiance (Fig. 8) for the existing and proposed conditions and resulting required LED electric lighting to maintain 300 lux calculated, then input into a Solemma ClimateStudio (version 2.0) simulation model to derive energy utilization.

4 – OUTCOMES AND REFLECTIONS

A biogenic façade retrofit system was developed for low-rise commercial construction that increases building resilience through improved seismic restraint, improved thermal performance of the building enclosure, which decreases load on the electric grid and supports indoor thermal conditions during an outage, improved daylighting and energy use through reduced reliance on

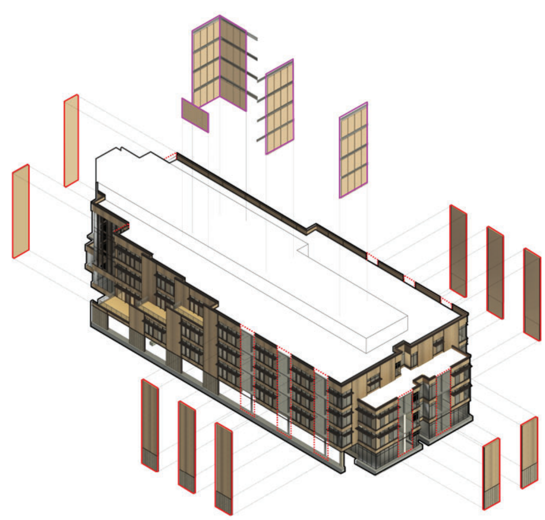

Figure 7. Upgraded condition depicting IR and ER locations.

https://doi.org/10.52202/080513-0295

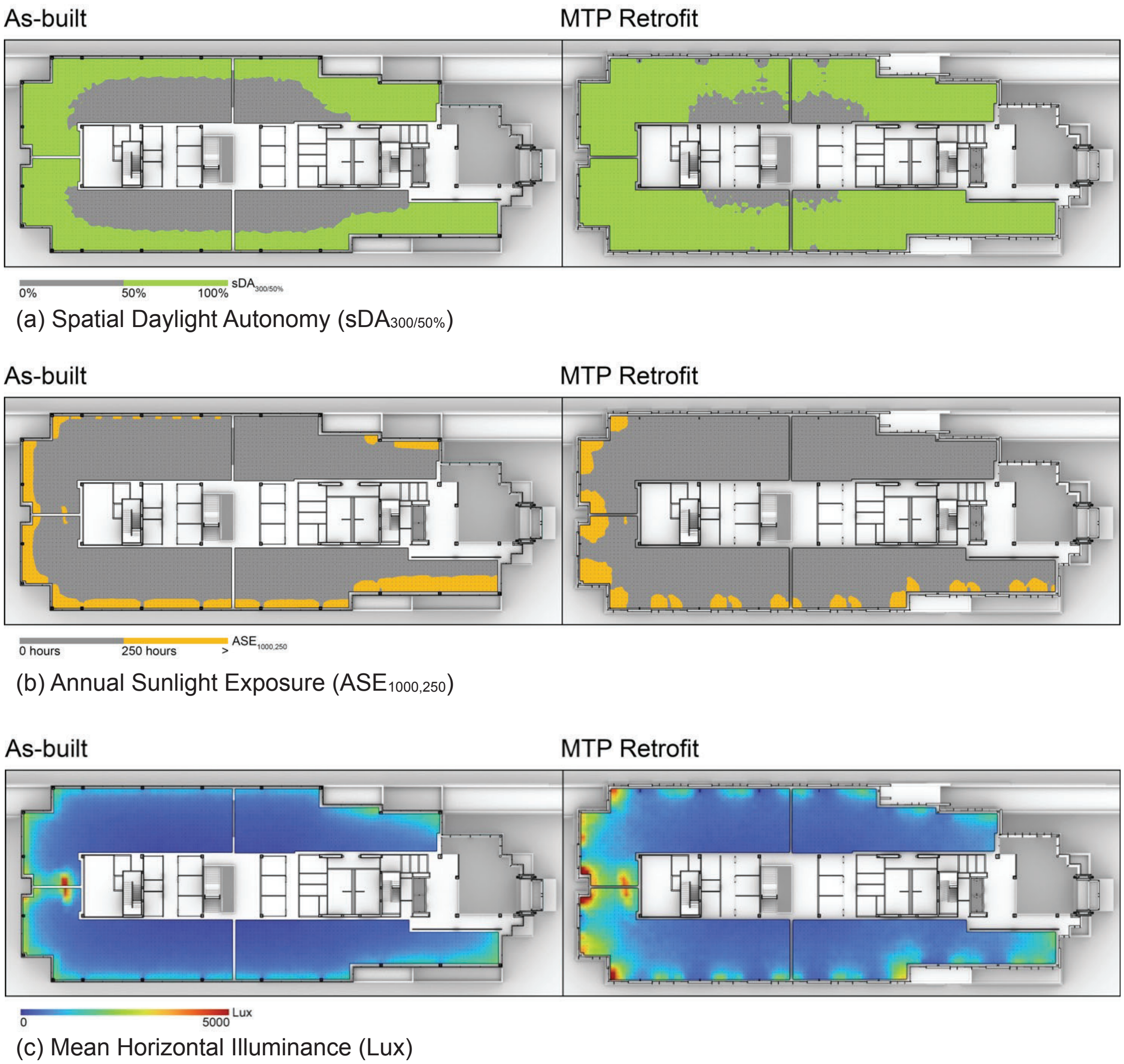

Figure 8: Horizontal spatial plots of the daylighting performance metrics which correspond to (a) Spatial Daylight Autonomy ($sDA_{300/50\%}$), (b) Annual Sunlight Exposure ($ASE_{1000,250}$), and (c) mean horizontal illuminance (Lux), as shown in Table 1.

electric lighting, and allowed installation of operable windows for passive ventilation. The design of the new façade system necessarily had a vertical expression as the rocking wall panels must span and connect all floors (Fig. 7). Moreover, the reality of the case study building was that the façade included architectural features, such as terraced outdoor spaces, glazed atrium and loggia walkways, which did not permit seismic restraint in these areas, limiting the amount of lateral restraint that could be achieved via the façade.

Updating the thermal envelope to meet ASHRAE Net Zero commercial building standards resulted in a mass wall with RSI 2.55 (R14.49), which represents a 50.7%

Table 1: Daylighting performance metrics

	As-built	MTP Retrofit
(a) Spatial Daylight Autonomy ($sDA_{300/50\%}$)	54%	86%
(b) Annual Sunlight Exposure ($ASE_{1000,250}$)	13%	9%
(c) Mean Horizontal Illuminance (Lux)	547	784
(d) LEED v4.1 Daylight credits (Option 1)	1	3

(a) daylight availability as measured by Spatial Daylight Autonomy ($sDA_{300/50\%}$), which considers the floor area that maintains 300 Lux for at least half of the annual hours between 8:00am and 6:00pm; (b) daylight excessiveness as measured by Annual Sunlight Exposure ($ASE_{1000,250}$), which considers the floor area that exceeds 1000 Lux for at least 250 annual hours and signals potential over lighting and visual glare issues when exceeding 10% ASE (as per LEED); (c) light levels measured as mean horizontal illuminance (Lux); and (d) the total LEED v4.1 Daylight credits earned.

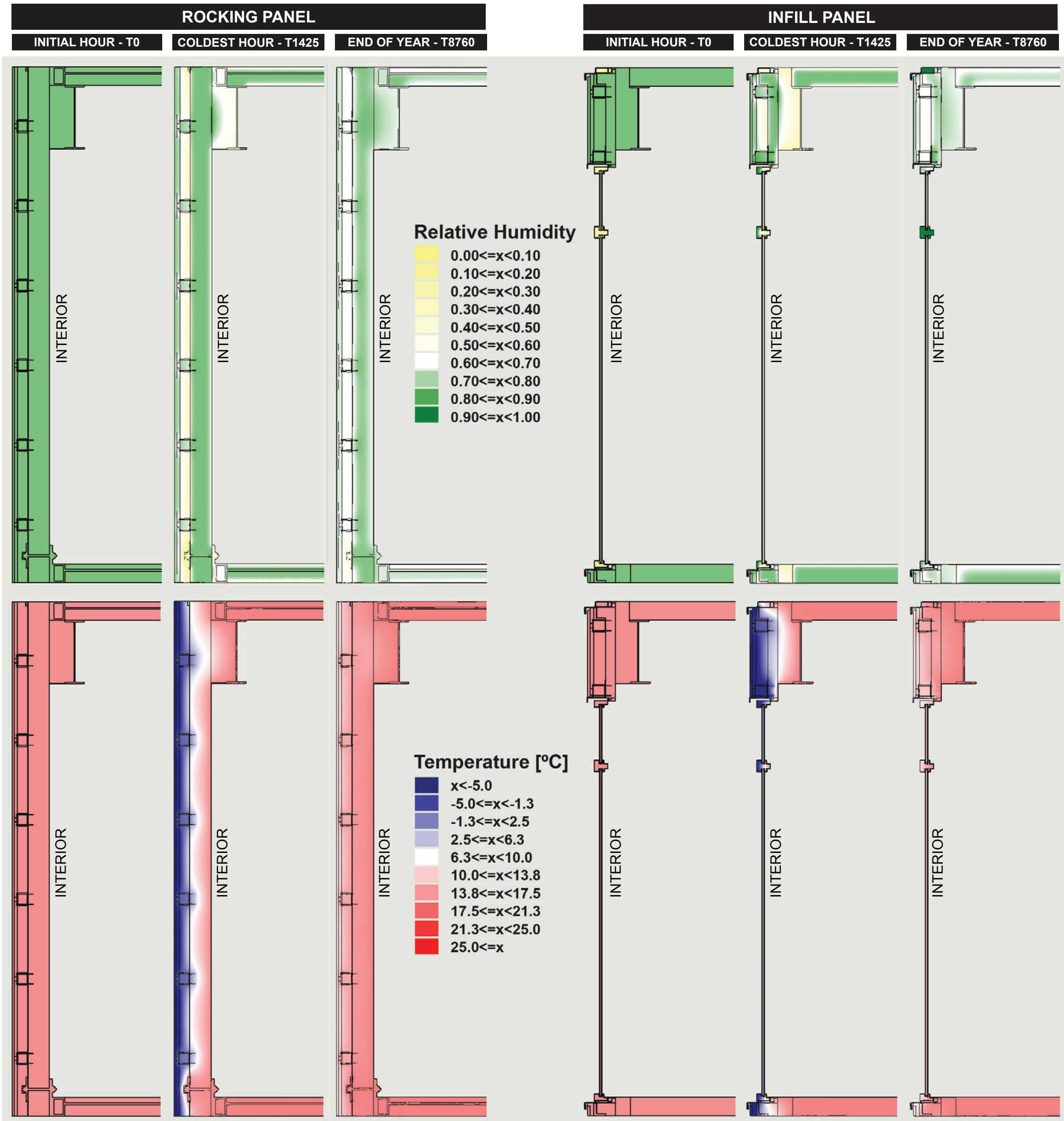

Figure 9: Horizontal spatial plots of the daylighting performance metrics which correspond to (a) Spatial Daylight Autonomy ($sDA_{300/50\%}$), (b) Annual Sunlight Exposure ($ASE_{1000,250}$), and (c) mean horizontal illuminance (Lux), as shown in Table 1.

improvement over the current Oregon energy code requirement of RSI 1.69 (R9.61) or a 103% improvement over the RSI 1.26 (R7.14) base case 1988 thermal envelope. Whereas, updating daylighting using a façade retrofit, the case study building improved daylight availability (Spatial Daylight Autonomy) from 54% to 86% and reduced daylight excessiveness (Annual Sunlight Exposure) from 13% to 9%. These two metrics satisfy daylighting performance requirements specified by the LEED v4.1 Daylight credit and earn all 3 possible points. Additionally, the mean horizontal illuminance increased from 547 to 784 Lux. These metrics are described by Table 2 and shown as spatial plots in Fig. 8. This also resulted in a modeled 44% reduction in energy use attributed to envelope performance. This study did not include a full building energy model incorporating mechanical systems and potential savings from management of latent heat loads with the hygroscopic MTP wall system, which could have significant additional energy savings during periods of cooling [8].

https://doi.org/10.52202/080513-0295

Figure 10: Building before retrofit (top), building after retrofit (bottom)

Since the new façade is constructed using a hygroscopic bio-based material and a vapor open assembly, the design team modelled 2D moisture and thermal flow using WUFI 2D (version 4.4.0.192) at two typical conditions (Fig. 9): through the solid rocking wall panel and through a window condition. Modelled conditions start with elevated moisture content for all materials and results indicate that materials dry out over the 1-year simulation and do not present any mould-related issues.

Given the multiple additional benefits of upgrading the façade with MTP as part of a seismic retrofit, it is difficult to directly compare pricing between this system and a baseline BRB retrofit in which the façade remained intact. However, based on a detailed costing exercise performed by Swinerton, the seismic MTP retrofit cost 516 USD per m^2 (48 USD per ft^2) at the time of publication, approximately 14% of the cost for new core and shell construction in the region. The entire façade system retrofit as designed resulted in 41% of the cost for typical new construction of core and shell only, or 26% of the cost for new core and shell plus full interior fit out.

5 – CONCLUSION

The integrated research team developed a mass timber panel facade retrofit system (Fig. 10) for low-rise commercial buildings that meets level 2 seismic resilience and improves facade energy performance to Net Zero Energy standards per ASHRAE Advanced Energy Design Guide. Using a case study of a four-story low-rise steel frame office building in the Pacific Northwest that was constructed in 1988, the team prepared digital models of the existing condition. Seismic forces and restraints for the case study building were modeled using finite element analysis to inform the design of panel sizing, solid/void relationships, connector specifications, and additional footing requirements. LFRS locations were identified in the model and cross-laminated timber (CLT) and mass ply panels (MPP) MTP were explored as structural and infill façade panels. Connection and fenestration details were developed with construction and mass timber fabrication collaborators from Swinerton and Timberlab, then analyzed using a 2D thermal model and WUFI hygroscopic model to verify energy performance and durability and optimize for constructability and cost. Once the design of the panelized system was established, Swinerton performed a costing analysis of baseline versus the proposed MTP solution.

The prefabricated MTP panelized facade systems for retrofit increases the resilience of existing commercial buildings by improving seismic response, energy use and indoor environmental conditions. Adapting existing buildings to climate and resilience goals will reduce embodied carbon compared to new construction; however, the system developed is also largely translatable to new construction, where issues of moisture migration, thermal bridging, structural connections, constructability, and panel transport are shared. Furthermore, the panelized facade system developed could be deployed on existing and chronically vacant commercial office space to convert it into new typologies (e.g., housing), where fenestration upgrades are desired for code compliance or resilience. MTP façade retrofit solutions that maintain existing building stock represent a sustainable and lower cost solution versus new construction, and a pathway to meeting climate goals while providing for a resilient future.

Funding was for this research was provided by a U.S. Department of Agriculture (USDA) ARS Grant #R0884C-B. We would like to thank University of Oregon architecture student Daniel Essaides, who provided BIM modelling of the existing base case building used for this project and early iterations of retrofit details.

6 – REFERENCES

[1] United States Energy Information Administration, *Monthly Energy Review*, Tables 11.1-11.6, April 2022.

[2] U.S. Energy Information Administration, *2018 Commercial Buildings Energy Consumption Survey*, Sept. 2021

[3] Reyner Banham, *Architecture of the Well-Tempered Environment*, Architectural Press, 1969

[4] International Council of Building Officials (ICBO), 1973, Uniform Building Code (UBC). Whittier, CA. (1973).

[5] ASCE/SEI 41-17. *Seismic rehabilitation of existing buildings*. Reston, VA: ASCE, 2017.

[6] ASCE/SEI 7-22. *Minimum design loads for buildings and other structures*. Reston, VA: ASCE, 2022.

[7] Orozco, G. (2024). Performance-based seismic design for multi-story building retrofit using mass timber walls. : Oregon State University.

[8] Olalekan F. Osanyintola and Carey J. Simonson, “Moisture buffering capacity of hygroscopic building materials: Experimental facilities and energy impact,” *Energy and Buildings* 38 (2006): 1270-1282.

https://doi.org/10.52202/080513-0295