CASE STUDY

UNIVERSITY OF MASSACHUSETTS OLVER DESIGN BUILDING

# Inspiration through Innovation

## At UMass Amherst, an Exposed Mass Timber Structure is a Teaching Tool

WoodWorks™
WOOD PRODUCTS COUNCIL

**PROJECT DETAILS**

**LOCATION:** Amherst, Massachusetts

**SIZE:** 87,500 square feet / four stories

**TOTAL COST:** $52 million

**CONSTRUCTION COST:** $36 million

**CONSTRUCTION TYPE:** IV

**COMPLETED:** January 2017

**PROJECT TEAM**

**CLIENT:** University of Massachusetts Building Authority

**ARCHITECT:** Leers Weinzapfel Associates

**STRUCTURAL ENGINEER:** Equilibrium Consulting • Simpson Gumpertz & Heger (EOR)

**CONSTRUCTION MANAGER:** Suffolk

**TIMBER SUPPLY:** Nordic Structures

**TIMBER INSTALLATION:** North & South Construction • Bensonwood

The goal for the John W. Olver Design Building at the University of Massachusetts Amherst was to create an innovative and inspired building that visibly demonstrates environmentally-sensitive design. The result is one of the most advanced mass timber buildings in the United States, a four-story, 87,500-square-foot structure that exemplifies the University's commitment to sustainability and, through generations of students who will learn within its walls, the future of the built environment.

Designed by Leers Weinzapfel Associates (LWA), the Design Building sets a high bar for mass timber buildings in the U.S. with a glued-laminated timber (glulam) column-and-beam frame, glulam brace frame, cross-laminated timber (CLT) shear walls, timber-concrete composite floor system, and unconventional cantilevered forms. It is wrapped in an envelope of copper-colored anodized aluminum which, combined with vertical windows, echoes the wood structure by evoking the color and pattern of regional forests.

Written for anyone interested in the expanding possibilities of mass timber, this case study examines key elements of the building's planning, design and construction with an emphasis on the advanced wood structural systems. It also reviews the variances needed for elements of the design that were outside the scope of the adopted building code at the time of jurisdictional review, and the process for achieving ultimate approval by the Authority Having Jurisdiction.

## Collaborative Design, Collaborative Learning

If the Design Building has a theme, it's collaboration.

The project's incentive was an outdated building housing the Department of Landscape Architecture and Regional Planning. Talk of a new facility led to the idea of a building that combined three related departments—folding in the Department of Architecture and Department of Environmental Conservation's Building Construction Technology (BCT) program—to facilitate interdisciplinary research and learning on a larger scale than the University had so far experienced.

Collaboration was an important part of the design process, which involved faculty of the three departments, all highly knowledgeable about building science and design, and their vision for sustainability, functionality and aesthetics. It informed the structure itself, and is a defining part of the curricula in the new facility.

"We imagined this building as a teaching tool for the design disciplines," said LWA Principal, Andrea Leers. "I know from my own teaching experience that there's nothing more potent than being able to talk with students about the space around you—in this case, the collaborative configuration, innovative structure, considered material and detailing choices, environmentally-driven site, and synergistic landscape concepts that define the project."

## From Steel to Mass Timber: The Decision to Use Wood

From a design perspective, one of the challenging aspects of the project was the University's initial assumption that it would be a steel structure. However, two faculty members of the BCT program, who had been teaching courses in wood design and conducting research related to wood building systems for more than a decade, made the case for wood as a more fitting and sustainable solution.

An Associate Professor, Peggi Clouston completed her PhD in engineering mechanics specializing in wood, with a minor in structural engineering. Alex Schreyer, a senior lecturer, has a background in structural engineering and wood science. Both were enthusiastic champions of the idea that mass timber could elevate the new Design Building to something truly remarkable.

The rest of the story, as Clouston says, has the twists of a Hollywood movie. The University agreed to conduct an analysis to explore the feasibility of mass timber, but a tight schedule required the project to proceed in the meantime. LWA was selected as the architecture firm—in part because of the firm's openness to accommodating a wood structural system should the University decide to do so. They began designing the project in steel, but also engaged Equilibrium Consulting, which has helped design and engineer some of North America's most innovative mass timber buildings.

LWA had never worked with mass timber, but they welcomed the challenge. "You have to be willing to do the research," said lead architect, Tom Chung. "We looked at structures built in the last five to eight years, post-and-beam versus CLT panels, elements that make timber buildings expressive, so different types of trusses and strategies for long-span spaces, the digital fabrication process—all of this helped us understand the possibilities."

As with many university projects, budget was a concern and, despite a preliminary life cycle assessment (LCA) demonstrating the environmental benefits of a wood design, initial cost estimates added a premium for the unknowns associated with this new construction type. There were also premiums associated with the desired configuration—which was necessary given the program and site, but is atypical of most mass timber structures built to date. This reduced some of the savings that could have been achieved with more modular and simpler rectangular forms.

It wasn't until Clouston engaged the support of a former Massachusetts congressman, John W. Olver, who secured additional state funding based on the fact that the building would be an important demonstration project for mass timber in the region, the decision was made to use wood.

## Architectural Design

Just as it unites three university departments, the Design Building serves as a bridge between the architectural styles of different campus buildings. It is carefully sited on a steep slope at the main campus artery, rising from three stories on the east side of the building to four on the west. In this way, its massing connects the smaller structures of historic Stockbridge Way with the brick Fine Arts Center and modern concrete structures on campus.

The steel design was more than half complete when the University decided on a wood structural system. However, knowing that a switch was possible, LWA made some smart design decisions early on, working with Equilibrium to select a structural grid that could accommodate either steel or mass timber, and paying close attention to floor-to-floor heights and overall building geometry. The team even created parallel schematic drawings of a mass timber building design.

"The Design Building was built for a very specific purpose on a very specific site with complicated geometries and campus circulation," said Chung. "So the shaping and programming configuration of the spaces was largely independent of whether this was a wood or steel structure."

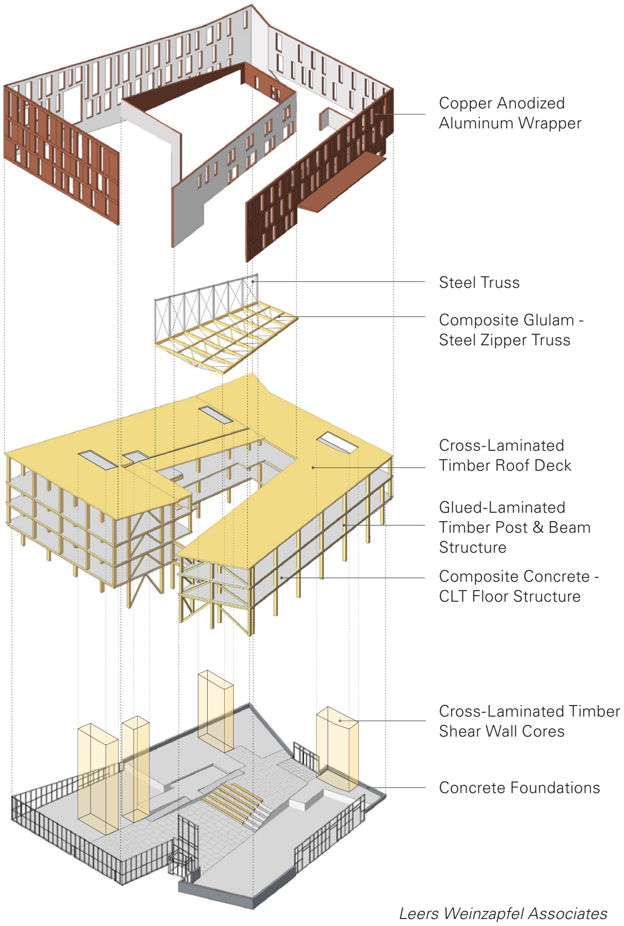
He also points out that mass timber doesn't have to radically change design concepts used with other materials. "We can accomplish what we're already familiar with in steel and concrete," he said. "Steel post-and-beam can be glulam post-and-beam. Concrete/masonry shafts can be CLT. Steel/concrete floors can be CLT/concrete floors. A steel deck roof can be a CLT roof. Steel braces can be glulam braces."

Intended to house 500 students and 50 faculty, the Design Building is organized around a two-story central atrium; a flexible gathering and event space with integrated tiered seating, movable partition boards, lounge seating and café. Dominated by the composite zipper truss roof structure, the atrium also features a three-story, folded CLT stair, hung from a single long-span truss with thin rods that give the impression it's floating.

**Verifying the Environmental Benefits**

At the conceptual stage, WoodWorks undertook a preliminary life cycle assessment (LCA) to demonstrate the environmental benefits associated with the wood option being considered. Once the decision was made to use wood, WoodWorks provided ongoing technical assistance as well as support related to a whole building LCA of the final design undertaken by the U.S. Forest Service Forest Products Laboratory in cooperation with the Athena Institute. It is the first LCA to examine the impact of CLT on a U.S. project. (See *Showcase for Sustainability* on page 10.)

Envelope & Structural Systems



*Leers Weinzapfel Associates*

Facilities used by all three academic departments surround the atrium in the building's main volume. The first floor features exhibition and lecture space, laboratories, fabrication and materials testing shops, dining and classroom space, while the second and third include studios, classrooms and offices, and the smaller fourth floor contains studios. Above the atrium is a green roof that functions as a public courtyard and outdoor learning space for students studying urban landscapes.

A curtain wall system exposes much of the building's first floor, including the timber structural system and atrium space, inviting interaction with passersby. The second story cantilevers several feet beyond the first, and the second, third and fourth stories are clad with a panelized rainscreen system.

The Design Building is Type IV Construction with a limited number of unprotected steel transfer beams in the two cantilevers and elements of the courtyard truss. Type IV Construction allows the use of exposed, solid or laminated wood members such as CLT, glulam and wood decking if certain provisions are met. For example, per IBC 2009 Section 602.4, minimum timber sizes must be used, concealed spaces are not permitted, and exterior walls must be of non-combustible materials or fire retardant-treated wood.

*The Design Building itself is a teaching tool for students. The mass timber structure is left exposed, as are many of the building's mechanical, electrical, and plumbing (MEP) systems. Leaving MEP systems exposed also helped meet the limitation on concealed spaces. (See below, Beyond the Building Code: Required Variances.)*

## Beyond the Building Code: Required Variances

As is often the case with innovative building designs, there were challenges to code approval.

"Transparent and early engagement with building officials was very important," said Chung. "We initiated discussions with the state building inspector during schematic design and provided updates at all critical stages. By the time the construction documents were done and we were ready to submit for official variances, the building inspector had all the information he needed to write a letter of support to the variance committee."

Robert Malczyk, Principal at Equilibrium Consulting agreed. "We provided a lot of research reports and technical approvals from Canada, the U.S. and Europe," he said. "But we didn't just submit 600 pages without explaining. It was a dialogue. We met in person to provide education on the systems we were proposing, including their history and performance, and showed projects from around the world. They asked questions we could answer face-to-face as part of the discussion. They're very smart people—they just hadn't been exposed to a lot of the international information. That was the process."

Variances were proposed as part of an Alternate Materials and Methods Request (AMMR). The AMMR process, recognized in IBC 2009 Section 104.11, allows building code officials to consider the *intent* of prescriptive code provisions when deliberating on new or existing technologies in materials, design and methods that are not explicitly addressed in the code.[1] In this case, the entire Design Building had to be considered an alternative structure.

### *Recognition of CLT as an Approved Building Material*

The project was permitted under the Massachusetts State Building Code, 780 CMR, 8th edition, which is based on the 2009 International Building Code (IBC) with amendments. Since the 2009 IBC does not prescriptively recognize CLT as a permitted building material—it wasn't prescriptively recognized until the 2015 version of the code—the variance review board had to sign off on its use.

### *Concealed Spaces in a Type IV Project*

Although concealed spaces are not prescriptively permitted in Type IV Construction, the team requested a variance to allow concealed spaces in up to 20% of the ceiling area. The request was successful with the inclusion of NFPA 13 automatic sprinklers in all concealed cavities. The code does not place restrictions on the use of concealed spaces in other construction types.

### *Timber-Concrete Composite Floor System*

Timber-concrete composite floor systems are a relatively new technology, and the IBC doesn't currently include prescriptive or standardized methods for their structural design. To support a variance, the team presented testing and research completed to date, including work by Clouston and Schreyer as part of the BCT program,[2] information from product manufacturers, and examples of similar projects built elsewhere.

### *Vertical Lateral Force-Resisting Systems*

CLT shear walls and glulam brace frames are not included as a seismic force-resisting system in ASCE 7 Minimum

Design Loads for Buildings and Other Structures, which is the referenced standard for establishing structural loads on buildings. As with the floor system, the team supplied research and testing data, information from product manufacturers, and examples of similar projects.

### *Shaft Walls*

Shaft walls require a 2-hour fire rating when connecting four or more stories per IBC 2009 Section 708.4, and a common wall assembly used to achieve a 2-hour rating in wood construction utilizes two layers of 5/8-inch gypsum wallboard on each side. However, stair and elevator shafts in the Design Building are made from CLT and LWA wanted to leave them exposed on the interior. To meet the 2-hour rating, the team proposed covering the outside of the shafts with two layers of 5/8-inch Type X gypsum and a layer of 1-inch shaft liner panel.[3]

Ultimately, the Authority Having Jurisdiction approved all variances. The review board requested a third-party structural peer review of the drawings and calculations as well as a third-party fire and life safety peer review. The team also provided the results of fire tests on CLT shaft walls, conducted by Nordic Structures and others, that demonstrate more than 2 hours of fire resistance. Once these reviews were complete, a construction permit was issued for the project.

## Structural Design

The relationship between Equilibrium Consulting and Simpson, Gumpertz & Heger was critical both to a smooth design and construction process and successful project outcome. With considerable expertise in mass timber building design, Equilibrium was responsible for structural calculations and drawings for all aspects of the project. As the structural engineer of record, SGH reviewed and stamped all construction documents. SGH also performed quality control and administration functions in the material fabrication and construction phases. They witnessed a sample installation of timber-concrete composite connectors at the Nordic Structures fabrication facility in Quebec, Canada, and tested product samples, connections and assemblies at their own facility in Waltham, MA. Equilibrium and SGH both played key roles in the variance submission and review process.

### Gravity Framing System

The structural gravity framing system includes glulam beams and columns supporting the timber-concrete composite floor system and CLT roof decking. Other than CLT shaft walls, walls are non-load bearing, cold-formed steel walls with standard gypsum finishes.

Common glulam floor beam sizes are 14-1/4 inches wide x 15 inches or 16-1/2 inches deep. Columns are 14-1/4 inches wide x 22-1/2 inches to 25-1/2 inches deep. Glulam members were sealed with standard factory clear-coat finishes, and members in areas of higher traffic were given an extra coating in the field. Most of the glulam members are black spruce with a balanced layup and an unadjusted bending capacity of 2400 psi.

## Exposed Mass Timber and Construction Type

CLT, when manufactured according to the consensus standard ANSI/APA PRG 320, was first prescriptively recognized in the 2015 IBC. In this version of the code, CLT is defined in Chapter 2 and recognized as a permitted building material in Chapter 23:

- ***IBC 202: CROSS-LAMINATED TIMBER.*** *A prefabricated engineered wood product consisting of not less than three layers of solid-sawn lumber or structural composite lumber where the adjacent layers are cross oriented and bonded with structural adhesive to form a solid wood element.*
- ***IBC 2303.1.4 Structural glued cross-laminated timber.*** *Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.*

Because CLT is prescriptively recognized for Type IV Construction, there is a common misperception that exposed mass timber elements can't be used in other construction types. This isn't the case.

In addition to Type IV buildings, mass timber elements—including CLT, glulam, nail-laminated timber (NLT), structural composite lumber (SCL) and tongue-and-groove (T&G) decking—are permitted as exposed structural elements, whether or not a fire-resistance rating is required, as follows:

- ***Type III*** – Floors, roofs and interior walls may be exposed timber in fire resistance-rated construction; exterior walls are required to be noncombustible or fire retardant-treated wood.
- ***Type V*** – Floors, roofs, interior walls, and exterior walls (entire structure) may be exposed timber in fire resistance-rated construction.
- ***Types I and II*** – Exposed wood may be used in select circumstances (e.g., roof construction of Type IB, IIA or IIB buildings when a 1-hour fire-resistance rating or less is required or when 20 feet or more of horizontal separation from the building is provided).

Section 703.3 of the 2015 IBC lists several acceptable methods of demonstrating fire resistance, one of which is calculations done in accordance with IBC Section 722. Section 722.1 states that *"The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AF&PA National Design Specification for Wood Construction (NDS)."* Chapter 16 of the NDS can be used to calculate up to a 2-hour fire-resistance rating for exposed mass timber members. In addition to these calcuations, ASTM E119 fire tests have been successfully completed on a number of mass timber assemblies.

According to Chung, changing the design from steel to timber allowed the team to reduce the number of beams by about half and get rid of beams perpendicular to MEP routing in many areas. "Had we stayed with steel, the most cost-effective way to span the structure would have been to use a metal deck, which typically spans 12 feet, so you'd need a beam at every 12 feet to pick up the deck. With a CLT panel you can span 24 feet, but you'd need a thicker panel. The timber-concrete composite system allowed us to put beams every 24 feet without a thicker panel. That, in combination with the one-way direction of beams, reduced ceiling cavity depth and was helpful for MEP coordination."

The roof assembly is made from 7-ply CLT panels, with rigid insulation and sheet membrane on the exterior. Panel-to-panel connections are surface splines with plywood and self-tapping wood screws.

Typical panel-to-beam and beam-to-column connections included a variety of self-tapping wood screws, which are common on modern mass timber projects, and concealed beam hangers. In their final condition, the steel hangers are protected from fire exposure by a minimum thickness of wood.

*Typical connections included self-tapping wood screws and concealed beam hangers.*

## Timber-Concrete Composite Floor System

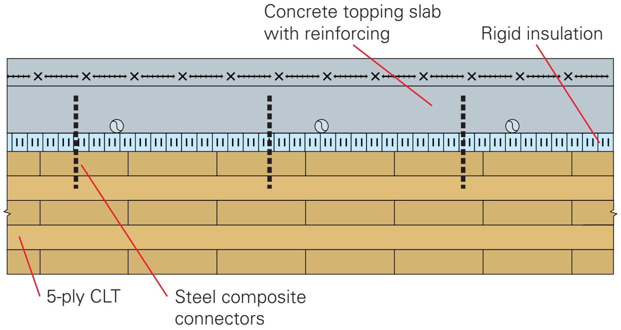
As part of their vision, Clouston and Schreyer wanted the Design Building to include a timber-concrete composite floor system, a technology they'd been researching and testing as part of the BCT program for more than a decade.

Common in Europe, these systems are comprised of a concrete slab integrally connected to wooden panels and/or beams below by means of shear connectors. In this case, the floors include steel mesh connector plates tested at the University known as the HBV® system, a patented product from Germany. The 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. As the floor system resists bending forces caused by gravity loading, the concrete slab experiences predominantly compression stresses and the wood experiences predominantly tension stresses, making the best use of each material's structural attributes. The end result is exceptional strength and stiffness as well as reduced weight when compared to an equivalent all-concrete section. The system also offers excellent fire resistance, sound and vibration performance. For the structural design of mass timber floor panels, including those used in composite action with a concrete slab, vibration is almost always the controlling factor (as opposed to bending or shear strength). This was the case with the Design Building.

For the Design Building, most floor spans varied from 20 to 26 feet, and the number and spacing of connectors varied with the floor span. The team used 5-ply CLT panels (6-7/8 inches thick) 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.

**Typical Timber-Concrete Composite Floor Assembly**



*In the floor system, composite action between the CLT and concrete provide exceptional stiffness and minimal deflection which, along with an insulation layer between the materials, results in excellent acoustic separation between floors.*

## Composite Zipper Truss System

The spectacular timber and steel composite zipper truss system—named for the way multiple structural members converge to a single point—resolved what may be the Design Building's most interesting structural challenge.

Because of the site's geometry, the form of an 84-foot-long atrium had become increasingly complex, transitioning from 54 feet wide at one end to 33 feet at the other. The system also had to accommodate skylights and heavy loads both from the working rooftop garden (i.e., a frequently wet garden on a wood structure), and the region's snowfall. There was also a desire to minimize structural depth.

"One of the biggest challenges of the entire project was meeting the heavy loads of the inside courtyard," said Malczyk. "We had to assume the entire courtyard would be filled with snow. And last winter it was—but there was no movement, no cracking, no damage to the structural system. We were very proud of it."

After several iterations, Chung says the final design offered the "combination of dynamic form, architectural consistency, structural efficiency, and cost. It reinforced the overall building column grid, allowed for various span lengths while keeping the same form, and highlighted the cost effectiveness of the digital fabrication process."

The system includes seven trusses in total, each 12 feet on center and 7 to 9 feet deep. Trusses span the width of the atrium without any intermediary structural columns. Each truss includes an 18-inch-deep glulam top chord compression member, which spans the width of the commons, is capped with steel ends, and is supported by a column at one end and a steel truss on the other. Four tubular glulam struts that are 9 inches in diameter, and four steel rods that are 1 to 2 inches in diameter attach to each compression member and transfer the roof's structural loads to a central steel connection that Chung calls the "bullet connector."

## Lateral Framing Design

The lateral-resisting system incorporates a combination of CLT shear walls and glulam bracing. "The nice thing about shear walls and brace frames is that they're both stiff," said Malczyk. "We couldn't have moment frames and braces because their responses wouldn't be compatible. But I don't see a problem using brace frames and shear walls, especially in structures where, architecturally, you don't want shear walls in certain areas. I truly believe that a proper and honest structure can be beautiful architecture."

Although designed for seismic and wind forces, seismic loads governed despite the building's location on the east coast.

The system accommodates the rules of capacity design, where certain elements are intended to yield and others to remain elastic. In this case, Malczyk explains that all of the elements of the lateral system are overdesigned except the

*The zipper truss is named for the way multiple structural members converge to a single point.*

hold down brackets in CLT shear walls and the end connection steel pins and plates in glulam braces, which are sized to yield at the level of the design earthquake. In a seismic event, these elements are intended to dissipate energy without causing further structural damage; the idea is that they could be replaced afterwards for faster building recovery.

The weight of the structure is relevant. "The seismic force is proportionate to the weight of the building," says Malczyk. "If this building were designed in concrete, the weight would be six times more than the mass timber design, which means the seismic forces could also be up to six times greater. All of the elements, including foundations, hold downs, and everything else, would have needed to be much stronger. This is part of the reason wood buildings are so popular in high seismic regions."

*The lateral-resisting system incorporates CLT shear walls and glulam brace frames.*

## Construction Process: Efficiency and Speed

Asked if there was an aspect of the project that went exceptionally well, Malczyk said without hesitation, "Speed of construction and the way guys accustomed to framing with steel handled the wood system. There's often a fear with mass timber—who will install it and will they be good enough—but there are great installers all over North America who could adapt easily and would embrace the challenge. It was a pleasure to see the beams and columns flying in. The guys put them in so fast and they loved doing it. You could tell watching them."

Clouston agrees, mentioning that four 60-foot-tall CLT panels comprising one of the building's shear wall cores were lifted and dropped into place with a crane, and anchored to the foundation, all in one weekend. Staff and students at the University also appreciated a relatively quiet and waste-free construction site—both typical characteristics of mass timber and heavy timber construction.

As with most other aspects of the project, the construction process was collaborative.

Timber was supplied by Nordic Structures, which also provided design assist services to ensure that the architectural intent was structurally sound, buildable, and within budget. "Assuring the assembly while maintaining an eye to jobsite conditions and manufacturing tolerances is essential to successful execution," said Nordic's Jean-Marc Dubois.

The singular nature of the Design Building and desire to provide a proof of concept for the timber-concrete hybrid floor system were critical factors in Nordic's approach to providing material and design solutions. "We had prior experience working with Equilibrium in Canada, so there was a familiarity to our initial design optimization process," said Dubois. Rather than relying on copious emails, Nordic engineers went to the Equilibrium office for several days of intensive review and design refinement. Given the innovative nature of mass timber buildings, this degree of collaboration can clear the path for subsequent review and approval of individual assemblies or components.

Supervision of the project was a shared effort with Bensonwood, which provided offsite safety and handling education, and on-site supervision and training. "North & South was familiar with heavy assemblies, so rigging wasn't an issue," said Bensonwood's Christopher Carbone. "Training covered things like connections, pre-building, and CNC technology—the way it works, fabrications, tolerances, etc."

According to Dubois, the North-South team demonstrated eagerness, not just to deliver the structure but to learn the intricacies of design and computer modeling, going so far as to seek additional CAD training for their supervisory staff.

*Advantages of mass timber construction include fast installation and a relatively quiet and waste-free job site.*

## Showcase for Sustainability

When the University of Massachusetts agreed to switch to a wood structural system, it did so because of a deeply ingrained commitment to sustainability. The preliminary LCA had highlighted benefits of a wood vs. steel structure in terms of reducing carbon footprint—referred to in the LCA world as global warming potential. (See sidebar below, *Reducing Carbon Footprint*.) From the outset, the University planned to prioritize environmentally-beneficial impacts wherever feasible in all aspects of the design.

## Reducing Carbon Footprint

Like all wood products, the CLT and glulam used in the Design Building will continue to store carbon absorbed by the trees while they were growing, keeping it out of the atmosphere for the lifetime of the building—or longer if the wood is eventually reclaimed and reused. Using wood in place of fossil fuel-intensive materials such as steel and concrete also "avoids" greenhouse gases that would have been emitted during manufacturing.

Information on this chart was calculated with the WoodWorks Carbon Calculator, which allows users to enter the volume and types of wood products in a building, and outputs information on the building's carbon footprint.

**Volume of wood products used:**
2,052 cubic meters (72,467 cubic feet)

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

**Carbon stored in the wood:**
1,826 metric tons of $CO_2$

**Avoided greenhouse gas emissions:**
706 metric tons of $CO_2$

**TOTAL POTENTIAL CARBON BENEFIT:**
2,532 metric tons of $CO_2$

*EQUIVALENT TO:*

**535 cars off the road for a year**

**Energy to operate 267 homes for a year**

*Source: US EPA*

*Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: $CO_2$ on this chart refers to $CO_2$ equivalent.*

### Energy Efficiency

The Design Building was required to meet Massachusetts' stretch energy code, which emphasizes energy performance (as opposed to prescriptive requirements) in order to facilitate cost-effective construction that's more energy efficient than construction built to the "base" energy code.

While the stretch code requires a 20% improvement over the baseline, the built, optimized building is already surpassing its energy targets (by far). It is predicted to have a total site energy use intensity (EUI) of 43 kBTU/SF/year, compared against an EUI of 62 kBTU/SF/year for the baseline design—a 50% improvement over the base code.

According to the University, this impressive achievement is the result of a collaborative team effort that included integrated design meetings, iterative energy analysis and simulation, and project coordination through each design phase.

Design elements that contribute to the savings include a highly efficient building envelope. The roof is 7-ply CLT (9-5/8 inches thick), which could achieve an estimated rating of R-12 on its own, and the team added a layer of continuous rigid insulation. This brought the energy rating of the roof assembly to R-45, which is about twice the energy code requirement. Exterior walls are non-load bearing light-gauge steel studs with gypsum on the interior, cavity batt insulation, exterior sheathing, 4-inch mineral wool insulation between z-girts, and metal panels in a rain screen system.

Other energy saving features include radiant flooring and chilled beams, heat-recovery systems, motion sensors, glazing and skylights designed to provide maximum daylighting, and high-efficiency fluorescent and LED lighting. Recent calculations indicate that the building will exceed its initial target of LEED Gold certification and achieve LEED Platinum.

### Transparent and Comparable Performance

With the design complete, the University—in cooperation with WoodWorks and the USDA Forest Service Forest Products Laboratory—sought to gain a more thorough understanding of the building's environmental performance with a whole building LCA and environmental building declaration (EBD).

Undertaken by the Athena Institute, the LCA entailed a cradle-to-grave analysis of the material effects of structure, envelope, and interior partition assemblies, as well as operating energy and water use, over a 60-year period. Similar to an environmental product declaration (EPD), an EBD is a vehicle for transparent reporting of measured environmental (LCA) performance data. Available from the Athena Institute,[4] it allows the University to publicly communicate the environmental implications of the Design Building—and wood-based construction in general—in a transparent and comparable manner.

As part of efforts to achieve LEED certification, the LCA data was submitted to support the Materials and Resources Credit, "Building life cycle impact reduction" Option 4, Whole-Building Life Cycle Assessment.

**Whole Building LCA: Comparing the Steel vs. Mass Timber Design**

| Life Cycle Assessment Impact Measures | Steel Design | Mass Timber Design | Units | Percent Difference (%) |
|---|---|---|---|---|
| Global warming potential | 4,612,572 | 4,009,240 | kg CO2 eq | -13.1% |
| Stratospheric ozone depletion | 8.53E-02 | 7.67E-02 | kg CFC-11 eq | -10.1% |
| Acidification of land and water | 23,883 | 21,755 | kg SO2 eq | -8.9% |
| Eutrophication | 1,378 | 1,378 | kg N eq | 0.0% |
| Tropospheric ozone formation | 382,026 | 368,320 | kg O3 eq | -3.6% |
| Depletion of non-renewable energy resources | 56,492,129 | 48,142,200 | MJ | -14.8% |

The whole building LCA compared the as-built mass timber Design Building with a baseline building that reflects the originally conceived steel structure, and determined that the wood building outperformed the steel design in five out of six environmental impact categories. (The designs performed equally related to eutrophication.)

The baseline building differs from the Design Building in the following ways:

It includes the use of metal deck with concrete-topped floors supported by steel framing, and concrete elevator and stair walls. The foundation employs the same scheme, but accommodates the dead loads of the originally conceived (non-wood) design. Material quantities were taken from the cost report produced during the design development phase of the project.

Average concrete "benchmark" mixes were assumed.

The building is assumed to be clad in brick veneer. A thermally comparable amount of polyisocyanurate board insulation (2-1/2 inches of polyisocyanurate insulation vs. 4 inches of mineral wool insulation) was substituted in the exterior walls.

The operating energy performance of the baseline building is assumed to be essentially the same as the Design Building since (a) thermal resistance of the exterior walls was maintained, (b) all other envelope assemblies are the same, and (c) both buildings have the same size, functions, orientation, and assumed mechanical systems.

***For details on the LCA process and environmental impact categories, visit the Athena Institute at www.athenasmi.org.***

## Education Today, Building for the Future

Completed in January 2017, the John W. Olver Design Building is now home to a bustling education community. Its innovative mass timber systems are an inspiration for students, practicing design professionals, and every passerby drawn by the extraordinary sight of the zipper truss within. It is also, in many ways, the embodiment of an optimistic future.

By inspiring designers and their projects, for example, there is a good chance that the Design Building will lead to increased manufacturing of mass timber products in the eastern U.S., spurring economic growth. Attuned to this potential, the BCT program is already researching the use of local Hemlock for CLT.

"I think of the building as an ambassador of change," said Clouston. She's discussing the concept of exposed structure as teaching tool, and the fact that generations of students will learn about mass timber technologies, but she's also referring to wood design in general. "Less than half of American universities teach about wood as a structural material, and that needs to change. We're giving future building designers a high-performing, low-carbon, beautiful option for their projects by teaching timber design."

As students learn about the Design Building, they will also learn about the importance of collaboration and communication. "It's hugely important to teach architects, engineers and the other disciplines that they should be working together," said Malczyk. "It isn't always easy because you often start with completely different interests and positions. But if you're open and clear and show respect to other parties—that's how you end up with innovative systems like the ones in this project."

## Considering mass timber?

### Contact WoodWorks for free project support.

The Olver Design Building was conceived to meet specific requirements of the University of Massachusetts and is atypical of most mass timber projects constructed in the U.S. As the architect notes, for example, potential cost benefits of a more rectangular, modular form weren't realized due to programmatic building requirements that were unrelated to materials chosen. Mass timber buildings are optimized when the decision to use mass timber is made early in the design process, rather than switching from a building designed with other materials. Also, depending on design objectives, project teams may find that Type III Construction offers advantages over Type IV while, in many scenarios, providing a similar allowable building size.

If you'd like assistance with a mass timber project, our technical experts offer support from design through construction on issues ranging from allowable heights and areas to structural design, lateral systems and fire- or acoustical-rated assemblies. WoodWorks also offers a wide range of education opportunities and other resources.

**www.woodworks.org/project-assistance**
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[1] *Getting to Yes: Making Effective Use of the Alternate Means Process*, Michael F. Malinowski, AIA, Applied Architecture Inc., Andrew Klein, PE, CEM, A S Klein Engineering, PLLC, www.woodworks.org

[2] For more information on timber-concrete composite systems, including research published by the University of Massachusetts Building Construction Technology program, visit https://bct.eco.umass.edu/research/research-areas/wood-concrete-composite-systems/. For a wide range of current mass timber research, visit the Think Wood research library at www.thinkwood.com.

[3] The desire for exposed CLT shaft walls made this an uncommon situation. Typical wood-frame shaft wall design is described in the WoodWorks paper, *Shaft Wall Solutions for Wood-Frame Buildings.*

[4] Environmental Building Declaration: http://www.athenasmi.org/wp-content/uploads/2017/04/UMass_Environmental_Declaration_31_January_2017.pdf, Summary Brochure: http://www.athenasmi.org/wp-content/uploads/2017/04/Web-ready_UMass_EBD-Summary_brochure.pdf

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