

Figure 1. Main entry to the Andy Quattlebaum Outdoor Education Center.

Situated on the shores of Lake Hartwell, the Andy Quattlebaum Outdoor Education Center serves as the new 16,500-squarefoot home of the Clemson Outdoor Recreation and Education program (*Figure 1*). The building is the first facility east of the Mississippi River and second in the country to use cross-laminated timber (CLT) made from southern pine (SP). It is part of the growing wave of interest in mass timber construction.

Clemson University's history with forestry and effective land use date back to its founding as a land grant university in 1889, but it received a significant push in 2014 with the establishment of the Wood Utilization + Design Institute (WU+D). The Institute is a multi-disciplinary group of members focused on forestry, architecture, construction, and engineering with the goal of better utilizing existing timberland throughout the state and developing creative ways to use timber in construction projects. This group has reached a significant milestone in completing the first mass timber building on campus in recent history. With the university's history as a land grant institution and the WU+D Institute pushing for advancement in timber construction, it was only fitting that Clemson build a structure to bring students closer to local forests and lakes using the same trees that surround them.

The new facility's focal point is a two-story building with an open atrium at the main lobby (*Figure 2*). The atrium incorporates expanses of glazing along with clerestory windows throughout to maximize natural light. This part of the facility includes classrooms, office space, equipment rental, a ground-level covered patio, and a second-floor terrace overlooking the lake that can be used for events or outdoor classrooms. Behind this building is an open-air boathouse with a patterned steel and timber slat wall for rain screening.

The desire to showcase an exposed timber structure required a more cooperative approach with the architectural team at Cooper Carry than a typical project to ensure the structural design and detailing met the architectural intent. Every exposed element and connection was thoughtfully considered to maintain a consistent appearance throughout the facility.

Structural Issues

The signature roof structure consists of a single-slope pitched roof with double glulam beams spaced at 16½ feet, spanning 60 feet between steel pipe columns. The 27½-inch-deep glulams cantilever beyond the building on each side with a 14-foot cantilever at the roof over the second-floor patio. The double glulam beams sandwich structural steel pipe columns at the two-story building and wide flange columns at the boathouse. The three-ply, 4½-inch-thick CLT panels cantilever out an additional 2½ feet beyond the end of the glulams on the panels' weak axis to create a strikingly thin profile. The CLT

Clemson's **MASS TINBER** Outdoor Education Center

By David Impson, P.E., S.E., Andrew Ruffin, P.E., S.E., and Brian Haygood, P.E.



Figure 2. Interior lobby with exposed CLT elevator shaft and glulam beams.

panels cantilever as much as 9 feet on their strong axis at the ends of the roof to further this design feature.

The second-floor framing consists of 27½-inch-deep double glulams spanning 30 feet between steel columns. The floor construction consists of a 2-inch concrete topping slab on 67%-inch-thick, five-ply CLT. These beams cantilever 10 feet to create the exterior terrace with the CLT extending an additional 18 inches to create a unique edge profile. One of the benefits to southern pine, aside from its abundance in the Southeast, is its material property strength. Because of its higher strength relative to other materials, southern pine CLT allows for longer spans without construction shoring that could be required for a comparable span using a composite metal deck.

A more challenging aspect of this project design was creating a lateral system that worked with the architectural desire for an open structure. At the two-story building, tension-only rod braces were used in one direction and were able to be accommodated within the enclosed two-story area. For the perpendicular direction, the covered patio provided no opportunities for bracing or wall elements. After considering various options, the design team elected to use a hybrid steel column-glulam beam moment frame approach. A 3-D model was created to accurately determine moment frame stiffnesses and the building's torsional response due to a relatively stiff rod brace at the north end and five sets of moment frames at the south end. This model was used to determine the required connection forces.

As is frequently the case with timber construction, the real opportunity for creativity lies in the connection design. Because wood's bearing capacity exceeds its dowel-action shear capacity, custom steel brackets were detailed with an L-shaped bearing plate for vertical support of the glulam beams. Bolts were used to transfer moment into these steel brackets welded to the columns. To accommodate the maximum bolt





Figure 3. Steel/glulam moment connection.

Figure 4. Detail of steel/glulam moment connection.

spacing of 5 inches for fasteners connecting wood to rigid elements (National Design Specification (NDS[®]) for Wood Construction 2015, Section 12.5.1.3), vertical slots were used at the top bolts to allow for wood shrinkage relative to the steel but still transfer moment between the beam and column (Figures 3 and 4).

The building's layout features a large open floor plan on the first floor with the elevator in a central location, meaning the shaft is a prominent feature. While not required for load-bearing support, the elevator shaft was erected with 5-ply CLT panels. CLT erection of the elevator shaft was completed in one day, saving between two and three weeks of erection time compared to the labor required for traditional CMU block walls. Because the building was designed for Type V-A construction, the shaft was required to have a one-hour fire-resistance rating. To achieve this with mass timber, the effective char depths table for CLT per NDS Chapter 16 was used to design for the required fire-resistance rating.

Trade and Mechanical Coordination

Due to the integration of structural steel supports for the mass timber framing, one of the challenges was coordinating between two trades with different subcontractors during the shop drawing review process. Because of the exposed nature of the building structure, the architecture team was involved in this coordination as well. As the EOR, the author's firm's responsibility was to help bridge the gap between the two trades and help guide the team towards a solution that met the architecture team's visual expectations.

The design team did not determine the CLT panel layout, but coordinating mechanical duct drops and general openings during shop drawing review was critical to the design. Because of the layout and the few duct-drops through the floor, duct openings were dictated to be centered in panels to avoid transferring forces across panel joints. This allowed for a slim deck profile without adding framed glulam beams around the openings. Panel capacities were analyzed by taking a moment and shear reduction of the section based on the percentage of panel width removed for an opening. These capacities were then compared to the design moment and shear along the panel length.

Costs

While many interested parties had a strong desire for this building to utilize mass timber, the design and construction team still needed to justify mass timber from a cost standpoint. Overcoming the perception

that mass timber would be a significant cost premium proved a challenge and required significant persuasion to include mass timber in the first round of pricing. In the early phases, the design team included a mass timber roof as the base concept but chose to use a traditional steel and composite deck for the 2nd floor. As an alternate, a mass timber floor structure was incorporated into the narrative as a final effort to have it included.

While the steel's installed cost was less expensive than the installed cost of the mass timber, the mass timber floor and roof eliminated additional costs for architectural soffits and ceiling finishes. With the mass timber serving as an architectural finish, the timber floor structure presented overall cost savings and became the base design moving forward. As CLT becomes more prevalent as a construction material and additional manufacturers come online, it is anticipated that mass timber will continue to become a cost-effective option for new construction.

Conclusion

When beginning any project where the exposed structure will be a focal point of a building's architecture, it is critical for the structural and architectural teams to understand the desired appearance early in the process. From there, the structural engineer can guide the architect on the most cost-effective combinations of CLT floor panel thickness and beam and column spacings. To create a costcompetitive wood structure, the maximum allowable span of the CLT panels must be used for beam spacing to reduce excessive cost in the CLT and reduce the number of beams and beam end connections. After the layout is set, the focus can shift to various exposed timber connections to ensure that structural and architectural needs are met to achieve a consistent look throughout the building. With this process in mind, the design and construction team created a building that serves as a natural bridge between classroom learning and the lakes and forests surrounding it, inspiring students to explore the world around them..



David Impson is a Principal with Britt, Peters & Associates, Inc. in Greenville, SC, and has been an advocate for mass timber construction in the Southeast. (dimpson@brittpeters.com)

Andrew Ruffin is a Project Manager with Britt, Peters & Associates, Inc. in Greenville, SC. (aruffin@brittpeters.com)

Brian Haygood is a Project Engineer with Britt, Peters & Associates, Inc. in Greenville, SC. (bhaygood@brittpeters.com)