

BUILDING AT A GLANCE

Name Clemson University Lee III

Location Clemson, S.C.
(28 miles WSW of Greenville, S.C.)

Owner Clemson University

Principal Use University academic building

Includes Studio space, seminar rooms,
faculty and administrative offices

Occupancy

Peak Transient Occupancy 292
Daily Average 657
Peak Full-Time Equivalent (FTE) 32
**Total Peak Building Users (FTE +
Peak Transient)** 324

Gross Square Footage 53,441

Conditioned Space 50,249
(does not include mechanical room)
Mechanical Room 3,192

Distinctions/Awards AIA National
Honor Award for Architecture, 2013;
LEED Gold-NC v3, 2012

Total Cost \$16 million
(excludes site work)

Cost Per Square Foot \$300

Substantial Completion/Occupancy
Dec. 16, 2011



COLLABORATIVE

BY MICHAEL G. TALBOT, P.E., MEMBER ASHRAE

Architecture students at Clemson University enjoy a leg up on their peers: the building where they study. Lee III's open plan situates students from four different disciplines side-by-side, providing them with organic opportunities to work with and learn from each other in this net zero energy-ready building—something that will reap rich dividends after they graduate.



LEARNING

Eric Piasecki/OTTO

“Students, when they emerge from these disciplines, are going to be working together the rest of their professional lives,” said John Jacques, professor emeritus of architecture and a member of the design team.

“Having a building that openly invites and promotes the whole idea of collaborative learning and collaborative work between disciplines will

most likely create a student body that graduates to collaborate in later life.”

The 55,000 ft² space, located in the rolling foothills of the Blue Ridge Mountains in upstate South Carolina, roughly doubles the space of the two other sections of the building, known as Lee I and Lee II. The new space is home to 12 professional degree programs in the

schools of architecture and of planning, development, preservation and landscape architecture, as well as the departments of art and construction science and management.

The building also serves as an example of how future buildings should be built sustainably, incorporating new technologies and “outside the box” thinking.

Design

Design studios, faculty offices and classrooms are mixed together in Lee III, which cultivates a sense of community in the two-story building and promotes teaching through discovery and discovery-based learning.

Students learn from their professors, as well as through their studio activities and by chatting with students in other departments. Carefully detailed glazing between spaces supports this type

Left This collaborative architecture and landscape architecture studio overlooks an undergraduate landscape architecture studio and review space. It is framed by the faculty offices (upper level) and seminar spaces (lower level).

Below Early evening in the east plaza looking through the north porch and façade into the open studio bays and enclosed office and seminar spaces. The skylights and “shrouds” are illuminated from within and backlit by the setting sun.



Annemarie Jacques



Eric Piasecki/OTTO

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of learning. The college plans to conduct research regarding the discovery-based teaching and learning at Lee III and the impact of the building’s design.

LEE HALL THREE SECTIONS, ONE BUILDING

The original Lee Hall (Lee I) was designed by Clemson’s first dean of architecture, the late Harlan McClure, and constructed in 1957–58. In 2010, the National Park Service placed the modernist facility on the National Register of Historic Places. In the 1970s, an addition provided some extra classroom, office and studio space (Lee II). Another small addition took place in the 1990s (also Lee II) before the recently completed 55,000 ft² expansion (Lee III), which roughly doubles the size of the complex.

Source: Clemson University

The transparent exterior façades blur the line between the natural world and the interior environment. The entire north and south exposures are glazed with ultra-clear low-e glass. This connection to the outside is enhanced through operable and motorized windows, opened when exterior conditions permit, allowing the mechanical systems to be shut off completely. Nearly 98% of regularly occupied space has outside views in multiple directions.

The exterior space to the north is carefully proportioned and intentionally flexible to foster full-scale fabrications, which further encourages informal learning through curiosity and observation. On the south side, a garden with a closely

In the northeast studio bay, undergraduate art students sit on the warm, radiant floor and use this open review space with northern, natural light to fabricate large scale cardboard sculptures, an “art in public places” project.

spaced bosque of trees provides an area for students to study or have small gatherings.

Pursuit of Energy Efficiency

The Lee Hall expansion is designed to teach sustainable building design by example—literally—making it a model for instructors and students. The energy use dashboard (available via Web browser or a touch screen kiosk at the building at <http://tinyurl.com/cmlpte4>) in this “learning laboratory” allows students to view real-time use of the structure’s electricity, water, and heating and cooling energy. Users also can compare

WATER AT A GLANCE

Annual Water Use 916,000 gallons

ENERGY AT A GLANCE

Annual Energy Use Intensity (EUI)

(Site) 34.6 kBtu/ft²

Electricity (From Grid) 34.6 kBtu/ft²

Annual Source Energy 116 kBtu/ft²

Annual Energy Cost Index (ECI) \$0.60/ft²

Savings vs. Standard 90.1-2007

Design Building 52%

Heating Degree Days (base 65°F) 2,111

Cooling Degree Days (base 65°F) 2,209

Average Operating Hours per Week 124

conditions; fully vegetated roof; twenty-four skylights and window walls that minimize the need for artificial lighting during daylight; and integrated exterior sunshades. The skylights automatically change angle and aperture depending on the need for lighting, and less light is let in when the building gets too hot.

A spray applied vapor barrier assembly was carefully detailed and monitored during installation, with 4 in. of rigid insulation installed in the masonry cavity to minimize air leakage and thermal transmission. Conduit is in place for installation of electric car power stations with preferential parking.



Eric Plasecki/OTTO

Above Perforated metal “shrouds” on the green roof shield the skylights and interior spaces from direct sunlight as the sun makes its journey across the sky.

Below Students take advantage of the building’s open floor plan and learn from each other in both casual and structured learning formats. Undergraduate landscape architecture studios are below, with a graduate architecture studio on the mezzanine “tray” above.

use between the expansion and older sections of the building.

The \$16 million project’s EUI of 35 kBtu/ft²·yr exceeds 70% energy use reduction for university building types outlined in the AIA 2030 Challenge, exceeds ASHRAE Standard 90.1-2007 baseline by 52% and is four times more energy efficient than the average building on Clemson’s campus. Much of the energy savings can be attributed to an eight-zone radiant heating and cooling system. Lee III is one of first projects worldwide to incorporate such a system in a mixed-humid climate (characterized by varied seasons, temperatures and humidity levels throughout the year).

Other energy-saving systems include a full closed loop, 46 well geothermal water-to-water heat pump system; mechanized natural ventilation fully integrated into the automated building controls that allows the mechanical system to be shut off during prescribed climate



Eric Plasecki/OTTO



Eric Piasecki/OTTO

Building Goals

Built as part of the university's commitment to create more energy-efficient buildings, the LEED Gold-NC v3-certified building also aligns with Clemson's goal of reducing energy consumption 20% by 2020. The structure is net zero energy ready with future plans to incorporate photovoltaic solar panels to help the

building generate as much—or even more—energy as it consumes. The PV installation and potential net zero energy performance is several years away since funds must be raised first to finance the project.

“Because it's housing programs for the School of Design and Building, it was especially important to make the Lee Hall expansion a



Eric Piasecki/OTTO

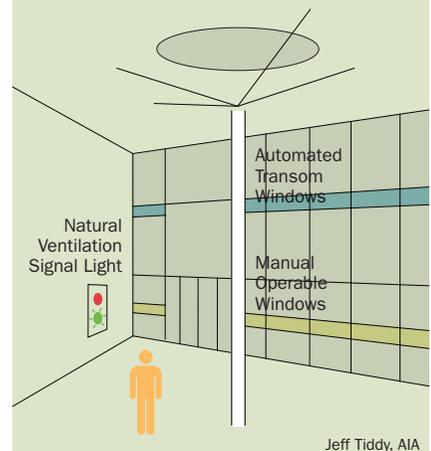
Above Free movement along the south façade provides easy access to all studio bays, while enclosed office and seminar spaces stand back from the outside window wall.

Left Tree-like columns lead to smaller “branches” that fan out to carry the roof load. Above each is an operable skylight that also allows ventilation in the spring and fall.

NATURAL VENTILATION

Lee III is the only building in the Southeast that combines radiant cooling and natural ventilation. The building envelope is designed to take advantage of natural ventilation when conditions are suitable. Automated operable transom windows are programmed to open to bring fresh air into the building for ventilation, eliminating energy costs for heating and cooling during times of cross ventilation.

The natural ventilation sequence of operation is controlled by three variables: dry-bulb temperature, wet-bulb temperature and pollen count. The control system accesses pollen data via a website to determine if pollen levels are within an acceptable range. Red and green lights indicate when building occupants should manually open or close the lower windows.



Jeff Tiddy, AIA



Detail of the perforated roof/ceiling of the north porch featuring one of the tethered light fixtures.

sustainable structure,” says Tony Putnam, P.E., director of utility services at Clemson. “Our goal for the building was to go outside our comfort zone for design to teach design professionals of the future,” says Putnam. “The idea was to make this building with the lowest energy consumption possible—even make it net zero energy use. We knew we had to be open to newer technologies to make that happen.”

Energy-Efficient Comfort

Brad B. Smith, AIA, managing principal at McMillan Pazdan Smith, was passionate about creating a structure that would embody true sustainable building.

“We wanted this project to make a statement and to exemplify what future buildings should be,” says Smith. “What better opportunity to do something different and highly sustainable than with a building that teaches students to be good architects.”

Each class that comes through the building has a “building stewardship committee,” which actively monitors the building performance and provides feedback to the University staff and fellow students.

The design team looked into a number of alternative energy and energy-efficient systems to minimize



Eric Plasecki/OTTO

The building envelope is designed to take advantage of natural ventilation when conditions are suitable. Automated operable windows bring in fresh air to the building.

energy loads, including geothermal and a radiant heating and cooling system to maximize the performance of the geothermal system. A radiant system involves warm or cool water flowing through tubes embedded in the slab of the structure to heat and cool the building.

Trying an in-slab radiant floor heating system was a new concept for Clemson. And proposing a radiant cooling system—in a high humidity environment like South Carolina—was really radical.

The owners were skeptical. Could it be done? Should it be done? Their concerns focused on how to control humidity in the building to prevent condensation forming on the floor surfaces.

The engineers performed an energy study on the life-cycle costs for a hydronic radiant system compared to a standard variable air volume (VAV) system for the life of the building. The team compared installation costs, energy costs, maintenance costs and replacement costs. The system had a payback

KEY SUSTAINABLE FEATURES

HVAC Geothermal water-to-water heat pump system; eight-zone radiant heating and cooling system; and mechanized natural ventilation system.

Daylighting Twenty-four skylights and daylighting sensors.

Envelope Integrated exterior sunshading.

Renewable Energy Net zero energy ready with planned addition of a solar panel array.

Site Project footprint on a disturbed site and 128 existing parking spaces eliminated by project footprint.

Transportation Mitigation Conduit installed for future electric car power stations with preferential parking; connected to the university public transit system.

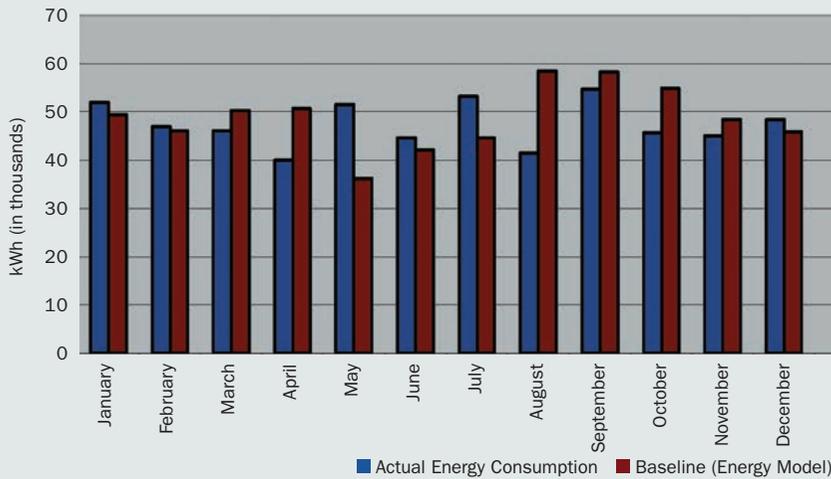
Storm Water Management Vegetated roof assembly retains 48% of annual precipitation; nearby reservoir collects site runoff, treats and redistributes to campus; and pervious paving material transfers water to ground.

Water Conservation High efficiency dual-flush valves and sensed faucets contribute to a 35% regulated potable water reduction from baseline.

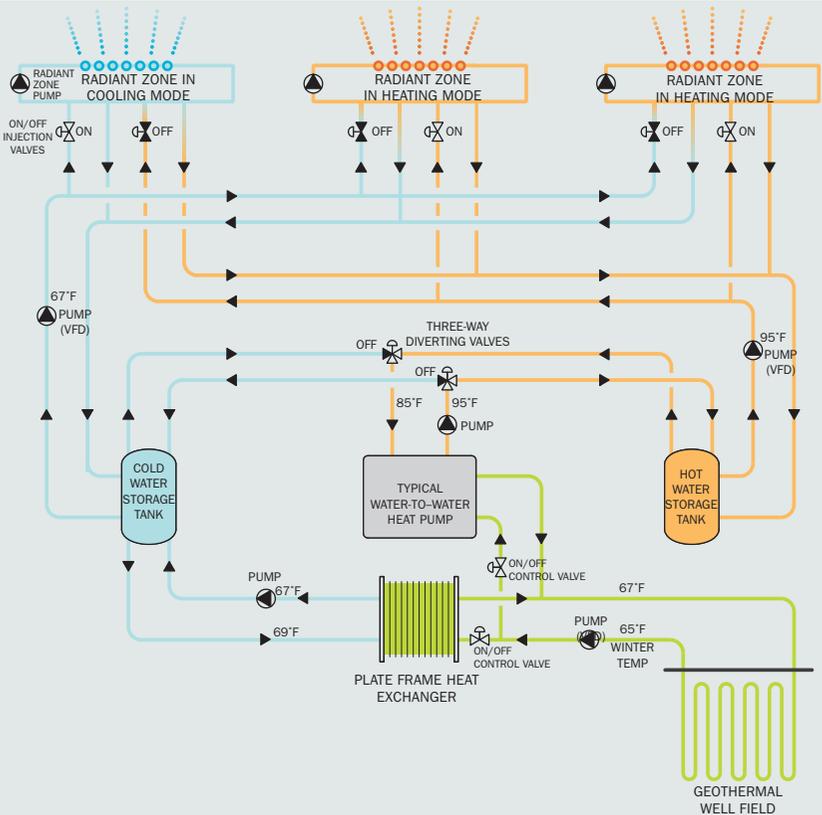
Materials LEED requirements for indoor environmental quality exceeded with material selection; and 95% of construction waste diverted from landfill.

Recycling Recyclable material collection (collection containers in convenient spaces).

FIGURE 1 ENERGY CONSUMPTION, 2012



FLOW DIAGRAM FREE ZONE COOLING DURING WINTER PERIOD



Additional Energy Savings from Water-to-Water Heat Pumps, Geothermal System

The heat pumps can provide simultaneous heating or cooling to various zones or air handlers via a reversible heat pump arrangement.

When certain low-load conditions exist (usually in early fall and early spring), water from the geothermal well field directly cools the southern zone and interior zones that require cooling. A frame heat exchanger transfers energy into the radiant slab system, bypassing the water-to-water heat pump chillers and saving more energy.



Eric Plaseck/OTTO

Lee III is one of the first projects worldwide to incorporate a radiant heating and cooling system in a mixed-humid climate. Other sustainable features include a green roof, geothermal heat pump and skylights.

of less than 10 years compared with the initial costs of a standard VAV system, but compared with the initial cost of additional PV panels (to achieve net zero energy), was very economical.

When all the costs were taken into account, the radiant system made the most sense from an economic standpoint. And because a radiant system keeps heating or cooling near the floor where people are located, it makes even more sense given the building’s high ceilings. The radiant system also eliminated ductwork and the need for a hung ceiling, further reducing costs.

Despite the economic and energy benefit of the proposed radiant floor system, the owners still were not sure about the idea of putting tubes of flowing water in the concrete slab of the building. Concerns circulated about maintenance issues and system longevity.

The engineers put the building owners in touch with other facilities that had radiant floor systems. However, few buildings in the U.S. use radiant cooling.

A senior associate at the project’s consulting architecture firm visited Cooper Union College in New York.



Annemarie Jacques

Lee III is a 53,500 square foot addition to Lee Hall, roughly doubling the overall size of the complex.

At the time, the pipe and manifolds for a radiant heating and cooling system were being installed. The visit helped him realize the coordination that would be required to ensure that the manifolds were properly incorporated into the design.

Clemson's steering committee also visited the Hunter Museum of American Art in Chattanooga, Tenn.,

one of the first structures in the U.S. with a radiant cooling system, which was installed in 2005.

Investigations also found that a radiant system offers increased comfort with lower operating costs. The floor system does not need any maintenance, which is a big plus.

Integrating Systems

To prevent condensation from forming on the floor, the radiant cooling system is designed to keep the floor temperature about two degrees above the inside air dew point. A dual wheel dedicated outdoor air system economically provides dry air to the building. Also, designers located radiant piping away from doorways and at least 18 in. away from the building perimeter, keeping it a safe distance from any potential sources of moisture and air leakage. The dual wheel heat recovery system saves energy by using the return and exhaust airstream to reheat the supply air after dehumidification through the cooling coil.

The 46 well, 100 ton geothermal water-to-water heat pump system serves as the project's heating and cooling source. The geothermal

system is designed to cool the building directly (with no mechanical refrigeration, eliminating the need for a connection to the campus plant) since the ground temperature hovers around 55°F to 70°F year-round.

Though the cooling and heating coils are fed by the geothermal heat pumps, the system operation is similar to any packaged air handler using hydronic coils. Each office and seminar room has a dedicated variable air volume box controlled by a thermostat.

Controlling the HVAC system involved finding a balance between the hydronic radiant system controls and the building automation system (BAS). Several meetings were held between the engineer, BAS contractor and equipment vendor on integrating the radiant controls, learning how to program the system and interfacing with it.

Performance

Since most energy modeling programs do not specifically address radiant cooling and natural ventilation, several assumptions had to be made to model these systems. As can be seen in *Figure 1*, the building's performance closely follows the energy model.

The operable temperature for the radiant system is lower in the winter and higher in the summer due to the effect that radiant heating and cooling has on the human body. For example, people feel just as comfortable when the air temperature is 78°F with a radiant cooling system compared to 76°F with an all-air system, as noted in ASHRAE Standard 55-2010.

BUILDING ENVELOPE

Roof

Type Metal decking, concrete, 8 in. insulation
Overall R-value 40
Reflectivity 0.30

Walls

Type 12 in. concrete block, 4 in. insulation (east/west walls)
Overall R-value 20 (east/west walls)
Glazing Percentage 100% fenestration (north/south exposures); 60% frit (east/west windows)

Windows

U-value 0.29 (summer) and 0.31 (winter)
Solar Heat Gain Coefficient (SHGC) 0.61
Visual Transmittance 80%

Location

Latitude 34.68° N
Orientation NE-SW



Eric Plasecky/OTTO

Above An office overlooks the east plaza as well as an art studio's review space. Across the way is a seminar room. This open plan environment encourages occupants to work with and learn from each other.

Below View of lower level during construction, before the radiant floor system was encased. The floor system requires no maintenance.

“The building is extremely efficient and is also very comfortable,” said Kate Schwensen, FAIA, professor and chair of the School

of Architecture at Clemson. “It does have a wider temperature range than some buildings, but our energy-guzzling culture has gotten accustomed to a very small temperature range for internal comfort. Getting thermally comfortable with a wider temperature range is something our society needs to do if we want to be more energy efficient.”

Other Measures

To further the building's energy efficiency, automated lighting (T-5

fluorescent fixtures) with on/off daylight sensors and occupancy sensors keep the building lit only when necessary. The design also includes task lighting for individual study areas to supplement natural daylight when necessary.

The vegetated roof helps reduce the heat island effect, treats storm water and doubles the building's roof life. The roof is the largest university garden roof in the southeastern U.S.

The plumbing system incorporates high-efficiency, 1/8 gallon per flush urinals, high-efficiency water closets and low-flow faucets with automatic sensors. These measures reduce the water consumption by more than 35% compared to a typical university classroom building.

A large percentage of the site is covered with pervious paving materials. These surfaces allow storm water to transfer into the ground instead of municipal treatment systems.

Priority was given to the selection of construction materials that contained a high percentage of recycled

BUILDING TEAM

Building Owner/Representative
Clemson University

Architect of Record
McMillan Pazdan Smith Architecture

Design Architect
Thomas Phifer and Partners

General Contractor Holder Construction

Mechanical, Electrical Engineer Talbot & Associates Consulting Engineers, Inc.

Energy Modeler Talbot & Associates Consulting Engineers, Inc.; Transsolar

Structural Engineer
Skidmore, Owings & Merrill LLP

Civil Engineer Dutton Engineering

Building Physicist Transsolar

Landscape Architect Pond & Company

Commissioning Agent RMF Engineering



Photo courtesy of Uponor, Inc.



Eric Piasecki/OTTO

The southern approach to Lee III is through a bosque of trees onto the south porch and into portals along the free façade that allows visual and physical access to the various spaces within.

content and that were extracted and manufactured from resources 500 miles or less from the building. Some materials were harvested on campus. For example, trees that were removed from the building site were

milled and used for shelving in the faculty offices. Interior finish materials were selected to provide a higher standard of indoor air quality. Paints, sealants, flooring and agrifiber products pass strict standards regarding VOCs and off-gassing compounds that would negatively affect the indoor environment.

Conclusion

On a grand scale, the building has realized the teams' expectations. The success stems from the teams' willingness to take big risks with new technologies for sustainable design. From an architectural perspective, staff, students and visitors can all appreciate the wonder and amazement that comes when sustainable design is beautiful.

"There is so much I appreciate about this building," Schwensen said. "I love its spatial and visual transparency that helps to create an engaged and engaging learning environment. I revel in how the changing nature of daylight transforms the structure — when combined with the reflection and transparency of the building and the views to and through, it is magical.

"But most of all, I appreciate how Lee III is supporting the creation of a more collaborative, public and innovative design education culture." ●

LESSONS LEARNED

Inform Contractors, Owner About Hydronic Radiant Systems. Just as convincing the building owners to go with a radiant heating and cooling system took several months of back and forth, moving from concept to reality also proved a challenge when it came to installation. Because most contractors are not familiar with hydronic radiant systems, the design team held a special pre-bid meeting so contractors could learn about installing the radiant system, which included laying a flexible plastic pipe called cross-linked polyethylene (PEX). As a result, only one leak occurred due to a nail going through the radiant tubing. This was easily repaired by the contractor. The design team also informed the building owner regarding the radiant system's installation and maintenance. The floor system requires no maintenance and the water-to-water heat pumps only require occasional lubrication.

Natural Ventilation Challenges. During the first year of building operation, one automatic window operator has failed. Students are not responding to signals indicating when the manually operated windows may be open, a problem attributed to a lack of training or awareness. The natu-

ral ventilation signal system and automatic windows are deactivated during pollen season. Each class has a building stewardship committee, which provides instruction to the students on how the natural ventilation system works.

Zoned Occupancy Sensors Could Decrease Energy Use. The school would like to have common area lighting controlled by zoned occupancy sensors. Because the building is open 24/7, all of the common-area lights stay on even if just a few students are working in the space.

Need for Additional Sun Control on South Side. Additional sun control on the south side would have been helpful, but budget constraints eliminated the sunshades. More pin-up surfaces have been added, improving acoustics and function.

As Planned, the Building's Design is Encouraging Collaboration. Students are learning from other students in both casual and structured learning forums. Faculty members are not only offering integrated studio projects that mix the disciplines throughout each semester, but are also proposing research projects that cut across disciplinary lines.

ABOUT THE AUTHOR

Michael G. Talbot, PE., LEED AP Member ASHRAE, is a certified building commissioning agent and is the founding partner of Talbot and Associates Consulting Engineers in Charlotte, N.C.