Radiant Cooling and Heating Systems Case Study

Photo: Jim Simmons

Photo: EHDD

OVERVIEW

Location: Claremont, CA

Project Size: Classroom/Laboratory: 75,000 square feet (SF)

Construction Type: New Construction

Completion Date: 2015

Fully Occupied: Yes

Building Type: Mixed: Classroom/ Laboratory

Climate Zone: 3B

Totally Building Cost: $63 Million | $840/SF

POMONA COLLEGE MILLIKAN LABORATORY & ANDREW SCIENCE HALL

The Pomona College Millikan Laboratory and Andrew Science Hall (Millikan Building) is a 3-story, 75,000 square foot (SF) building comprised of physics laboratories, machine shops, a computer lab, teaching spaces, faculty and administration offices and student common areas located in Claremont, California.

The Millikan Building was studied under a California Energy Commission EPIC research project on radiant heating and cooling systems in 2016-2017. While forced-air distribution systems remain the predominant approach to heating and cooling in U.S. commercial buildings, radiant systems are emerging as a part of high performance buildings. Radiant systems transfer energy via a surface that contains piping with warmed or cooled water, or a water/glycol mix; this study focused on radiant floor and suspended ceiling panel systems.[1] These systems can contribute to significant energy savings due to relatively small temperature differences between the room set-point and cooling/heating source, and the efficiency of using water rather than air for thermal distribution.[2] The full research study included a review of the whole-building design characteristics and site energy use in 23 buildings and surveys of occupant perceptions of indoor environmental quality in 26 buildings with 1645 individuals.

Planning and Design Approach

The newly rebuilt Millikan building is Pomona's first LEED Platinum science/ laboratory building. The building design was informed by a collaborative design process that encouraged input from the building's stakeholders including faculty, students and staff from math, physics and astronomy. This integrated process allowed the vision and aspirations of the departments to be realized and has resulted in a weave of spaces to support student learning and 21st century skills while meeting ambitious sustainability and user comfort goals.

1 Thermally Activated Building Systems (TABS) and Embedded Surface Systems (ESS) are located in the floor. Note: Chilled beams also use water distribution but typical 'active' beams provide cooling predominantly by convection by blowing building ventilation air across cooling coils, and were not the study focus.

2 Water transfers thermal energy about 7 times more effectively than air. CBE Brower Study, CEC EPIC 2011 http://escholarship.org/uc/item/7tc0421f#page-1

nbi new buildings institute

CBE CENTER FOR THE BUILT ENVIRONMENT

STATE OF CALIFORNIA ENERGY COMMISSION

Team/Owner Details

Owner: Pomona College

Architect: EHDD Architecture

General Contractor: MATT Construction

Structural Engineer: Rutherford + Chekene

MEP Engineering: Integral Group

Civil Engineer: Stantec

Daylighting Consultant: Integrated Design Lab

Laboratory Consultant: HKS / Earl Walls Associates

Photo: Price Industries

TELUS Spark Radiant Ceiling Panels

Energy Use Intensity (EUI)[1]: 52

Figure 1: Percent difference of energy use intensity benchmarks compared to the Millikan Science Building measured performance. CEUS and CBECS are for offices. Labs21 data includes various offices with laboratory space similar to the Millikan Science Building. ASHRAE Std. 100 is for a mixed-use office in climate zone 3B.

1 Energy Use Intensity (EUI) is a common metric to measure energy consumption in kBtu/square foot/year

Radiant System

Over 20,000 SF of radiant ceiling panels serve the heating and cooling comfort in the 60% of the building (45,000 SF) that contains offices and classrooms. The team selected Steel Ceilings Airtite Radiant Torsion Spring panels to integrate with other ceiling design, lighting and acoustical systems. For the higher load portion of the building (40%) with labs and machine shop the team chose to apply active chilled beams for cooling, with heating from a coil on the airside Variable Air Volume box.

Ventilation - Supplemental Cooling

A dedicated outside air system (DOAS) compliments the radiant panels by addressing the ventilation needs and incorporating heat recovery and dehumidification to deal with outside air latent load. It also responds to CO_2 sensors in the space to supply demand control ventilation and has night set back on air change rates. A small pony chiller provides low temperature water for the small percent of time in this climate needed to dehumidify incoming outdoor air. Occupants can add natural ventilation through operable windows to supplement mechanical ventilation in the classrooms and offices. The large lecture hall, planetarium and lobby/atrium have supplemental fan coils to address infrequent peak cooling loads.

Cooling and Heating Plant

A dual-temperature chilled water system serves the building, with medium temperature water delivered to the radiant panels and chilled beams and cooler water delivered to the ventilation system for dehumidification. The medium temperature chillers provide the panels and beams with water at 58°F which increases efficiency due to a lower lift on the chiller. When the outdoor air conditions are favorable, the chillers can be bypassed with a water side economizer using a simple heat exchanger which allows the cooling towers to directly serve the medium temperature chilled water loop without having to operate the chillers, thereby saving energy. These cooling plant efficiencies contribute to the high performance outcomes of the Millikan Building.

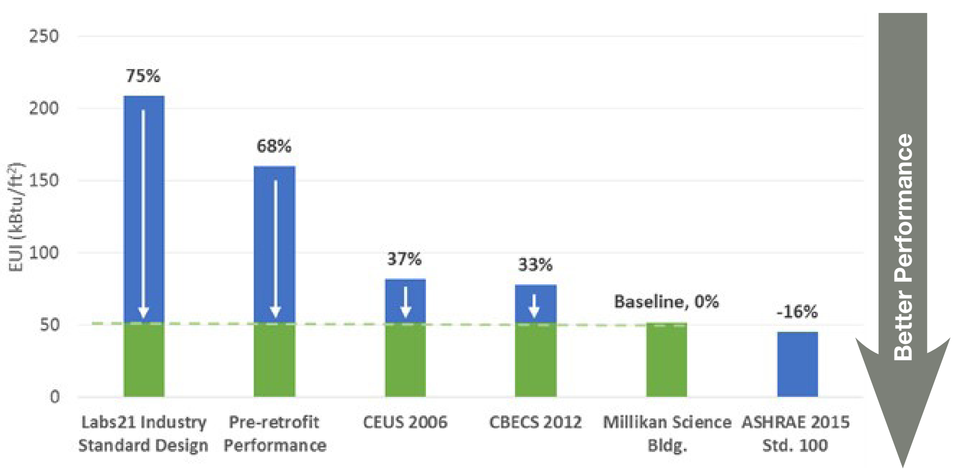

Photo: Jim Simmons

“The radiant system was vastly more energy efficient than an “all-air” solution. With the potential to drastically reduce ‘complaint calls’ due to thermal comfort issues during all seasons, and reduce energy costs, the radiant system became a win-win for the Client.”

Nate Eppley, Integral Group

Building Energy Use

The Millikan building has a whole building site Energy Use Intensity (EUI) of 52 kBtu/ft^2. Despite the inclusion of the very high energy use of labs and shops, Millikan Building’s energy use is significantly lower than the office-only EUI of the national CBECS[4] and California CEUS[5] datasets by more than 30% as seen in Figure 1. When compared to other mixed-use lab and office buildings with nearly equal ratios of these uses, and in similar climate zones, the Millikan Building is using an impressive 75% less energy. Further, the building achieved significant savings (68%) compared to its pre-retrofit levels. Through a range of factors, including the selection of a radiant system for heating and for cooling the office portion, the Millikan Building energy use is very low for its type and design.

Research Data Set Energy Use

The Millikan building is part of 23 radiant buildings in the full CEC research study where the bulk of the buildings were clear leaders compared to peers. Two thirds receiving an EnergyStar score of 90 or above, signifying that these buildings outperform 90% of comparable buildings. The research study set is on par with the high efficiency target set by ASHRAE in Standard 100 and several of the full research dataset buildings even reached zero net energy (ZNE)[6] performance levels (~25 EUI) demonstrating the use of radiant as a path to high performance buildings.

Thermal Comfort Feedback

Overall the thermal comfort of the occupants in the Millikan building is exceptionally high. 84% of the occupants reported that they were satisfied, 8% reported that they were neither satisfied nor dissatisfied and only 8% reported that they were dissatisfied. The satisfaction reported at the Millikan building is much higher than the full study sample dataset overall. The full occupant survey analysis shows that radiant and all-air buildings have equal indoor environmental quality, including acoustical satisfaction, with a tendency towards equal or improved thermal comfort in radiant buildings. The full report detailing the occupant satisfaction will be available in Fall 2017 at www.cbe.berkeley.edu.

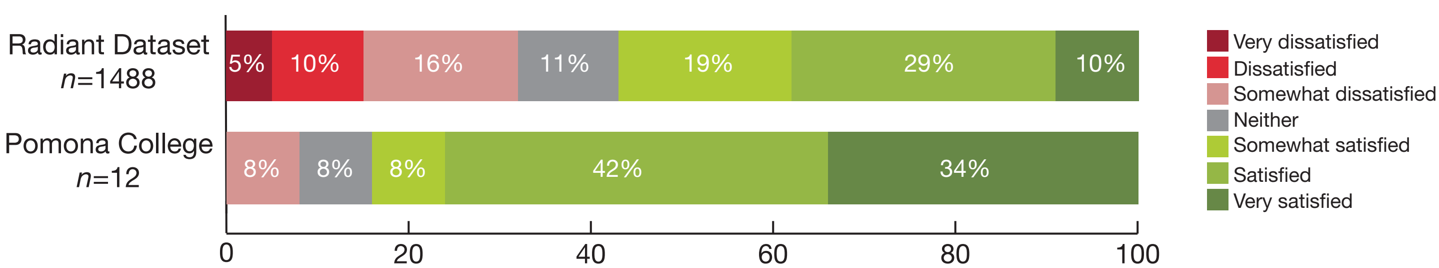

Figure 2: Results on thermal comfort question within the CBE occupant satisfaction survey. *Credit: Caroline Karmann*

3 ZNE buildings annually produce onsite energy from renewables equal to or greater than their annual energy use.
4 U.S. Energy Information Agency Commercial Buildings Energy Consumption Survey (CBECS)
5 California Commercial Energy Use Survey (CEUS)
6 ZNE buildings annually produce onsite energy from renewables equal to or greater than their annual energy use.

Photos: EHDD

Additional Efficiency Strategies and Features

Envelope

With the warmer temperatures in Southern California a key passive strategy was to manage solar gain to minimize cooling while optimizing daylight. The narrow east-west oriented building incorporated effective shading on the south using the roof overhang and external sunshades. The west façade minimized glazing and blocks direct sun with exterior horizontal shades. All exterior windows feature solar control glass with low-emissivity coating.

Lighting and Daylighting

Access to natural light for all occupants and a related reduction in the use of electric light are at the heart of the Millikan approach to illuminating the building interior. The east-west narrow design provides deep penetration of side daylight into the building while bi-directional skylights on the north facing roof provide constant illumination while minimizing unwanted solar heat gain. Tall windows in the main learning spaces were included to provide views and ambient daylight. The LED lighting throughout the building incorporates timers, daylight and occupant sensing through the Lutron Ecosystem management system.

Renewables

Millikan produces 6% of its own electricity needs through on-site renewable energy generation comprised of 105 solar photovoltaic panels rated at 34 kW.

Role of Radiant in High Performance

Although a radiant system is not solely the driver of good energy performance it can be an important part of an integrated approach from design and technology selection through to occupancy and operations. In California, low-energy outcomes rely on strategies to address the HVAC system which represents the highest proportion of commercial building energy use (32%)[7]. This research found the majority of the study set buildings (96%) were pursuing high levels of LEED certification, where reduced energy is a requirement. This mirrors the findings in the largest database of ZNE buildings where more than half of ZNE buildings in North America use a radiant system[8], and in a survey of 29 advanced ZNE and near ZNE buildings in California where 11 include radiant systems[9]. Both the Pomona Milliken Science Building and the full research data set use far less energy than various benchmarks and radiant is part of that outcome.

7 California Commercial Energy Use Survey (CEUS) 2006 http://www.energy.ca.gov/ceus/
8 New Buildings Institute Getting to Zero Database http://newbuildings.org/resource/getting-to-zero-database/
9 TRC and PG&E, ACEEE 2016 http://aceee.org/files/proceedings/2016/data/papers/3_636.pdf

This case study is part of a project focused on energy and occupant factors within the larger study Optimizing Radiant Systems for Energy Efficiency and Comfort. Additional case studies and the full research findings on energy use and occupant perceptions of the indoor environment will be available in Fall 2017 at cbe.berkeley.edu/research/optimizing-radiant-systems.htm and at newbuildings.org. The larger study will include design optimization, cost assessment and savings opportunities and will be available on the CEC EPIC site in 2018 at energy.ca.gov/research/new_reports.html.

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