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HONORABLE MENTION: RESIDENTIAL, NEW

The Sierra Terraces dorms are designed to perform 41.6% better than California's Title 24 energy code.

ENERGY-SAVING DORMS

By Glenn Friedman, P.E., Member ASHRAE

The California Central Valley is one of the most productive agricultural areas in the world. It's paradise for plants with 100°F (38°C) summertime design temperatures. In this valley the University of California (UC) started it's tenth campus in the town of Merced. Two dormitory buildings were added in 2005 as interest in sustainable buildings was increasing.

Its first phase of development in 2003 consisted of four projects: a central plant and associated infrastructure, a library, a science laboratory building, and an academic building containing classroom and office space. The second phase included one dormitory complex and a recreation building. The third phase included the two Sierra Terraces dormitory buildings, the focus of this article. To emphasize energy efficiency, the university set guidelines for the campus building energy use that included aggressive peak cooling targets for the different building types. The initial cooling energy budget for housing buildings was 0.7 tons (2.46 kW) of cooling per 1,000 ft^2 (93 m^2) or 1,425 ft^2 per ton (38 m^2 per kW) of cooling.

The Sierra Terraces project requirements included a low height, 350-bed dormitory and LEED Silver (New Construction, version 2.1). The early design team work included a series of design charrettes and integrated design team meetings. The design team embraced a low energy design concept but was daunted by the University's cooling target. Energy simulation and life-cycle cost analysis were done throughout the design process to assist design decision making.

Building Design

The design team looked at different building heights, site orientations and number of buildings. The final configuration was two long, narrow two-story buildings at right angles to one another with a high attic space to house HVAC

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Figure 1: Long narrow dormitory with high attic.

equipment and distribution. The rooms were against the outside walls with a central corridor. The window area was reduced to a level that was no larger than what was needed for the daylighting requirements.

The Sierra Terraces Dormitory Buildings 1 and 2 contain approximately 80,000 ft^2 (7432 m^2) of conditioned space including dorm rooms (70%), lounge rooms (5%), study rooms (2%), data closets (less than 1%), one residence leader's unit (1.5%), and other corridors and supporting areas (~20%).

HVAC systems for the dormitory buildings include four air-handling units (AHUs), two for each building. The AHUs are located in the penthouses below the roofs. Each long and narrow dormitory building is zoned by façade; each AHU serves a single façade of the building.

Zone control is provided by variable volume, variable temperature, change-over, control. The air-handling units have gas-fired heating, chilled water cooling, and variable temperature, variable-volume controls with economizers. Cooling is provided by the campus central plant chilled water.

The campus central cooling plant includes a large chilled water storage tank that is charged with chilled water at night and discharged during the day. Early in the life of the campus there is excess capacity in the tank, and it is discharged between 9 a.m. and 10 p.m. each day. Later in the campuses development, the capacity of the tank will more closely match the demand of the building, and the tank will be discharged only during hours of peak electricity charges, from noon to 6 p.m. each day. Heating of the Sierra Terraces buildings is provided by local high-turndown modulating gas-fired furnaces.

The dorm rooms are situated in pairs. Each pair of dorm rooms is an independent zone with a variable air volume (VAV) box. Each dorm room has one thermostatic sensor, and the two sensors per zone are both used to control the zone. The temperature sensors in each room control from the room sensor further from setpoint in a zone but ignore any sensor that drifts too far from setpoint (indicating a window being open). Zone VAV damper airflow is dual maximum control, allowing reduced minimum airflow.

Energy Efficiency

eQuest was used as the energy modeling tool to evaluate the buildings' energy performance. *Figure 2* shows the 3-D representation of the building in the energy model.

The energy efficiency measures were studied independently as well as combined together into energy efficiency packages to compare with a minimal code compliance base case model. The energy modeling outputs were then applied together with first cost, maintenance cost and economic parameters into an overall life-cycle cost (LCC) analysis. Based on LCC analysis results, the fol-

Building at a Glance

Name: University of California Merced, Sierra Terraces

Location: Merced, California

Owner: University of California, Merced

Principal Use: Dormitory

Includes: Corridors and supporting areas

Employees/Occupants: 350 students

Gross Square Footage: 84,000 ft^2

Conditioned Space: 80,000 ft^2

Substantial Completion/Occupancy: 2008

Occupancy: 100%

National Distinctions/Awards: 2010 ASHRAE Technology Award, Honorable Mention

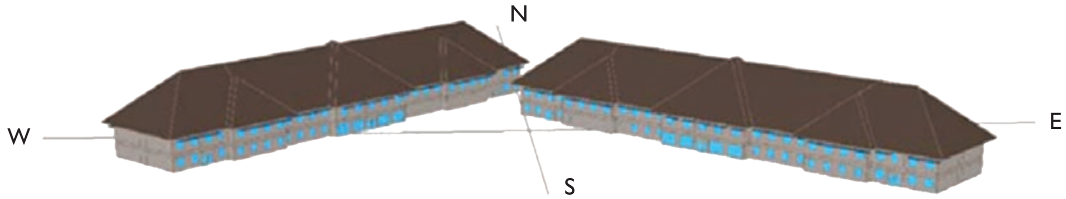

Figure 2: 3-D representation of the project buildings in eQuest.

Roof overhangs were optimized for solar shading the fenestration.

lowing energy-efficiency measures were incorporated into the buildings' design:

- Exterior shading from roof overhangs on the second floors;
- Double pane low-e window glazing;
- Low window-to-wall ratio;
- Low peak lighting power;
- Skylights with daylighting control in corridors;
- Campus cooling plant with thermal energy storage;
- Variable speed drives on the AHU supply and return fans;
- Variable speed drives on chilled water pumps;
- CO_2 demand-controlled ventilation in all study rooms and lounges;
- Direct digital controls at plant, system and zone level;
- Zoning by exposure and variable volume variable temperature changeover AHUs to eliminate supply air reheat;
- Static pressure setpoint reset: the static pressure setpoint for the central supply fans is reset from the most open VAV-box damper position. This allows the supply air pressure setpoint to drop at low loads, reducing fan energy;
- Outdoor air economizers to naturally cool the dormitory; and
- Heating generated by local high-turndown modulating gas-fired furnaces eliminating the hot water piping and the associated thermal losses of a boiler.

The following measures were also analyzed but not adopted because they were either not more efficient or did not meet the LCC analysis criteria:

- Packaged-through-the-wall heat pumps for the dorm rooms and split systems for lounge and study rooms;
- Airside heat recovery;
- Indirect evaporative precooling coils to precool outside air; and
- Boiler plant.

Table 1 summarizes the actual building annual energy consumption. The data was metered between July 2008 and June 2009. Since cooling is provided from the central cooling plant, the electricity use listed does not include the electricity use in the central plant. Instead, chilled water use is listed.

Based on modeled energy efficiency, the final design enables the buildings to perform 41.6% better than the California Title 24 2005 energy code baseline building. (California uses its own energy code, Title 24, rather than the national 90.1 energy code.) The two energy codes are considered closely aligned for energy efficiency. The buildings qualify for nine LEED credits under the Energy and Atmosphere Credit 1 category since it beats the LEED budget building by 45.6%. The overall project achieved a LEED Gold certification. The campus goal of 0.7 tons of cooling per 1,000 ft^2 (38 kW per m^2) was not achieved. In the end, the university understood its dormitory energy goal may have been too restrictive and was satisfied with achieving 0.8 tons (2.81 kW) of cooling per 1,000 ft^2 (93 m^2) or 1,240 ft^2 per ton (33 m^2 per kW).

IAQ and Thermal Comfort

The following measures were adopted to improve the buildings' IAQ and thermal comfort:

- Operable windows for natural ventilation;
- CO_2 demand-control ventilation in densely occupied areas;

Energy at a Glance

Energy Use Intensity (Site): 98.85 kBtu/ft^2

Natural Gas: 15.1 kBtu/ft^2

Electricity: 23.3 kBtu/ft^2

Other: 60.45 kBtu/ft^2 (chilled water from campus chilled water plant)

Annual Source Energy: 157 kBtu/ft^2

Savings vs. Standard 90.1-2004 Design Building: 41.6% (comparing to Title 24, 2005)

University Targets Evolve

The university chose a goal of energy efficiency, which requires low internal loads. Many internal loads are introduced by the occupants and are beyond the control of the design team. When the Sierra Terraces' design team discussed internal loads with the university, the university made commitments to limit the students' plug loads by allowing the students to bring only energy-efficient devices to their rooms.

For example, the university said it would limit refrigerators to small ENERGY STAR models. However, from the time these commitments were made to the time the Sierra Terraces project was completed, the university fell short of its projected enrollment. Based on this enrollment shortfall, the university decided that limiting the students' plug loads to energy-efficient devices might discourage new students from attending and enjoying their time at UC Merced.

The university abandoned its limitations on high-efficiency internal loads. As a result, the actual building energy consumption is higher than anticipated.

Advertisement formerly in this space.

- Locally controlled ceiling-mounted toilet exhaust fans operating fewer hours than a central building exhaust (reducing building exhaust and enhancing the buildings' positive pressurization);
- Central AHUs allow higher efficiency MERV-13 filtered air and improve the indoor air quality; and
- Adjustable thermostatic sensors in each sleeping room accessible to the occupants.

Innovation

The project's innovations include an integrated and collaborative design approach using energy modeling to make design decisions about building envelope, HVAC, domestic hot water and lighting. The collaborative design included energy modeling comparisons to help assist in the design decision-making process.

The HVAC innovations include:

- A highly efficient central cooling plant with thermal energy storage;
- AHU zoning by exposure and using variable volume temperature change-over AHU systems to eliminate reheat while ensuring thermal comfort;
- Local intermittent bathroom exhaust, resulting in better building pressurization and reduced infiltration;
- High turndown modulating gas furnace heating to eliminate hot water piping, the related pump energy and piping thermal distribution losses; and
- Temperature sensors in each room that allow control from the room sensor that is furthest from setpoint in a zone (but ignoring sensors in spaces that drift too far from setpoint due to a window being open).

Use	Quantity	Utility Cost	Normalized to Building Area	
Electricity	553,098 kWh	$59,699	6.83 kWh/ft^2/yr	$0.74 ft^2/yr
Gas	12,235 therm	$9,760	0.15 therm/ft^2/yr	$0.12 ft^2/yr
Water	9,505,061 gallon	$45,616	117.35 galllon/ft^2/yr	$0.56 ft^2/yr
Chilled Water	408,019 ton·h	$43,704	5.04 ton·h/ft^2/yr	$0.54 ft^2/yr

Table 1: Metered building annual energy consumption.

Operation and Maintenance

Dormitories are challenging for operations personnel since access to the rooms is limited and not desired by the occupants or the staff. The following measures were adopted to provide better operation and maintenance:

- Provide stairs to full height attics with floors to house the HVAC equipment;
- Central attic-mounted air-handling units are out of the weather for protection and easy central maintenance;
- The terminal zone boxes are attic mounted so no dorm room access is required; except for the local direct drive exhaust fans, which do not require maintenance; and
- The controls are direct digital controls to the zone level, which allows remote monitoring.

Cost Effectiveness

Cost effectiveness of this project is achieved through two approaches.

First, energy-efficiency measures were adopted into the buildings' design. The buildings consume less energy and have lower energy demand, reducing the buildings operation costs. The cost effective measures are listed in the energy-efficiency section.

Right-Sizing Equipment

The air-handling unit fan motors were selected for design conditions. However, these design conditions did not account for the first day the dormitories were opened. That day, when the students arrived and moved in, all the exterior doors to the central corridor were propped wide open. The outside temperatures reached 107°F (42°C), and the buildings heated up and did not cool off all night. After parents' complaints reached the university administration, the design team was given a new design direction: to replace all of the air-handling unit motors with the largest motors the units could accommodate to maximize the AHUs cooling capacity for move-in days.

Second, when analyzing the impact of each energy efficiency measure, life-cycle cost analysis for each measure, and for packages of measures, was performed according to university's LCC analysis guidelines. Only those measures that save energy and have a positive LCC impact were incorporated into the design to ensure the buildings are cost effective.●

Unanticipated Personal Control Consequences

The students have personal control over their dorm room windows. When the campus opened, the students were not given any advice on how to operate their windows. During the first week of school the daily temperatures were consistently reaching 107°F (42°C), and the rooms were hot, not able to cool off at night. When the design team investigated it was discovered that the students got up in the morning when the temperature was in the 70s and opened their windows to let in the lovely day's fresh air. Then, the students left for class. The design team found that as many as one-third of the windows were left open all day, overloading the HVAC system. The design team worked with the housing authorities and trained the students to close their windows when not in their rooms. This student education changed the students' daily habits, and the buildings were comfortable.