Science Building Rebirth

BY JEFFREY DEGREGORIO, AIA, AND ANDREA LOVE, A I A, HIGH PERFORMING BUILDINGS
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At the time of its completion in 1981, the Sherman Fairchild Biochemistry Building was groundbreaking as one of the first buildings for biochemistry in the world, but in 2009 it was in desperate need of renovation. In the spirit of the original building's innovation, the renovation meant to reestablish the building as home to the laboratory of the future for Harvard in terms of its design and sustainability. Located within the heart of Harvard's Faculty of Arts and Science campus, the Sherman Fairchild building was an ideal location to incubate the new SCRB department, which had previously been scattered among multiple institutions and buildings throughout the Boston area. The renovation needed to simultaneously develop a prototypical laboratory environment for the department, and also set the standard for environmental responsibility of the laboratories at Harvard. The design included multiple strategies at the building and user levels to achieve the greatest level of sustainable design possible.

Key departmental needs included:

- Increase of population density by 50%;
- Increase (doubled as compared to the existing building) in tissue culture and support zone requirements where significant time is spent versus the more traditional bench area;
- Increase density of high energy demand equipment and core facilities;
- Focus on shared floor and departmental resources versus two to four person laboratory rooms;
- Variability of group size;
- Importance of collaborative spaces and serendipitous interaction;
- Identity of newly formed department; and
- Centralized cores and services.

The laboratory renovation focused on the increased population density while also changing the fundamental relationship between bench-based laboratory space and equipment-based laboratory space. Support spaces were traditionally located in the center of a building in a series of rooms without natural daylight and disconnected from the bench area. The renovation design radically altered this relationship by locating an entire zone of support spaces along the exterior wall, allowing as much daylight as possible to penetrate deep into the building, which changed the working environment for researchers.

To better understand how researchers used their space, the design team shadowed researchers as they worked in their space for several days. Based on these "shadow studies" of researchers conducted early in the design, it was observed that they had migrated most of their workday to those support spaces. An additional support zone was established in the center of the building, which alternated between open cross corridors that functioned as shared equipment zones, and also connected the entire width of the building and smaller support rooms, such as freezer space, which did not need natural daylight.

Typically, existing buildings are renovated for lighter laboratory or non-laboratory uses because a 1980s era building includes many challenges such as low floor-to-floor height (only 10 ft, 11 in. of usable space), inflexible structural systems, and envelopes that are either failing or do not meet today's energy conservation goals. Because the Sherman Fairchild building uses a concrete waffle slab structure, it does not have many significant beams that would impede proposed mechanical solutions; however, the system is fairly inflexible and the size and quantity of any new holes in the floor slabs is limited. All of these challenges ultimately became the drivers for a highly sustainable renovation methodology that can be applied not only for the Sherman Fairchild building, but for many other existing buildings of this era and older.

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MECHANICAL

The laboratory program for the building is one of the highest intensity uses found on university campuses. In addition, the SCRB research required a much higher percentage of high load support spaces than most laboratories. The cooling of these spaces in conjunction with the challenges associated with the existing building's concrete frame and low floor-to-floor height led the team to focus on minimizing the ventilation rate for the building. This would provide the biggest energy impact and collateral benefits including the size of the necessary ductwork.

Following discussions with Harvard's Environmental Health & Safety group, the design team set the ventilation rate at 1 cfm/ft2 based on the minimum values set in the 2003 International

Mechanical Code (also consistent with ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality). Occupancy sensors further lowered the ventilation rate to 0.67 cfm/ft2 during non-occupied periods. The existing building also had multiple distributed smaller shaft spaces, which created an opportunity for a vertical distribution system for the ductwork and also reduced horizontal ductwork sizing. These strategies were essential elements in achieving the programmatic and sustainability goals for the project.

In addition to the minimum ventilation rate, supplemental cooling was provided for spaces that have high internal heat gains. This was provided by a hydronically based system that primarily used active chilled beams in open lab spaces and interior labs. The chilled beams are coupled with VAV boxes and two position boxes that are ultimately tied to occupancy sensors to provide supply and exhaust fan savings, reduce ventilation conditioning loads and steam consumption.

Active chilled beams require less energy than a conventional forced air system and allow the air-handling system to provide ventilation air while the space cooling requirements are provided locally, resulting in maintaining a reduced ductwork size, supply and exhaust fan savings, ventilation conditioning savings, reheat load reduction and chilled/hot water pumping savings. In areas with higher loads, such as tissue culture rooms, sensible-only fan coil units are provided. Since water has the ability to hold more heat per unit volume than air, it is also more efficient to pump chilled and hot water through pipes to active beams, rather than conveying conditioned air through ductwork using fans. Compared to an all-air system, the peak reduction is estimated to be 634,705 kWh annually and 7.5 MMBtu of steam annually, with a payback of 4.7 years.

The design team reviewed the ventilation rate with the users to ensure that we could meet the fume hood needs of the scientists. To maximize the quantity of fume hoods on a floor, designers selected high performance fume hoods so that the fume hood exhaust did not exceed the minimum ventilation rate. Also, we achieved further energy savings through the use of fume hood occupancy sensors that automatically shut the sash when unoccupied.

We incorporated a new manifolded system into the existing penthouse space while simultaneously building in N+1 redundancy. N+1 redundancy operates all five units in unison, but allows the use of a redundant unit to reduce pressure drop and lower fan energy use. Waste heat recovery is accomplished by capturing sensible and latent heat from laboratory general exhaust and transferring it to incoming supply air through the use of an enthalpy wheel. This system reduces the need to heat and cool the lab's 100% outdoor air supply, and results in the use of less campus chilled water and steam. A refrigerant heat pipe recovers sensible heat from exhaust air from a zebrafish housing facility. A heat pipe in lieu of an enthalpy wheel is used within the zebrafish facility to ensure no cross contamination occurs. The enthalpy wheels are anticipated to provide a discounted payback of less than five years.

Further energy savings were realized through the use of a 50 ton internal heat shift chiller. The system uses internal heat produced

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by program equipment plus the heat of compression needed for cooling in lieu of fossil fuels or campus steam for reheat in low load spaces needed due to minimum laboratory ventilation rates. Because heat is rejected within the building and not to the outdoors, the system does not require the installation of a heat rejection device (i.e., cooling tower) or the associated water use. This system is expected to pay back within approximately six years.

The original building included operable windows in all areas of the building. However, due to the tight operating conditions required in the laboratory the existing operable windows were secured shut, but could be made operable again in the future if the program in the building changes. Operable windows were maintained in all non-lab areas and reduced HVAC demands.

The project also included submetering by floor. This allows for accurate assessment of energy demand and consumption patterns. Touchscreen monitors/building dashboard displays are located at the end of each of the floors in the building and will provide building performance information to the occupants. The intent of these green screens is to help foster occupant awareness of energy consumption and sustainable building practices.

LIGHTING

Due to the tight floor-to-floor height, ceilings were minimized throughout the design in favor of exposing the existing concrete waffle slab and painting it white. The constraints of the existing building also provided opportunities to rethink the overall lighting strategy. Bench lighting levels can be as much as three times higher than standard office lighting levels and have traditionally been applied to the entire laboratory versus just at the work surface. However, observations made during a shadow study conducted early on forced the team to revisit the typical approach to laboratory lighting. The strategy focused on the optimization of daylighting, the reduction of laboratory ambient lighting and the focus on task based illumination to achieve the required light levels. Including the task light, the lab had an LPD of 1.16, which is a 17% reduction from the baseline for a lab (1.4 W/ft2).

Using a task light at each bench meant the overall ambient lighting could be reduced from 80 footcandles to 30 footcandles throughout. The team then developed a custom designed task light with integral vacancy sensor to provide the ability to achieve 80 footcandles at the work surface. Vacancy sensors differ from occupancy sensors in that they do not turn the lights on when they detect motion, they only turn lights off when no motion is detected. In lieu of traditional under counter lighting that can be blocked by equipment the team designed a new fixture to attach to the leading edge of an extended upper shelf, positioned to provide optimal illumination while casting the smallest shadow. This user-controlled fixture is so minimal that the light source is not immediately apparent. Energy-efficient fluorescent lighting and LED options were selected to provide optimal lighting in the research environments while reducing electricity demand of the lighting system.

The task ambient approach was implemented alongside a lighting control system, which actively turns down the ambient lighting when the appropriate amount of daylighting is achieved. Daylighting control is provided at the entire perimeter of the building. The system is so effective that the task lighting is often never turned on. These strategies combined have lowered lighting energy use by 55% as compared to previous lighting strategies at Harvard.

WATER

With minimal exterior scope, the project concentrated its efforts on internal water use reduction. As one example, the reverse osmosis system for the research labs is collected in a dedicated piping system and directed into two 750 gallon storage tanks in the basement. The water is then filtered, dyed blue (to distinguish it from potable water) and delivered to flushing fixtures throughout

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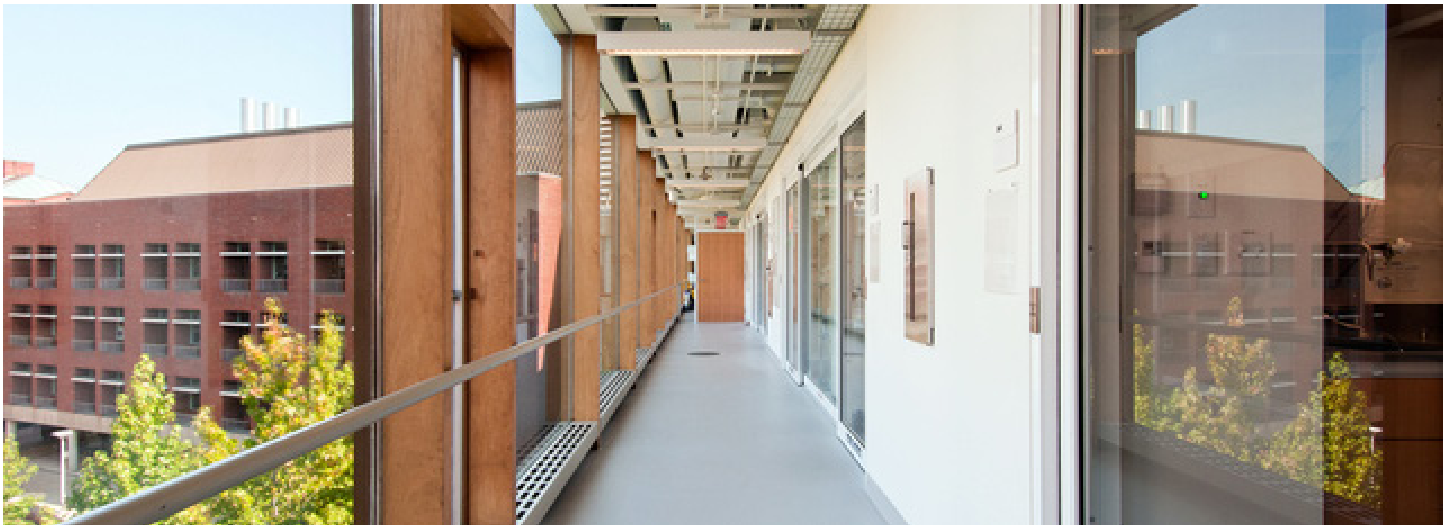

the building. This is equivalent to a 62% reduction in potable water used for toilets. Overall, with the greywater system and lowflow plumbing fixtures, the project has estimated a 42% reduction in potable water consumption from code and 79% reduction from the water use in the building before the renovation.

MATERIALS

When considering the overall interior design concepts the design team looked back to some of the concepts that made the building so popular with the original users. This included the use of butt glazed glass partitions for deep penetration of daylighting into the center of the building, natural materials and a fairly simple approach to exposed concrete flooring and exposed ceiling. The first step to achieve this was to remove any hazardous materials that were part of the original construction. This included the removal of asbestos-containing laboratory fume hoods and tabletops; as well as asbestos containing duct sealants.

The ceilings were removed in many of the areas where they had been added, and the existing cast in place concrete waffle slab was once again exposed in the majority of laboratory spaces and painted white (in lieu of the original brown) to allow light to reflect and penetrate deep into the building. The team selected materials with light colors and high reflective values to further perceptions of brightness and augment the lighting strategy. We complemented the minimal loft like spaces by using natural materials such as rapidly renewable cork and rubber flooring, wood doors and shelving (50% of new wood by cost is Forest Stewardship Council certified), and painted accent walls to provide interest and contrast. More than 33% of new materials on the project were manufactured regionally and 20% contain recycled content. In addition, 100% of the adhesives, sealants, paints and coatings are low VOC emitting.

PERFORMANCE

According to the Labs21 Benchmarking Tool, a high use, biochemistry research lab in Climate Zone 5A uses an average of 504 kBtu/ft2 annually. Although the density of the building was doubled, Sherman Fairchild was modeled to use an average of 20% less energy than a typical building at 401 kBtu/ft2. Since its opening in 2011, the actual energy use of the building has been closely monitored and has consistently been performing below the modeled expectations. The first year of operation was at 18% less than the model at 327 kBtu/ft2 but this has continued to go down as the building has been tuned and optimized/

The electricity has consistently operated at about 30% to 35% less than what was anticipated, piquing an interest of the design team to further delve into the building submeters to better understand the cause of the lower than anticipated use. Additionally, the chilled water use has been consistently less energy than was anticipated, and it currently operates at about half of the modeled load. The building's steam use was initially higher than the model, but adjustments to the heat shift chiller in September of 2014 brought that to almost perfect alignment with the model. In the last year, at 260 kBtu/ft2 the building has been operating using 48% less energy than the Labs21 average.

CONCLUSION

The challenges presented for the Sherman Fairchild Biochemistry building renovation created an opportunity to look for novel laboratory designs and innovative solutions surrounding the supporting infrastructure. By focusing on reducing demand, decreasing the size of required infrastructure, shifting toward hydronic-based cooling, and leveraging the latent qualities of the building without sacrificing the needs of the scientists, the designers created a roadmap for the next generation of renovations for laboratory use.