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RESEARCH REVOLUTION

ENERGY LAB WITH UNIQUE ROTATING TEST BED INSPIRES GLOBAL STUDY OF INTEGRATED SYSTEMS

BUILDING A RESEARCH 'SANDBOX'

Carousel test bed is challenging centerpiece of a 'plug-n-play' lab for green-system experiments

By Nadine M. Post

On Sept. 12, crews successfully rotated a 64-ft-dia turntable, complete with its unique cable management system, for the world's first revolving rent-a-lab for full-scale green-building-systems performance tests. The 40%-completed lazy-Susan building, which tracks the sun from the southeast to northeast by rotating 270°, is the trickiest part of FLEXLAB, a $15.7-million research complex at the Lawrence Berkeley National Laboratory, sited 100 yards from the Hayward fault in earthquake-prone Berkeley, Calif.

The 1,610-sq-ft turntable test bed is "undefined territory," says Steve Blankinship, project manager for FLEXLAB's general contractor, C. Overaa & Co. "It is an experiment within an experiment."

Adds Geoff Adams, project architect for Stantec Architecture, "No one has built a turntable with a building on top, especially in a seismic zone."

FLEXLAB, which stands for "Facility for Low-Energy Experiments in Buildings," includes a total of four stand-alone test beds designed as small office buildings but with interchangeable parts for "plug-n-test" experiments. When it becomes operational next year, the lab will be the first to run full-scale, dynamic tests that measure and compare the energy use of various green-building components and systems operating in concert.

"The building [sector] does not have a very good track record of putting together integrated systems that work," says Stephen Selkowitz, scientific leader for FLEXLAB's research-and-development program and the mastermind behind the revolving test bed. FLEXLAB is intended to improve that, he adds.

One goal is to validate energy-use analysis software. "You can talk theory, but the only way to convince anyone is to test through a mock-up," says Selkowitz.

The U.S. Dept. of Energy, which owns the Berkeley lab, is funding FLEXLAB through the American Recovery and Reinvestment Act of 2009. DOE will support the facility until it is self-sustaining.

Toward that end, FLEXLAB is casting a global net for research partners and sponsors, especially to rent the test beds. Owners, designers, contractors, utilities, universities, cities and vendors are all welcome.

"We are the first new user facility of the building-technologies branch of DOE," says Cindy Regnier, the manager of FLEXLAB, which is part of the Berkeley lab's environmental energy technologies division.

The lab already has collaborators (see sidebar, p. 6). FLEXLAB clones are in the works in Norway and Singapore, which is planning a rotating lab.

"FLEXLAB will help designers and technologists to widen their views from a silo technology perspective to one that values intersystem dynamics," says Stephen Mok, deputy director of the Centre for Sustainable Buildings and Construction of the Singapore Building and Construction Authority.

Regnier plans to take FLEXLAB's findings into the marketplace. "I am hopeful we can come up with off-the-shelf solutions for integrated designs," she says.

For that goal, the Berkeley lab has an agreement with PROSPECT Silicon Valley, which finds places to beta-test new technology. "There is no place like FLEXLAB, where you can test any number of building environments in one place," says Doug Davenport, PROSPECT SV's executive director.

FLEXLAB is a mix of new and retrofitted space. New construction consists of the rotating test bed and three static test beds, which contain 4,844 sq ft. The three single-story sheds are 40 ft x 30 ft in plan, plus a bump-out for mechanical and electrical closets. A high-bay shed has a 50-ft x 25-ft plan.

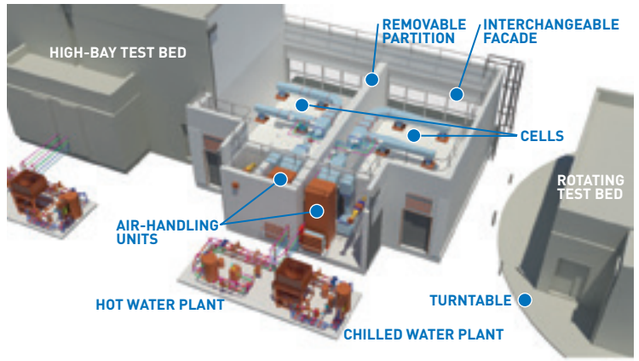
FLEXLAB also has two "living labs," occupied by Berkeley lab staff, in retrofitted space in an adjacent building. One 3,274-sq-ft room is for lighting and plug load tests. The other, a 379-sq-ft "smart" room, is for exploring virtual design and construction. The existing building also contains FLEXLAB's control rooms.

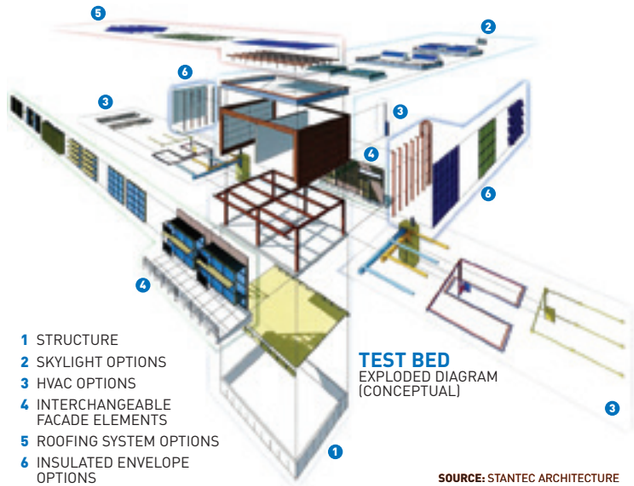
Stand-alone test beds have interchangeable parts, including cladding materials, windows, sunscreens, lighting, and heating, ventilating and air-conditioning (HVAC) systems. Users can adjust floor and ceiling elevations, remove partitions and, for ventilation studies, open windows. Researchers also can test most HVAC distribution systems, including underfloor air, radiant slab, displaced ventilation and chilled beams.

PHOTO BY ROY KALTSCHMIDT, LAWRENCE BERKELEY NATIONAL LABORATORY

SUN TRACKER Building the world's first turntable lab building—complete with utilities and located in a seismic zone—turned out to be more difficult than expected.

FOR RENT *Outsiders can "rent" FLEXLAB's reconfigurable test beds—full-scale mock-ups of office space with interchangeable facades, mechanical systems and more—for performance studies of green systems.*

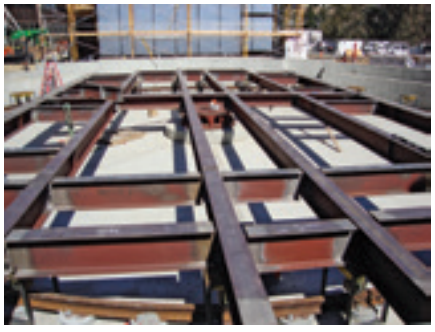




SOURCE: STANTEC ARCHITECTURE

RENDERING: TOP COURTESY OF INTEGRAL GROUP

$1-MILLION CAROUSEL RIDE *When FLEXLAB bids came in $1.7 million over the budget estimate, it looked as if the world's first rotating test bed might not get built. But the team cut out a static test bed and other elements, saving the turntable.*



SQUARE PEG, ROUND HOLE Unlike most turntables that have radial framing, FLEXLAB's has a grid of beams to better accommodate seismic forces.

BOGEYS The turntable stands on 22 bogeys, wheels that ride on a circular perimeter rail that sits on hockey-puck-like concrete bases.

GUIDANCE As turntable rotates, it pulls flexible-conduit slack from storage tray onto 11-ft-dia guide ring, attached under turntable near the central pivot.

TRY OUT The fabricator-installer first shop-assembled the turntable's custom trolley-in-a-tray cable management system before shipping it to the site.

FIXED TRAY Flexible conduit line for four types of cables comes in along concrete slab and wraps around a trolley drum before it feeds into guide ring.

CONGESTION Flexible-conduit route from trolley (right) to guide ring is devised to avoid sprinkler pipes and allow maintenance access in tight crawl spaces.

It will take a half day to two weeks to reconfigure a test bed, depending on the study. For comparative experiments, test beds can be divided into mirror-image cells. Wall insulation will prevent thermal transfer.

Initial fit-outs of the new test beds will match different eras of construction, from the 1980s forward, and be compliant with different energy codes. One cell will mock up a net-zero annual energy-use building.

FLEXLAB is outfitted with about 1,000 sensors for data collection, with potential for thousands more. Cameras record internal sun patterns for daylighting studies, while meters measure power, thermal loads, airflow, lighting and glare. The lab even has a weather station.

For vendors concerned about trade secrets, FLEXLAB's $1-million data-acquisition (DAQ) system is set up so that performance data from different vendors participating in a single test is not shared.

Selkowitz, who has been studying window materials, facade systems and daylighting at the Berkeley lab for 36 years, has long pushed for a rotational test bed. In the 1980s, he built a lab on a trailer chassis and rotated it either 180° or 90° by hitching it to a truck cab.

Orienting a test facade to different solar exposures enables direct, simultaneous comparison of identical strategies and technologies facing different directions,

SELKOWITZ

REGNIER

COVER STORY
GREEN BUILDINGS

says Selkowitz. The building also can be oriented for natural ventilation studies, either toward prevailing winds or non-ideal wind orientations. Rotation also can simulate some seasonal solar conditions.

For all the promise of rotation, Selkowitz's dream carousel almost died when Overaa's low bid of $10.3 million for the entire FLEXLAB came in $1.7 million over the $8.6-million budget estimate.

The turntable does not rotate 360° because the other sheds are to the east. Even so, the cost of 270° rotation is $1 million. That was "a real eye-opener" for the lab's scientists, says Richard Stanton, FLEXLAB's project director for the Berkeley lab's facilities group. "It is expensive to incorporate rotation into a permanent structure, meet seismic and safety codes, and deal with electrical feeds," he says.

After two months of value-engineering, including eliminating a static test bed and other elements, Overaa's price came down by $948,620 to an acceptable $9.4 million. The rotating test bed had survived the cuts. The lab issued a notice to proceed in June 2012.

Overaa's current contract, including add-ons, is at $9.8 million. The overall project is within budget, thanks to a contingency fund, says Ross Schaefer, FLEXLAB's project manager for the Berkeley lab.

The diminutive size and shed-like looks belie

PHOTOS COURTESY OF LAWRENCE BERKELEY NATIONAL LAB

FLEXLAB's complexity. "We've had to overcome many technical challenges," says Schaefer.

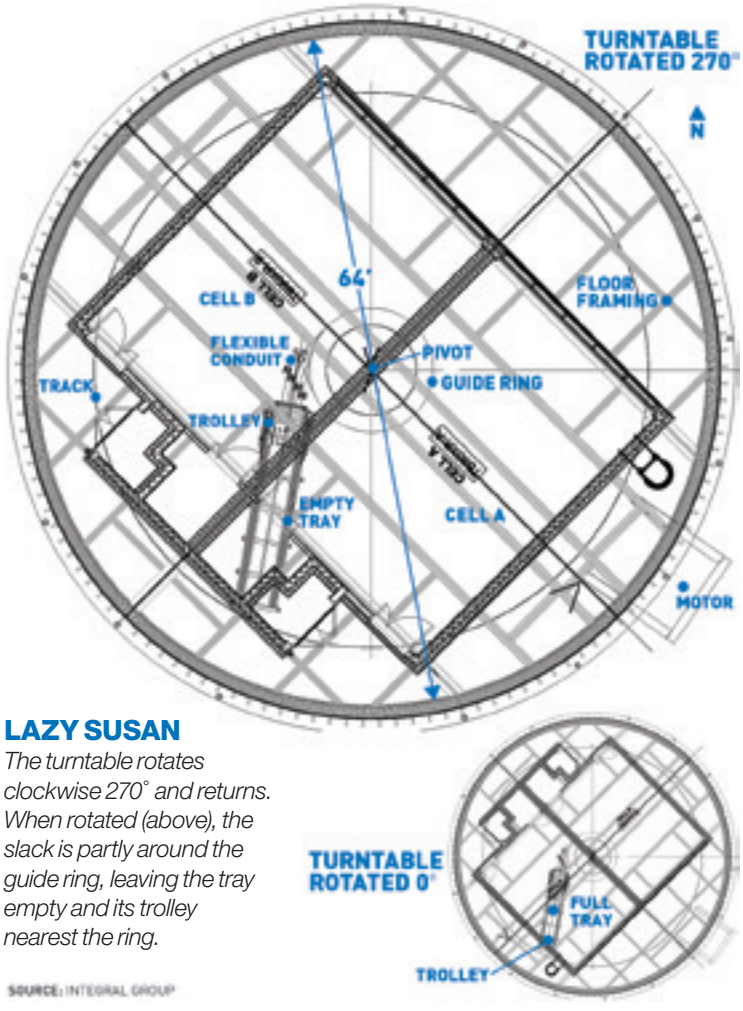
The test cells are really science labs disguised as office space. "You couldn't use rules-of-thumb on this job because it was so different," says Tyler Disney, project engineer for Integral Group, the mechanical engineer. "You really had to examine every detail."

For example, the HVAC systems must have the precision and data-collection ability of scientific apparatus, but Integral had to specify off-the-shelf components. For an office building, chilled-water supply temperature to a radiant slab is within ±2° F of accuracy; for the lab, it has to be within ±0.5° F. Integral's workaround, to reduce the water temperature variation, was to specify a buffer tank.

Achieving plug-n-play capability has been especially difficult. "It took a lot of care, planning and meetings to understand the [special] details and more than the usual amount of coordination and cross-team communication," says Overaa's Blankinship.

Building information modeling would have helped, but it was a casualty of the value-engineering, he adds. Only the mechanical contractor used BIM.

The interface of the DAQ elements, especially with the HVAC controls, is a huge effort, says Schaefer. DAQ system designer Cal-Bay Systems, a provider of medical-device and other monitoring systems, had no



LAZY SUSAN
The turntable rotates clockwise 270° and returns. When rotated (above), the slack is partly around the guide ring, leaving the tray empty and its trolley nearest the ring.

SOURCE: INTEGRAL GROUP

11TH-HOUR SOLUTION SOLVES CABLE-PROTECTION HEADACHE

Stantec Architecture was stumped, having gone down several dead ends trying to design a system to manage the 48 ft of flexible conduit in the crawl space under FLEXLAB's rotational green-systems test building in Berkeley, Calif. The team worried about the conduit slack, which allows the turntable to rotate without ripping out the electrical service, snaking around on the concrete slab and getting tangled up or damaged.

Without a solution, construction had begun on the $15.7-million FLEXLAB, which stands for "Facility for Low-Energy Experiments in Buildings." Finally, Geoff Adams, Stantec's project architect, approached mechanical engineer Tony Zavanelli, a Stantec principal.

Zavanelli—who engineers building mechanical systems, not widgets—saved the day. He devised a trolley-in-a-tray system that, like a lawn hose as it retracts into a reel, manages the flexible conduit. "The cable never slides. It is always going across a rolling surface, so there is no external wear," says Zavanelli.

The system—which was engineered with assistance from the 64-ft-dia turntable's fabricator-erector, Metalset—consists of an 11-ft-dia conduit guide ring attached to the underside of the turntable framing; a 20-ft-long steel tray attached to the crawl-space slab; and a trolley with a drum that moves back and forth in the tray. The drum is a horizontal cylinder with four sections, one for each conduit.

As it rotates with the turntable, the guide ring moves the trolley by means of a chain drive. The conduit slack loops halfway around the drum and either collects in the tray or is spooled out to the guide ring, depending on the direction of rotation.

The guide ring is made up of four rolled-steel angles, one for each conduit. The conduits wrap and unwrap around the guide ring as the building rotates.

At the zero point of rotation, there are no conduits wrapped on the ring. The zero point is the maximum slack position, with all the conduits in the tray—half in the bottom and half above—looped around the drum on the trolley, which is at the far back end of the tray, away from the guide ring.

As the building slowly rotates clockwise away from the zero position, the conduits are pulled around the guide ring, which, by means of the chain drive, simultaneously moves the trolley and drum forward in the tray, releasing the slack cable. The motion continues to the 270° point of maximum rotation, when all the conduits are wrapped around the guide ring, the trolley is in its fully forward position, and the slack is entirely out of the tray. The system works in reverse as the building rotates counterclockwise back toward zero. ■

RESEARCHERS IN NORWAY, SINGAPORE ARE CLONING FLEXLAB

Cindy Regnier, manager of the world's first research laboratory for full-scale performance mock-ups of integrated green-building systems, is canvassing the world to find partners and research sponsors for the facility, called FLEXLAB. Regnier is bent on doing her part to create a new paradigm for energy conservation in buildings. And she is using the lab as a springboard.

She seems to be succeeding. The $15.7-million FLEXLAB, which stands for "Facility for Low-Energy Experiments in Buildings," is still under construction on the campus of the U.S. Energy Dept.'s Lawrence Berkeley National Laboratory in Berkeley, Calif. Yet researchers in Norway and Singapore are so impressed with the idea of multisystem validation tests for energy conservation in office buildings that they already are planning to build FLEXLAB clones.

"It's exciting to see that, before we're even operational, we're having an impact abroad," says Regnier.

FLEXLAB is different from all other test facilities because users can reconfigure its "plug-n-play" test beds, swapping in different cladding systems, windows, sunscreens, lighting and mechanical systems.

This has caught researchers' attention. "Facilities like FLEXLAB are very important for reaching the policy goals set for energy efficiency in the buildings sector as these facilities will enable research and testing on a level not yet common," says Arild Gustavsen, director of the Research Centre on Zero Emission Buildings at the Norwegian University of Science and Technology.

The center plans to start construction next month on an office-building test bed, modeled after FLEXLAB, and a residential living lab. "We are planning to use the same data acquisition and control system developed for FLEXLAB," says Gustavsen.

Singapore's Building and Construction Authority expects to begin construction next year on Asia's first rotational test bed, also modeled on FLEXLAB's. The 11-meter x 11-m test bed will be on the roof of a new building currently under construction at the BCA Academy. The rooftop location will facilitate the study of building facade design and sun-shading solutions in relation to the sun path pattern in the tropics, says Stephen Mok, deputy director of BCA's Centre for Sustainable Buildings and Construction.

FLEXLAB also has other collaborators, including a non-profit start-up in San Jose, Calif., called PROSPECT Silicon Valley. Like a matchmaker, the group plans to help connect FLEXLAB researchers with new-system field testers in real, occupied office environments. The goal is to demonstrate the commercial viability of building-energy conservation systems developed at FLEXLAB. ■

experience with construction submittals. It took a while to work out an approvals process, he adds.

Still, the rotating test bed, not designed by the bid deadline, caused the greatest angst. In most so-called revolving buildings, only the floor rotates around a stationary core that contains utilities, says Stantec's Adams. The Berkeley building has no core.

During design, Stantec's vision was to route services up through the turntable's central pivot foundation, where rotation could be handled easily. During construction, the approach became problematic due to the foundation's complexity and the quantity of utilities.

In the end, only the 4-in.-dia fire-sprinkler main is located in the center. All cabling conduit for various systems was stubbed up into the crawl space, 8 ft from the center. The location is one of two fixed cable ends. The other, on the turntable's underside, moves with the rotation. That lengthens the distance between the two cable end positions, which creates a need for slack.

The carousel's reset speed is 180° in 10 minutes; its test speed is 10% slower. Despite that, the team decided it would be unacceptable to allow the slack conduit to slide like a loose hose on the crawl-space slab.

Tensioning devices and pulleys would apply too much load on the cable ends. The solution, designed by Stantec with a design-assist from fabricator-installer Metalset, is a system that relies on a trolley-in-a-tray assembly that spools the slack to a guide ring (see sidebar, p. 5). Macton Corp. supplied the turntable itself under a design-build contract.

The static sheds, which are 80% complete, are slightly ahead of schedule for year-end completion, but the rotating shed is one month behind schedule.

The lag isn't dampening anyone's enthusiasm. "We are convinced FLEXLAB's impact on energy conservation will be significant," says Chun-cheng Piao, a senior manager of HVAC maker Daikin Industries Ltd. and a member of FLEXLAB's advisory committee.

FLEXLAB is "a sandbox for ideas," adds Integral's Disney. "We brag about projects, but this one is really gratifying because it will support energy-efficiency work throughout the industry." ■

OFFICE BUILDING MOCK-UPS The $15.7-million FLEXLAB development at the Lawrence Berkeley National Laboratory consists of four stand-alone test beds in a row, including one that rotates (far left) and one that is two stories. There are two occupied test beds in retrofitted space in the Berkeley lab's existing building, which also contains FLEXLAB control rooms.

RENDERING COURTESY OF LAWRENCE BERKELEY NATIONAL LAB