centerline

Newsletter of the Center for the Built Environment at the University of California, Berkeley

Summer 2009

Designing Integrated Systems

Director's Note

Contents

Feature

Integrated Systems Design 3

Project Updates

New Center for Resource Efficient Communities 6

Occupant Surveys for Hospitals and Abroad 7

UFAD Simulation Workshop Planned for October 8

Exhibition and Website on High-Performance Facades 8

Survey Kiosk for Stores and Public Spaces 9

Clothing Interface for Comfort Simulation Model 10

People

Interview with Corinne Benedek 11

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Dear Industry Partners,

Although the campus seems quiet during the summer, CBE has been humming with new research activities. This summer we started two new research programs supported by the California Energy Commission's Public Interest Energy Research program. These programs have been under development by CBE and PIER staff (notably Chris Scruton, Norm Bourassa, and Elaine Hebert) for quite some time, and we are very happy to have them underway.

The Center for Resource Efficient Communities (CREC) extends CBE's research beyond the building envelope to urban streets, pedestrian spaces, and suburban communities. An initial technical goal is to help move people from cars to sidewalks, to bike lanes, and to transit. An article on this new center is included on page six of this *Centerline*, and we will report more on CREC's work in the near future.

We also began a three-year research program entitled Advanced Integrated Systems Technology Development, which will support the integrated systems research described in the article beginning on page three, along with other topics that we will report on in our fall conference.

As with all of our research, we look forward to collaborating with you on these projects, as your continuing input adds tremendous value to our work.

Sincerely,
Edward Arens

Designing Integrated Building Systems

Researchers and practitioners are learning that two (or more) systems are often better than one.

As the green building movement expanded in the 1990s, *integrated design* became the mantra of green building proponents. The traditional design process, (cynically described as tossing the plans over the transom) in which engineering was done after the architectural concept was complete, became obsolete for many practitioners. Integrated design was the new paradigm, allowing the entire design team—along with owners, building operators, and other stakeholders—to provide early design input. Opposed to the conventional linear design process, integrated design is an iterative process in which multiple options are evaluated and the design carefully optimized for performance.

In this sense design integration describes a *process*. However, there are other ways to consider how to integrate building design for optimal performance. Researchers at CBE are beginning to catalogue and study buildings with integrated *systems*, that is, buildings that use two or more technologies or strategies to provide a level of performance that one system alone can not. Preliminary surveys of dozens of innovative projects show that many high-performing buildings rely on multiple HVAC solutions to reduce energy consumption while achieving good indoor environmental conditions.

Designing a building that uses two or more systems concurrently can be complex, and there is very little in the way of design guidance or modeling tools to assist design professionals. As we've seen with other emerging energy-efficient technologies, such as underfloor air distribution (UFAD) and advanced facades, there is typically a gap between the work done by early adopters and the research necessary to understand the performance of completed projects. For integrated systems design, there is a need for case study research and detailed monitoring data to provide better feedback and design standards. A series of CBE projects currently underway have started to address this.

To understand current design practices with multiple systems, CBE first conducted a literature review to identify high-performance buildings that include two or more of the following systems: underfloor air distribution, displacement ventilation, radiant panels and slabs, natural ventilation, direct outdoor air supply, chilled beams, geothermal temperature control, and demand-controlled ventilation. Based on the 35 high performance projects CBE profiled, the most common integrated systems involved radiant slabs or natural ventilation, and in many cases both.

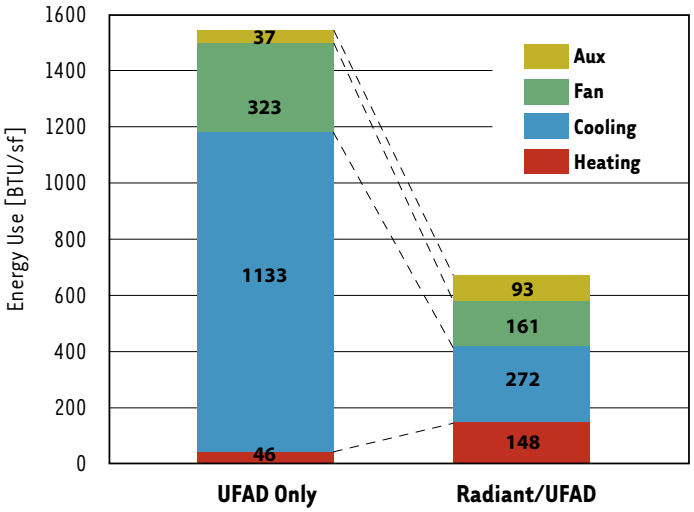
Designers are combining radiant systems with underfloor air distribution and/or natural ventilation to meet aggressive energy goals.

From this survey of projects we found that designers are relying more and more on radiant heating and cooling, taking advantage of water's superior thermal capacity and distribution efficiency. Because radiant systems provide no ventilation and may have limited ability to reduce loads, these systems require integration with other systems for air supply and sometimes additional cooling. Our

preliminary survey found that radiant systems are being integrated with underfloor, displacement, overhead and natural ventilation. In many cases, the driving factor is new aggressive energy savings targets required by new state and federal goals, and the 2030 Challenge.

One combination that shows promise is the use of radiant slabs with UFAD. In addition to providing low-energy air delivery, combining radiant slabs with UFAD offers the added synergy of allowing the slab system to efficiently remove heat loads that would normally lead to thermal decay in the underfloor supply plenums.

Fred Bauman, Research Specialist at CBE, believes the Radiant/UFAD combination represents a very promising integrated HVAC solution. "We've had some impressive results from preliminary EnergyPlus simulations, which showed a cooling energy savings of over fifty percent compared to a conventional overhead VAV system or a UFAD system alone." Earlier this year, CBE collaborated with Paul Raftery, a Fulbright scholar and visiting PhD student from the National University of Ireland, Galway, who spent time working at Lawrence Berkeley National Lab (LBNL). The focus of Raftery's work was a detailed simulation of the Radiant/UFAD strategy using EnergyPlus, which includes the new UFAD capabilities developed by CBE. He presented preliminary findings at CBE's April 2009 Conference, including a comparison of energy use time series-data, and the pros and cons of combining UFAD with radiant systems (see graph and inset box above).



Preliminary simulation results for UFAD only and Radiant/UFAD buildings in a San Francisco climate, for the month of August. Source: Paul Raftery presentation, CBE April 2009 Conference

Energy and Design Implications of Combined Radiant/UFAD Systems

Advantages	Disadvantages
Reduced HVAC energy use in cooling season	Increased summer morning heating
Improved electricity demand profile	Reduced comfort in early morning (7–9 am)
Reduced thermal decay	Added cost and complexity of radiant system
Higher chilled water and lower hot water temperatures	Increased size of cooling tower (50% larger)
Improved thermal comfort (10 am – 6 pm)	Acoustical mitigation required for exposed concrete ceiling
Reduced costs from smaller chilled water plant (75% smaller) and air system (50% smaller AHU fan), and reduced floor height	
Eliminates return plenum	

Source: Paul Raftery presentation, CBE April 2009 Conference

To further explore the energy and operational impacts of Radiant/UFAD buildings, CBE has begun a field study of the David Brower Center in Berkeley, which opened last May. The innovative system design by Rumsey Engineers incorporates radiant slabs in combination with UFAD, using a nighttime pre-cooling strategy for the radiant system. CBE has been in close contact with the design team and facilities personnel to better understand the building's energy management system, and to implement the detailed energy monitoring planned to begin this fall. With support from the California Energy Commission PIER Program, CBE will install

Contractors completing the David Brower Center (building at right) earlier this year.

and monitor additional metering equipment so that the building's performance can be broken down and analyzed by end-use.

We are planning additional research on Radiant/UFAD systems, including detailed energy simulation of the Brower Center for comparison to results from the field study. One of the project's major goals will be to refine the control capabilities of EnergyPlus, and to identify and correct imitations identified in the early simulation exercise. For example, the current version of EnergyPlus poses an obstacle to researchers and designers because it can not model the simultaneous operation of air and radiant systems. For designers optimizing integrated systems, control strategies are critical to success, and accurate simulations must include concurrent as well as change-over control options.

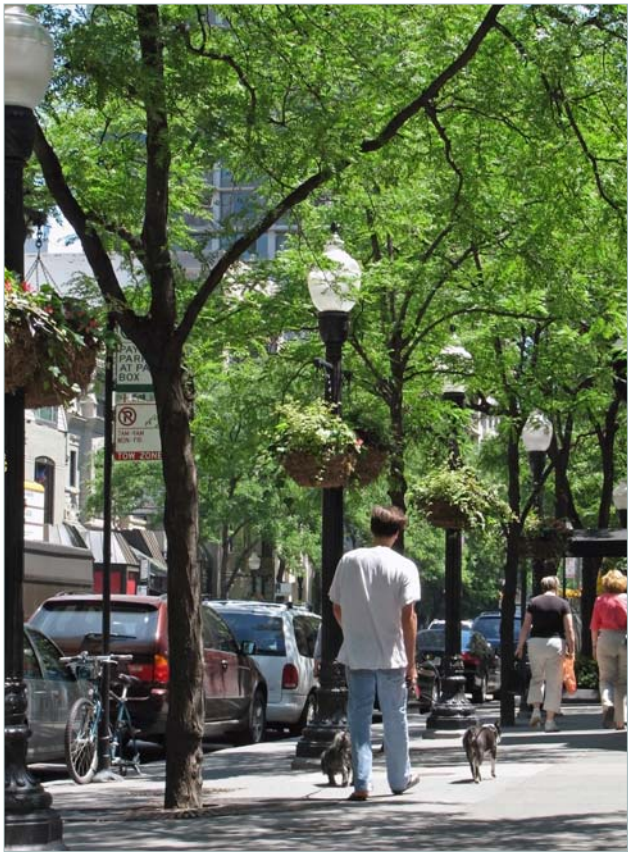
Some practitioners debate the use of EnergyPlus for HVAC design and compliance, citing its complexity and the lack of a usable interface as barriers. However, CBE post-doctoral researcher Kwang Ho Lee, who has used EnergyPlus extensively in his work, points out that the tool has many advantages that make it a valuable research tool. "It considers thermal decay in the UFAD system, performs the simultaneous simulation of zone, system and plant components, it conducts heat balance on each surface including the radiant heat exchange, and it considers thermal mass in slab-based radiant systems. These are things other energy modeling tools can't do." (CBE will be hosting a workshop on simulating UFAD buildings using an EnergyPlus Toolkit, and will discuss using the tool for Radiant/UFAD systems. See page eight for more information.)

CBE has also studied design strategies that integrate natural ventilation with radiant cooling. This combination has become increasingly popular due to its high potential for reductions in both overall energy use and peak demand. The Kirsch Center for Environmental Studies, Aldo Leopold Center, Nueva School Learning Complex and the IDeAs office building are among the high-performance buildings using this strategy. One reason for the enhanced energy performance is that no fan energy is required when natural ventilation is adequate. A further advantage is that the lower mean radiant temperature of interior surfaces permits higher air temperatures while providing the same level of comfort. In some climates, the radiant slab can be cooled at night solely with an oversized cooling tower, with no need for a chiller. For research recently completed in collaboration with Phil Haves from LBNL, CBE developed an EnergyPlus/Google SketchUp model of a radiant-cooled, mixed-mode building using the Kirsch Center as a prototype. The study used parametric simulation to test how the integration of natural ventilation and mechanical cooling varies in different California climates. The research also offered lessons for how EnergyPlus could be improved to model mixed-mode control algorithms used in practice.

The rate of innovation in the building industry appears to be increasing rapidly, and we expect to see design practitioners experiment with new combinations of technologies as they strive to meet low-energy goals. In addition, new products such as active and passive chilled beams are being adopted, providing additional options for designers. As we have done in the past, CBE plans to work closely with our industry partners to monitor and evaluate new design concepts, in order to provide feedback and guidance to the building industry.

Project Updates

Berkeley Launches New Center for Resource Efficient Communities



This summer marks the start of a new research center at UC Berkeley that will study community-scale resource and energy efficiency. Launched with support from the California Energy Commission PIER Program, in its first year of operation the Center for Resource Efficient Communities (CREC) will conduct research on four specific research topics, and also produce a scoping study to define a research plan for future years.

Two of these research topics build on work previously conducted at CBE, including a study of outdoor comfort of pedestrians and bicyclists, and the development of a wireless monitoring system to study pedestrian behavior. Two additional topics will integrate research being conducted by other groups at UC Berkeley and Lawrence Berkeley National Lab, including the assessment of the resource efficiency of pedestrian and transient-oriented developments, and the development of new approaches to the evaluation of "cool communities."

Louise A. Mozingo, Associate Professor of Landscape Architecture & Environmental Planning and Urban Design, will serve as Director of the center. Bill Eisenstein will be the Executive Director. As Mozingo explains, "Our work is to take the qualitative and quantitative research that has been done, and to bring it into a coherent picture that can be brought to bear on planning and zoning in the state." She points out that as CBE has conducted research to impact building standards, the work conducted at CREC will target planning standards, ultimately to meet greenhouse gas reductions required by AB32 and SB375. She also notes that affecting planning standards is a long process. "First you need robust data from verifiable sources, then you must connect with and convince people who set policy, finally you need to influence state and local jurisdictions."

CBE Director Edward Arens, who was influential in establishing the new center and will serve as a Faculty Associate, looks forward to expanding the scope of UC Berkeley's building science research to an urban scale. He explains that the center will focus on a range of scale between individual buildings and the city planning scale, looking in detail at sidewalks, bike lanes, and transit stops. This work can have important impacts in warm climates such as California's Central Valley, where much of the state's future development is expected. He explains, "Cars are an extension of the air conditioned environment in buildings, so to get people to use cars less, we have to quantify how to keep them comfortable outdoors."

New Versions of Occupant Survey Tool to be Implemented in Hospitals and Abroad

CBE's survey team has been involved in several new research efforts this summer, including planning for the implementation of a new survey for use in healthcare facilities. This survey resource has been developed with a special focus on acoustical performance, an aspect of indoor environmental quality that CBE has found to be poor in many buildings. In this survey we have included new questions to investigate acoustical performance, with a special focus on occupants' expectations regarding acoustics and speech privacy.

In order to populate our database with these types of projects, we have offered the use of the healthcare survey for free. Several firms and organizations plan to take advantage of this offer, including CBE Industry Partner HOK. We are planning to implement the new survey in at least seven HOK-designed healthcare buildings, as part of an extensive post-occupancy evaluation study planned by the firm. In addition to the occupant surveys, HOK staff plan to gather and analyze data on energy use and generation, water use, and stormwater runoff.

Zorana Bosnic, HOK Vice President and Sustainable Design Director, says that occupant feedback about indoor environmental quality is "invaluable to HOK's healthcare design concepts that focus on individuals' experience and comfort as a key to a positive impact on the healing process," and that HOK's collaboration with CBE is a unique opportunity to approach the post-occupancy evaluation of these projects in a holistic way.

CBE's survey research team hopes to implement the hospital survey in a large number of buildings by the end of this year, and to present the results at the 2010 Healthcare Design Conference. This survey instrument was developed with input from a wide range of industry partners including Armstrong, Cohos Evamy, HOK, and Mahlum, and also from the Center for Health Design.

William Beaumont Hospital, one of the locations where the CBE hospital survey will be implemented. Architecture: HOK; Photo: Doug Snower

We have also been successful in extending the use of our survey research internationally. The survey has now been translated into Finish, Italian, German, and is currently being translated into Spanish by Bath Engineering and partner PG&E. We will also be translating the survey into Chinese this fall. Working with the University of Padua and an Italian energy certification agency, we have completed surveys in two buildings in Northern Italy, and have contributed to the Italian Air Conditioning Journal, *CDA*. One of the buildings, a new office building in the city of Bolzano, received some of the highest survey results of all buildings in the survey database. The building includes several high performance features including underfloor air distribution and geothermal heat pumps.

We are currently collaborating with Urban Land Institute (ULI) on the planning of a lunch-time seminar to be held in San Francisco in early 2010, on optimizing the performance of existing buildings. We plan to present case studies of retro-commissioning projects, with a panel of three presenters followed by Q+A. We are seeking speakers for the seminar and would welcome participation from our industry partners.

Reminder: We are offering free surveys for hospitals and multi-unit residential buildings, and any buildings in Europe (language permitting).

UFAD Simulation Workshop to be Held at Brower Center

In conjunction with our Industry Advisory Board Conference this fall, CBE will host a workshop for industry partners and invited guests on the use the Underfloor Air Distribution (UFAD) EnergyPlus Toolkit that has been developed by CBE. This toolkit, which uses the newest version of EnergyPlus, includes an Excel-based interface and associated EnergyPlus input files that allow users to easily simulate a prototype three-story office building with either a UFAD or conventional overhead variable air volume (VAV) system.

The event will be held at the David Brower Center in Berkeley, a recently completed building designed by WRT Soloman and Rumsey Engineers, which will be the focus of a future CBE field study on integrated systems (see page two).

Although the standard interface for EnergyPlus may be a barrier to many potential users, the interface provided in the UFAD Toolkit allows users to easily change selected design and operation parameters that drive system performance. Among these are internal loads, window area, climate, floor area, and orientation, as well as HVAC parameters for both UFAD and overhead VAV systems. Users can easily conduct side-by-side comparisons between various HVAC systems to understand their impact on building performance. Parametric runs can also be made to study the impacts of different design and operating strategies.

In addition, the toolkit allows users to view simulation results in a number of ways, including hourly zone-by-zone results, monthly or annual energy use intensity for the building and HVAC components.

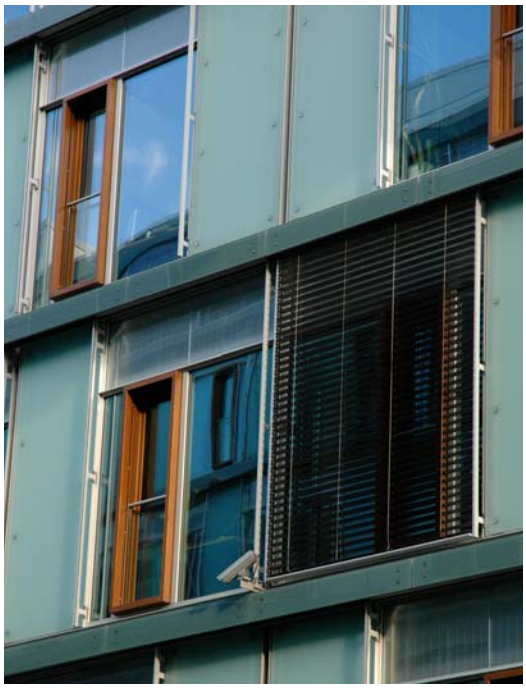
CBE's simulation research team is already using these tools for our studies on the optimization of UFAD systems and other research. We hope to put these tools into the hands of practitioners to get users' feedback and to enable the design of high-performance UFAD buildings. We will also discuss modeling buildings with both radiant slab and UFAD systems. The workshop will be held in the afternoon of Wednesday, October 22nd. For more information please email us at cbe@berkeley.edu.

Exhibition and Website on High-Performance Facades

Mark Perepelitza, an architect with CBE Industry Partner ZGF, and also a graduate student researcher at UC Berkeley, recently completed an exhibition and associated website on high-performance facades in Northern Europe. The exhibition, "Intelligent Skin: Green Innovations from Northern Europe," was on display at the Portland chapter of the AIA through the month of July. Perepelitza also completed a website that explores facade performance topics in detail, with 21 cases study buildings that he documented during his field study research. The site discusses how facade design can address human needs, and tools and analysis methods available for the design of high-performance facades.

Perepelitza notes that these examples demonstrate how extremely high-performing buildings can be aesthetically compelling with good energy performance and comfortable interior environments. "Rather than a static enclosure, the building skin has the potential to capture, filter, and integrate natural ventilation and daylight, manage solar heat, and provide visual and physical connections between inside and out."

The research and exhibition was done in collaboration with BetterBricks, CBE, LBNL, and the University of Oregon Energy Studies in Buildings Lab. The website is online at: http://betterbricks.com/design/integratedfacades



Innovative facade elements on the Jakob Kaiser Haus 2, Berlin. Photo: Mark Perepelitza

Survey Kiosk Will Enable Occupant Comfort Studies in Stores and Public Spaces

This summer we developed a freestanding survey kiosk that will allow us to gather information from transient building occupants in retail stores, lobbies, museums, and other public spaces. The kiosk will initially be used to investigate the potential for using thermal mass and pre-cooling strategies to reduce peak cooling loads, a multi-year project being conducted by the PIER Demand Response Research Center at Lawrence Berkeley National Lab.

CBE's role in this project has been to evaluate the impacts of pre-cooling strategies on building occupants. In previous hot weather studies, we developed simple push-button "polling stations" that allowed shoppers to indicate their sensation and thermal comfort using a simple 5-point scale. Our new device consists of a commercial kiosk with an interactive touch-screen interface. Users are prompted by a Flash-based interface to input information on three screens: (1) gender, age range and the amount of time spent in the store; (2) the clothing they are currently wearing; and (3) their sensation and comfort levels. After submitting their information the users are shown a 5-letter code that they can use to enter a raffle for $5 discount cards.

The project team is planning to implement the pre-cooling control strategy and the kiosk in a Cost Plus World Market in San Jose. The study will be conducted for a number of weeks to collect a significant number of responses, and we will simultaneously measure the air temperature in the store. Additional information on the demand response pre-cooling project is available at http://drrc.lbl.gov/drrc-3.html.

We also plan to use the kiosk in future studies, including the outdoor comfort studies to be conducted with the Center for Resource Efficient Communities (see page six).

Graduate Student Researcher Elliot Nahman configuring the kiosk software in CBE's building science lab.

Welcome screen of survey to be used in the demand response study.

Clothes Make the Model: Advanced Clothing Interface for the Comfort Model Simulation Tool

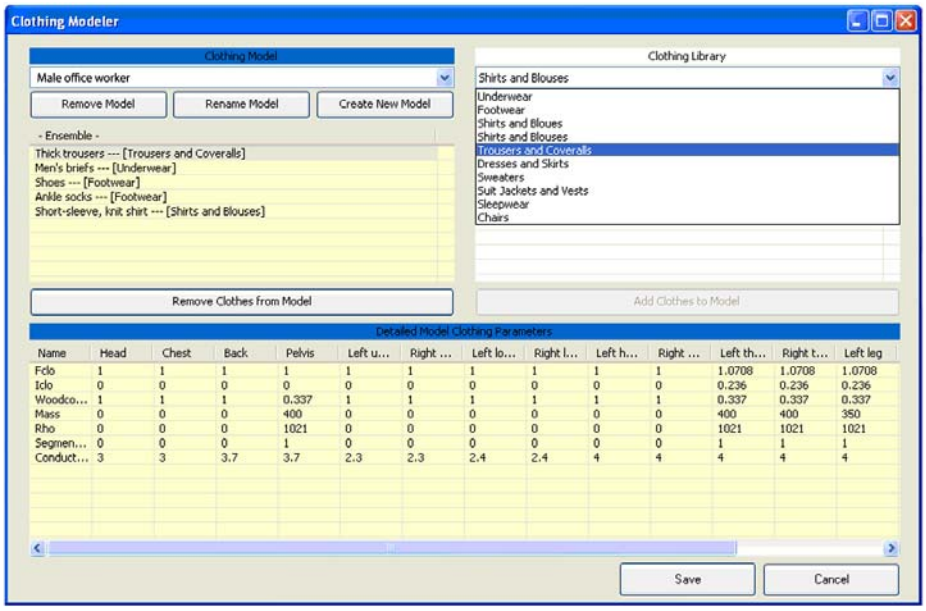
One of CBE's primary goals is to provide building industry practitioners with tools for creating effective and comfortable indoor environments. The Berkeley Comfort Model (BCM) has been used by both our industry partners and our research team to predict thermal sensation and comfort in a variety of indoor conditions in buildings, vehicles, and in one case, in city subway systems.

At our April conference we outlined our plan to improve the capability of this tool with the addition of an advanced clothing interface. In the current version of the BCM, the default clothing ensemble is based on typical office wear, consisting of cotton pants and long-sleeved shirt, with a clo value of 0.6 Although it is possible to model other clothing options, doing so is cumbersome (and can only be done by CBE research staff).

The new interface capability will allow users to configure custom clothing levels in comfort simulations. To enable this, we first had to identify the insulation values for each clothing element on a body-part specific level, which we did from a review of thermal comfort and physiology literature. Based on our findings we developed algorithms to calculate the characteristics of each clothing part and clothing ensembles. We then developed a new interface that allows users to select clothing options, displaying detailed information for each clothing element and the entire ensemble as it is created.

We completed the new interface in the spring, and are currently validating it and testing a beta version. We plan to release a new version of the software for industry partners in time for our October meeting.

Research Specialist Hui Zhang, who led this effort, explains that this new capability will greatly expand the usefulness of the tool. "Of course we can't assume that everyone wears the standard summer clothing. The new clothing selection capability will allow users to model anything from beach wear to outdoor winter clothing." The new version of the BCM will also be more useful for predicting comfort outdoors. CBE staff plans to use the new capabilities of the model to conduct outdoor comfort studies in support of the UC Berkeley's new Center for Resource Efficient Communities (see page six).



Beta version of new clothing editor interface. Users select clothing from pull-down menus at top right, ensemble is shown top left, and detailed parameters are shown in the table below.

People

Corinne Benedek
Mechanical Engineer, Arup

Corinne Benedek, right, shown here with another Cal graduate also now with Arup, Kirstin Weeks.

You completed your studies in Building Science at UC Berkeley, and started at Arup soon after that. How did you decide on that career path?

I had been interested in Arup since college, and the firm was a fixture at CBE meetings. Also, it seemed like a place I could be involved in an interesting variety of projects, and would not simply have to do the quickest solution, but would be able to do things right.

Has that turned out to be true?

It has been. I have been encouraged to do analysis, not just use rules of thumb. Also, I have been able to use Arup's internal funding to do some independent research on Arup's methods.

What types of projects have been most interesting?

I started doing energy analysis for LEED compliance, and my own design projects, including a lot of projects with aggressive energy goals. I enjoy the mix of projects. You need to be involved in mechanical design to really do a good job with energy modeling. I worked on a skyscraper in Qatar, and now I'm very excited about a new nanotech-lab at Princeton designed by Todd Williams Billie Tsien Architects. It's interesting because Princeton gets a little more ambitions with each project, and this is our third lab for the school.

Arup is known for its international work. Are you doing projects overseas?

I am actually doing a lot of local projects, such as energy modeling for a church in the Bronx, and design and energy work for projects at Princeton University. But I'm also working on competitions and projects in Korea, China, Europe and the Middle East.

What are the main tools you use?

We really do a lot of Excel spreadsheets, and for modeling we use Trane Trace, and eQuest. We are starting to look at IES, and may use EnergyPlus too. Arup also has software called Room that we use for some things, its good for basic energy calculations, and does some thermal comfort simulations, providing PMV data.

What aspects of your time at Berkeley are you finding to be beneficial in your work at Arup?

Several things, such as human comfort knowledge, access to the wind tunnel, and the time I spent in Gail Brager's research methods course. Though the graduate architecture studio [Arch 200] wasn't my favorite, I need to communicate with architects, and the course helped me to understand the process and how they look at things.

How did you decide to work in Arup's New York City location?

My family is here. I live in Brooklyn Park Slope, and our office is in Soho. It's about 40 minutes by train, and 30 by bike. I take the route over the Brooklyn Bridge, but I can't do it year round.

How is life in the office?

Its pretty great, we have about 340 people, many are in their late 20s and early 30s, many from the UK, and from all over the U.S. It's a very bright, friendly group. We are in an older building that was renovated, with bike storage and showers. And I can open my window!

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Summer 2009

Industry Partners at the Center for the Built Environment

CBE's research is supported and guided by CBE's consortium of industry partners, a diverse group of leaders in the building industry. The Center's membership includes the following firms and organizations:

Armstrong World Industries
Arup*
California Energy Commission
Charles M. Salter Associates
Coherent Structures
Cohos Evamy
DPR Construction
EHDD Architecture
Environmental Systems Design
Glumac
Haworth
HOK
KlingStubbins
Larson Binkley
Pacific Gas & Electric Company
Price Industries
Rumsey Membership Team:
- Rumsey Engineers
- CPP
- Mahlum Architects
- Mithun
- Perkins+Will

Skidmore, Owings & Merrill
Southern California Edison
Steelcase
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Tate Access Floors*
Taylor Membership Team:
- Taylor Engineering
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