GREEN MECHANICAL CONTRACTOR

FIRST PASSIVHAUS U.S. SCHOOL BUILDING

The building doubles as a demonstration lab and learning facility

The Center for Energy Efficient Design (CEED) in Franklin County, Va., is the first public school (K-12) in the United States designed to the Passivhaus building performance standard. This demonstration lab and learning facility, situated at the edge of the scenic Blue Ridge Mountains, showcases a variety of renewable, sustainable and energy efficient features.

Adam Cohen, LEED AP, co-owner of Structures Design/Build LLC, Roanoke, Va., first became involved with the CEED project in 2007 after it had languished for a few years after receiving initial funding.

Cohen grew up with a dad who was a builder, and has always had a passion for low-energy buildings and alternative technologies. His interest in Passivhaus began a few years ago when he read a case study on the Internet about a townhouse project in Germany with ultra-low energy use. Turns out it was a Passivhaus project.

Passivhaus is a performance-based building standard that results in an extremely airtight, ultra-low energy use structure. The concept was developed in Germany in 1996 by Dr. Wolfgang Feist, a physicist. When Passivhaus training came to the United States (through the Passive House Institute U.S.), Cohen was one of the first people to sign up for the three-month program. He is now one of approximately 300 certified Passivhaus consultants in the nation.

While tens of thousands of residential and commercial Passivhaus buildings exist in Europe, there are only around 60 completed projects in the United States; there are, however, many additional projects in the pipeline all around the country.

A BUILDING THAT TEACHES

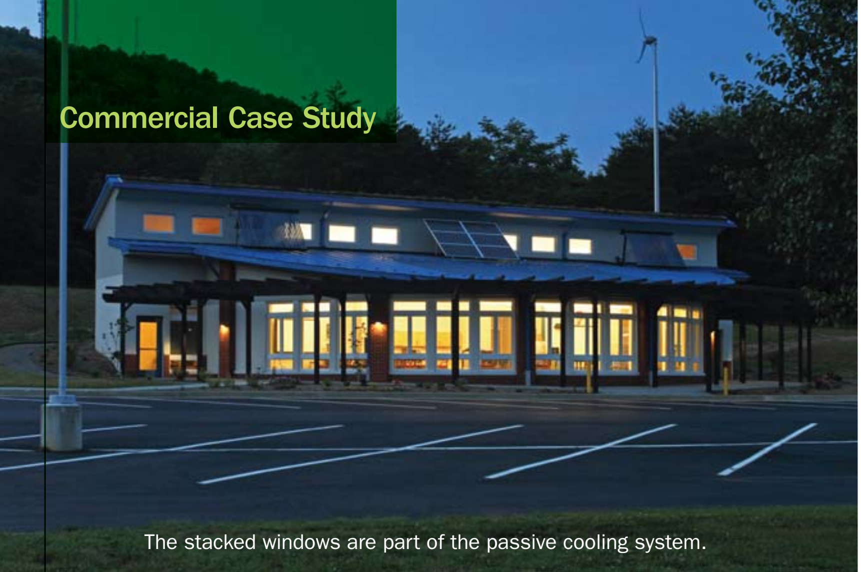
The CEED was conceived as an extension of The Leonard A. Gereau Center for Applied Technology and Career Exploration in 2002 by educators John Richardson and Neil Sigmon. They envisioned it to be a learning model for environmental science, advanced learning technologies, architecture and building systems. It also was intended to be a demonstration project for Southwest Virginia and the Mid-Atlantic region, open to surrounding school jurisdictions, featuring real-time data and curriculum available on the Internet for long-distance teaching.

The project received initial funding in 2003. “The funds were used to commission a design concept from Virginia Polytechnic,” Cohen says. “The concept was to be an ‘energy efficient’ building, but there was no definition of how this goal was to be achieved.”

After the initial concept plan was completed in 2004, the project languished. Approximately $400,000 had been pledged but there was no plan to bring the concept to completion.

“The educators called us in 2007,” Cohen says. “They heard of our firm through a student whose parent works for us. At the first meeting, they shared their vision of a ‘building that teaches’ and we took on the project development for no fee.”

Cohen’s team originally recommended an earth-sheltered approach, which would yield approximately 40% in energy savings. They also recommended that principles of LEED certification be incorporated. The project received final funds needed to begin construction in 2008.



The stacked windows are part of the passive cooling system.

It was during this time that Cohen received his Passivhaus training and became a certified Passivhaus consultant.

"We figured that we could save an additional 30% energy if we redesigned the project as a Passivhaus building — with the ultimate goal of creating a plus-energy building as funds became available for on-site generation," Cohen says. "The superintendent of schools gave us the green light to pursue this option but it could not cost more than the amount the school board had already approved."

After exhaustive studies and analysis, the team settled on a revised design that would meet Passivhaus standards and actually cost $26,000 less than the original building. They received permission to pursue the design and began the final documents and construction.

A SUSTAINABLE APPROACH

"Passivhaus is an effective and affordable strategy and it's how the Europeans build," Cohen says. "It's a fabric-first approach to low-energy use. You lower your energy use with a high-efficiency air exchanger. The design strategy is all about numbers, revolving around three metrics: heating and cooling annual demand, air tightness and overall energy use."

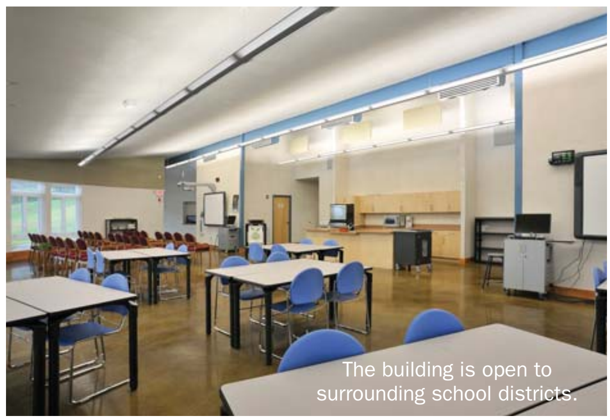
The CEED building is small, with a treated floor area of 3,503 square feet. Constructed of timber and concrete, it has a specific heat demand of 3.69 kBTU/sq.ft./yr.; a specific cooling demand of 1.00 kBTU/sq.ft./yr.; and a specific primary energy demand of 32.2 kBTU/sq.ft./yr. The location is a rural setting in a mild mixed humid climate and the building is situated at an altitude of approximately 1,050 ft. above sea level.

Windows proved to be a challenge. Triple-pane windows that meet prescribed Passivhaus U-values are readily available in Europe, which is not the case in the United States. The team worked with a local window manufacturer that modified an existing product for the project. "With modifications in both the windows and installation, we were able to achieve satisfactory performance. We didn't achieve the Passivhaus values but we were close enough," Cohen says.

The CEED building incorporates many sustainable features in addition to the Passive House design:

- A traditional wind turbine and three small PV systems
- A solar thermal indirect hot water heating system (120-gal. tank)
- Natural deciduous shading techniques in addition to the principle of passive cooling through the stacked window arrangement
- A plumbing system that uses water-saving fixtures, gray water recycling, non-toxic piping and rain water harvesting to save 80% water use over a standard building
- An electrical system that incorporates low-energy fixtures, daylight harvesting, occupancy controls and on-site power generation
- A partial green roof
- Indigenous drought-resistant edible and medicinal plantings in the landscape design
- Demonstrations of recycled, local, sustainably harvested and non-toxic materials.

The project team factored sustainability into all decisions and has applied for the LEED platinum rating.



The building is open to surrounding school districts.

The building features real-time data and curriculum available on the Internet.

MECHANICAL DESIGN CHALLENGES

The building has a diverse and challenging occupant loading pattern. "For the most part, the building is used by one teacher with about 24 students," Cohen notes. "However, the intended use as a demonstration project also allows for groups of up to 100 people to use the building for tours and events. We had to model the project with this very diverse usage to ensure that the building would perform under all conditions.

Airflow is variable speed from 200-2,000 CFM.


Second stage heating and cooling is a 3-ton, two-stage ground-source heat pump.

“U.S. buildings are typically kept in a very tight comfort range in all climates, in all seasons, through the use of massive heating and cooling systems,” he continues. “This building had to provide for this U.S. expectation of comfort, as we recognized that we may not have a second chance to prove the Passivhaus approach to potentially skeptical public policy makers.”

Taking those factors into account, the team modeled the building with a worst case scenario of 100-person occupancy in mid-summer with high humidity to determine the mechanical system loads.

“What we found was that under most conditions the building would require only minimal additional heat or cooling, but under the worst case design, we needed about 2.5 tons (30,000 Btuh) cooling to overcome the sensible and latent loading from the occupants,” Cohen explains.

The mechanical system employs a variable-speed, rotary energy recovery ventilator (ERV) with a two-stage heating and cooling strategy. Stage one is pre-heating, pre-cooling and pre-dehumidification provided by a water-to-air-heat exchanger in the intake of the ERV. This water-to-air-heat exchanger can circulate both solar-heated water and a passive brine ground loop.

Finding an acceptable ERV was another challenge. “For the majority of time, a small U.S.-made ERV would handle the CO_2 load but during the times of larger occupancy a much larger air flow would be required,” Cohen says.

After failing to find a U.S.-made high-efficiency, variable-speed ERV that would fit the bill, the team reached out to Ultimate Air Inc., an Athens, Ohio-based manufacturer of ERVs.

“The company engineer told us they were already working on some commercial-scale prototypes,” Cohen says. “We funded the remaining development; over the next nine months, Ultimate Air developed a variable-speed (200-2,000 CFM) unit with a projected 90% efficiency.”

Stage two is a 3-ton (36,000 Btuh) two-stage ground source heat pump (GSHP) for occasions when the occupant load will spike, requiring additional cooling.

“There had been discussions about using a high-efficiency, mini-split heat pump unit for the second stage,” Cohen says. “This would have saved almost $25,000 but all equipment had to be U.S.-made. We couldn’t find what we needed in the U.S. market, so the school board opted for the GSHP.”

A humidistat was installed on the heat pump to combat the possibility of high humidity during summer conditions; however, it was precautionary and Cohen says it probably won’t be required. The ERV is equipped with an automatic sensor that controls a summer bypass to decrease temperature and humidity gain during humid months.

“Our calculations indicate that on a day with 90°F, 70% RH, with 60°F brine circulating in our intake water-to-air loop, the stage-one system should be able to remove around 30,000 Btuh latent heat and 20,000 Btuh sensible heat. We have installed temperature and humidity monitors pre- and post-unit to analyze the accuracy of our calculation methodology,” Cohen explains.

SIMPLE CONTROLS

To keep in-line with the budget, the team opted for a simple control system. “The ERV is controlled by a CO_2 sensor with four pre-set levels of flow,” Cohen says. “We then installed two digital thermostats: one to control the water-to-air heat exchanger and one to control the heat pump. We could have used a single thermostat, but U.S. ‘off the shelf’ thermostats do not allow for three stages in the cooling mode, which meant we wouldn’t have the option of using the two stages on the GSHP, which would ultimately lead to higher energy use.”

The thermostats were installed in sync and programmed to a 2°F difference between stage one and stage two.

Solar will allow the structure to eventually deliver more energy than it uses.

"When we contacted control manufacturers for the stage-one logic controller, we were quoted $15,000 U.S., which was beyond our budget, so the stage-one heating and cooling is controlled by a 'homemade' logic controller that a friend and I constructed for under $250 in parts," Cohen notes.

Multiple monitoring points are installed in the mechanical system to provide real time data on the performance; the controls will be adjusted as required to optimize the building.

REAL-TIME DATA

The project received a grant in December 2010 from the Virginia Department of Mines, Minerals and Energy to install a real-time Web-enabled monitoring system. At the time of this writing, 44 monitoring points were being installed; it was anticipated that real-time data would be available on the Web by Fall 2011. The information will be available to anyone interested in studying a high-performance building.

In addition to Web-enabled monitoring, the grant has made possible the installation of another wind turbine (a vertical axis version) and three new PV systems. Once these additions are complete, the CEED will become a plus-energy building, producing significantly more energy than it is using.

According to Cohen, stage-one heating (solar heat delivered through ventilation air) was sufficient enough from November 2010 through February 2011 to prevent the second-second stage GSHP from having to come on. In May 2011, the building was using less than 8 kWh/day of electricity, or about 79 cents/day.

"There is still a lot of resistance to Passivhaus in the United States because of a lack of education and misunderstanding," Cohen says. "But Passivhaus works. There are thousands of successful European projects to look at for proof. This is a huge opportunity to improve our nation's energy efficiency. It's also an opportunity for U.S. manufacturers to develop new products to serve the emerging Passivhaus market."

Cohen's team is working on additional Passivhaus projects. These include a student center at Virginia Polytechnic University, a dental office and three homes.

"We want to build upon the success of the CEED project," Cohen says. "We basically delivered a $1 million state-of-the-art building for $800,000. It's comfortable, it's efficient, and eventually it will be a plus-energy building. The fact that it will serve as a learning lab — as well as a model for other school districts, policy makers and building professionals interested in learning how to design a Passivhaus building in a mild mixed humid climate — made it all a very worthwhile endeavor." ♻

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Portions of this article were adapted from a working group presentation that Adam Cohen gave at the Passivhaus Institute convention held in Innsbruck, Austria, in May 2011. For more information, contact Cohen at acohen@structuresdb.com.