Empa Quarterly

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NEST – building the future together

Lightweight concrete shell design

Wooden building materials for the 21st century

Working in the office of the future

Empa
Materials Science and Technology

HiLo – futuristic building construction turns real

The HiLo unit of ETH Zurich is to take shape in NEST in 2017. The project extends far into the future: a self-supporting lightweight concrete roof will form the visual 'crown' of NEST. The south and west-facing walls will incorporate an adaptive façade with moving solar modules that regulate light and shading as well as the temperature and energy balance of the unit.

TEXT: Rainer Klose / PICTURES: ETH Zürich

From 2017, the architectural crown of the research building will reign from the uppermost platform in the southwest corner of NEST: the HiLo unit. This ambitious project is focusing on further developments in lightweight construction and energy management of buildings. At the same time the partners – two research groups at ETH Zurich – also want to lend new impetus to design. They are endeavoring to bring about a renaissance of filigree concrete shell architecture that is compatible with today's energy standards. Arno Schlüter and Philippe Block, both professors of architecture at ETH Zurich, are managing the project together.

Schlüter is responsible for the energy concept and management of the unit. The concept is centered around efficient on-site energy generation and self-learning, automatic control approaches for energy supply and space conditioning. One core element is the adaptive solar façade on the south and west-facing sides: square modules of 40 x 40 cm in size are coated with thin-film solar cells from Flisom, an Empa spinoff. The modules are controlled pneumatically and can rotate around two axis to either follow the sun to collect energy, provide a maximum of shading for the interior or or open up the view to the outside.

The indoor climate follows the person

When the room is unoccupied, the unit is supposed to maximize the solar energy yield. Either electricity is generated actively using the thin-film solar cells on the envelope or the incident sunlight to passively heat up the interior of the unit to the desired temperature. The decision on what action to take is also supposed to be taken in interplay with other NEST units, which pass on their needs to HiLo via the Energy Hub (see page 21).

As soon as an occupant enters HiLo, his/her requirements take priority. The aim is to save the occupant from having to use dozens of buttons on a control panel in order to obtain the right room temperature of pleasant lighting conditions. Instead, HiLo is familiar with certain preferences of its occupants and can use these discreetly in the background to optimize energy consumption and maximize comfort. Take for example an occupant who likes a bright, cool room during the day in order to work or concentrate on reading. The solar modules open up the view to the outside, the LED light is adjusted to the brightness and the heating and cooling system creates the desired temperature using the most opportune energy source available at the time. Towards the evening, the occupant wants privacy and slightly warmer conditions. And so, the modules shade the interior and at the same time the temperature increases slightly. The occupant only has to intervene if he/she wants to change the lighting or temperature in the room from his/her probable preferences. The system learns from these interventions to even better adapt in the future.

"Occupant-Centered Control" is the name given to this principle by Schlüter and his team, which they have been testing in their own offices at ETH Zurich for 18 months now. Schlüter's team fitted a first version of the adaptive façade to the "House of Natural Resources" of ETH Zurich (www.honr.ethz.ch) in August 2015 and has since been researching and further developing the façade, the effect and the control technology. For HiLo, the technology is taken to a next dimension, with two façades influencing the climate of the indoor space, which due to its spatial sophistication, is more complex to control.

"The research on comfort in buildings has created a vast body of knowledge over the past 30 years", says Schlüter. "Nowadays we pretty much know at which conditions most people feel comfortable, but we don't consider the context enough, like cultural and psychological aspects. In HiLo, we want to revisit and validate these findings, which also mostly stem from laboratory situations, in a real-life environment." The research project is to run several years, as the intention is for guest scientists from different cultural regions to spend time living in HiLo and have their preferences and impressions collected. What, for example, does a Norwegian, a Somalian, a Chinese person and a Colombian need to all feel comfortable, and how is this different? HiLo will help to gather these data and to refine the automation and control of the systems accordingly. At the same time the effectiveness and efficiency of the technology will be tested in real-life conditions.

Designed by two ETH-Zurich workgroups and under construction on NEST's southwestern face, the HiLo unit is set to enchant visitors to Empa with its extravagant appearance.

Lukewarm water for heating

The whole endeavor is even more ambitious due to the fact that HiLo is not only a building with a large percentage of glass on the façade, but also has different, controllable heating system components. One of the design innovations, an activated lightweight concrete floor, will be used for the ceiling of the private en suites of HiLo. The floor system incorporates water piping that heats or cools the room facing surface as required, thus functioning as a radiant heating or cooling element. "Using large surfaces for radiation exchange is a very efficient way of achieving a pleasant interior climate", says Schlüter. And there is another advantage of the integrated design: "We can use water with a low temperature for the heating – for example from free waste heat supplied from the NEST backbone that cannot be used for any other purpose." And so the designer apartment also recycles 'leftovers'.

Shell roof as a sandwich design

With the elegant concrete shell designs of architect Heinz Isler (1926-2009), Switzerland has a strong tradition of interesting, modern shell architecture. These structures include the highway service area at Deitingen Süd, the indoor swimming pool in Brugg and the Flieger-Flab-Museum in Dübendorf. Together with the Block Research Group at ETH Zurich, Philippe Block is continuing his legacy with research into thin and expressive lightweight construction using concrete. Unlike Isler, however, the conditions he is working in are different, as single-layer concrete shell roofs don't even come close to meeting today's energy standards. That also applies to the multi-curved shell designed by the team as the roof of HiLo.

Schlüter sees this obstacle as a sporting challenge. "Unlike in cold buildings, such as service stations, our roof covers a heated residential space. This means it has to be well insulated and cannot have any thermal bridges." According to Block, this is very doable. "We have already created several shells on different continents." Nevertheless, the HiLo roof is an ambitious individual piece. "To address the building physical requirements, we are building it in four layers," explains Block. "The inside layer is exposed architectural concrete with an embedded heating and cooling pipe system. Then, an insulation layer follows onto which the second layer of concrete is applied. Finally, there is another layer of insulation with thin-film solar cells on top."

Ultra-thin concrete interior cladding

Particularly the roof's construction process is innovative, with its individual layers applied one by one on a carefully engineered cable-net and fabric formwork. The shell is 30 centimetres thick at its five point supports. However, its optimised form allows an average structural thickness of just 8 centimetres and as little as 3 centimetres thick at the shell's outer edges. Remarkably, because of the innovative flexible formwork, there is no need for any scaffolding under the roof. While the roof is being concreted, other trades can carry on in the interior of the HiLo.

1

2

3

Lightweight floors for skyscrapers

A further innovation being made a reality by the Block Research Group in HiLo is the design of the novel, self-supporting, concrete floors. They do not need the usual steel reinforcement that has been used to build concrete slabs for more than 100 years. “Concrete cannot really withstand any tensile forces, but it is very happy to carry loads in compression as an arch”, explains Block, “so we designed a stiffened vaulted floor that carries all applied loads in compression.”

As a result, the ribbed floor is around 70 % lighter than traditional concrete floor slabs, so it could help to save considerably on materials and thus on costs in skyscrapers in the future. In NEST, the floor will be used in a real-life environment for the first time. It separates the lower level of the duplex apartment from the open space under the curvaceous shell roof.

Prototype will confirm the concept

Because not only the construction method but also the layered structure of the HiLo roof are so unique, the team is currently planning a full-scale prototype of the roof design. Together, scientists and practitioners are entering into a venture that could represent a huge step forward for construction technology in Switzerland. //

1
An early prototype of the HiLo roof construction in an improvised stress test.

2
These lightweight ceilings separate the upper floor from the lower floor. They are around 70 percent lighter than conventional concrete ceilings.

3
HiLo’s interior will be characterized by a lot of light and a futuristic loft atmosphere.