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Uplift

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№14

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ETH Foundation

Building on science

ETH Zurich / Markus Bertschi

Joël Mesot
President of ETH Zurich

EDITORIAL

Increasing urbanisation, an environment under pressure, and high levels of resource consumption are all major challenges facing the construction industry today. At the same time, digitalisation, AI-aided fabrication methods and new materials open up a host of opportunities when it comes to designing sustainable infrastructure systems, preserving raw materials and reducing emissions.

Young entrepreneurs and researchers at ETH Zurich are working hard to develop solutions that will enable us to harness these opportunities. Key to their efforts is the dialogue with industrial partners. Learn more about sensor technology designed by spin-off company DuraMon and inter-disciplinary projects run by the Design++ centre. Both examples demonstrate innovative ways of making our built environment more sustainable.

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Stable prospects

With her ETH spin-off DuraMon, Yurena Seguí Femenias aims to ensure that large public infrastructures built from reinforced concrete are safer and more sustainable – in Switzerland and beyond.

When asked whether she has another day job besides her start-up DuraMon, Yurena Seguí Femenias's eyes light up: "Since 2021 I've been fully employed by DuraMon. And we've just successfully completed our first round of seed funding." The young entrepreneur from Menorca, who has lived in Zurich for 13 years, is proud of the services her spin-off provides: "Steel corrosion in reinforced concrete is a huge challenge, especially in large public infrastructures like bridges and parking garages. We provide tailored solutions to detect potential damages at an early stage and reduce costs."

More security with sensor technology

Long overlooked, the potential consequences of corrosion were finally brought to public attention in 2018 with the collapse of the motorway bridge in Genoa – in which it's assumed that undetected corrosion damage played a role. The topic has far-reaching relevance, as reinforced concrete is the most widely used building material in the world. Corrosion damage is by far the main degradation mechanism in reinforced concrete and often becomes critical after an average of 50 years – a lifespan that many building structures in Europe and the USA have already exceeded. It's not only dangerous, but generates high costs when infrastructures need to be repaired or even demolished and rebuilt.

Damage to the steel is caused by the penetration of chloride ions, as is found in seawater or de-icing salt, and by CO_2 from the atmosphere. It's a slow process and difficult to assess, as it takes place within the concrete and signs of damage often become apparent when it's already advanced. "Our sensors monitor all the significant parameters simultaneously, like pH and chloride values, inside the structure. We use these to make an assessment of its present condition, deliver forecasts and identify areas in need of repair," Yurena Seguí Femenias explains. "This is how we ensure that fewer costly, time-consuming, and energy-intensive repair activities are required." The sensors can be used in new or existing buildings, and a key part of DuraMon's service is to analyse and interpret the data the sensors provide. The spin-off came out of Ueli Angst's Durability of Engineering Materials research group and is co-founded by the professor, who ensures the constant integration of the latest scientific findings.

Lucky coincidences and plenty of stamina

In 2010, when Yurena Seguí Femenias came to ETH Zurich for an exchange year during her studies at the Universitat Politècnica de Catalunya in Barcelona, the dream of founding her own start-up lay far in the future.

DuraMon's novel pH sensors are immersed in alkaline solution to calibrate before being placed in concrete.

During her Master's thesis, which she did at Sika Technology AG, she was supervised by ETH Professor Robert Flatt. Once she'd completed her Master's degree, he offered her a job as research assistant in his Physical Chemistry of Building Materials group. It was there that she met Ueli Angst, then a post-doc, as well as the now professor emeritus Professor Bernhard Elsener, under whose supervision she did her doctorate. After receiving funding from the Innosuisse BRIDGE programme and further advancing the sensor technology she'd developed during her doctoral studies, an ETH Pioneer Fellowship finally gave her the chance to launch her own start-up. "Thanks to the Pioneer Fellowship, I was able to draw on a large network and an enormous amount of expertise, which gave me the critical momentum I needed to go ahead with the start-up," Yurena Seguí Femenias explains.

"I'm a very curious person and want to find out how things work. And how they could work even better," is how she describes her motivation. "On top of this, I have a lot of stamina." This quality also helped her get through the strenuous financing period of her start-up, as fundraising for DuraMon was one of the greatest challenges she'd faced along the journey so far. "It's a huge amount of work. You need a thick skin and a lot of self-confidence," the young entrepreneur reveals. "The fact that you never know if the effort will pay off in the end also wears you down."

As it now stands, the effort has paid off. Yurena Segui Femenias is currently busy with projects in Zurich, Basel, Aargau and Saas Fee, as well as her first project in Germany. And the budding entrepreneur is going full steam ahead with her next major goals: to see DuraMon established in Europe and beyond.

6 The sensors are inserted into the concrete samples.

Pioneer Fellowship programme

The programme funds outstanding researchers with entrepreneurial ambitions along the road to a market-ready product. Judged by a panel of experts, ten to fifteen Pioneer Fellowships are awarded every year from funding donated by foundations, companies and over 200 private individuals. ETH Zurich wants to expand the programme so that even more young researchers have access to up to CHF 150 000, coaching opportunities, and the chance to further develop their research results to the point of commercial application.

Find out more:
ethz-foundation.ch/en/pioneer-fellowship

Virtual design for real-world buildings

At the Center for Augmented Computational Design in Architecture, Engineering and Construction (Design++), ETH is looking at new ways to innovate the construction industry. Executive Director Danielle Griego tells us more.

“We want to empower future engineers and architects to reshape processes in the construction industry with the help of digital technologies.”

Danielle Griego

Who are the people behind Design++ and how does the initiative help accelerate a shift in the construction industry towards more resource efficient and productive methods?

DANIELLE GRIEGO – Design++ bridges the domains of architecture, civil engineering and computer science at ETH Zurich. In total, more than fifty professors, scientists and staff members teach courses and conduct research in projects across the interdisciplinary network. For example, a new lighthouse project – which examines how extended reality for inspection, assembly and operations in the buildings and construction sector creates new emission-reducing opportunities – combines the expertise of professors Robert Flatt, Catherine De Wolf, Bernd Bickel, and many more. The purpose of our activities is to reduce the ecological impact in the construction sector and increase systematic construction productivity while simultaneously ensuring high quality standards in the built environment.

What methods do you use to pursue these aims?

Our work focuses on developing digital methods and tools using artificial intelligence and extended reality to advance the architecture, engineering and construction (AEC) industry. An important resource is our – globally unique – Immersive Design Lab, pioneered by Gramazio Kohler Research. Here we can merge immersive visualisations and 3D spatial acoustics and test extended reality in architectural and civil engineering projects in an interactive way. This could be a virtual walk-through of a building project, for example, or intuitive interaction with a 3D design model using gestures or voice commands. Equally important are regular exchanges with industry partners to share information and align objectives.

What form do these exchanges take?

For our research to make a difference to society, it must be firmly anchored in the AEC industry. Important platforms in this regard are events such as the Future of Construction symposium or our seminar series, which we also publish on our YouTube channel. We host exchanges with each of our strategic partners Basler & Hofmann, Hexagon and Halter AG where both sides provide updates on new technological developments from their perspective.

Why is this collaboration with partners necessary?

It’s thanks to them that we can build and grow Design++! For example, their support made it possible for us to appoint Bernd Bickel, Professor of Computational Design, and to start a fellowship programme for postdocs. At the same time, both parties benefit when the industry can make good use of the results of our projects on digital design, planning and construction. Building projects are usually tightly calculated in terms of time and costs. This often means that innovation falls by the wayside, because new technologies and processes typically require additional time and money when newly introduced. Companies like our strategic partners, who are willing to take risks and support innovation in the AEC industry, are indispensable for driving sustainable construction.

In concrete terms, what applications could emerge from Design++ research?

Take the very promising development of the AI design co-pilot to support bridge design, a collaborative project between Professor Walter Kaufmann’s group and the Swiss Data Science Center. The deep-learning-based software tool isn’t bound to a specific structure and supports engineers in the early design stages. By combining AI’s computational power with human creativity and an immersive user interface, the design co-pilot contributes to the development of efficient and reliable future structures. This was applied in a real project for a pedestrian girder bridge located in St. Gallen in collaboration with Basler & Hofmann. Another example is the 7DayHouse project, which explores solutions for the exceptionally high demand for housing in urban areas. The overall goal is to create a fully customised home design in just one day while maintaining supply-chain continuity for fabrication and delivery within seven days. The team, led by professors Daniel Hall and Benjamin Dillenburger, is working on AI design methods which incorporate the fabrication and construction process, collaborative AI, and mixed reality. The research utilises digitally fabricated cross-laminated timber (CLT) elements and benefits from the experience and knowledge of Erne AG Holzbau.

Why is ETH the right place to drive innovation in the construction industry?

The potential of digital technologies for the architecture and construction industry is huge, but implementation is still in its infancy. When it comes to infrastructure and expertise, ETH has some of the best resources worldwide. This is also reflected in its graduates. If we can empower ETH’s future engineers and architects to challenge conventional design and building processes and use digital technologies to achieve pioneering breakthroughs, we can make a significant difference.

Design++

At the ETH Center for Augmented Computational Design in Architecture, Engineering and Construction, innovative digital methods and tools for a more sustainable construction industry are being developed, supported by strategic partners Basler & Hofmann, Hexagon and Halter AG. Danielle Griego has been the Executive Director of Design++ since its foundation in June 2020.

More on Design++:
designplusplus.ethz.ch

For the entire life cycle

From planning and erecting, through to usage and ultimate deconstruction: research and teaching at ETH Zurich on innovative building practices covers the entire life cycle of a built structure.

The professorships and projects are funded by the Albert Lück-Stiftung, BASF, Basler & Hofmann, Bouygues Construction, the Escher Circle, Geberit, Halter AG, Hexagon, Holcim, Implenia, the Ricola Foundation, Max Rössler, the Swiss National Science Foundation, Siemens, Sika, the Stavros Niarchos Foundation, the Toni Piëch Foundation and Ziegelindustrie Schweiz.

Ueli Angst
The Professor of Durability of Engineering Materials examines corrosion processes and how new technology and prediction models are used to detect and mitigate them.

Bernd Bickel
The Professor of Computational Design wants to find new ways to efficiently model, simulate and fabricate digital content.

Philippe Block
The Professor of Architecture and Structures combines computational design methods with state-of-the-art manufacturing processes to develop material-efficient load-bearing structures based on circular economy.

Eleni Chatzi
The Professor of Structural Mechanics and Monitoring fuses sensing data with models to diagnose and prognose the condition of engineered systems to facilitate optimal management and resilient operation.

Benjamin Dillenburger
The Professor of Digital Building Technologies explores the great potential of 3D-printed architecture and robotics for the construction industry.

Guillaume Habert
The Professor of Sustainable Construction researches regenerative materials that improve the environment, inhabitants' well-being and regional supply chains at the same time.

Anna Puigjaner
The Professor of Architecture and Care studies how the built environment could have a positive impact on our ageing society in terms of care, rehabilitation and social integration.

Walter Kaufmann
The Professor of Structural Engineering (Concrete Structures and Bridge Design) analyses the mechanical behaviour of reinforced concrete to find innovative structural solutions.

Arno Schlueter
The Professor of Architecture and Building Systems initiated the Zero Carbon Building Systems Lab, enabling heating systems, sensor technology, solar systems and much more to be tested on a 1:1 scale.

Robert Flatt
A project led by the Professor of Physical Chemistry of Building Materials explores how the use of extended reality in inspection, assembly and operation helps achieve net-zero infrastructure (see p. 8).

Andrea Frangi
By investigating the robustness of timber, the Professor of Timber Structures aims to optimise timber construction methods in large buildings such as skyscrapers.

Max Maurer
The Professor of Urban Water Systems seeks to develop visionary solutions for water supply and drainage systems.

Jan Vermant
The Professor of Soft Materials develops methods that lead to new, long-lasting and energy-efficient materials and processes.

“Every structure deserves a digital twin”

Dominik Courtin, CEO of engineering company Basler & Hofmann, explains why digitalisation in his industry is not driven by productivity and speaks about his many relations to ETH.

What do we need to understand about digitalisation in the construction industry?

DOMINIK COURTIN – That it's not just about digital planning and building per se, but about future operations. I always say that every structure deserves a digital twin to serve as a source of information and a platform for communication beyond the conventional end of the project. It could provide answers to very simple questions such as when apartment owners are renovating and would like to know how much wall surface needs to be painted. Or in more complex questions such as when the ecological footprint of different conversion options needs to be assessed. In order to make the right judgements and effective interventions, a sound basis of information is required. There should be a requirement that all data generated in the building process remains available for future users. In the cruise industry today, new ships already have digital twins, providing access to all conceivable information. You have to bear in mind that we construct a building for two years and then use, manage and repurpose it for decades. In my opinion, this is what counts – and not the increase in productivity during the planning and construction processes, even though this is often claimed. Buildings are prototypes; unlike other industries, scaling is only possible to a limited extent. I advise building owners to stick to CAD if they have no interest in using a digital model for operations.

Why does Basler & Hofmann support research into digital design, planning and construction at the ETH Zurich Design++ centre?

For one thing, we’ve held close relations with ETH for many years. Konrad Basler senior was a member of the ETH Board, for example, and we also employ large numbers of ETH graduates and offer internships. Secondly, digital construction is a topic of importance we recognised years ago. We believe that it requires a holistic approach, which is why we helped with the “birth” of Design++: when asked at the time by ETH whether we would support a centre that would operate across departmental silos, we immediately saw the huge opportunity it represented. This interdisciplinary thinking is entirely in keeping with the way Basler & Hofmann works: we have experts from over 30 disciplines collaborating on projects in the fields of engineering, mobility, energy, safety and the environment.

ETH Foundation / Valeriano Di Domenico

Much has changed here since his time as a student: Dominik Courtin in the Bauhalle, the Institute of Structural Engineering’s lab for experimental research.

In this context, what's your opinion on the selection of Bernd Bickel, the new Professor of Computational Design funded by Basler & Hofmann, among others?
He's a very good fit. Bernd Bickel brings a lot of added expertise and already knows the university well through his studies at ETH and his time at Disney Research Zurich. His vision of how we'll interact with the digital twin of our built environment corresponds to our vision and matches the expectations that our clients have of us: How do you make these things not only available, but also really tangible? Bernd Bickel's background means he can bring a lot to the table – it's not for nothing that he received an Oscar in 2019 from the Academy of Motion Picture Arts and Sciences for his technical successes.

How do you remember your time as a student at the ETH Department of Civil, Environmental and Geomatic Engineering (D-BAUG)?
As one of the best phases of my life. I was away from home. Students came from all over and spent a lot of time together. That broadened my horizons immensely. It was also very intense – we sat in the technical drawing rooms from early in the morning until late at night. Time and time again, we asked ourselves whether we would ever manage to finish our studies at all.

What did you take away from this time for your future career?
A way of thinking. One of my professors once said: A good engineer solves a problem they've never seen before. So it's not about applying a standard procedure, but learning ways and methods of approaching problems. This way of dealing with things is what I gained most from ETH.

Today you're a honorary consultant on the Advisory Board of D-BAUG – what do you notice when you compare past and present?
I see an openness, a willingness to let go of the familiar. This generation is really interested in developing itself, there's a great desire to change. I think that's great. If I could express another wish, it would be that the full professors at ETH were more vocal in public – they have nothing to lose! I'd like to see them get involved in debates more often in a provocative but, of course, constructive way and initiate changes.

You support the ETH Excellence Scholarship programme as a private individual – why?
I do this with great passion because I'm very grateful for my education and want to give something back to ETH. I also donate because I find it valuable to stay connected with young people and gain new impulses.

"The way of thinking is what I gained most from ETH."
Dominik Courtin

For an eco-friendly construction industry

New, durable materials and circular production processes: thanks to new professorships, ETH ensures that future infrastructure is built not only to be safe but in ways that protect the environment and the climate at the same time.

zvg

Electrochemical measurements are carried out in the Corrosion laboratory of Professor Ueli Angst (centre), who heads the Durability of Engineering Materials group at ETH Zurich.

As one of the world's largest consumers of natural resources and generating high levels of emissions, the construction industry's footprint is substantial. The concrete-manufacturing industry alone creates around eight percent of global human-made CO_2 emissions – around three times as much as aviation. The detrimental effects on biodiversity and the climate are equally high. At ETH, numerous experts are working on finding new ways to build more sustainably in the future, including Professor Ueli Angst, head of the Durability of Engineering Materials group.

New possibilities for corrosion prevention

The bulk of his research focuses on the corrosion processes taking place in large infrastructures made of reinforced concrete. One of the major problems of this material is the corrosion of the inner steel reinforcements which can, in the worst case, lead to the collapse of a bridge or a burst gas pipeline. Preventing corrosion and renovating corroded structures is therefore crucial, but both costly and harmful to the environment.

The group led by Ueli Angst is researching the exact mechanisms of corrosion processes. From their findings, the aim is to develop more precise methods for diagnosing, predicting and monitoring corrosion in order that infrastructures either don't corrode at all or corrode more slowly and can be remediated in good time. This is particularly relevant for Switzerland with its extensive road and rail network and innumerable bridges, tunnels and safety structures located in often inaccessible terrain. A better understanding of corrosion can also help scientists find the breakthrough needed to develop new, eco-friendly types of concrete. In the future, these concretes could perhaps even function as CO_2 sinks – initial projects have already shown promising results. Also important is Ueli Angst's key role in transferring vital expertise on corrosion to the building specialists of tomorrow; and by supporting spin-offs such as DuraMon (see p. 4), he's also helping to ensure that the latest research findings are speedily translated into real-world applications.

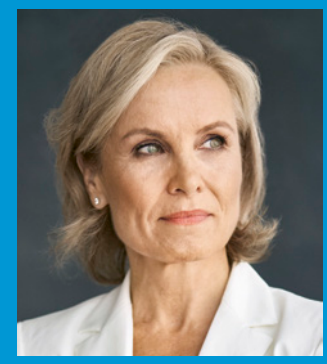
Research for safer, sustainable materials with longer lifecycles

The planned professorships "Sustainable materials and devices" and "Circular materials for sustainable future infrastructure" also focus on materials and production cycles that are circular and resource efficient. The key to reducing the environmental impact of material extraction and processing in the construction industry is a circular economy in which new materials are produced on a sustainable basis and used materials are transformed into valuable resources for new products. The "Sustainable Materials and Devices" professorship plans to address the sustainability of the materials themselves and their production, by optimising processes to reduce resource and energy consumption and developing strategies for reuse. Materials that are designed for circularity at the molecular level are particularly attractive when it comes to reuse, as this allows for full recovery of the initial structures and properties.

Composite materials present a particular challenge when it comes to reuse, as it's often difficult to separate the different materials. In addition, many of the chemical additives used in the materials are hazardous to humans and the environment. The aim of the new "Circular materials for sustainable future infrastructure" professorship is to research and develop solutions to maximise the reuse and recyclability of building materials. Here the focus will be set on identifying easy-to-recycle additives causing little impact to the environment and human health, and on designing new hybrid and composite materials. Such efforts bring the vision of a circular construction industry one step closer.

Find out more:
ethz-foundation.ch/en/sustainable-materials-and-structures

"Innovations in the construction industry hold enormous leverage in the climate issue and, with the support of committed players, ETH Zurich can make a real difference."



Tina Wüstemann
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Oxara, the spin-off set up by former Pioneer Fellow Gnanli Landrou and by Thibault Demoulin, produces innovative building materials to promote a low-emission and closed-loop construction industry.

Your support

Science and technological innovation are of greater importance than ever if we are to find solutions to meet the pressing challenges of our time. When it comes to reducing emissions and optimising our use of the Earth's resources, the construction industry harbours great potential. What's needed are talented individuals with groundbreaking ideas, excellent research and teaching, strong partners – and you. **Play your part and support innovation in the construction industry!**

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