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Tremendous potential for sustainability in construction

The energy revolution will also fail without sustainability in construction, believes Prof. Dr.-Ing. Carl-Alexander Graubner. In conversation with the Director of the Institute of Concrete and Masonry Structures of the TU Darmstadt.

Ecologically optimized concrete: The reduction of the clinker component in cement is the key for minor environmental impacts.

Photo: Katrin Binner

Prof. Graubner, what is the significance of sustainable buildings with regard to the protection of resources and the environment?
Some 42 percent of Europe's energy is consumed by buildings. Clinker manufacture in cement production alone is responsible for between five and seven percent of the global CO_2 output. This illustrates the potential: sustainable construction plays an extremely significant role in the success of the energy revolution and in achieving ambitious environmental targets.

Where do you see the approaches for increasing these potentials?
There are adjusting screws along the entire life cycle of a building, from the planning and materials to its demolition. Important themes that are the focus at our institute are above all the development of new building materials, the efficient creation and use of energy in buildings and accommodation, but also the increased use of a building's storage capacity.

Your institute is currently developing eco concrete. What exactly is this?
This is ecologically optimised concrete that has a lower environmental impact than conventional concrete. The aim and the challenge are to reduce the amount of clinker in the concrete whilst retaining the freshness and hardness in the cement or concrete.

How does that work?
At our institute, we substitute the clinker with climate-neutral and abundant raw materials such as ground limestone or granulated slag. We also reduce the water content and optimise the packing density of the particle system. This enables us to manufacture concretes that emit around thirty percent less CO_2 than conventional concretes and yet have the same properties.

„…solid construction is in fact superior to lightweight construction in terms of sustainability…"

Some people use wood for building today. Isn't that more sustainable than solid construction with concrete?
That depends on the overall rating. Certainly, as a building material, wood initially has certain advantages in the CO_2 balance. However, a sustainability assessment should not focus on just this one aspect. If I take all the criteria – economy, ecology, functionality and technical quality – into consideration over the entire life cycle, then solid construction is in fact superior to lightweight construction in terms of sustainability.

Why is that?
More than 80 percent of the CO_2 output associated with buildings occur during use. Buildings made of solid materials are far better at storing heat than those in lightweight construction. This reduces energy consumption over the 50-year life cycle of a building, and compensates for disadvantages in the CO_2 balance during the production stage. Furthermore, solid constructions are usually more economical, and also have technical advantages with regard to sound insulation, fire protection and comfort.

How can the storage capacity of buildings be improved?
By largely avoiding energy losses at thermal bridges, for instance around the columns on a parking level with a residential development above it. We are currently developing a new column connection in lightweight concrete for this, and are producing the necessary construction rules. The result is a product that is extremely stable and has a low thermal conductivity. This means loads can be transferred, and a heat buffer created between the column and the level above at the same time.

Publications

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Proske, T; Hainer, S.; Rezvani, M.; Graubner, C.-A.: Eco-Friendly Concretes With Reduced Water and Cement Content: Mix-Design-Principles and Experimental Tests, in: Handbook of Low Carbon Concrete, 2017, Elsevier, p. 63-87.

Information

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Professor Carl-Alexander Graubner in his testing laboratory.

Photo: Katrin Binner

Research project

The research project „Zemente mit reduzierter Umweltwirkung bei effizientem Einsatz von Hüttensand" [„Cements with reduced environmental impact with the efficient use of granulated slag"] (supported by the German Federal Foundation for the Environment [Deutsche Bundesstiftung Umwelt], duration July 2014 until June 2016) concerned the reduction of environmental impacts in concrete production through the use of reduced-clinker multi-composite cements. It investigated the processability and mechanical properties of concrete in various compositions with variable proportions of clinker, granulated slag and limestone meal. It was found that by using adapted concrete technology with multi-composite cements, it was possible to reduce the greenhouse potential by up to 55 percent compared with conventional compositions.

The Institute

In addition to the core competencies in solid and masonry construction, the Institute of Concrete and Masonry Structures of the TU Darmstadt in Germany is highly profiled in the field of sustainable building. The key principles of the German Sustainable Building Council [Deutsches Gütesiegel Nachhaltiges Bauen] were developed here. The research portfolio of the interdisciplinary team also includes the calculation and construction of concrete support structures and the development of mineral eco building materials. LCEE, the Spin-Off Life Cycle Engineering Experts, which specialises in sustainability certifications, and participation in committees and standardisation bodies ensure that scientific expertise is transferred into practice.
Further information:
www.massivbau.tu-darmstadt.de

You are also developing new concepts for efficient energy supplies to buildings. Where do you start?
We consider the topic as a whole, look for synergies and way to network accommodation beyond the individual building, and then to link this perspectively with the traffic sector. What is also extremely important when using the potentials of volatile renewable energies is having suitable storage technologies for the surplus energy that occurs at peak loads and are used later on. If we want to make better use of renewable energies in buildings, we must also develop the storage capacities.

Are there any synergies?
What is exciting is the number and variety of networking opportunities within the buildings: a school needs to be heated during the day, a residential building more usually in the evenings. This means that school and residential building achieve an energetic load balance. And waste heat from industry can be used to provide heating and hot water in other buildings.

What is your aim?
We want to use energy efficiently where it is needed, and to store it near the consumer. To achieve this, we will consider all the proven technologies, and use data from energy suppliers and obtained from dynamic simulations to calculate the energy feed and consumption over the course of a day as precisely as possible. This creates innovative supply concepts – ecologically, energetically, economically and also with regard to climate policy.

Can the concepts be implemented?
Taking them into account when planning new buildings is not the problem. The actual challenge now is to strengthen our heterogeneous building stock. This is where we can show those involved what is possible, provide arguments and find acceptance.

Interview by Jutta Witte. The author is a science journalist with a doctorate in history.

Vision teacher

Digital images and videos contain much more information than computers currently extract from them. With the help of intelligent algorithms, a research team led by Professor Stefan Roth aims to obtain the maximal amount of knowledge from images.

Photo: Katrin Binner

Professor Stefan Roth adjusting a camera for a controlled image recording.

By Christian J. Meier

A typical street scene can be seen on the screen in Stefan Roth's office – but from the 'viewpoint' of a computer. Cars tinted red pull in and out of parking spaces, purple pedestrians bustle about, green-marked plants indicate the verge. "For the computer, a video first of all only consists of pixels", explains computer science professor Stefan Roth. "We teach it to interpret the pixels", adds the head of the Visual Inference Lab at Technische Universität Darmstadt. Roth's team teaches intelligent algorithms to detect cars, pedestrians, or even potentially dangerous objects in X-ray images from transportation security. The software developed by the scientists of TU Darmstadt also reconstructs the image information that may be hidden behind blurred or out-of-focus images. The research question that guides them: How much information can be extracted from a digital image?

The need for automatic image analysis is huge. Millions of digital cameras create an unprecedented flood of images. If computers could reliably interpret not only ordered road scenes such as on a motorway, but also traffic that may appear rather chaotic, for instance at a junction, "then fully autonomous driving would also be possible in busy inner cities", says Roth. "There are many other potential fields of application", adds the computer scientist. Intelligent image analysis systems could assist users in tedious tasks, such as baggage control at airports. Land use can be automatically classified in satellite images, for example to ascertain on which fields wheat grows.

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for Computer

But teaching computers to see is difficult. Decades ago, researchers tried to directly create programs that imitate human perception. But this was largely unsuccessful, at least so far. "Today's approaches are very data-driven", says Roth. Computers learn by means of a large quantity of examples. The basis are often so-called artificial neural networks. These are inspired by the structure of the brain: Nerve cells, referred to in technical language as neurons, are interconnected by neural pathways. When photos of cars are shown to such a network, recurring patterns such as chassis, wheels, and headlights, reinforce certain neural pathways. If similar patterns appear on unknown photos, the same neurons become active via the intensified neural pathways as during training: The neural network has learned to recognise cars in images. Or pedestrians and plant pots.

"We aim to access data sources that already contain some of the information."

The catch: During training one has to literally show the computer on each sample image where the car is, where the pedestrian is, and where the plant pot is. "This used to take us an hour and a half per image at the beginning", says Roth. Because computers only reliably recognise objects after tens of thousands of examples, that is not always practical. "For this reason, we first of all try to get by with less data and secondly, aim to access data sources that already contain some of the information," says Roth. Computer games, for instance, show deceptively realistic street scenes. On a photo of a real scene, the researchers first have to painstakingly separate the individual objects from each other by tracing their outlines. "In a computer game, however, the individual objects are already separated", explains Roth. Then one only has to tell the neural network where the cars and the road surface are.

To get by with less data, the researchers come up with more tricks. "Based on the information contained in the computer game, we can detect which object that is already known re-appears at a later point in time", explains Roth. This means that the object, for example a particular car, no longer needs to be re-annotated on each frame of a video sequence.
The success of the approach developed by the scientists of TU Darmstadt is made apparent by the computer-interpreted video of a busy shopping street. Even further down the street, distant pedestrians and vehicles are detected.

The amount of information that algorithms trained by Roth's team are able to extract from blurry photos is similarly impressive. Even the cracks in the rock, in front of which an ibex stands, become visible again. On an image of the Berlin Victory Column, Roth zooms in on the laurel wreath that the statue of Victoria holds in the air. After being completely blurred at first, individual leaves can be seen after processing. However, the computer detected neither leaves nor rock cracks. Rather, it detects the disturbance itself at the pixel level. "The computer looks at the neighbourhoods of the pixels and examines their statistics", explains Roth.

On an undisturbed image for example, typical contrast differences appear in such neighbourhoods. The computer learns these statistics from many examples. If an image deviates from these typical distributions, the computer adapts it to the normal case. The goal of the researchers is a universal correction method for camera shake, motion blur, and other unwanted image effects. "This could further increase image quality, even with the computing power of a smartphone", Roth predicts. New features could also be realised, such as the depth of field effect currently seen with SLR cameras.

However, the corrected images are not yet completely free from artefacts. "There is still a lot of research to be done", says Roth. The reliability of computer-interpreted images is central to Roth's research. "The acceptance of autonomous driving will depend on this", he says. Was the movement of the pedestrian predicted correctly? Does the computer recognise a flower trough on the roadside in Rome as reliably as in Darmstadt? "The challenge is to recognise objects well enough so that the system does not experience too much uncertainty, which would make the vehicle slow down unnecessarily", says Roth. He is optimistic that this will be accomplished. In any case, the scientists of TU Darmstadt are certainly very resourceful in teaching computers to see. Still, Roth believes that the limits of machine perception are not yet foreseeable.

The author is a science journalist and holds a doctorate in physics.

Information:
Research project: ERC Starting Grant "Visual Learning and Inference in Joint Scene Models (VISLIM)": **www.visinf.tu-darmstadt.de/vi_research/funding/index.en.jsp)**

Publications:

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New enzymes for Green Chemistry

Wolf-Dieter Fessner relies on Nature's toolbox. The chemistry professor and his team develop biocatalysts for the chemical industry.

By Uta Neubauer

A traditional chemical process involves organic solvents, high temperatures, sometimes high pressure and often precious metal catalysts. Wolf-Dieter Fessner, Professor of Organic Chemistry at TU Darmstadt, discovered that it could also be done differently at a conference in Freiburg in the mid-1980s. Amongst other topics, the conference programme included talks on biocatalysis. "What I learned there was a real revelation to me," he remembers. "I had never thought that complex molecules could be specifically produced under mild reaction conditions in water and at room temperature just by adding a few enzymes to the pot." Fessner has followed one goal since then: He develops enzymes for industry to enable chemical processes designed in a more environmentally friendly way.

Enzymes are proteins that as biocatalysts drive almost all biochemical reactions, our metabolism as well as the process of photosynthesis in plants. Just like all catalysts, enzymes simplify and accelerate chemical reactions. Fessner emphasises that these biocatalysts have achieved an unparalleled level of perfection in the course of evolution: "Nature has chemistry firmly in its grip. It operates an optimal catalytic process." The chemical industry should learn from this example because, aside from the harsh reaction conditions and high consumption of energy in traditional processes, standard metal catalysts also have some other issues: They are not only expensive but also sensitive to handle and damage the environment. "In the mining of precious metals, millions of tonnes of heavy metals are released into the atmosphere," points out Fessner. "By using biocatalysis we are developing more sustainable processes."

Fessner is coordinating the EU project CarbaZymes since 2015. It focuses on biocatalysts used for carbon-carbon bond forming reactions. These fundamental reactions that play a key role in almost all chemical processes combine small organic fragments with one another, such as for making precursors to mass-produced plastics. The components must come together in the correct spatial orientation, emphasises Fessner, thus selective reactions pose a challenge to chemists. In contrast, enzymes easily control the reaction because they bind the starting molecules for a brief moment and position them perfectly to one another. It is exactly in this way, for example, that our bodies can build up complex hormones and other biomolecules from simple fragments.

In the chemical and above all pharmaceutical industries, many enzymatic processes have already become established, yet the formation of carbon-carbon bonds is an underdeveloped field according to Fessner: "The enzymes required for this purpose have long been thought to be too specific and thus not suitable for industrial application." The problem is that many of these types of enzymes only catalyse a certain reaction because they bind the starting molecules in a highly specific way according to the lock and key principle. However, tolerant enzymes also exist that can convert various compounds. "This is what we're looking for," explains Fessner, "plus we can now change enzymes so that they are suitable for a whole range of molecules, even for those that are unreactive under natural conditions."

Fessner's group use a fermentation process to obtain the enzymes out of cells of Escherichia coli, also known as coliform bacteria. The blueprint for the enzyme is hidden in the genes of the cell. Using molecular biology methods such as implanting artificial gene sequences, the researchers can change the blueprint and optimise the enzymes. Biocatalysts that do not occur naturally in coliform bacteria can also be produced in this way. In the search for and development of enzymes the method of directed evolution is helpful: It induces random gene changes and thus results in numerous related enzymes, from which the scientists can identify those variants best suited for the task. This selection proceeds over multiple cycles.

The researchers in Darmstadt are working closely together with Prozomix in England, one of their

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Photo: Katrin Binner

Professor Fessner, head of the research group, is proud of the efficient collaboration in a interdisciplinary and international team of experts in the field of biocatalysis.

partners in the CarbaZymes project. This company provides them with hundreds of proteins that all catalyse the same reactions but originate from various different organisms. These also include many microbes that live under extreme environmental conditions and cannot be cultivated in the laboratory – but which are particularly interesting for industry. Bacteria from hot springs, for example, have particularly heat-stable enzymes. From the pool of proteins provided by Prozomix, the scientists select suitable enzymes that can then be further refined as required.

"By using biocatalysis we are developing more sustainable processes."

Fessner already holds multiple patents for enzymatic processes, and the CarbaZymes project has also already resulted in two patent applications. In cooperation with their Spanish partners in the CarbaZymes project, the team at Darmstadt published a new biocatalytic process for the production of homoserine, a precursor for pharmaceutical ingredients and essential amino acids for animal feed, in early 2017.

The chemical industry is showing great interest in biocatalysis says Fessner: "There are a lot of companies investing heavily in this area and a number of processes have already been converted." Instead of pure enzymes, living cells are often utilised at an industrial scale. Whole cell biocatalysis makes more sense economically because it is not necessary to isolate the enzyme. The use of whole cells is particularly advantageous for complicated syntheses that require multiple different enzymes. A classic example is the production of vitamin B2: The fermentation process using fungal cells produces the vitamin in one step from vegetable oil. In contrast, the old chemical synthesis required eight steps and caused more carbon dioxide emissions, more waste and higher costs.

The biocatalytic production of vitamins and other complex molecules is highly appealing to Fessner as a chemist but he prefers to dedicate himself to the enzymatic synthesis of basic chemicals: "Billions of tonnes of these chemicals are produced every year. If we could design these processes in a more environmentally friendly way, it would have a much bigger impact on the future of our planet."

The author is a scientific journalist with a PhD in chemistry.

EU-Projekt CarbaZymes

A total of 14 research institutions and companies from Germany, Spain, the Netherlands, Croatia and England are cooperating on the EU project CarbaZymes titled "Sustainable Industrial Processes Based on a C-C Bond-Forming Enzyme Platform". Chemistry professor Wolf-Dieter Fessner at TU Darmstadt is coordinating the activities that started in April 2015. The EU is funding this cooperative project with 8.2 million euros until the end of March 2019. "By involving small start-up companies, we have access to the most recent technology, which has significantly speeded up the development of our enzymes," Fessner emphasises. Further information is available at CarbaZymes.com

Current publications

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- Y.-C. Thai et al., Bioorg. Med. Chem. 2017, 25, in press. DOI: 10.1016/j.bmc.2017.05.024
- R. Roldán et al., Chem. Eur. J., 2017, 23, 5005-5009, DOI: 10.1002/chem.201701020
- K. Hernandez et al., ACS Catalysis, 2017, 17, 1707-1711, DOI: 10.1021/acscatal.6b03181

Well organised to defeat hacker networks

Cyber criminals expertly plan their activities while their victims act rather clueless in isolation. A research team headed by Professor Max Mühlhäuser wants to change this – by bundling the victims' defences.

Photo: Jan-Christoph Hartung

A view to a "Honeypot" located in Greece: in a short order attacks occur from all parts of the world.

Profile and projects
The research carried out by Max Mühlhäuser's team is part of the Cybersecurity profile area at the TU Darmstadt (CYSEC), and incorporated in several national and international projects including:
Special research area CROSSING, **www.crossing.tu-darmstadt.de;**
CRISP (Center for Research in Security and Privacy), **www.crisp-da.de;**
EU project „TAKEDOWN", which investigates the structures of organised crime and terrorism, **www.takedownproject.eu.**
Publication:
Vasilomanolakis E., et al: Did you really hack a nuclear power plant? An industrial control mobile honeypot, 2015. (IEEE CNS 2015 Poster Session).

By Christian Meier

A green line is creeping across the world map towards Athens. "There – look – another attack," says Florian Volk of the Telecooperation Group, Department of Computer Science (CS) at the TU Darmstadt. The screen, which measures about two square metres, displays hacker attacks on computers that the research team has set virtually as bait, so-called honeypots. Professor Mühlhäuser and his team want to record as many of these attacks as possible in order to identify patterns in them. Learning computer programs are becoming increasingly reliable at discovering identifying features. The idea is to uncover the tactics used by an industrially organised digital shadow economy. The aim: to organise an equally efficient defence by bundling the power of the affected individuals. "Coordinated distributed defences," Volk calls it.

At the moment, according to the specialist, there is no equality of arms between the malicious hackers and the people who are the targets of their attacks. The lonely hacker unleashing his computer viruses on an unsuspecting world is a cliché. "There is a clear division of labour in cyber criminality: one section sets up an infrastructure, known as a botnet. They hire these out to the others for massive distributed attacks," he explains. Botnets are essentially an army of electronic helpers: hijacked PCs or, increasingly, devices such as thermostats that are connected to the Internet. Invading the computers is by itself a computer-automated task. While the CS specialist is speaking, there are countless attacks on the honeypots – more than 60,000 a month. The actual perpetrators now use the botnets for attacks with names like "Denial of Service". In this example, thousands of hijacked computers simultaneously send queries to the victim's server, which collapses under the load.

The victims, mostly companies, tended to keep the attacks to themselves, says Volk. "Which is a shame," he adds. "Were attack patterns more regularly exchanged, the next victim could be able to identify the attack in advance and respond, perhaps by deliberately rejecting the queries."

At the heart of the TU researchers' work is the development of a tool that will allow potential victims to fight the hacker industry's superior strength collaboratively. Companies could then exchange information about the attack without revealing any knowledge of their own IT infrastructures. Volk explains that the attack would be displayed in the form of a "basic data structure". This is a kind of fingerprint of the event, which would enable other companies to instantly identify such an attack and be able to defend themselves in time.

"As identifying a pattern is easier and more successful the more data you have, it would be important to set far more honeypots," he adds. This would result in an infrastructure that could face up to the well-organised substructure of the hackers.

The author is a science journalist with a doctorate in physics.

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