Bioeconomy in construction and architecture

Development of innovative, ecological construction materials and methods at the University of Stuttgart

The Baden-Württemberg construction sector is currently experiencing a similar boom to the one that occurred in 1996. Between January 2016 and January 2017, low interest rates and uninterrupted demand for housing has led to an increase in orders of almost 10%[1]. A shift from conventional building materials to biobased building materials and products would likely also support the transition to a bioeconomy in this economic sector. The Institute for Building Structures and Structural Design (ITKE) at the University of Stuttgart could help make this transition possible.

As part of the German Resource Efficiency Programme (ProgRess), Germany has set itself the target of doubling its 1994 resource productivity figures by 2020[2]. This target can only be achieved through a drastic reduction of the quantity of abiotic raw materials used and by simultaneously keeping the gross domestic product (GDP) on an even keel[3]. The construction sector, a high growth economic sector that is by far the most resource-intensive in Germany, is strongly opposed to both of these things. The European construction and housing sector uses almost exclusively mineral, cement-based building materials[4]. 5.5 million tonnes of steel and 28 million tonnes of cement are used in Germany every year, simultaneously generating 192 million tonnes of construction waste, which accounts for more than half of the general waste volume that accumulates in Germany every year[2].

Research in Stuttgart could potentially increase sustainability in construction and architecture

ITKE researchers use bionic principles to produce innovative shading systems.
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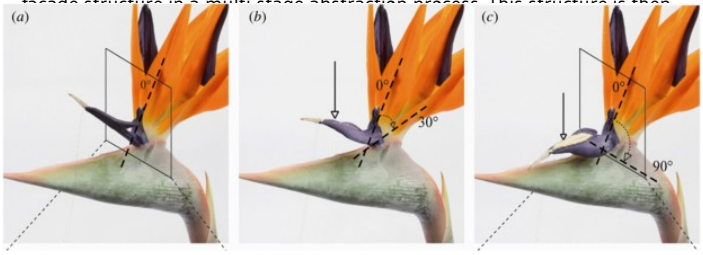
Scientists from the ITKE in Stuttgart are looking into the construction of buildings of the future by investigating sustainable solutions for the construction sector. This includes the development of biobased building materials, supporting structures and interior design elements. They attach great importance to using locally sourced natural fibres, so that furniture and wall coverings not only stand out for their optical design and interactive elements, but also for their ecological added value. By establishing close connections between research, teaching and industry partners, the researchers are using state-of-the-art, digital modelling tools and production methods (such as 3D printing) to convert their ideas into prototypes. In addition to biobased furniture, the IKTE researchers are working on the development of biobased materials for heat and sound insulation as well as on new conversion methods, all of which make it possible to convert biomass into robust and durable building materials. Moreover, the ITKE's bionically inspired materials and glue-free connection elements and methods contribute to the reduction of fossil resources in the building sector. Even though this cannot automatically be put on the same level as biobased economies, reducing the use of fossil resources is nevertheless an important step towards a more sustainable economic approach.

The award-winning Flectofin® shading system is a resource-conserving building enclosure based on bionic principles (= the combination of biological and technical principles for the development of innovative technologies based on nature's model). The researchers based their hinge-free louvre system on a principle found in the tropical plant Strelitzia reginae which depends on ornithophilous pollination, i.e. the transfer of pollen from one flower to another by birds. When a bird lands on a Strelitzia reginae flower, the bird's weight triggers the pollination process, the pollen sack opens and the pollen sticks to the bird's feet. This non-autonomous deformation principle (= deformation caused by external forces) was translated into a lamella-like

able to increase energy efficiency in buildings. The modern glass fronts of many (office) buildings lead to overheated spaces in the summer and enormous energy losses of up to 40% in the winter. If air-conditioning systems were replaced by shading systems such as Flectofin®, which would also reduce passive energy losses during winter, approximately 41 million tonnes of oil and 111 million tonnes of CO_2 per year could be saved[5].



The pollination mechanism of the South African plant Strelitzia reginae is based on a non-autonomous deformation principle of its blossom in response to external forces. Researchers from the ITKE copied this biological principle to make innovative shading systems.
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Integrative construction methods moving towards a bioeconomy

The research pavilion at the University of Stuttgart campus is based on a lightweight scaffolding structure made of thin veneer panels that are sewn together by robots[9].
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However, innovative façades alone are not enough to make the construction and architecture sectors more sustainable. The ITKE is therefore carrying out intensive research on new construction methods, which both conserve resources and produce fewer emissions. One such example is a research project called "Homes". It is focused on modular construction methods involving finished building components to replace conventional ways of constructing buildings on site[6]. Wall elements are fitted with power lines and water pipes at the production site and later connected into a building on the actual construction site. Alongside well-thought out material circuits and the use of recycled materials, modular design (also used in the automotive industry), is likely to help reduce building waste[7].

The ITKE is one of six European academic partners that are currently working with 14 industry partners on the InnoChain project. The project aims to develop innovative design solutions. Major focus is being placed on the combined use of digital design tools, adaptive, sustainable materials and robotic manufacturing technologies[8].

How this can be done in practice was demonstrated with a research pavilion made from lightweight wood constructions that was erected on the Stuttgart University campus in April 2016. Inspired by the structure of a sea urchin shell, beech veneer panels a mere 3 to 5 mm thick were produced and sewn together using automated manufacturing methods, thus completely obviating the need for metallic connecting pieces. Veneer panels make construction easier and also help save material as they serve as support structure, shell and inner wall of the construction. In addition, wood is a renewable resource and the use of locally available wood sits particularly well with the idea of a recycling-oriented bioeconomy[9].

Do biobased materials have a future in the construction sector?

Instead of focusing on wood, junior professor Dr.-Ing. Hanaa Dahy, who has been head of the ITKE's Department of Biobased Materials and Material Cycles in Architecture (BioMat) since 2016, is working with renewable resources such as straw as a starting material for producing biobased building materials. Straw is particularly suited for this purpose as huge quantities accumulate in grain production. "The biggest problem associated with straw is its low density and high volume. At the same time, straw has a high silicate content. The latter is very positive for us, as the silicate minerals can be used as natural flame retardants in building materials," says the junior professor. Another advantage is the cost. "A tonne of straw costs only around €46; so it is very cheap. Production costs can be reduced and competitiveness increased," says Dahy.

Dahy believes that the biggest challenge as far as the use of biobased materials in the construction sector is concerned, is to increase the acceptance of such innovative, sustainable materials on the market. She complains that many customers are relatively quick to see these "green" materials as a step back to mud huts or similar building constructions. "A good marketing strategy is needed to convince customers of the benefits of environmentally friendly building materials and eliminate prejudices," she notes. However, she is absolutely convinced that biobased materials will in the future be able to find a slot on the market because of their aesthetic and functional values, the combination of digital and robotic manufacturing technologies, but above all because of their ecological added value. "This is clearly visible in the interest that the industry is expressing in our research and our materials," concludes the junior professor.

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Jun.- Prof. Dr.-Ing. Dahy in her office at the ITKE showing a selection of biomaterials she has developed.

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