Can carbon-reinforced concrete replace steel in the long run?

Textile concrete is currently one of the most popular raw materials in construction: "*In the upcoming ten years, we will lay the foundations to replace at least 20% of steel by carbon for the reinforcement of concrete.*"

Carbon-reinforced concrete is an innovative composite material even though it is still competing with steel-reinforced concrete. With a worldwide use of 8 billion m^3, concrete is currently the most popular raw material. Already 2,000 years ago, in ancient times, buildings like the Pantheon in Rome were built with materials comparable to concrete, a mixture of cement, clay, sand and gravel with water [1]. Then, by the end of the 19th century, iron and later steel were used to reinforce the construction and increase the life cycle of buildings, car parks or bridges. Steel for the reinforcement of concrete has a major disadvantage: it is not corrosion resistant in the long run and needs an additional concrete cover to protect the steel reinforcement from corrosion. Bridges are particularly affected.

There are around 140,000 bridges in Germany, 40,000 of which are part of highways or main roads, mainly made from steel-reinforced concrete.

According to Dr.-Ing. Christian Kulas, managing director at Solidian GmbH, 19 % of all bridges in Germany are acutely in need of repair [2]. Economic losses due to redirections and congestions resulting from damaged bridges that cannot be crossed normally are extremely high and are estimated to reach 2 billion euros annually in Germany.

A milestone on the way to a less corrosive material is the research in carbon concrete. Carbon-reinforced concrete is a blend of high-performance concrete and a reinforcement made from carbon. Carbon is famous for its lightness, flexibility and strength. Another striking advantage is that it can reduce energy consumption and CO_2 footprint by up to 50%. The Tudalit e.V. association was founded in 2009 with the overall goal to support the development of construction with non-metallic reinforcements, particularly carbon. JEC Composites Magazine met Roy Thyroff, managing director at Tudalit e.V.

"C^3 undeniably triggered a paradigm shift in the perception of carbon-reinforced concrete and we are expecting further quantum leaps in the upcoming years, when we will have joined forces."

The Bosphorus bridge in Istanbul: Cladding of bridge pylons at an altitude of 320 m ©Fibrobeton (Istanbul, Turkey)

Roy Thyroff

Roy Thyroff has an education as a technical business economist.

He joined V. Fraas GmbH in 2000 and, since 2012, he has been part of the management of V. Fraas Solutions in Textile GmbH and managing director of Tudalit e.V.

Fig. 2: The Solothurn hospital in Switzerland - horizontal and vertical elements made of carbon concrete ©Sulser AG (Trübbach, Switzerland)

JEC Composites Magazine: : What are the primary goals of the Tudalit association?

Roy Thyroff.: Tudalit is currently heading for a new line of approach, evolving from a trademark to an internationally-recognized industry association that will be located in Berlin in the future. We consider that the proximity to other leading institutions such as Deutscher Beton- und Bautechnik-Verein e.V. will be very favourable to accomplish our ambitious goals. The community needs a strong industrial representation that confers crucial confidence regarding technical approvals, standards and guidelines. We are currently organizing a two-day annual networking conference illustrating the latest trends in textile- and carbon- reinforced concrete. The construction sector is highly specific, epitomizing a truly sustainable mindset. Establishing mutual trust and thus gaining acceptance in the market is a key advantage when interacting and working with this community. The Deutsches Zentrum Textilbeton initiative was started in 2007 to accelerate knowledge transfer at first hand, and is now incorporated as a division at the Technical University Dresden AG (TUDAG). The Tudalit association was founded in 2009 with the overall target to enhance applications and future developments of the Tudalit protected trademark.

From your point of view, what are the most important applications for carbon and textile reinforced concrete?

R.T.: Let us start with the milestones… The first approval for the application of carbon concrete reinforcements in building interiors, particularly ceilings and walls, was granted in 2014 and then the Deutscher Zukunftspreis was awarded by federal president Joachim Gauck in 2016. These were pioneering landmarks for the market acceptance of carbon-reinforced concrete. In the meantime, multiple authorizations were granted on a case-by-case basis. This means we can present a large list of splendid showpieces from residential or office buildings, to schools, car parks or bridges. For example, the construction of car parks using finished parts with textile reinforcements (glass fibre) was achieved in a common effort by Solidian, Beton Kemmler and RWTH Aachen. Hering Architectural Concrete developed cost-effective architectural concrete facings, thus meeting the demand for thin and light components. Due to its corrosion-free properties and a more convenient installation, textile-reinforced concrete is noticeably more economic to install than steel-reinforced concrete. However, unlike steel-reinforced concrete, we are still not included in traditional directives or standards. The material's classification in standards is still in progress. We need visionary construction companies that are looking into the future, who address problems and are willing to provide the required resources and support the Tudalit association.

To what extent is carbon-reinforced concrete a true alternative to steel-reinforced concrete?

R.T.: You always need an overall cost consideration and then decide about the materials to be used. This cost efficiency needs to be evaluated across the entire value chain. We need a totally new cost calculation approach, away from a single system to the entire project. One of the major assets of carbon-reinforced concrete is its shorter execution times: when using carbon concrete in façade panels or flooring panels on balconies, transport and assembly costs may be reduced significantly. This is also true for substructures or fastening structures due to the overall reduction of component weight. Carbon is four times lighter and six times stronger than steel. Components can be designed much thinner, thus saving up to 50% of resources.

How important is the research project C^3 - Carbon Concrete Composite to achieve the objective of triggering a change of reinforcement material from steel to carbon?

R.T.: As the largest research programme in the building & construction sector in Germany, C^3 – Carbon Concrete Composite – had ground-breaking effects on our way to a larger acceptance of the material in the construction community.

With a turnover of approximately 10% of the gross domestic product and more than 330,000 companies, the construction industry is the most important industrial sector in Germany.

Approximately 6% of all employees work in the building industry.

The Federal Ministry of Education and Research is funding the project as part of the «Twenty20 – Partnership for Innovation» initiative with up to 45 million euros [3]. The companies involved add another 15 million euros capital. The interdisciplinary consortium currently consists of 164 partners. C^3 undeniably triggered a paradigm shift in the perception of carbon-reinforced concrete and we are expecting further quantum leaps in the upcoming years, when we will have joined forces.

Dr.-Ing. Frank Schladitz

Dr.-Ing. Frank Schladitz MBA, is the representative of the executive board of the C³ - Carbon Concrete Composite e.V. and coordinates the research project on behalf of TU Dresden. After completing his studies in civil engineering, he spent five years planning bridges before joining the Institute for Concrete Structures at TU Dresden.

Frank Schladitz: The great challenges with regard to environmental protection, carbon footprint reduction and resource saving can only be mastered if the construction industry is willing to accept changes. The vision of C³ is to initiate a new era of building design by using carbon reinforced concrete and replacing steel in the long term. Most of the concrete used as a cover to protect steel from corroding can be spared. Carbon reinforced concrete offers new solutions. Whereas the production of cement accounts for 6.5% of global CO_2 emissions, three times the volume produced by global aviation. The solution is: carbon concrete. The use of carbon concrete allows up to 80% material savings.

Since the start of the C³-project in 2014, a lot has changed for the better [4]. Six more admissions have been granted in the last five years and all major construction institutes have started their research on carbon reinforced concrete- before that, only Aachen and Dresden were engaged in this field. The project made its way from research to applications. Several companies are developing their own products now and opt for innovative construction solutions. One of our 164 members, the construction company Goldbeck, covers the entire process chain from planning, design and support to the finished building, offering turnkey solutions. In 2014, only pedestrian bridges were made of carbon reinforced concrete but more and more road bridges can now be expected. Saxony is planning a road bridge entirely made of carbon reinforced concrete. My plea to the industry: sustainable companies that are heading for a future-proof employer branding should commit themselves to the carbon reinforced concrete megatrend. C³ wants to lay the foundation to replace at least 20% of steel with carbon for the reinforcement of concrete by 2025.

The world's longest bridge made from textile-reinforced concrete (96.75 m) in Albstadt-Lautlingen ©Solidian

The first bridge ever made of carbon reinforced concrete in Albstadt-Ebingen ©Solidian

Dr.-Ing. Christian Kulas

Dr.-Ing. Christian Kulas is managing director at Solidian GmbH, a leading producer of glass and carbon reinforcements. After structural engineering studies in Konstanz, teaching activities and an MBA at RWTH Aachen, je joined Solidian in 2013, where he was responsible for technical and engineering parts. He was appointed managing director in 2017.

JEC Composites Magazine: What were Solidian's most outstanding construction projects during the past years?

Christian Kulas.: We handled many fascinating projects, but the most outstanding one was probably the cladding of the Bosphorus bridge pylons in Istanbul at an altitude of 320 metres. We were in charge of providing a technical solution and producing the glass/carbon reinforcements.

Without such an innovative material as textile-reinforced concrete, the façade design of the pylons would not have been technically feasible. A maximum panel weight of 110 kg/m² was required for the façade panels geared to protect the steel structure on the pylon heads and for handling purposes at high altitudes. The challenge was to build these panels with a maximum dimension of 3.0 m x 4.5 m, being only 30 mm thin.

Last but not least, we had to struggle with huge wind speeds at this height. But time pressure was also an issue.

We managed the whole project within four months, including the development of technical solutions, the testing stage, and the production and shipping of 3000 m² of reinforcements to Turkey.

A more recent example for the application of carbon-reinforced concrete is the new hospital in Solothurn (Switzerland) that will be completed in 2020.

The planners put a lot of emphasis on designing bright and friendly rooms while shielding the structure from heat-inducing sun rays.

This was achieved through the use of suspended elements, which also serve as

screens and ensure the privacy of patients from public areas.
The horizontal and vertical elements, which should not be latticework, but optically rather massive, would not have been possible with steel-reinforced concrete as they would have been too heavy to be easily anchored to the load-bearing walls. The planners opted for a hollow-core cross section with a shell that is only 30 mm thick. This way, the weight of the precast elements was reduced by roughly 60%.
As a third example, I would like to mention the first bridge ever entirely made from carbon-reinforced concrete in Albstadt-Ebingen.
The 15-m-long bridge is used by pedestrians and cyclists and can also accommodate a 10-ton snow-removal vehicle. This is a perfect example to demonstrate the potential of this innovative material.

What are the core advantages of textile- or carbon-reinforced concrete applications?

C.K.: The main advantages are unequivocally corrosion resistance and lightness. Take a façade panel for example.
A carbon-reinforced concrete panel is 2-3 cm thick compared to 8-10 cm for steel-reinforced concrete.
This is an enormous material saving.
With regards to the worldwide sand shortage, a shift to this innovative material is mandatory. In bridge building, it is rather the durability aspect that has a major impact. For steel-reinforced concrete, a sealing cover or an asphalt layer that needs a restructuring every 5-10 years is required. With carbon-reinforced concrete, this layer is not needed any more, resulting in minimized maintenance costs and increased durability. Bridges made of carbon-reinforced concrete have a lifespan of 80-100 years with no renovation cycles in-between.
Ten years ago, we built the world's longest pedestrian bridge in Albstadt-Lautlingen, with a total length of nearly 100 meters. No deterioration has been observed so far.

What trends are you foreseeing for textile-reinforced concrete over the next ten years?

C.K.: As far as façades, bridges and restructuring are concerned, this innovative material will continue to gain importance and extend its position in the marketplace. I would even go further and say it is going to replace steel in these niches.
However, all the players in the process chain still have some homework to do from application-oriented research at institutes and universities to standardization activities.
I assume we will be able to rely on standardized norms within a few years.

How important is it for Tudalit to accelerate knowledge transfer and how important is this network for your activities?

C.K.: The envisaged transition of Tudalit from a trademark to an international industry association could ring in a new era.
We see enormous potential since there is a need for this format to pool the resources of the entire carbon industry and enhance the application of carbon concrete as an interesting alternative to metallic reinforcements. □

More information:
www.solidian.com

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