Innovations for climate protection

May 2022

Smart Circular Bridge made of Bio-composite

An old material is being rediscovered: flax has been with us for thousands of years in the form of clothing, sacks, and robust ship's ropes. Now the plant fibres are experiencing a renaissance and could become the building material of the future. Combined with a special bio-resin, it can be made into a light and highly stable material with properties comparable to aluminium or steel. The EU project "Smart Circular Bridge" shows what is possible with this innovative new material: via the development of three bridges from this so-called bio-composite. A first one has now been built, and two more will follow.

In times of climate change and dwindling raw materials, bio-composites offer a great opportunity for the construction industry with its huge CO_2 footprint and immense consumption of resources. They hold enormous potential for a bio-based circular economy.

Interdisciplinary teams drive development

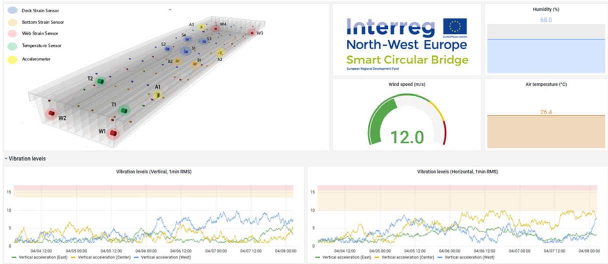
The first "Smart Circular Bridge" with a span of 15 metres has now been realised by an international consortium of 15 partners led by Eindhoven University of Technology in the Netherlands. The project team consists of five universities, seven innovative companies, and three municipalities. The first bridge set up at the Floriade international horticulture exhibition in Almere, Netherlands will open April 22nd. Two more “Smart Circular bridges” for pedestrians and cyclists will be built in Ulm, Germany and Bergen op Zoom, Netherlands later in 2022 and in 2023 respectively. Through this intensive cooperation between science, industry, and local authorities, a multitude of innovations is launched.

Laboratory tests to understand the long-term behavior

One focus of the Smart Circular Bridges research is to understand the long-term behaviour of natural fibre-reinforced composites. The goal is to use them for large projects that have a lifespan of several decades.
To this end, the bio-composites were investigated in laboratory tests with regard to their tensile and compressive strength as well as material stiffness under various environmental conditions, for example UV radiation or moisture. The focus was on findings on fatigue strength and material ageing.

Real-time monitoring – on a public dashboard

A complementary aspect of the research is the differentiated structural health monitoring of the three bridges. The system used is similar to that used for offshore wind farms. This means that the bridges are not checked periodically, but continuously monitored in real time.



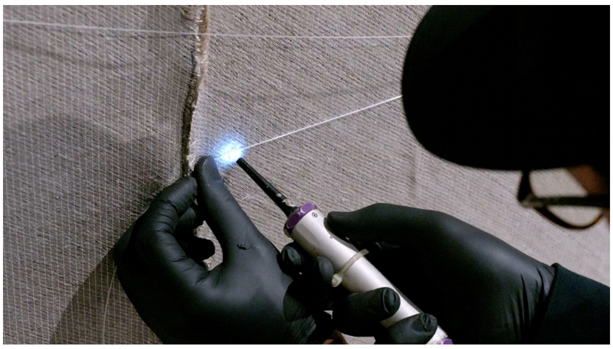
The data from the sensors can be viewed in real-time on a dashboard on a public website.

The monitoring system has two main tasks. First, it ensures the safety of the bridge with regard to the static requirements - an important aspect when using a relatively new group of materials in supporting structures. The continuously provided data draw a precise picture of the condition of the bridge and thus also allow an estimation of the lifetime.

Above all, however, the almost one hundred sensors continuously provide a mass of data from the material’s behaviour in everyday life. Just like the test results carried out in the laboratories, the real-time data serve to verify the applied finite element models and the predicted material properties. In this way, the project contributes to intensive research on the material in a comparatively short time. The data from the sensors can be viewed in real-time on a dashboard on a public website: dashboard.smartcircularbridge.eu/

Monitoring with three types of sensors plus artificial intelligence

Fibre-optic sensors provide information about the deformations of the bridge in different directions. The sensors are not located on the outside



Structural Health Monitoring: artificial intelligence evaluates data from almost 100 sensors within the bridge in real time.

of the bridge body, but are embedded longitudinally in the bio-composite material on the inside. They have a great advantage: even if an optical fibre breaks, the integrated sensors still deliver their data to the server via the second, unbroken interface.

Temperature sensors provide data for a comparison with the deformations. They are also located inside the bridge.

Acceleration sensors detect even slight vibrations and provide information, for example, about the frequency at which the bridge is moving due to the influence of wind or dynamic traffic loads.

These measurement data are continuously recorded and already evaluated on the bridge itself in a first step, then forwarded to a server and reduced. Features and characteristic parameters are extracted from each data set using artificial intelligence; they describe the behaviour and condition of the bridge. Should a predefined limit value be reached, the system immediately sounds an alarm to ensure the safety of the bridge.

In the first phase of the project, tests have already been carried out on large models. Monitoring on the real bridge continues the data collection at a higher level under everyday loads. In combination with materials research, the monitoring can also be used to estimate the so-called remaining service life.

The partners are aiming for a lifetime of the Smart Circular Bridges that is just as long as that of conventional bridges made of glass-fibre reinforced polymers, for example – but with all the advantages of the bio-composite material for the circular economy and climate protection.

Material

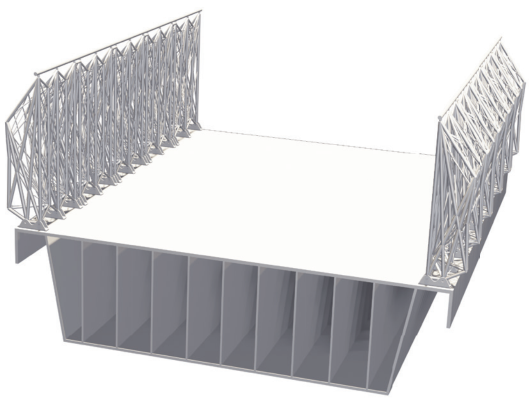
The first Smart Circular Bridge in Almere uses around 3.2 tonnes of flax fibres, mainly from French production. The fibres, woven into mats, are impregnated with a polyester resin. In the first Smart Circular Bridge, 25 percent of this resin is based on biomass. For the coming bridges,

Flax fibres could become a building material of the future. Flax mats combined with bio-resin can be made into a light and highly stable material with properties comparable to aluminium or steel.

the goal is to increase this share to about 60 per cent. To achieve this goal, waste products from biodiesel production and recycled PET bottles are used. Innovations in the project include not only the development of a suitable resin that can handle the residual moisture of the flax fibres, but also the development of a cobalt-free accelerator. One of the advantages of this composite material is that flax is a fast-growing plant - compared to wood, for example. In addition to flax, other fibres are also available as raw materials for high-performance bio-composites in the global perspective.

Construction

The bridge structure consists of the deck and a railing made of bio-composites as well as abutments with approach ramps. A multi-cell, rectangular box with continuous longitudinal webs forms the bridge deck. A transverse web terminates each end. The width of the hollow box is 3



metres, the height 90 centimetres and the span is 15 metres. The thickness of the box panels varies from 15 millimetres for the longitudinal webs to 20 millimetres for the soffit and 25 millimetres for the carriage surface. The static calculation by the Eindhoven University of Technology shows that these dimensions can carry the required loads – i.e. the permanent loads from the structure and the surface, the areal traffic load as well as a vehicle load with 2 x 25 kN axle.

The abutment construction consists of a sheet pile wall construction, two bored piles and a steel beam that connects the bored piles and serves as a support for the bridge. The vertical support reactions from the bridge are transferred to the bored piles via the steel beam. Horizontal support reactions in the longitudinal and transverse directions are introduced into the sheet piles. As an access route, concrete drag slabs are placed on a sand bed between the sheet pile walls on both abutment sides.

Production

Production process: fibre mats made from flax are wrapped around lightweight foam cores.

The bridge is produced as a complete element in a vacuum infusion process. In the first step, a negative mould of the bridge element is laid out with mats of flax fibres. On top of this, blocks of polyurethane foam (35 kg/m3) covered with flax mats are positioned close together. The entire package is now wrapped again with flax mats and wrapped with a vacuum bag. After the air has been extracted, the resulting vacuum ensures that the polymer can flow in in a controlled man-

ner and fill all the cavities. In the course of this infusion process, all the blocks are force-fitted together. The polymer takes about one day to cure. This completes the entire element.

The bridge deck is manufactured as a complete element using a vacuum infusion process

Design innovation

Another innovation in the project is the bridge railing: this component is also made of a bio-composite. It is produced robotically using a coreless winding technique. The resulting triangularly cross-linked natural fibre bundles made of flax are connected to the main girder of the bridge on both sides via cantilevered transverse stiffeners. This emphasises the lightness and delicacy of the design and underlines the aesthetic and technical possibilities of bio-composites and natural fibres.

Further information

www.nweurope.eu/smartcircularbridge

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Online Symposium June 23 2022

Save the date: We kindly invite you to our online symposium on June, 23: “Smart Circular Bridge: Bio-composite Solutions for Infrastructure”. Final programme coming soon.

Smart Circular Bridge

Location

Archerpad 8, 1324 ZZ Almere, Netherlands: Floriade 2022, International Horticulture Exhibition

Partners

TU/e, Eindhoven University of Technology (NL), Lead Partner
Centre of Expertise Biobased Economy (NL)
KU Leuven (BE)
Universität Stuttgart (GER)
Vrije Universiteit Brussel (BE)

24SEA (BE)
Com&Sens (BE)
FiberCore Europe (NL)
FibR (GER)
Lineo - groupe NatUp fibres (FR)
Proesler Kommunikation (GER)
Van Hattum en Blankevoort (NL)

Gemeente Almere (NL)
Gemeente Bergen Op Zoom (NL)
Stadt Ulm (DE)

Main suppliers

Jos Scholman Infra
Nouryon
Polynt

Budget

Realisation of three bridges, research and development
Total budget: € 6.86 m
EU Funding, Interreg North-West Europe: € 3.93 m

Timeline

2019 – 2023