Protecting concrete with new technologies

Durability of concrete structures is one of the main concerns of project owners, and researchers continue to develop new ways to protect concrete from damage. We spoke to **Dr Arnaud Muller** about the work of the EnDurCrete project in developing new, more durable and more sustainable types of concrete, which include a number of novel technologies.

A number of different types of degradation can affect concrete and limit its load-carrying capacity. One type of degradation is caused by exposure to seawater, when chloride ions penetrate into the concrete matrix. "This is called chloride ingress, while there is also sulfate ingress from certain soils or carbonation by the CO_2 present in the ambient air. The end result of CO_2, chloride, and sulfate ingress is the same: damage of the reinforced concrete structure that loses its load-carrying capacity," says Dr Arnaud Muller. "Concrete is formed of a mixture of aggregates, sand, cement and water" outlines Dr Muller. As the coordinator of the EnDurCrete project, Dr Muller is leading a consortium working to develop more durable and more sustainable types of concrete, including novel additive technologies.

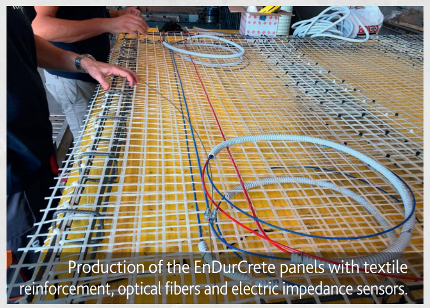
EnDurCrete project

The EnDurCrete project aims to develop a new cost-effective sustainable concrete ensuring enhanced durability with self-healing and self-monitoring capacities. The EnDurCrete project involves 16 European partners, including industry leaders in the fields of cement and concrete production, construction companies, chemical admixture producers, universities and technological research institutes.

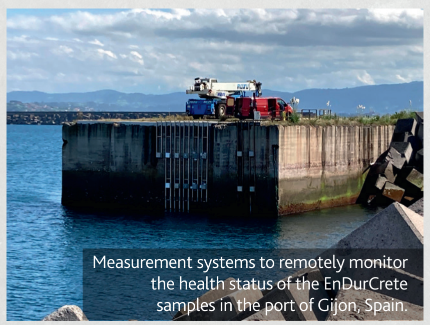
The EnDurCrete project started with the development of multi-component Portland cements with high substitution of Portland cement clinker by industrial by-products. By adjusting the fineness of each of the cement constituents independently, in order to maximize their reactivity and their synergies, researchers were able to improve performance. The new novel cements contained only 47-53% clinker, for which concrete recipes were specifically engineered to deliver the required performance.

Researchers in the EnDurCrete project are exploring the possibility of adding new technologies to concrete, with the wider aim of enhancing durability of the construction, while also reducing the environmental impact. One part of this work involves the addition of modified clays to the concrete. "Nano-clay is an additive, which has the ability to immobilise chloride coming from the seawater and hence prevent concrete damage," explains Dr Muller.

Researchers in the project are also developing multi-functional coatings, which Dr Muller says are designed to offer surface protection to the concrete, reducing its exposure to aggressive substances coming from the environment. "These coatings contain micro-capsules with a sealing agent," he says. "If a crack occurs, then these micro-capsules open and the sealing agent is released. This fills the crack and closes it as it forms." The primary purpose of the coating is to stop aggressive substances from penetrating the concrete, but if this does happen then the micro-capsules provide another layer of protection.


Production of the EnDurCrete panels with textile reinforcement, optical fibers and electric impedance sensors.

A further topic of interest in EnDurCrete is self-sensing technologies, with one of the project partners developing a textile equipped with fibre-optic sensors. "This is basically a mesh which is placed into the concrete element as it is cast," outlines Dr Muller. This mesh is embedded into the concrete, which provides a way to monitor damage over time, besides replacing the steel net as concrete reinforcement. "We can see how the element deforms by the signal we get from these fibre-optic sensors. As the element bends or deforms, the signal we get changes," explains Dr Muller. "This is why we call it self-sensing. We can essentially monitor the deformation of the elements, for example as a truck pass over it."


Measurement systems to remotely monitor the health status of the EnDurCrete samples in the port of Gijon, Spain.

A second self-sensing technology is also being developed in the project, namely micro-sized carbon fibres and carbon filler materials, that increase the electrical conductivity of a block of concrete. Multiple sensing electrodes are embedded in the concrete, providing continuous monitoring capability. "This improves our ability to sense the modification of concrete electrical behaviour due to the penetration of aggressive substances," says Dr Muller. Research in this area is still ongoing, with scientists looking to classify the different contaminants based on electrical impedance variability, yet, Dr Muller says. "This means we can use low-cost monitoring devices, allowing us to detect changes in the exposure conditions much earlier." he stresses.


EnDurCrete samples exposed to the sea water at the coast of Norway.

High durability is always a priority in the application of concrete as a building material. The technologies developed within the EnDurCrete project are being tested at four sites across Europe, where they are exposed to different environmental conditions. The proportions of different components in the concrete mixes have been engineered for each specific demo site, and the associated local regulations. "If you are going to expose the concrete to seawater, the local authorities will give you a prescription. If it is going to be exposed to frost, they will give you another specific prescription," explains Dr Muller. These prescriptions state the minimum cement content and the maximum water content required for the concrete to function effectively in a given environment. "For example, it might say that if you are going to place the concrete in the sea, you need a certain minimum amount of cement per cubic meter of concrete and no more than a certain amount of water," outlines Dr Muller.

Sustainability

The sustainability of concrete production is also taken into account in the project, with researchers developing efficient low clinkers cements, which have lower CO_2 emissions. However, the major advantage of these new EnDurCrete concretes and solutions in terms of sustainability is the improved durability. "A bridge or offshore platform constructed with these new concretes will last longer before it needs to be reconstructed than if made with conventional concretes," says Dr Muller. This initiation of ingress. This is what we are going to monitor," he outlines.

Alongside this work at different demonstration sites, researchers are also using accelerated test methods in the lab to assess their technologies. "We have exposed the concretes in the lab to very harsh chloride and harsh sulfate conditions, and accelerated the real conditions," continues Dr Muller. "This is called accelerated durability testing, it is how we validate the improved durability. Data collected during the testing will be further used as input

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leads to lower maintenance and repair costs, while also helping operators to rapidly identify and address any issues in a concrete structure before repair becomes prohibitively costly. "If you have a self-healing capability, you have a more durable concrete and then you are going to reduce the costs of repair. Or you might not even have to repair it at all if you sense the initiation of damage and act rapidly," continues Dr Muller.

A lot of energy has been devoted to developing the cements and the concretes embedding the different technologies; now the EnDurCrete consortium is applying them in four different settings across Europe. These environments are quite harsh, for example at the harbour in Norway and also in a tunnel in Northern Spain, yet Dr Muller says they will not observe dramatic changes over the first year. "We will see maybe the beginning of the for modelling of concrete performance and to develop service life prediction models."

The target here is to develop highly durable concrete, while at the same time keeping costs low and limiting CO_2 emissions. The EnDurCrete consortium is looking to develop mass concrete for everyday applications. "In EnDurCrete we are looking at regular concrete, with a strength of between 30-60 MPa at 28 days," he says. The EnDurCrete consortium took the opportunity to share ideas and collaborate with other projects in the cluster, especially the ReSHEALIENCE project, which is developing very high-performance concretes. "While these projects are developing different products, they have the same purpose of producing more durable concretes. We both work with concrete, and we can hold joint activities and workshops, as well as conduct webinars together," says Dr Muller.

Installation of the EnDurCrete technologies at the Krk Bridge in Croatia.

EnDurCrete

New Environmental friendly and Durable conCrete,integrating industrial by-products and hybrid systems, for civil, industrial and offshore applications

Project Objectives

The main goal of the EnDurCrete project is to develop a NEW cost-effective sustainable reinforced concrete for long lasting and high impact applications. The concept is based on the integration of novel low-clinker cement including high-value industrial by-products, new nano and micro technologies and hybrid systems ensuring enhanced durability of sustainable concrete structures with high mechanical properties, self-healing and self-monitoring capacities. The functionalities of the developed concrete structures are being proved under severe operating conditions supported by experimental and numerical tools to better understand, theoretically and in real application conditions, the factors affecting durability, and to capture the multiscale evolution of damage.

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Dr Arnaud Muller is working as a Senior Scientist at the Global R&D department of HeidelbergCement AG since 2015. He specializes in the development, characterization and performance evaluation of cements and binders. Since January 2018, Arnaud has also been the project coordinator of the EnDurCrete project, whose goal is to develop sustainable concretes using novel low-clinker cements.

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