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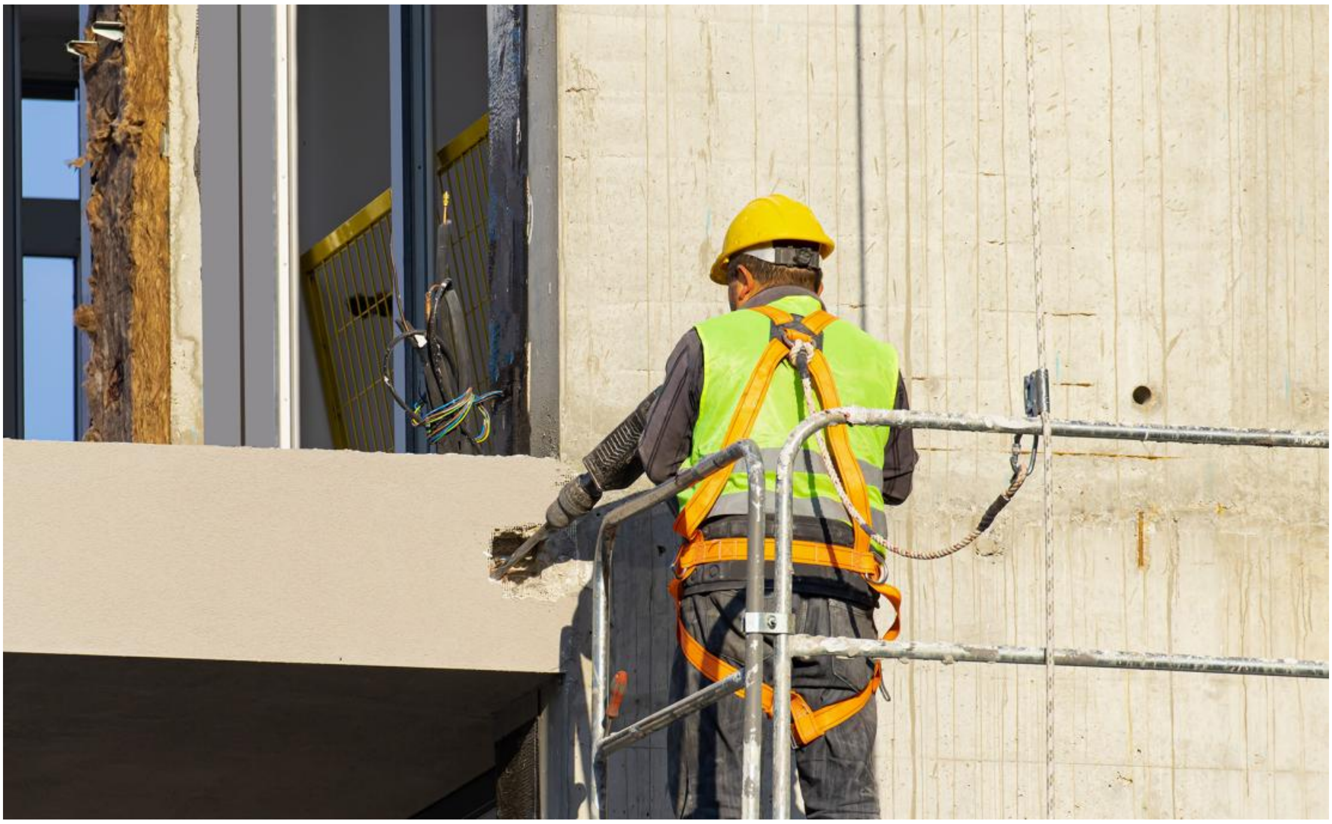

Building the future with self-healing concrete and biocement

After water, concrete is the most widely used substance on Earth. With applications from housing and industry to coastal defence and infrastructure, concrete and cement are at the cornerstone of life, quite literally.

19 July 2022 - By GARETH WILLMER

Unfortunately, the construction industry also has a major environmental impact. Cement production alone generates up to 8% of global carbon emissions, more than aviation (2.5%) although less than the agriculture sector (12%), according to one report.

Innovative thinking is needed to make construction materials more sustainable, while keeping them affordable and versatile. Some in the industry are using new technologies to make concrete ultra-durable, while others are turning to biology to make sustainable biocement.

New types of sustainable concrete are key to providing the foundations for other sustainable infrastructure, such as wind farms, said Professor Liberato Ferrara, a professor of structural analysis and design at the Polytechnic University of Milan in Italy.

‘If we think of all the needs that we have now for the energy transition, I would say that we cannot do this without concrete,’ he said.

Punishing settings

He led a project called ReSHEALience, which set out to develop ultra-high-durability concrete (UHDC). Such concrete is able to withstand extreme conditions and self-heal when used for construction in punishing settings like marine environments and geothermal energy plants.

‘These environments are among the most aggressive situations that you can have for concrete structures,’ said Prof Ferrara.

The tailored recipes are what gives these concrete mixes their strength and durability, including components such as crystalline additives, alumina nanofibres and cellulose nanocrystals.

Concrete inevitably cracks during its service life, but one of the features of crystalline mixtures is that they stimulate self-healing. By reacting with water and constituents in the concrete, they form needle-shaped crystals that grow to fill the cracks. The nanofibres mixed through it add mechanical strength to the material and help to enhance its toughness, allowing it to endure extreme conditions.

UHDC has been tested as a durable substitute for traditional wooden rafts in mussel farming, and to make parts of floating wind-turbine platforms in coastal areas. It has also been tested in the harsh conditions of a geothermal power plant, where its performance improved on traditional methods of construction.

Its use in the restoration of an old water tower in Malta demonstrates the concrete’s potential for the maintenance of heritage architecture.

Sustainable material

‘The pilots are matching expectations from all points of view,’ said Prof Ferrara. ‘We succeeded in demonstrating that UHDC is intrinsically a sustainable material. It allows the use of less material to build the same structure, so in the end the environmental footprint and economic balance is better.’

The material slashes resource use both by reducing the amount of material needed in the first place and by lasting much longer, with Prof Ferrara predicting that it may have the potential to last up to 50 years before requiring significant maintenance.

It can be produced in a wide variety of locations for many different applications using local materials. Moreover, crushed UHDC shows promise as a recycled constituent to produce new concrete with the same mechanical performance and durability as the parent concrete.

The increasing urgency of meeting sustainability goals calls for fresh ways of looking ‘holistically’ at construction, Prof Ferrara added.

‘It’s about spreading a new way of thinking for concrete structures’ that considers the whole value chain and service life of the planned structures, he said. ‘You have to think of the structural design, the procurement of materials, and the materials’ durability and life cycle. If you do not think like that, you will always have partial information and innovation will not break through.’

Biocement

Elsewhere, researchers are looking at quite different ways of innovating in the construction sector, harnessing the natural processes of living organisms.

For rail companies, the settlement of soils over time in embankments beneath railways can create serious problems and add to maintenance costs and passenger delays.

Mechanical methods for firming up ground materials or chemical-based stabilisers are usually employed as a solution. However, these can be disruptive and costly, have environmental side-effects and generate carbon emissions.

The NOBILIS project is therefore getting bacteria to do the work, viewing the ground as a living organism rather than a nondescript mass to be moved by bulldozers.

The idea is that stronger soil, created through a process called ‘biocementation’, can reduce the need for earthworks and materials like concrete.

Bacteria-built

In the process of biocementation, the bacteria's growth and metabolic activity are stimulated by providing them with nutrients and so-called cementing agents. The resulting enzymes produced by the bacteria catalyse reactions that ultimately form substances such as calcium carbonate, which bind the soil particles together.

The technique has been recognised as having potential in soil with larger particles, such as sandy soils, including forming beach rocks to protect against coastal erosion and for other applications in civil or environmental engineering.

However, a bigger challenge emerges with finer-grained soils like clay and peat, due to more restricted movement of bacteria, water and other substances. Undeterred, NOBILIS is seeking to explore ways to use biocementation on a wider range of soils.

Recent work in East Anglia, UK has demonstrated the possibility of biocementing peat soils. The NOBILIS project will aim to scale up this work through trials in the field, said Professor Maria Mavroulidou, a geotechnical researcher and project lead at London South Bank University (LSBU).

Paradigm shift

Prof Mavroulidou said this kind of biology-inspired approach requires new ways of thinking and faith in unfamiliar techniques.

‘To tell a practising civil engineer that you’re going to use bacteria to cement the ground raises eyebrows,’ she said, because it’s a paradigm shift for the industry.

Wilson Mwandira, an environmental engineering researcher, also at LSBU, said NOBILIS is investigating techniques to lock up carbon dioxide in the soil as biocementation occurs, as well as looking at the potential of using more indigenous bacteria in the process.

Using bacteria already present in the soil would avoid having a negative impact on organisms already in the environment, explained Mwandira. ‘If you bring new bacteria into a community, you are going to have a disruption in the system,’ he said.

The hope is that such biocementation techniques will become more widely applicable to construction work in general. ‘We’re also trying to extend the technique more generally to other geotechnical materials found in foundations under buildings and civil-engineering construction,’ said Professor Michael Gunn, a geotechnical engineer also at LSBU. ‘All construction requires some form of ground improvement.’

He thinks that it could take a number of years for the techniques to be used in a more routine way, but that it is essential such innovative methods are explored to address long-term challenges in construction.

‘A significant proportion of greenhouse gas emissions in the form of carbon dioxide is down to the construction industry,’ he said. ‘So we need to move away from the traditional processes.’

Water tower Malta

The Water Tower conservation project at the Public Abbatoir in Marsa took advantage of UHDC materials when it was reopened earlier this year.

Built in the early 20th century, the landmark water tower was one of the first concrete structures in Malta, but had been slated for demolition because of its run-down condition.

Researchers at the University of Malta were able to head that off by using the new advanced concrete, which is much stronger than average.

With 12 columns and a religious statue underneath, the water tower is the height of a five story building and has been saved for use. The restoration of the 15m high tower has been awarded prestigious architecture prizes.

Follow the link to learn more about the restoration of the water tower in Malta.

More info

- ReSHEALience
- NOBILIS