Durable, low-impact concrete

By integrating industrial by-products and hybrid systems, EnDurCrete will develop a new environmentally friendly and durable concrete for harsh environmental applications using low-clinker cements.

■ *by* ***P Colantonio,*** *FENIX TNT sro, Czech Republic, and* ***P Blaum***, ***P Durdzinski*** *and* ***A Muller***, *HeidelbergCement AG, Germany*

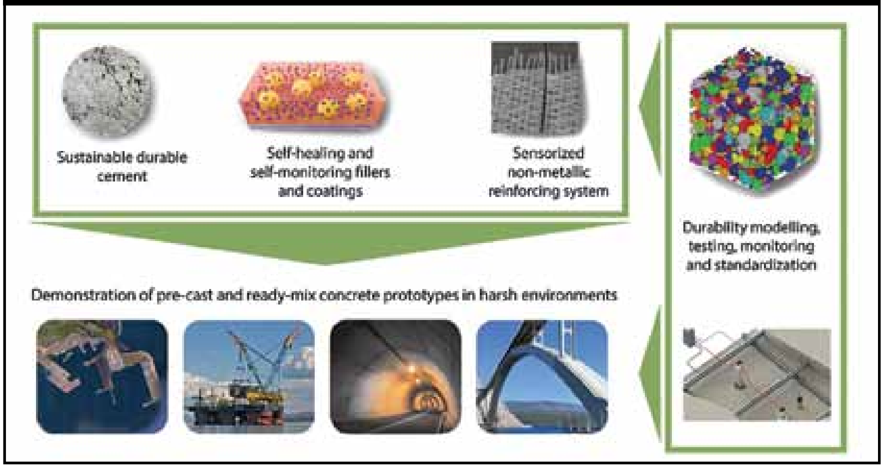
Concrete based on ordinary Portland cement (OPC) has been for many years the principal structural material for durable construction. Although, compared to wood or steel, concrete is a more sustainable construction material, the production of one of its key components, cement, consumes significant amounts of limestone, clay, energy and fuel, and creates around five per cent of the world's man-made CO_2 emissions.

Replacing part of the cement's Portland clinker by supplementary cementitious materials (SCMs), such as industrial by-products from other industries, has increasingly become the focus of the construction industry in past decades and is now a well-established strategy.

The main reason for this development is the potential of Portland composite cements (PCC) not only to increase production capacity of cement plants but to reduce the environmental impact of cement while maintaining or improving the long-term performance of the concrete. In future the substitution of clinker by ground granulated blastfurnace slag (GGBS), fly ash and ground limestone is expected to increase, but the industry should also prepare to use alternative SCMs and mixes thereof.

Current state-of-the-art concrete types based on Portland cement with very high substitution by SCMs tend to fall behind in terms of performance and durability, which is particularly critical when applied in harsh environmental conditions. Therefore, projects aimed at improving formulations and production methods to reduce CO_2 emissions, energy demand and material consumption from cement and concrete manufacturing are high on the agenda of the European construction industry and at the European Commission. One of such projects is the EnDurCrete project sponsored by the EU Research and Innovation Programme Horizon 2020 and led by HeidelbergCement AG.

Figure 1: overview of the EnDurCrete project modules



Research project

The EnDurCrete project aims to develop a new cost-effective, sustainable reinforced concrete for long-lasting and added-value applications. The concept is based on the integration of novel and optimised low-clinker cement, new nano- and micro technologies and hybrid systems ensuring enhanced durability of concrete structures with high mechanical properties, self-healing and self-monitoring capacities. The durability aspects are inevitable from a life cycle perspective as the overall energy and material consumption, ie the carbon footprint of concrete, is improved by increasing the service life of buildings, which lowers the environmental and economic costs of repair and replacement.

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 as well as service providers. The research is organised in work-packages, from the development of new ecological low-clinker cements, innovative corrosion inhibitors, microfillers, special reinforcement and self-healing solutions to the testing of durability in laboratory and on large-scale demonstrations in real environment conditions. Data collected during the testing will be further used as an input for the modelling of concrete performance and development of service life prediction models. Furthermore, the knowledge and experience gathered by the project is supporting the preparation of novel standards for eco-friendly cements and concretes.

New low-clinker cements

The EnDurCrete project work started with the development of multi-component Portland cements with a high substitution of clinker by fly ash, GGBS and limestone. Substitution levels exceed the currently-standardised limits in EN 197-1 and target new cement types to be standardised in the coming years – CEM II/C and CEM VI – containing 35-64 per cent clinker. These novel types of multi-component cements open up opportunities to incorporate SCMs more flexibly, fully utilise their potential and beneficial synergies, and make better use of locally-available materials.

Here, one of the key aspects for cement producers is to adjust the fineness of each cement component in relation to each other and thus maximise reactivity and synergies between cement constituents.

Thanks to a close collaboration with cement plants within the EnDurCrete project, it has already been possible to transfer the laboratory knowledge of the chemical, mineralogical and physical properties of cement components into the first pilot industrial-scale production of the new CEM II/C and CEM VI cements. Back in the laboratory, samples of the new cements were used to gain key data on their reactivity, hydration processes and related mechanical performance. This data will constitute an important input for further optimisation of the binder composition and later to relate it to the concrete's long-term durability and performance in harsh environment.

Figure 2: test sites for real-scale demonstrators include tunnel and marine exposure

Smart innovative solutions

The EnDurCrete project is now entering the concrete development stage, of which smart innovations are an essential part. The objective is to produce eco-friendly, low-clinker and high-performance concrete using a number of cutting-edge technologies:

- new multifunctional coatings enabling concrete self-healing properties, based on resin microencapsulation, and protecting both concrete and rebar from aggressive agents.
- new smart fillers based on nano-modified clays for anti-corrosion properties, and on micro carbon-based materials for mechanical and self-sensing properties (such

"One of the primary targets of EnDurCrete is to significantly improve the service life of concrete structures compared to current solutions and thus to create durable, sustainable and environmentally-friendly building materials with high added value and long-term cost efficiency."

© ZAG

Krk Bridge in Croatia is already a testing site for concrete. New test elements from EnDurCrete will be applied there soon

as carbonaceous inert materials like char and the finer fraction of a used foundry sand, derived from industrial by-products). The structural self-sensing properties will be complemented with the development of advanced non-destructive tools for non-intrusive in-field inspection.

• concrete non-metallic multifunctional reinforcing systems, based on technical textiles equipped with optical-fibre sensors, enabling both structural reinforcement and continuous structural health monitoring. The systems will be optimised for a trade-off between productivity, robustness and concrete reinforcement adhesion.

Real-life testing

Following the concrete development stage, full-scale demonstrators will be cast and placed in working sites of tunnels, ports, bridges and offshore structures, to prove the enhanced durability and improve the long-term cost efficiency of the new concrete structures in such critical applications.

However, EnDurCrete is not only about developing concrete but also about pushing forward test methods and analysis tools. Advanced non-destructive continuous monitoring and testing tools and procedures will be developed and used, including technologies tuned for self-sensing concrete systems. They are intended to complement the conventional durability testing procedures in laboratories.

Durable and cost-efficient concrete

One of the primary targets of EnDurCrete is to significantly improve the service life of concrete structures compared to current solutions and thus to create durable, sustainable and environmentally-friendly building materials with high added value and long-term cost efficiency. Therefore, a carefully optimised mix of SCMs in new low-clinker multi-component Portland cements with high performance should lower the interconnected porosity and decrease permeability and diffusivity of concrete structures. This way they will be less prone to degradation, including carbonation, chloride ingress and sulphate attack. Moreover, the new smart corrosion inhibitors that are being developed in EnDurCrete are expected to increase the lifetime of concrete up to three times according to accelerated corrosion tests, compared to benchmark concrete without inhibitors.

EnDurCrete will be tested in demanding environments, including tunnels

Improved understanding as added value

One added value of EnDurCrete should be an improved understanding of the factors that affect concrete durability. Modelling and simulations applied at micro-mesoscale will be carried out for cement paste, mortar and concrete. Modelling at macroscale will take it a step further and tackle the whole concrete structure. The combined experimental and computational approach will improve the assessment of long-term durability and service life in harsh environmental conditions.

It is also expected that EnDurCrete will promote technical guidelines for novel standards in the field of durability monitoring and testing as well as of new sustainable concrete materials and systems. Alignment with other European initiatives such as COST TU 1404 Action will accelerate knowledge transfer and exchange of expertise. ■