

Customer-driven innovation

The drive to find the most sustainable and cost-effective solutions to complex challenges and megatrends in the building materials and construction sectors has spurred leading cement producers to push the boundaries of binder research. Cementir has developed ultra high-performance concrete solutions based on its white cement.

■ by **Michele Di Marino, Erik Pram Nielsen and Bi Zhuo Qin**, Cementir Group, Italy, and **Stefan Lubbers, mbX, The Netherlands, and Frank Brandt and Yves Terneu**, Aalborg Portland Belgium

The introduction of Aalborg InWhite Solution™ as a generator of high-value adding and technologically-advanced products based on the company's white cement and Aalborg Extreme™ Light 120, the ultra high-performance concrete (UHPC) premix product, marks the start of a new range of products developed by Cementir Group.

This new commercial development for the group clearly represents two of the strategic pillars embedded in the company's current 2019-21 business plan: 'Pursue Innovation' and 'Consolidate Global Leadership in White Cement'.

"We want to unlock the full potential of working with customers by having a new strategic focus towards product- and technology-based applications. By enhancing the visibility into the customer's value chain, the group aims to provide a differentiated and tailored value proposition that starts from the product offering and develops into value-added services to co-development and innovation initiatives. Cementir values this mutual and close relationship based on a common desire to find the most sustainable and cost-effective solutions to complex challenges and mega-trends in construction and building materials. We think Aalborg InWhite Solution is the right enabler, ready at the right time," says Cementir's Group Chief Sales, Marketing and Commercial Development Officer, Michele Di Marino.

White cement-based UHPC technology

Cementir Group's innovation process, InWhite, has the purpose of generating a prioritised and actionable pipeline of high-potential customer value propositions through global initiatives, bringing new solutions for well-known applications, or completely new applications for white



Precast UHPC façade of Beijing Cheng Yin Business Center, produced by OmegaZeta, Nanjing, China

cement-based products in line with megatrends, such as customisation, the circular economy and highly energy-efficient solutions. The InWhite process benefits from the group's global knowledge of well-established and emerging white cement applications and the technical know-how of its internationally-acclaimed R&D centre in Aalborg, Denmark.

One of these emerging and rapidly-growing white cement applications that is largely related to the chemistry, purity and superior mechanical properties of the cement is UHPC. Thanks to these properties and advanced production technologies, UHPC has the potential to become one of the most sustainable construction materials. It supports fast-track construction and prefabrication of building. Its low weight allows for easy installation and enduring aesthetics. Moreover, UHPC is highly efficient in material optimisation with excellent strength-to-mass ratios, minimising material consumption in finished components. Properly-designed and -installed UHPC building elements yield high energy efficiency, great resilience and

durability, are low in maintenance and can have a high degree of component reuse.

A key ingredient of high-quality UHPC is white cement with its higher degree of chemical purity when compared with grey cement and inherently-stable quality following a very selective use of raw materials to ensure colour performance. This results in an enhanced interaction with admixtures, and a predictable and reliable performance.

Given that whiteness is a key performance parameter for white cement, only raw materials with very low iron content are used in white cement production. This also results in reduced formation of very slowly-reacting iron-containing clinker, leading to a much denser structure of the hydrated white cement, with higher potential strength and lower porosity of the concrete.

Strengths and benefits

UHPC has the potential to achieve very high compressive strength. A product of nanotechnology, UHPC is composed of homogeneous, high-strength aggregates with a smaller diameter compared to

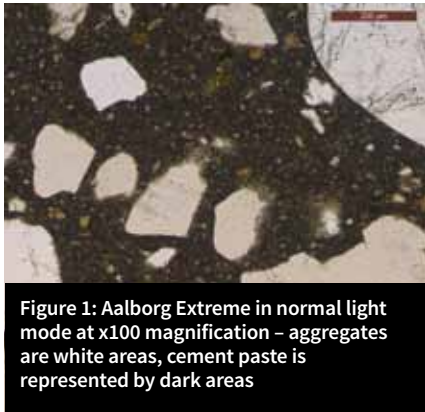


Figure 1: Aalborg Extreme in normal light mode at x100 magnification – aggregates are white areas, cement paste is represented by dark areas



Figure 2: Aalborg Extreme Light 120 in crossed polarised light mode at x100 magnification – dense cement pastes with minor amount portlandite (small sparkling in cement matrix)



Figure 3: Aalborg Extreme in fluorescent light mode at x100 magnification – dense and homogeneous cement pastes and no micro-cracking is observed

conventional concrete, as well as cement and a selection of different fine powders, of which some react with cement but all are able to fill the gaps inbetween with high precision, maximising the relative content of solids. The latest generation of admixtures is used in the production of UHPC to achieve a fluid concrete with self-compacting properties at very low additions of water, whilst still maintaining a very high strength potential.

In addition, UHPC has an extremely-high durability due to its high-density and low-porosity structure, minimising the ingress rate of deleterious substances into the concrete and the action of degrading mechanisms such as freeze/thaw. This high density and low porosity translates directly into outstanding aesthetic durability of the finished surface. It becomes increasingly difficult for dirt and dust to set on microscopic porosity defects of the surface, and effectively reduces algae growth at the surface.

Furthermore, due to the selection of suitable intermixed fibres that support the ductile behaviour of the concrete, UHPC has the ability to safely reduce the amount of the concrete cover to protect the reinforcing steel from corrosion as well as reducing, or even replacing, conventional reinforcing steel, adding to the sustainable design potential of UHPC.



Aalborg Extreme Light 120 is an easy-to-use material suitable for the production of thin and lightweight high-strength concrete products

All these advantages of UHPC are based on the assumptions that what can be designed, mixed and manufactured in small specimens under laboratory conditions is transferable to the conditions in a full-scale production facility, where completely new requirements are decisive for the quality of the placed UHPC in the final structure or element. For example, this means ensuring a proper open time of the fluid UHPC mix to enable a controlled casting operation and minimising UHPC shrinkage, potentially leading to cracks, through the selection of a suitable chemistry and particle size of the components.

There are certainly many manufacturers that master the discipline of manufacturing high-quality UHPC end products. However, this has required an extensive investment and commitment to develop and document the properties of workable UHPC mixes, building up suitable quality control systems, knowhow, casting techniques, etc. This may appear a considerable challenge to other producers wanting to explore the possibilities of this material.

To provide a safe and reliable solution of the manufacture of UHPC products, Aalborg Extreme Light 120 has been developed, designed to successfully match the requirements of industrial manufacturers, whilst still offering tailor-made possibilities in terms of colouring, and further allowing a customised selection of fibre type and dosage. The robust UHPC mix has a high viscosity but excellent, high flow properties with an open time suitable for industrial use.

To evaluate its microstructure in terms of characteristics

such as micro-cracking, water-cement ratio, homogeneity of the binder paste, adhesion of cement pastes to aggregates, evaluate secondary reaction and degree of hydration, a thin section of UHPC by Aalborg Extreme premix product was prepared for microscopic investigation. A thin 20µm slice of concrete was fixed and placed between two glass plates. This enables the transmission of light through the concrete and a view into the microstructure. The concrete was impregnated with fluorescence dye to enhance air voids and capillary porosity. Three different light modes were then applied for mineral identification and cement paste evaluation:

- normal transmission light (Figure 1)
- crossed polarisation light (Figure 2)
- fluorescence light mode (Figure 3).

As the microscopic evaluation shows, the UHPC is a very homogeneous concrete with a very low water-cement ratio, with no macro- or microcracks and proves to be a good bond to aggregates.

A new generation of UHPC

In the 1980s the laboratories of Aalborg Portland A/S in Denmark, conducted pioneering research to develop very dense cement-based binder-matrices to fully exploit the performance of concrete. These efforts resulted in the first-ever patented ultra high-performance steel fibre-reinforced concrete – bearing the name Compact Reinforced Composite, CRC®. This technology is based on the Aalborg White Cement, which offers perfectly-suited chemistry and purity, as well as superior mechanical performance.

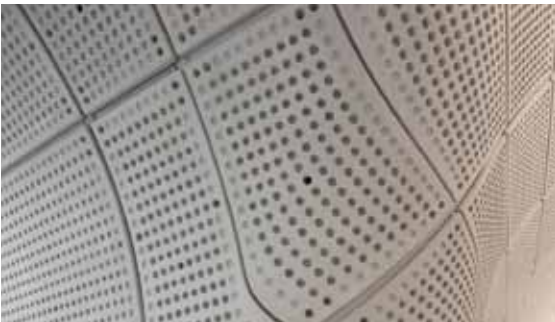
Now the innovation team from Aalborg Portland's parent company, Cementir Holding, is further developing the very complex binder technology behind UHPC with an optimised mixture of materials, bringing together Aalborg's research expertise and Cementir's market knowhow.

UHPC projects in Europe

Dutch UHPC precast producer, mbX has been using its own developed mixture of UHPC in award-winning architectural projects. Now mbX is exploiting Aalborg Extreme™ Light 120 application in the UHPC projects.

Central Station, Arnhem, The Netherlands

The OV Terminal Arnhem is designed by architect Ben van Berkel, UNStudio, and won the Dutch Concrete Award 2015 and the European Concrete Award 2016. The innovative roof panels are double-bent prefabricated UHPC elements based on White Cement and were produced by using specially-designed mbX-patented flexible moulds. Re-using the moulds increased efficiency and reduced costs. All 1500 elements are one-of-a-kind and when assembled, create a uniquely-curved rooftop.



Farringdon Station, London, UK

In 2017 mbX was asked to partner as a concrete specialist to work on the realisation of Farringdon Station in London, UK. The project was challenging and complex, partly because of the highly-aesthetic requirements but also due to the needed care for public safety. To meet both, mbX designed a special UHPC mix that included white cement (which was successfully bomb-blast tested) and unique single- and double-curved moulds to produce the required elements. The panels were nominated for a Quality Award by Crossrail.

The technology is based on a further refinement of Cementir Holdings' recently-patented binder technology, Futurecem™. This employs a unique selection of binder components known to the cement and concrete industry, offering highly advantageous pozzolanic reactions that are not constrained by the availability and quality of industrial waste materials.

This has resulted in the formulation of Aalborg Extreme Light 120, a new generation of premixed UHPC, based on Aalborg White cement. The product targets industry leaders who pursue an "extreme" level of product performance to achieve excellent architectural aesthetic and functional possibilities.

Aalborg Extreme Light 120 is a practical and affordable material suitable for the design and manufacture of thin and lightweight high-strength concrete products, such as façades, cladding, sun-screens, garden ornaments or city furniture. The ability of the product to provide an easy solution for the safe production of high-quality UHPC products fitting into the framework of a typical industrial production process, yet offering a significant degree of customisation, summarises its main value proposition to industrial precast manufactures. The UHPC product offers, among many other properties:

- workability – self-compacting properties and long flow retention
- high early and final strength
- predictable and reliable performance
- reduced shrinkage, minimising the risk of cracks
- highly durable, even in harsh environments
- colour performance – high whiteness, ideal for architectural and ornamental elements.

Precast manufacturing practice and experience of UHPC

In Europe the market of UHPC precast elements has been growing in recent years and has already achieved a high standard of industrialisation. Local manufacturers supply the elements to domestic and export markets for construction projects with high aesthetic requirements.

One such UHPC precast manufacturer is mbX in The Netherlands, a young and innovative company with a fresh view on the use of concrete. It believes that a designer should never be limited by the material, and uses its experience and industry-inspiring techniques to develop unique and impressive UHPC elements, and implementing challenging and complex architectural projects (see box story).

"We see that there is increasing demand in free geometry elements/ designs. By using a high-quality product with high strength properties, it is possible to produce larger and thinner elements, which results in less gaps/joints between the elements," explains Stefan Lubbers, director of mbX.

The company has been the first industrial user of Aalborg Extreme Light 120 in a global context and Mr Lubbers gives a positive assessment on the product: "Together with Aalborg White Innovation Team, we have carried out several tests to monitor the workability and strength. The product contains excellent properties to perfectly meet the demand in the market."

In terms of user experience, mbX mentions that UHPC products prove many benefits/values but mainly:

- free geometry products
- reduced use of construction materials
- low weight of structures
- optimised logistics of finished products
- highly-enhanced durability.

mbX plans to manufacture products that are even smarter, thinner, larger and more complex than is currently the case, and invites the industry to challenge the limits, accelerating and promoting innovation in concrete. ■

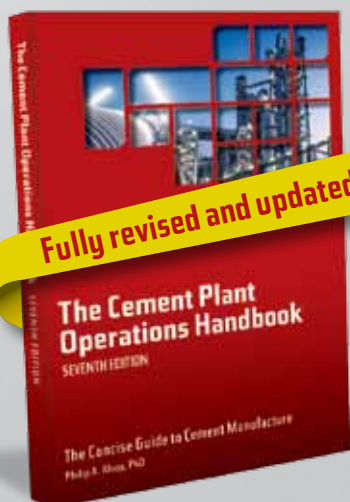
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