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Sustainability Quest Yields Ultra-High-Performance Solution

Mineral components help to reduce the carbon footprint of this new prepackaged mixture

by Larry Rowland, Michele Di Marino, and Jesper Sand Damtoft

A newly developed ultra-high-performance concrete (UHPC) product, AALBORG EXTREME™ Light 120, was launched in November 2018 as a shrinkage-reduced, self-consolidating, high-performance concrete for the production of thin concrete products with high aesthetic, mechanical, and durability performance requirements. The binder, admixtures, and aggregates are included—only water is added when mixing this prepackaged material. A portion of the Aalborg White® portland cement has been replaced with a combination of ground carbonate and reactive metakaolin as mineral components that give the mixture its high-performance characteristics with a much lower CO₂ footprint than comparable portland cement-based mixtures.

Sourcing a More Sustainable Binder

Fly ash, slag, and silica fume all have proven track records in concrete production. However, due to the nature of their sourcing as waste streams from other industries, they can be scarce in some locations. In contrast, clay is a plentiful resource that has generally been underexploited. With this in mind, an investigative team formed by Cementir Holding SpA at their Research and Quality Center in Aalborg, Denmark, strove to find a way to use commonly occurring natural resources—high-purity clay and carbonate materials—to produce UHPC mixtures.

The research team used advanced modeling of hydration kinetics to find the optimum balance of particle packing,

carbonate dosing, and optimized cement chemistry with state-of-the-art chemical water-reducing technology to make a user-friendly UHPC mixture.¹ The mixture combines highly reactive metakaolin produced by thermally processing kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$) to produce the dehydroxylated reactive material called metakaolin ($\text{Al}_2\text{Si}_2\text{O}_7$).² Because it is heated to much lower temperatures than are required to produce portland cement, it is less energy intensive to produce. The process also does not liberate CO₂ through calcination.



These geometrically complex concrete elements in the Crossrail Farringdon Station, London, England, demonstrate the strong potential of UHPC mixtures for architectural precast concrete (photo courtesy of mbX, Bergen op Zoom, the Netherlands)

The result is a binder system that is more environmentally friendly than others. UHPC has the potential to become one of the most sustainable construction materials of the future; however, the full sustainable design potential of this product can be realized only when embodied energy and emission advantages are coupled with design solutions that exploit its excellent strength-mass ratio, great resilience, near-zero porosity, and high durability.

Building on a Legacy of Innovation

This type of cutting-edge research is not new to the Research and Quality Center. The precursors to today's UHPC can be traced back to the work of research engineer Hans Henrik Bache and his team in Denmark, who produced densified systems containing homogeneously arranged ultrafine particles in the 1970s and compact reinforced composites in the 1980s. Today's successes in combining materials to produce less energy-intensive and emission-



A batch of AALBORG EXTREME Light 120 is discharged from a laboratory pan mixer. The prepackaged material exhibits excellent stability and a slump flow of 900 mm (35 in.)



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intensive high-performance binder systems can be traced back to this previous work.

Like its UHPC predecessors, AALBORG EXTREME Light 120 has the potential to fundamentally change the way many researchers and designers see concrete.³ Because the clay-based binder additives can be manufactured in a very light color, the new UHPC mixture has been produced with white portland cement, yielding a white mixture suitable for use in architectural applications. The material's high flow rate further encourages its application in architectural contexts.

The binder technology and predosed admixture loading is formulated to deliver at least 45 minutes of open working time. Once consolidated, it has a relatively short setting time. It also develops strength rapidly and is able to achieve compressive strengths of 85 MPa (12,000 psi) in just 24 hours at standard production temperatures of about 23°C (73°F).

Opening Opportunities

Applications for this material are expected to include structural-architectural building components suited for UHPC, such as thin geometrically complex building elements. Examples of these types of applications include the single- and double-curvature concrete panels produced by the innovative Dutch concrete producer mbX. Using their own white UHPC mixture, mbX produced the architectural concrete screens for the London, England, Crossrail Farringdon Station as designed by Grimshaw Architects. mbX is now using AALBORG EXTREME Light 120 as their high-performance concrete mixture of choice.

The search for more sustainable concrete binder systems drove the innovation behind the new product. It makes use of cutting-edge combinations of white portland cement, ground carbonates, and dehydroxylated clays, along with other specialized materials. This new material has now arrived in North America and is expected to provide a more sustainable way to achieve the design aspirations of an architectural community poised to tap into the promise of UHPC.

—Lehigh White Cement Company,

www.lehighwhitecement.com

References

1. Ferreiro, S.; Herfort, D.; and Damtoft, J.S., "Effect of Raw Clay Type, Fineness, Water-to-Cement Ratio and Fly Ash Addition on Workability and Strength Performance of Calcined Clay—Limestone Portland Cements," *Cement and Concrete Research*, V. 101, Nov. 2017, pp. 1-12.

2. Kunther, W.; Dia, Z.; and Skibsted, J., "Thermodynamic Modeling of Hydrated White Portland Cement—Metakaolin—Limestone Blends Utilizing Hydration Kinetics from ²⁹Si MAS NMR Spectroscopy,"

Cement and Concrete Research, V. 86, Aug. 2016, pp. 29-41.

3. Antoni, M.; Baquerizo, L.; and Matschei, T., "Investigation of Ternary Mixes Made of Clinker Limestone and Slag or Metakaolin: Importance of Reactive Alumina and Silica Content," *Calcined Clays for Sustainable Concrete*, K. Scrivener and A. Favier, eds., Springer, 2015, pp. 545-553.

Selected for reader interest by the editors.



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