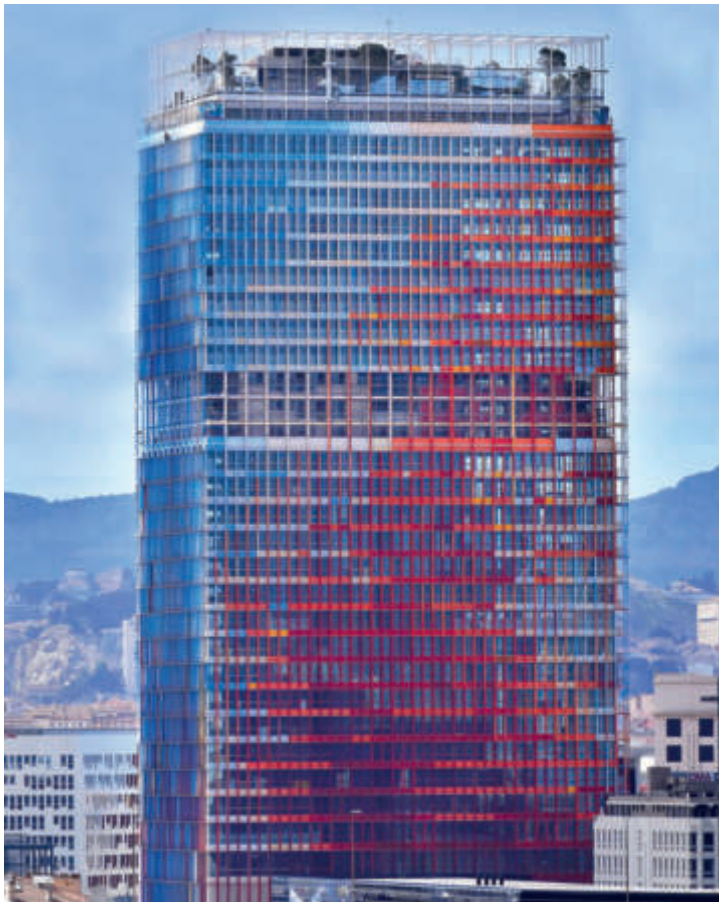
Concrete Plant International
Worldwide English Edition

5 | 2020
www.cpi-worldwide.com

REPRINT | CONCRETE TECHNOLOGY

Applications and opportunities of ultra-high-performance fibre-reinforced concrete

REPRINT
CPI 5/2020



State of development and practical examples

Applications and opportunities of ultra-high-performance fibre-reinforced concrete

M.Arch. Carlos Piles, Head of Ductal® EMEA & Asia, Ductal® a member of LafargeHolcim
Dipl.-Ing. Stephan Müller, Sales Manager International, KrampeHarex GmbH & Co. KG

The term UHPFRC (ultra-high-performance concrete) was first used in 1994 to refer to a material with optimized particle packing, made with a special selection of fine and ultrafine particles that result in low porosity, high durability and self-compactability. It is a cement-based material with a minimum specified compressive strength of 130 MPa with specified durability, tensile ductility and toughness requirements. Fibers are generally included in the mix to achieve specified requirements. UHPFRC construction is simplified by generally eliminating/reducing the need for reinforcing steel and by the material's high flow characteristics that make it self-compacting. The UHPFRC matrix is very dense and has low porosity and low pore connectivity, which results in low permeability, reduced penetration of adverse chemicals and superior durability characteristics. The combination of superior properties and design flexibility supports architects and engineers in creating attractive, curved façade shapes or panels with large spans. Overall, this material offers solutions with advantages such as speed of construction, improved aesthetics, superior durability and waterproofing, as well as protection against corrosion, abrasion and impact, which translates to reduced maintenance and a longer life span for the structure.

The following three examples demonstrate different applications and the overall potential when designing with Ductal® UHPFRC. The first sample shows the largest bridge repair project in France to date; the second example shows the highest full façade system tower built in the world to date; and the last example demonstrates the ability to design very large elements while maintaining organic and free-form shapes.

Introduction of the fibers material aspects

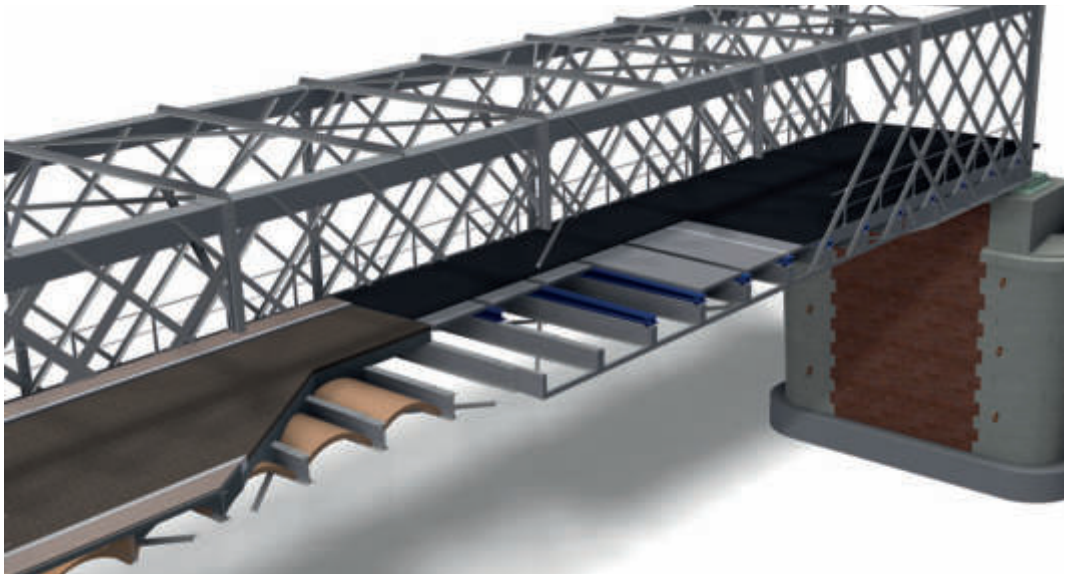
The choice of the fibre in UHPFRC has a strong influence on the composition, workability, strength, ductility and price of the concrete and the final product. The most commonly used fibres in UHPFRC are straight formed and made from cold drawn steel wire since they are the best choice economically and since they significantly contribute to the properties of the fresh concrete and the final concrete product. The usual steel fibre lengths for UHPFRC are in the range of 6 - 20 mm, while fibre diameters are 0.15 - 0.5 mm. In cases where UHPFRC is exposed to a corrosive environment the use of carbon steel fibres can cause aesthetic degradation. Therefore, stainless steel fibres matching with the required exposure class have been used successfully. Polypropylene fibres are used for non-structural applications to control plastic shrinkage cracking and to obtain a certain degree of fire resistance of UHPFRC. For non-structural applications also other materials such as polyvinyl alcohol (PVA), carbon and basalt are used as fibres in UHPFRC.

UHPFRC projects

Mauves-sur-Loire

The rehabilitation of Mauves-sur-Loire bridge consists in substituting the existing deck (3,500 m²) made of brick vaults with a thin deck made of thin precast UHPFRC slabs. The main objective of the project is to upgrade this historic landmark by increasing its bearing capacity and allowing the addition of cantilevered footbridges. This technical challenge is met with the use of ultra-high performance concrete solution and the implementation of lightweight precast slabs (with an average thickness of 10 cm), which will reduce the total dead load of the bridge by 50%. In this project, the fibers used were 14 mm / 0.2 mm steel brass coated.

The UHPFRC precast elements were produced at the Delta Prefabrication plant located in Privas (France). Assisted by the Ductal LafargeHolcim technical team, Delta Prefabrication has mastered the several challenges of the project by strictly following the UHPFRC French Standards (NF P18-470 / NF P18-710 / NF P18-451) during the suitability test and then during the production control. Particular methods and additional rebar were implemented in order to increase the bonding in the joints between the slabs. Bouygues TPRF/VSL, the general contractor in charge of the project, is responsible for the slab installation and their connection to the structure. The latter was done by in-situ casting the Ductal joint fill solution. The project will be completed by November 2020.



The Mauves-sur-Loire bridge consists of UHPFRC precast elements which have been made at Delta Prefabrication plant located in Privas (France). In this project, the fibers used were 14 mm / 0.2 mm steel brass coated. Joints were poured with ultra-high-performance fibre-reinforce concrete.

La Tour La Marseillaise

La Tour "La Marseillaise" is designed by architect Jean Nouvel as a 'sketch to the sky', a high rise building of 135 m height (31 levels) and façade fully cladded with 2,100 tons of UHPFRC. The façades of Marseille's new high-rise tower are composed of ultra-high performance fibre reinforced prefabricated concrete elements that participate in the building envelope's thermal insulation, solar control, building maintenance and fire partitioning (according to high-rise towers regulation).

Thanks to the use of UHPFRC it was possible to achieve such thin elements (25 - 35 mm) and reduce the time needed for moulding and unmoulding, allowing complex casting in enclosed moulds with difficult access conditions. Also, the material's high resistance to aggressive environments helped to improve the overall durability of the building. The full façade

Marseille's new high-rise tower façades are composed of Ductal prefabricated elements that participate in the building envelope's thermal insulation, solar control, building maintenance and fire partitioning.

is built out of 3,500 UHPFRC precast elements manufactured by Méditerranée Préfabrication (Vinci Group), in a factory unit specially built in Marignane. Assisted by steel fibres (14 mm / 0.2 mm brass coated), the precast elements can be produced with a reduced amount of structural reinforcing bars, reduced cover depths and reduced section thicknesses.

UHPFRC precast elements, fixed to the tower steel supporting frame, are insuring the following features:

1. Air sealing and water proofing with a 35 mm thick ultra-high performance fibre reinforced concrete layer monolithically supported by ribs.

2. Thermal insulation: 65 mm of polystyrene are embedded in the UHPFRC shell to provide a first layer of the necessary thermal inertia.

3. Solar control is provided by the elements sun-shading and by the 'waffles' that are laterally fixed to the elements as additional lattices.

4. Building maintenance is facilitated first by the peripheral UHPFRC cantilevered slab along the facades and also more commonly by a maintenance pod hung from the top. The supporting ribs (100 mm x 160 mm) are designed for flexural, compression and shear strength.

5. Fire partitioning is ensured by UHPFRC elements that have proven stable to fire and able to keep C+D > 120 min.

This building achieved LEED Gold Certifications and was awarded HQE Excellence.

China Cultural Center Belgrade

Chinese architects TF 铨赋, Xiaofeng Zhang, Shan Huang, have designed this unique building that will serve as the China Cultural Center in Novi Beograd, Serbia, at the former location of the Embassy of the Republic of China of Yugoslavia. The building's façade design has been chosen by an architectural competition and the design shows the inspiration of the ancient Chinese art painting guóhuà, which is one of the oldest continuous artistic traditions in the world. The project consists of the China Cultural Center, a hotel, as well as apartment and office space. The building height is 36.7 m and the building's total floor area is 32,340 m^2.

For the secondary (outer skin) façade material, the architects decided to pursue the structural and design capacities of UHPFRC, at the same time allowing perforation on the elements. In this particular project, the Ductal White ultra-high performance concrete solution was implemented with stainless steel E304 fibers (14 mm / 0.2 mm). The perforations on the panels were covered with mechanically connected glass elements.

The precast company Fibrobeton® faced a great challenge ahead, having to produce the 6,000 m^2 of façade divided into 1,365 panels within six months, considering that 1,200 of the panels had different combinations of eight different glass dimensions and also perforations, making them unique in shape, size and dimension. Larger panel dimensions were 5.5 m in height x 1.2 m in width, with a thickness of 40 mm and a frame thickness of 150 mm. The façade was divided into sections according to their installation priority and panel uniqueness. This facilitated high efficiency in the installation.

Another design challenge was the limitation of the outer skin weight, which was targeted to stay below 110 kg/m^2 including the glass elements and embedded anchorages. Fibrobeton was able to design the elements with a thickened edge frame for obtaining the required flexural performance.

Chinese architects TF 铨赋, Xiaofeng Zhang, Shan Huang designed this unique building that will serve as the China Cultural Center in Novi Beograd, Serbia. In this particular project, the White UHPFRC solution was applied with stainless steel E304 fibers (14 mm / 0.2 mm)

The production team consisted of 55 individuals to handle structural and architectural design, mold design & production, casting, curing, packing and transporting, all of which was done in house at the Düzce facility in Turkey. The UHPFRC panels were transported with specialized trucks to the site in Serbia, and installed by the China State Construction Engineering Corporation.

Fibrobeton followed a very tight quality control policy for structural and aesthetic properties of the panels and also established a good collaboration with the façade contractor and the Ductal LafargeHolcim team along the process. ■

FURTHER INFORMATION

KRAMPE HAREX®
KNOW WHY.

KrampeHarex GmbH & Co. KG
Pferdekamp 6-8
59075 Hamm, Germany
T +49 2381 977 977
F +49 2381 977 955
info@krampeharex.com
www.krampeharex.com

About Ductal LafargeHolcim

Ductal is the UHPFRC technology of LafargeHolcim. Ductal was developed in the 1990's and during the last 30 years, it has been used for UHPFRC projects around the globe from North America to Mozambique and Brazil to China, making Ductal one of the leading UHPFRC suppliers in the world.

Ductal is characterized for its high compressive strength, reaching average values of 200 MPa, combined with high flexural strength with values up to 22 MPa. All this has been possible thanks to a dedicated R&D centre in Lyon that continues to develop new innovative solutions for its customers.

The Ductal solutions portfolio ranges from the infrastructure segment focused on bridge repairs, building rehabilitation, protection of hydraulic structures, and rehabilitation of corrugated steel culverts to the building segment, where Ductal has been offering solutions for ventilated facades, sun-shading and full façade systems.

During the last years, Ductal solutions have helped to reduce CO_2 emissions/m² in building construction, thanks to its reduction in material usage for the final elements. Moreover, the Ductal supply chain has demonstrated its commitment to reduce its CO_2 emissions related to raw materials and finished products, receiving the certification from FRET 21.

About KrampeHarex

KrampeHarex® is one of the world's largest privately-owned fibre manufacturers with a capacity of 70,000 tons per annum. Since 1982, the Krampe family business has been producing steel fibres and polypropylene fibres in three factories in Germany and the Czech Republic. KrampeHarex works with clients in 40 nations and from a wide variety of industrial fields, including structural, underground, and civil engineering. Over the past 30 years, together with the leading UHPFRC producers, KrampeHarex has developed a wide range of steel and stainless steel fibres. This was possible because in addition to fibre forming and cutting, KrampeHarex draws their own wire.

Since 2015, KrampeHarex has been purchasing green electricity (CO_2-free) and reducing their CO_2 footprint considerably. The KrampeHarex energy management system according to DIN 50001 promotes sustainable energy usage encompassing the optimal use of resources and the reduction of greenhouse gas emissions.