Ductal® Solutions

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Special issue
Site Applications

LAFARGE
bringing materials to life™

The Mackenzie River twin bridges near Thunder Bay, Canada: the largest field-cast Ductal® project in North America.

CONTENTS

PAGES 2 - 5 I
Field-Cast UHPC Connections for Resilient Precast Bridge Decks: opportunities and technical issues

PAGES 6 - 9 I
Technical Performance Opens Up New Horizons

PAGE 10 I
"Situating UHPC at the Heart of Global Building Solutions"

PAGE 11 I
"More Potential Still to be Discovered"

PAGE 12 I
Lafarge On-Site Technical Assistance

Technical performances and site applications

The Benefits of Ductal®

The last decade has seen Ductal® earn a great reputation for original and innovative architectural achievements, yet its full potential in the realm of technical solutions remains largely unrecognized. Bridges and other engineering structures designed in the 1960s that are now ageing and deteriorating require technical solutions for reinforcement and repair involving materials that were once out of reach but have today become indispensable. Ductal® ultra-high performance concrete (UHPC) is one of these: it can deliver the highest standards, especially in terms of durability and sustainability. Ductal® has been used with growing success on numerous bridge structures in North America, and for the renovation of road structures in Europe. Beyond its use as a solution for structural retrofit projects, UHPC can be deployed for applications that require specific performance – such as resistance to abrasion and chemicals in the case of structures exposed to sea water or resistance to impact and blast from explosions in the case of structures at risk of terrorist attack or seismic activity. In this special issue of Ductal® Solutions, we will explain how, with its impressive technical performance, Ductal® can be used effectively – and provide superior results on-site!

Dominique Corvez
Technical Director, Ductal®
Lafarge Group

According to a report by the Portland Cement Association, 72,749 out of 474,182 bridges (listed in the National Bridge Inventory) in the United States are structurally deficient and 80,716 are functionally obsolete for a total of 153,565 which are structurally deficient or functionally obsolete. Ductal® ultra-high performance concrete field-cast connections, when used with reinforced, high performance concrete precast panel systems, offer a synergistic, new approach for the construction of extremely durable, sustainable bridge superstructures built for the future.
In this issue, Vic Perry (Vice-President & General Manager – Ductal®, Lafarge North America) and Dr. Benjamin Graybeal (Structural Concrete Research Program Manager, Federal Highway Administration) discuss this superior solution and explain its many advantages.

Field-Cast UHPC Connections for Resilient Precast Bridges Decks

Business market, opportunities and technical issues

Interview with Vic Perry

North America's vice president and general manager – Ductal®

Mackenzie River Twin Bridges

What are Ductal® Field-cast connections?
Vic Perry: Precast bridge decks are recognized by highway authorities (owners) as a durable solution meeting the needs of highway users. However, the joints in precast decks can leak and create maintenance problems. As a result, many authorities will not use precast bridge decks. The joint in a precast bridge deck is historically "the weakest link" in the system. The use of Ductal® ultra-high performance concrete (UHPC) as a field-cast connection material provides a new solution for these joints. Ductal® has a very short bond development length, resulting in a very narrow joint that is much stronger, tougher and durable than the adjacent precast deck panel. The Ductal® field-cast material is batched on site and cast in the joint surrounding the panel, in the shear pockets to connect the panel to the girder and in the haunches between the panel and the girder.

What are the main advantages of the field-cast connections?
V.P.: Ductal® UHPC field-cast connections (also known as "Joint Fill"), when used in conjunction with reinforced, high performance concrete (HPC) precast panels, provide a synergistic, new approach for the construction of sustainable bridge superstructures. Due to the material's combination of superior properties, the bridge performance is significantly improved and the joints become the "strongest link". The advantages and benefits are numerous: reduced joint size and complexity, improved durability and continuity,

speed of construction, elimination of post tensioning, reduced on-site risk, cost savings, low maintenance and overall, a more resilient and durable, longer lasting bridge deck solution.

What types of bridge projects are using field-cast connections?

V.P.: Several U.S. state and Canadian provincial highway departments are using Ductal® field-cast connections on a variety of conventional and advanced precast bridge deck systems for the replacement of deteriorating highway bridges. These systems include: adjacent, single and multiple span box girders, bulb-tee girders, full-depth precast deck panels, and waffle slab modular panels.

Can you provide an example of an outstanding field-cast project?

V.P.: The Mackenzie River project is a good example because it is a twin, 2-lane bridge; each is 3-span continuous and 180 m long! We have done previous jobs with full depth deck panels and previous jobs with live load continuous over the interior pier. This project combines both and was by far the largest project to date. Ultimately, more than 20 m^3 per day of Ductal® field-cast material was placed, for a total of 175 m^3.

What opportunities have you explored and what are the innovative solutions that have resulted from the use of field-cast connections?

V.P.: Ductal's combination of superior properties (strength, durability, fluidity and increased bond capacity), when used with precast deck panel systems, provides engineers with the ability to design optimized solutions for bridge construction. Ductal® UHPC field-cast connections is a relatively new solution and has been used in fewer than 20 bridges since 2006. However, this early adoption has provided excellent field experience and validation of the methodology. It has also provided exposure and confidence in the technology which has led to innovations for the use of Ductal® UHPC for other types of field connections for precast bridge systems, including:

- Precast waffle deck panels and hidden shear pockets
- Precast parapets/barrier walls
- Piles to abutments
- Expansion joints
- Thin bonded overlays
- Accelerated bridge construction

We are currently working with more than 15 state/provincial Departments of Transportation on projects for 2012/2013.

JS1000 Characteristic Values for Design							
		Test Data				Design Values	
		Mean		Standard Deviation			
		MPa	psi	MPa	psi	MPa	psi
Compression		150	20,000	10	1,400	100	14,500
Flexural		30	4,300	5	700	-	-
Direct Tension	ftj	8	1,160	1	145	5	725
Youngs Modulus		GPa	ksi	GPa	ksi	GPa	ksi
		50	7,200	2	300	45	6,500
Durability							
Freeze/thaw (after 300 cycles)							100%
Salt-scaling (loss of residue)							<0.10 g/m²
Carbonation depth							<0.5 mm

ZOOM - Project Profile: Mackenzie River Bridge

The Mackenzie River Bridge is part of the new TransCanada Highway realignment near Thunder Bay, Ontario, Canada. The project consists of twin, two-lane bridges; each consisting of three-spans for a total length of 180 m. The bridge crosses a deep gorge of the Mackenzie River (Canada's longest river) using variable depth continuous steel plate girders with full-depth precast deck panels that are lightly prestressed and run the full-width of the bridge. There are 130 precast deck panels, 2.99 m wide x 14.5 m long x 225 mm thick. The transverse joints between the panels are filled with Ductal® field-cast as well as the shear pockets and haunches between deck panels and the steel girders. The project also used precast approach slabs with Ductal® field-cast connections. This is the largest field-cast Ductal® project to date in North America. Lafarge supplied twin 0.5 m^3 Ryan mixers, providing over 20 m^3 per day of production for a total of 175 m^3. The casting of the joint fill material was completed with an 18-man crew which consisted of two men on the mixers, one man on the scales, one loader operator to load the mixers, one man to guide the loader, two men on power buggies transporting the material from the mixer to the bridge, four men guiding the buggies, one man floating the material and six men on the forms. It took the crew ten days to cast the 175 m^3 required for the project.

Mixing Ductal® on-site

Using UHPC Connections for Precast Concrete Bridge Decks

by Ben Graybeal,
Structural Concrete Research Program Manager,
Federal Highway Administration

The use of precast concrete components has been shown to produce very high quality and extremely durable bridges. Ultra-high performance concrete (UHPC), whose mechanical and durability properties far exceed those of conventional concretes, presents an opportunity to significantly enhance the performance of field-cast connections. Of particular interest, UHPCs can exhibit both exceptional bond when cast against hardened concrete and can significantly shorten the development length of embedded steel reinforcement.

Field-Cast connection details

Field-cast UHPC connections between prefabricated bridge components have been implemented in nine bridges in Ontario, Canada, and two bridges in the United States as of 2010. These bridges use a range of details to connect multiple types of precast concrete components, including adjacent box beams, full-depth precast deck panels, and deck bulb-tee girders. The connection designs used to date have tended to mimic non contact lap splice connections with a female-female shear key profile. The UHPC concept provides good performance and allows for small, simple connections without requiring the use of post tensioning or the use of large volumes of field-cast concrete.

Physical testing program

The Federal Highway Administration (FHWA) recently completed an experimental study* focused on the performance of field-cast UHPC deck-level connections. The results of this test program, in combination with the experience gained through field deployments, have demonstrated the viability of the system for precast modular bridge deck components. The system emulated behaviors that would be expected from a monolithic concrete bridge deck. Noncontact, lap-spliced reinforcement in the transverse and longitudinal UHPC filled connections was not susceptible to debonding under cyclic and static loadings. The most severe cyclic test concluded with the metal fatigue failure of a series of straight, uncoated no.5 steel reinforcing bars, which were lapped over a 5.9 in. (15 cm) length in a noncontact lap splice configuration. There was no evidence of the reinforcing bars debonding from the field-cast UHPC, nor water leaking through the UHPC joints during the fatigue testing.

Future implementation

The concept of using field-cast UHPC to connect precast concrete bridge components is gaining interest. The Ontario Ministry of Transportation and the New York State DOT are continuing to use this technology as appropriate projects arise. The Iowa DOT is planning to construct two projects in 2011**. Other states are also considering the benefits of this technology as they move toward increased usage of modular components and other accelerated bridge construction technologies.

Placement of UHPC into the longitudinal connection between deck bulb-tee girders

**A summary of the study and results can be found in FHWA-HRT-11-022, at https://www.fhwa.dot.gov/publications/research/infrastructure/structures/11022/index.cfm. The full study results are in NTISPB2011-101995, at www.ntis.gov.*

Editor's Notes:
***Two UHPC Bridge projects were completed by Iowa DOT in 2011.*

This article is reprinted (with the author's permission) from the Summer 2011 issue of ASPIRE magazine (page 50). For more information about this concept, see the Route 31 Bridge over Canandaigua Outlet article in the Fall 2009 issue of ASPIRE™, and the FHWA articles on UHPC in the Spring and Summer 2010 issues, pages 46 and 50, respectively.

ZOOM - Project profile: Chukuni River Bridge

The Chukuni River Bridge, Ontario, was completed in the summer of 2010.
It is 101 m long with a clear span of 83.5 m and is the longest single span bridge in Canada. It was constructed with four 3.7 m deep steel beams and 54 precast concrete deck panels. The UHPC field-cast connections were used to interconnect the precast concrete panels to each other (transverse joints and center line longitudinal), the shear pockets to connect the deck to the girders and in the haunches between the underside of the deck and the girders.

Chukuni River Bridge: the longest single span bridge in Canada

TECHNICAL EXPERIENCE

The Development of Joint Fill/Field-Cast Connections

Precast bridge deck ready for joint fill

Early development of Ductal® field-cast connections began in 2004, through a collaboration with the Ministry of Transportation of Ontario (MTO). The main objective was to develop a new solution for the replacement of deteriorating highway bridge decks. The project selected to implement this solution was a highway bridge at Rainy Lake, Ontario. By utilizing the material's superior characteristics, we learned that precast panel fabrication and installation processes were greatly simplified, resulting in improved tolerances, reduced risk, cost savings and a more durable solution. Through design, testing and construction of the Rainy Lake project, we were able to validate a precast bridge deck with a 200 mm wide UHPC joint (a conventional joint is 600 mm wide). The success of this project led the way to several repetitive field-cast connection projects with the MTO and other transportation officials in the U.S.

The introduction of new methodologies and innovative material technologies facilitates the ability to develop and implement new solutions for deteriorating bridge replacement. In North America, there are thousands of bridges that are structurally deficient or functionally obsolete.

Transportation authorities are constantly seeking new ways to build better bridges, reduce travel times and improve repair techniques; thereby reducing maintenance costs which are diverted from capital budgets required for building much needed new highways and bridges. Furthermore, bridge owners are frequently faced with the need to replace critical bridge components during limited or overnight road closure periods. The development of a superior Ductal® field-cast connection solution has made it possible to meet these challenges and exceed expectations.

For this application, compressive strengths range from 120 to 200 MPa and flexural strengths range from 15 to 40 MPa. The material's high mechanical properties are a result of proportioning the constituent ingredients to produce a modified compact grading with a nominal maximum coarse aggregate size of 400 µm, and a fiber geometry of 12 mm x 0.2 mm. The ratio of maximum coarse aggregate size to fiber is important to facilitate random orientation of fibers and a ductile behavior - resulting in improved micro-structural properties of the mineral matrix, especially toughness and in this application, also between the matrix and rebars in the joints.

ZOOM

Motorway Bridge Renovation: a Stronger, More Watertight Structure

While renovating drainage systems on a stretch of the A9 motorway near Lausanne, Switzerland, the contractor (Deneriaz) observed that when replacing the asphalt surface, the upper transverse reinforcement bars had reduced concrete cover, some were not coated at all and some were corroded.
"Consequently, the reinforcing bars were no longer providing adequate flexural strength," explains Jean-Luc Jaquier, a director of Deneriaz. "We therefore needed to find a solution that would enable the bridges to remain in use while ensuring the owner, the Federal Roads Agency, that the works would be carried out rapidly in order to minimize traffic interruptions and other disruptions for motorway users."

Original state of the corroded reinforcement bars

Watertightness and resistance to chemical aggression

To rectify the problem with corroded reinforcement bars, it was necessary to refurbish the bridge using a minimum amount of material in order to avoid increased deadload while ensuring that the structure regained its strength. The material also had to have high resistance to the salt used in road de-icing and other aggressive substances. Clearly, the use of standard concrete could no longer be envisaged. "The choice of Ductal® then became crucial," continues Jaquier. "One of the benefits of the material is that its mechanical strength in compression is four to five times higher than that of conventional concrete, and can be used to stiffen structures with the application of very little material, and therefore without significantly modifying the weight of the structure itself. The use of Ductal® also meant that no separate waterproofing was required. With only 2 cm to 5 cm of Ductal® mixed on site and poured in record time, we managed to deal with each of the challenges set by the renovation of these bridges."

A fine layer of Ductal® is poured, both strengthening and waterproofing the structure

Technical Performance Opens Up New Horizons

An interview with Laurence Jacques, head of Ductal® for France, Belgium and Luxembourg

Laurence Jacques gives us an overview of opportunities that are made possible by the performance of Ductal®, taking as illustrations a number of projects that have been carried out in Europe.
These examples are not exhaustive, but they provide a starting point for Patrick Guiraud, Vice President, Civil Engineering at Cimbeton, and Philippe Gegout, head of the Materials Engineering unit at Bouygues Construction, to look into the future and forecast new applications for Ductal®.

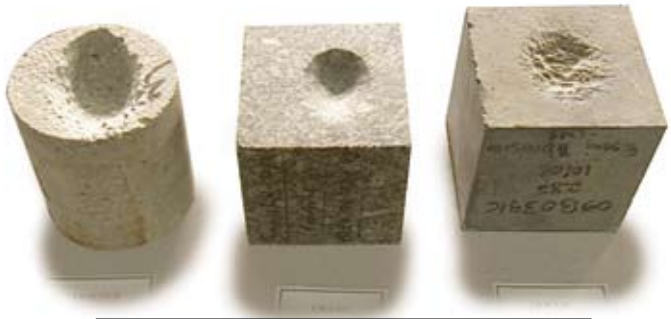
ZOOM

Renovation of the Caderousse Dam

Repairs to abrasion damage on the Caderousse Dam (caused by the impact of solid matter carried by the Rhône River) called for a material which would not only provide the best possible durability but also minimize the logistical and economic impact of the operation. Field-cast in a single morning, Ductal® offered an innovative solution to this delicate renovation project.

The apron structure of the Caderousse Dam hydroelectric power plant is subject to continuous abrasion caused by solid elements (sand, pebbles and a variety of waste materials) that are carried by the river. There is a rake designed to remove the solid matter, which also entails scraping the concrete, exacerbating wear caused by abrasion. "We have long-term maintenance programs in place which define routine maintenance operations carried out on Compagnie Nationale du Rhône (CNR) structures. These ensure that all hydraulic structures remain safe by keeping them in good working order," explains Pierre Soutier, a manager in CNR's Rhône regional division.

"We have developed two specific tests," adds Jacques Perrier, Construction Materials Manager at CNR. "The first is to test abrasion by reproducing the effects of wear from sand on the apron, and the second simulates the impact of pebbles. Ductal® was the chosen material because of its high performance in the impact test and its good resistance to abrasion." High durability materials traditionally used for refurbishment projects generally have to be brought by barge and often require complex site deployment, frequently necessitating the use of a crane, which results in the closure of neighboring roads.



Wear test carried out on mortar, granite and Ductal®

In what fields and for which applications would you say the extraordinary performance of Ductal® is most significant?

Laurence Jacques: The technical performance of UHPC makes it an "extraordinary" material. In mechanical terms, it is positioned midway between metal and concrete. In terms of durability and resistance to impact and harsh environments, it delivers remarkable properties. Whether it is used alone or in combination with other materials, it opens up an entire range of new solutions for construction. For economic reasons, Ductal® is not intended to replace conventional concrete, which is an inexpensive material that has proved its worth for centuries, with a wide range of applications. On the other hand, it can allow engineers and architects to benefit from original solutions, delivering higher performance or at lower cost than traditional methods.

The diversity of questions to which Ductal® provides answers is astonishing because it keeps pace with new demands for improved application times, durability, resistance to harsh environments, sustainability and project economics.

High strength and easy application on site

Can you give some examples?

L.J.: Materials that are required to meet the toughest demands for durability can be difficult to apply. As a general rule, workability time is low or difficulties are encountered in pumping, meaning that it has to be mixed on-site. In this context, being able to pump Ductal® over several dozen meters without segregation of fibers can be quite a benefit for sites where access is difficult. This technique makes it possible to transport large quantities of material rapidly to the site, thereby helping to reduce construction time drastically.

Production of self-compacting Ductal® in a ready-mix plant and application on site

Replying to a call for tenders from the CNR, general contractor Mérillon, working in partnership with Lafarge, proposed to carry out the maintenance operation using Ductal® delivered by concrete trucks and pumped over a long distance.

Liquid granite

"The method that we used for placing Ductal® was quite special as we had to install a large concrete pump that would transport the UHPC to the middle of the dam, a distance of more than 140 m, so that it could be field-cast," points out Tony Mérillon, President of Mérillon. "This is completely different from traditional concrete, which hardly spreads in an even way. Ductal® behaved almost like using a self-spreading material. Our solution enabled us to place Ductal® in a single operation and avoid the need for a concrete joint."

Ductal® engineer Thibault Lagrange takes up the story: "This application process allowed us to work under relatively normal concrete supply conditions: production in a ready-mix plant, transport in concrete trucks and on-site delivery. It was only at that point that the 12 m^3 of Ductal® required to repair the apron had to be pumped over a long distance for pouring on the floor of the dam. This optimized process meant that we could carry out the work in a single morning without disrupting traffic on the local highway. Furthermore, because Ductal® has a particularly low water content, it is protected from drying-shrinkage during the setting phases, therefore the dam could be reopened to water just a few days after the operation."

As Tony Mérillon concludes, "Just as with its durability, the adaptability of this 'liquid granite' is truly exceptional."

The renovation of the apron structure of the Caderousse dam, carried out by the contractor in 2009, was a good example (see pages 6-7). Ductal® achieves resistance to abrasion and impact identical to granite, according to tests performed by CNR, and it also has the capacity to be pumped over a distance of 140 meters, which meant that it was possible not to interrupt traffic, so the material allowed us to reply to key points in the specification.
Ductal's resistance to abrasion and impact is without a doubt one of the strengths that leads the way to highly diversified developments. One such application which, if not original, is still a flagship application in more than one respect, is durable surfaces for yards used for the dismantling of SNCF's (Société Nationale des Chemins de fer français/ "National Corporation of French Railways") rolling stock, a process that subjects the ground to extreme stress. It has to resist impact caused by the manipulation of metal components weighing several tons yet be sufficiently watertight to protect the subsoil from residual waste oil that remains after the fluids purge.

In addition, the durability of the yard is a key element in the company's performance. Refurbishment is a major project, bringing operations to a temporary halt and therefore incurring substantial financial losses. In a test carried out on a 5 cm thick Ductal® sample, the SNCF dropped a metal component weighing 5 tons from a height of more than 10 meters. The Ductal® sample only suffered a slight indentation of 1 cm. But when the test was carried out on a sample of traditional concrete, the metal component caused 20 cm-deep depression. This development bodes well for a range of applications that take advantage of Ductal's outstanding performance including: watertightness, resistance to impact and durability.

Both protective and structural qualities

You also mentioned its resilience in harsh environments…
L.J.: That's right. Ductal® is a thousand times less penetrable by chlorine ions than traditional concrete, which means that the thickness of coatings can be halved. This property was utilized for the renovation of a swimming complex in Amiens, France. The anchor plates and bases of the complex's internal pillars had been degraded by chlorine corroding the original reinforcements. Ductal® was used to create new anchor plates, and also to renovate the truss columns on the facade, which were also corroded at the base and anchor plates. The material will allow the load to be taken up and ensure the durability of the structure while protecting it from corrosion.

Taking advantage of the structural capacities of UHPC opens up new horizons with respect to renovation and rehabilitation operations. As well, beyond ensuring the durability of existing structures, it can facilitate the ability to increase their capacities. This was the case for a project in Perpignan, in the South of France, where a property developer wanted to construct a building that would stand above a functioning parking lot; structures which would be unable to sustain the necessary load. The operation consisted in scraping the structural pillars over 2 cm and surrounding them with a new 3.5 cm layer of Ductal®. As a result, a building with the required number of storeys could be constructed with no impact to the capacity of the parking lot.

ZOOM

Ductal® is used to renovate the anchor plate of a metal pillar with a badly corroded base

Renovating a Swimming Complex

thanks to Ductal's resistance to chlorine ions

A project to renovate a swimming complex in Amiens, France, illustrates Ductal's ability to resist chemical aggression. Anchor plates of the steel pillars that support the building's glass roof were being eroded by chlorine in the water, therefore renovation of the plates required consolidation with a material that would resist this form of chemical attack. Chlorine ions migrate approximately one thousand times more slowly in Ductal® by comparison to conventional concrete, which explains why this was the chosen solution.

Inside the complex, the area around the base of the pillars was stripped and descaled, and then Ductal® was cast around the existing blocks. The new base plates, located 20 cm above the old ones, were fitted with steel stiffening plates to facilitate a subsequent transfer of load. Once the original bases of the pillars become totally corroded, the entire load of the pillars will be carried by the new base plates.

This project demonstrates how knowledge of Ductal® UHPC makes it possible to envision new, original solutions that provide a balance between the overall economic optimization of the operation and rationalization of the site.

What other avenues of development are being explored at the present time?

L.J.: One of the principal ideas is to combine precast elements with a field-cast application, even if this is just to benefit fully from all the advantages of field-casting and the technical and esthetic qualities made possible by precasting. But over and above, the esthetic advantage, the combination of different methods of application can lead the way to other developments. Once again, to improve the watertightness of an existing structure, it could be possible to pour Ductal® UHPC between precast shells serving as permanent formwork. This solution has the advantage of avoiding the construction of a second watertight shell. Because separate elements in Ductal® can reliably be joined together, the technique of combining precast and field-cast elements may also prove suitable for projects to widen bridges to deal with new traffic demands. Lastly, studies are currently underway on producing Ductal® pillars capable of limiting damage following explosions or earthquakes. Its fibers better deflect the energy from an explosion, so protecting concrete from the effects of blast. As you can imagine, events of recent months have led research teams to focus on performance in this area.

Improved safety for high-risk structures

We are still far from having explored all aspects of the technical performances of Ductal® and UHPC. Each individual construction project raises a distinct series of issues calling for a specific response. This is why Ductal® teams around the world offer far-reaching technical assistance, intended to help designers, consulting engineers and civil engineering contractors carry out contracts whose overall project economics benefit from the product's technical performance, which combines durability, strength, resistance and minimal upkeep.

Another area of the renovation was the truss columns forming part of the facade of the building. The nine columns had also suffered considerably from corrosion at the level of the anchor plates. Four new stainless steel stud connectors were set in each column with resin. Ductal® was then injected into the principal member of each truss column up to a height of two meters. 8 cm-wide apertures were made in the columns for the Ductal® to be injected, and then welded shut. In this case, it was the fluidity of Ductal® that proved to be a key benefit for strengthening the columns.

A renovated pillar base in the swimming complex

How does the world leader in civil engineering take full advantage of the performance of UHPC? What are the developments envisioned by its materials engineering laboratory? These questions were asked of Philippe Gegout, who heads up the Materials Engineering unit at Bouygues Construction.

Situating UHPC at the Heart of Global Building Solutions

> *We are working on defining what would be the best trade-off between technical performance, adaptation of the building system and optimization of cost for owners and consulting engineers to result in efficient development.*
>
> ***Philippe Gegout,***
> *Head of Bouygues Construction's Materials Engineering unit*

From your perspective, what does Bouygues consider the major strengths of UHPC and of Ductal® in particular?

Philippe Gegout: Ultra high-performance concrete is a material whose properties considerably exceed the average demands of current standards relating to concrete. It has only come into existence fairly recently and we are still a long way from having discovered all of its properties, or the building systems that it can give rise to, whether used alone or in association with other materials such as steel or other types of concrete.

For Ductal®, the benefits that are most frequently highlighted are its esthetic qualities and its extraordinary strength. But that doesn't mean that these are its only advantages, and at the end of the day they are perhaps not the ones that differentiate it most from a traditional concrete or an HPC (High Performance Concrete). The hyper-strength of Ductal® far exceeds the values associated with current standards – with compressive strengths up to 150 MPa, we are a long way from the average 40 MPa strength of traditional concrete – but this rather tends to overshadow some of its other known properties, such as its resistance to abrasion, structural capacities, resistance to penetration by such aggressive agents as chlorides and sea salt, and so on. In general terms, UHPC can be used in different ways: alone, field-cast or precast, or in combination with other materials. Information garnered from these different solutions, such as bridge repair operations carried out in the United States, will enable us to tweak our calculations and offer increasingly high performance solutions.

How do you anticipate the future for these materials?

P.G.: We are just at the start of a new era that will certainly see UHPC bringing radically new solutions. Innovation will come from trials and site work – the only way of opening up potential fields for more widespread applications. This development is therefore correlated to active R&D that benefits from completed projects to envision new uses, as well as to a normative framework that will evolve in line with discoveries that are made. A future such as this cannot be foreseen without situating Ductal® at the heart of global solutions, integrating the development not only of production methods but also of new, innovative building systems adapted to the various possible scenarios for exploiting its properties.

What possible applications is your laboratory considering?

P.G.: We are working on defining what would be the best trade-off between technical performance, adaptation of the building system and optimization of cost for owners and consulting engineers to result in efficient development. This entails perfecting the process enabling us to bid for major contracts, thereby extending the areas of product application and fully showcasing its performance capabilities. I'm thinking, for instance, of the construction of pipelines and confinement tanks, but also complex anchor plates or precast walls.

Patrick Guiraud Vice President, Civil Engineering at Cimbeton

"I think that we are far from having explored all the possibilities opened up by the mechanical performance of UHPC and the way in which it is likely to change our construction methods."

Yet More Potential for Use is Still to be Discovered

In your opinion, what is the potential for the development of UHPC?

Patrick Guiraud: The principal quality of UHPC, which has been widely taken advantage of since it was launched, is the good appearance of the structures that are created using it. But the use potential that is offered by its mechanical performance, its durability and its resistance to chemical aggression is still largely unexploited.

If designers only focus on optimizing strength while being able to reduce quantities but staying within traditional construction methods, they are depriving themselves of UHPC's full innovative potential. It is the fact that Rudy Ricciotti's Passerelle des Anges footbridge is radically innovative that makes it competitive.

I think that we are far from having explored all the possibilities opened up by the mechanical performances of UHPC and by the way in which it is likely to change our construction methods. As well, we are far from developing the applications in which UHPC will genuinely prove its utility. Just imagine to what extent UHPC, when used in conjunction with very high-performance steels, will make it possible to benefit from the respective advantages of both materials and envision optimal combinations wherever necessary. Clearly, evolution occurs far more slowly in building and construction techniques than in IT, for example, but the knowledge of UHPC that we possess today should enable the development of applications that are much broader, much more diversified and much more recurrent than the applications for which it has been used to date.

Renovate, don't demolish

Can you give us some examples?

P.G.: In a world where Eurocode mix design standards stipulate a 50-year period of use for buildings and 100 years for bridges, UHPC is much too durable. As a result, this durability is not properly taken into account in economic calculations.

But aren't there areas in which we will need this exceptional durability?

P.G.: Particularly on structures that are in contact with chemical aggression, structures in a coastal setting, off-shore drilling platforms and wind farms, port amenities built to keep pace with the development of ocean transport, and so on. Let me give you another example. Public infrastructure owners are increasingly concerned about minimizing disruption to users. For maintenance or repair works, there are more and more stealth sites, and with the use of plant manufactured structures that are lighter in weight for equivalent strength, it has become possible to erect footbridges in a day. The renovation of existing structures using UHPC has become one of the most popular areas being explored. Reinforcing the structures of buildings or carrying out maintenance on a legacy of concrete structures – either for pathological reasons or because we are voluntarily changing their use – open up fields as yet unexploited. If we are talking about road bridges that are required to carry tram lines, transforming parking lots into buildings or raising the height of existing buildings, doesn't it make sense in both ecological and economic terms to take advantage of the mechanical performance of UHPC rather than demolish the original structures?

You bring up the question of the environment: what sort of innovations does UHPC bring in terms of sustainable development?

P.G.: I would say that savings in materials and transportation, reduced construction times, durability and the overall economy of structures in UHPC have already been widely commented on and proven. I personally see other aspects, particularly from a social viewpoint, which would seem to me almost more inspirational. UHPC makes work easier on site. The benefit of a concrete that doesn't require vibrating has basic repercussions in terms of safety and making work less arduous for operators. In addition, because UHPC is a much higher performance material, it requires workers to be more technical and more highly qualified. Such an upgrading of our profession is one aspect of the social dimension that sustainable development seeks to promote.

Is there one UHPC project that you consider to be iconic?

P.G.: I'm not sure that it's iconic, but the love of wine and the alchemy that for a long time operated between concrete and wine before the era of stainless steel vats allow one to think that making vats out of UHPC would in some way be the consecration of the material, for it would be based on all its intrinsic properties: it is natural, durable, innovative, high performance and protective. It would become a partner of the great vintages that improve with age.

On-Site Technical Assistance

The Lafarge Ductal® technical assistance team provides three major services to support its customers: training, technical tests and a presence on site. For owners, this means quality assurance; for consulting engineers, it means technical back-up.

Interview with Kyle Nachuk, Technical Services Engineer, Lafarge North America
"Assuring Clients that Procedures are Being Done Properly"

What field services does Lafarge offer?
Kyle Nachuk: We provide a range of services, from concept to completion of the bridge. On-site services start with a contractor preconstruction meeting, supply of mixers, testing equipment and site supervision during the batching and placing of all Ductal® materials. Additionally, we conduct QA/QC testing and reporting to the owner.

Could you explain the services you provide to the owner, consultant and the contractor for field-cast applications?
K.N.: Prior to a bridge construction, we help contractors and owners with casting details and development of a plan and specifications. On-site, we can make changes to the mix design if necessary and provide solutions if problems occur. We also coach people on the best way to cast sections and provide feedback on setting and strength gain characteristics for upcoming phases. We also supply a variety of mixers for field-cast applications, as well as everything needed to perform the quality control duties in order to produce a good finished product. This includes monitoring of batch times, flow tests, temperatures, casting cylinders, and the supply of labs familiar with testing of UHPC cylinders.

Why does Lafarge offer field services?
K.N.: Our presence adds a level of comfort; our clients can be assured that procedures are being done properly. Many people have never seen nor heard of UHPC, let alone know how to work with it. Although UHPC contains many of the same ingredients as HPC, the two concretes behave very differently. Batching and placing UHPC is different from conventional concrete therefore it is critical to do these things correctly to achieve a quality result. The contactors appreciate having an expert onsite who knows what to expect before casting begins and can eliminate potential issues before they occur. The owners appreciate that we are there to ensure a quality product is placed and to assist the contractor in the execution of a successful project.

Where are the opportunities for Lafarge to expand its services to its customers?
K.N.: As we develop and expand new uses for Ductal®, opportunities will exist for services specific to each application. Because we are in an innovative and developing market, we are constantly looking for opportunities to provide value-added services for our customers.

Gérard Molines, Ductal® Technical Services Manager, Lafarge Group.
"We Can Perform Testing For You"

"Our first duty is to train precasters who are learning about Ductal®," says Gérard Molines. "We take one day to cover the application process for Ductal®, inspect and approve the plant and machinery, assist with designing and producing molds, describe the different casting techniques and recommend safety measures that comply with Lafarge safety standards. We also provide the necessary testing equipment which allows customers to test the Ductal® premix that they will be applying or their precast prototypes. These include flexural and compressive tests, porosity tests on hardened Ductal®, granulometric and morphological tests and chemical analyses of particles on a range of premixes. We are called upon to perform a wide variety of tasks as our customers' needs are very specific. These may include validation of the mixing cycle of a new batch mixer or performing the suitability tests required by AFGC/SETRA recommendations on samples cut from a prototype element produced to scale. We also assist our customers by extracting samples to carry out mechanical strength tests at set time periods. We also produce small-scale prototypes or specific tints for architects."

On-site quality control

The Ductal® team can also provide support for on-site application and carry out quality control of the finished structure. "We also carry out quality control procedures on the mix, the mixing process and casting, with both contractors and such precast manufacturers as Il Cantiere in Italy, Deneriaz (MFP) in Switzerland, Preinco in Morocco and Bonna Sabla, Béton FEHR and Mérillon in France," continues Gérard. "We are even called out on emergencies by owners, such as the Paris Fire Department, who required casting of two piers in a single day in order to carry an increased load resulting from a parking level addition to a fire station."

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