THE FONDATION LOUIS VUITTON TAKES MATERIALS TO A NEW LEVEL

CLADDING: A NEW OFFER FOR LIGHTWEIGHT FACADES

ENGINEERING STRUCTURES: UHPC IN ACTION
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Ductal® is a new material that combines the fineness of steel and the strength of concrete. Recent applications in the Fondation Louis Vuitton, the MuCEM and the Jean Bouin Stadium have demonstrated how its esthetic and technical qualities enhance architectural creativity. Ductal® is now entering a new phase in its development, with applications that will contribute to changes in the construction markets. Gérard Kuperfarb, Lafarge Group Executive Vice President - Innovation, shares his vision of the future.
Ductal® is a new material that responds well to the new challenges of construction. Three of these challenges reflect our desire to supply sustainable and effective solutions for our sector.

1 - Increase infrastructure service life. For the construction of new structures and the renovation of structures built during the last century, Lafarge has chosen to work upstream, as far as possible, with architects, construction engineers, precasters and contractors.

Our ambition is to work with these people to define construction site solutions which, in addition to providing the best mix designs, we incorporate technical and logistical support services. Acclaimed in the United States and Canada for the renovation or replacement of hundreds of deteriorating bridges, this "products + service" innovation is today, contributing to the extended usage life of infrastructures around the world. It was because of this approach that Ductal® was chosen for the structural strengthening of the bridge decks for the Chillon Viaducts in Switzerland.

2 - Develop industrialized solutions which help reduce the cost of construction. With this in mind, Lafarge has designed a standard range of cladding panels for facades, intended for the external thermal insulation market. This new solution makes it possible to ensure that the facade achieves the specified energy efficiency requirements and, by speeding up the application phase, reduces construction time.

"Ductal® is an innovation that is ideal for architectural and structural creativity and for renovation, which helps to reduce construction costs and extend the usage life of buildings and structures."

The roof of the GBWAY DC open-air pavilion, a multi-use facility in Washington DC: architectural creativity in the heart of the city.

Ductal® panels contrast with glazing at the Rotman School of Management - University of Toronto, Canada.
Engineering structures: Ductal® increases the service life of infrastructures around the world - such as the Nipigon River Bridge in Ontario, Canada, opening in 2017.

Facade panels provide external thermal insulation - student residence, Paris, France.

3 - Make it easier to pour complex shapes that are lightweight and more creative, with new mix designs for sprayed Ductal® applications which are already providing solutions for the maintenance of engineered structures.

Finally, the development of digital tools such as "BIM" (Building Information Modeling) will speed up the processes of specifying and delivering Ductal® and provide users with an additional service. By creating Ductal® elements using BIM, Lafarge is taking part in the construction industry's digital revolution, which also makes it possible to reduce design and construction costs. This development requires greater cooperation (as far upstream as possible) between all players in the construction chain.

For us, Ductal® is an illustration of our capacity to innovate. Today, the material's extraordinary technical and esthetic qualities are leading to bright prospects in the energy/wind and nuclear sectors, seismic and offshore markets, building protection and physical security fields. Thanks to our innovation, our sales representatives' listening skills and our desire to advance alongside architects and project owners, we are continuing to invent new solutions to meet the needs of our fast-changing world.
Fondation Louis Vuitton

TEMPO, RESONANCE, PHYSICALITY, THE FONDATION LOUIS VUITTON ALSO TAKES MATERIALS TO A NEW LEVEL
To bring to life the architectural project imagined by Frank Gehry and meet the expectations of Bernard Arnault for this showcase dedicated to contemporary creation, over 120 architects and engineers joined forces.

In particular, for the 18 blocks constituting the “Iceberg”, emerging from glass sails, it took six years of engineering studies to determine the solution that would provide the material effect desired by the brilliant architect: “a white porcelain-like cementitious material.”

The search for the right material and method of application was contracted to two consulting engineering firms, RFR and T/E/S/S. The process required significant prototyping, factory testing, calculations and the development of new molding and manufacturing techniques in order create this incredible, intricate marquetry in Ductal®, using 19,072 panels.

Three key participants in this technological, collaborative experience tell us about a challenge that fully lived up to three of LVMH Group’s core values: creativity, quality and determination.

Philippe Bompas (RFR) together with Bernard Vaudeville and Simon Aubry (T/E/S/S) respond to our questions.
Was the choice of fiber-reinforced UHPC for the skin of the Iceberg the architect’s original idea?

Bernard Vaudeville: Not exactly. At the outset, the first sketches imagined lacquered titanium. But then, back in 2006, Frank Gehry expressed a desire for a finish in an unpolished, white cementitious material, recalling that of his famous “Rock Vases”. Considering that the Iceberg did not have any primary structural function, the search for materials was wide open (by an architect who inspires, explores possibilities and opens doors) and several solutions could have been imagined. Options such as painted or enameled aluminum, sprayed concrete, and even painted plaster were rejected one by one, whether for technical reasons or because they didn’t meet the quality sought by the designer. Towards the end of 2006, just at the point when we were contemplating these questions, an exhibition called “Bétons: étonnez-vous” (“Concrete: prepare to be surprised”) was running at the Paris Arts et Métiers museum. Ductal® was on display, presenting all of its formal potential. It appeared to correspond with the architect’s expectations so I contacted Paul Acker, scientific director of the Lafarge Central Research Laboratory, and Mouloud Behloul, Ductal® director for France (at the time), who set us on the trail of a casting technology that was still in its infancy, but could be perfectly suited to our project.

Simon Aubry: The idea was to cast each panel in a deformable silicone mold and place it on a template to give it the correct geometry. The process is adaptable to a vast range of surface finishes, with panels of identical dimensions. This principle proved to be perfectly compatible with Frank Gehry’s project.

Bernard Vaudeville: The architect showed an interest in both the material and this method of forming it. Lafarge, working with Cogitech and ourselves, focused on developing the process to adapt it to the project and industrialize it. It was an extraordinary time, with numerous false starts. The work would come grinding to a halt and then start up again at breakneck speed! Throughout this work, there was ongoing interaction with Frank Gehry’s teams and, especially, unwavering support from the owner.
This project required us to achieve what is best described as “detailed layout engineering”.

Bernard Vaudeville

Philippe Bompas: We still had to find THE solution that would enable us to satisfy multiple criteria: longevity of at least 100 years; compliance with the geometry and the precision needed for an extremely complex layout; quality of whiteness; the state of surface finishing of a “noble” material; capacity to receive water-repellent and anti-graffiti treatments and; the invisibility of attachment systems, etc. Without losing sight or consideration of the budget, which would have been vastly overrun if we had limited ourselves, for all the panels, to be working to the dimensions of the most exposed panel, or the one under the greatest stress, without making use of the resources provided by 3D modeling and BIM. This ambition, to industrialize the process down to the last detail, could only be achieved thanks to the perfect synergy between all the teams working on the project – including those at: Gehry Technologies; the prototype producer Cogitech; Patrick Mazzacane at Bonna Sabla and of course; Mouloud Behloul’s team at Lafarge; RFR and; T/E/S/S. The interaction by all these parties resulted in the development of prototypes, a new Vacuum Molding Process (“MSV”, as patented by Lafarge in 2008), testing of new panels and attachment systems and; the development of new quality control processes that had never been previously imagined.

Sculpture & museum

Frank Gehry’s project draws a great deal of its originality from the structural intermingling of glass, timber, steel and mineral skin.

Many visitors have likened the Fondation Louis Vuitton to a contemporary sculpture in itself... albeit one that contains eleven exhibition galleries for contemporary art as well as a 400-seat auditorium.

The interior spaces are enveloped by a white skin with chiseled, irregular forms, hence its name, the “Iceberg”. Its cladding consists of 19,072 curved panels made with Ductal® UHPC and almost all of them are different.

The openings and spaces that separate the opaque masses of the Iceberg are closed by glazed envelopes that break down into 46, diversely configured structures that are distributed throughout the building. The challenge was to combine their geometric complexity and singularity along with the very high levels of performance expected, including the facade’s waterproofing, thermal insulation and fire resistance. RFR and T/E/S/S joined forces in a consortium dedicated to this project. The collaborative team, working very closely with the architects, contractors and project owner, carried out the technical design of the glass sails, their timber and steel structures, the Iceberg and its glazed facades, from the earliest stages of the project through to completion.
This ambition to industrialize the process, down to the last detail could only be achieved thanks to the perfect synergy between all the teams working on the project.

Philippe Bompas

Can you give us a few examples of technical issues that were particularly challenging?

Bernard Vaudeville: The project required us to achieve what is best described as “detailed layout engineering”. In particular, we had to find a way to anticipate the effect of tolerances during manufacturing and installation so that we could avoid them from building up.

Philippe Bompas: Unlike other Gehry projects, particularly those using flexible sheets of steel, we couldn’t rely on the overlapping of elements which would normally allow you to make small adjustments. The architect wanted the panels to meet perfectly, edge to edge, with regular joints of less than 10 mm. Bearing in mind that every panel was different, it was very ambitious! This is why we insisted on the geometrical accuracy of the panels and their supports when they were being manufactured and, of course, installed by Hofmeister.

Bernard Vaudeville: At the feasibility study stage, we realized it was crucial to produce a support structure for the panels which would provide a perfect geometrical reference for installing them. To do this, we designed shells in aluminum (or in stainless steel in some cases) of 6 m² on average, carried out to millimeter accuracy. These shells covered the building like an armor before the Ductal® panels were hung on them, using rail.

Philippe Bompas: Undoubtedly, the beauty of the edifice also owes much to its propensity for capturing lights and playing with the contrasting shadows that the glass sails cast on the facades.

Simon Aubry: Each of the panels was scanned as it left the casting bed and subject to a visual inspection for compliance with 18 different characteristics required to meet the finishing standard. Apart from the accuracy required with respect to handling the elements, it also had to be possible to disassemble each panel individually. This meant that the attachment system had to be flexible and each hidden clip had to be accessible in order to monitor if the panel was properly attached to the substructure. Therefore, we had to come up with a method of visual inspection through the joint. Even though the applied surface treatments considerably reduced the need to clean the panels, it was important to ensure that the rappel line workers, who would eventually perform the facade upkeep, could support themselves - using the facade without damaging it. Furthermore, full-scale mock-up tests were conducted to determine the loads on the basis of very precise anchorage points. Calculations were also developed to identify which panels would be under the most stress and therefore require strengthening and; identify which panels that would not require further strengthening.

All in all, was a certain degree of perfection expected?

Bernard Vaudeville: In view of the architect’s creativity, the customer’s requirements and the high quality we were seeking, the Fondation Louis Vuitton is obviously a project that people expect to be perfect. As far as the Iceberg was concerned, this ambition was greatly increased by the fact that we were working with a noble material - concrete. Frank Gehry was seeking precise authenticity, including the slight variations that still managed to get through the industrial process. These are tiny variations in shade or brilliance, which give the Iceberg a vibrancy and verve that matter greatly to Gehry. When you step back, Ductal® creates a precise, calm surface which echoes the curved panes of glass in the twelve sails and highlights the expansive and contrasting structure of timber and steel between the two skins. Thanks to our successful collaboration with Lafarge, we were able to meet these challenges with an acceptable solution.
MULTIPLE AWARDS FOR TECHNOLOGICAL INVENTIVENESS

For their work on the Fondation Louis Vuitton, Gehry Technologies received the Building Information Model (BIM) Excellence Award from the American Institute of Architects (AIA). In France, the Ministry of Ecology, Sustainable Development and Energy and the Ministry of the Industrial Recovery bestowed the Grand Prix National Engineering Award to Setec Bâtiment, Quadrature Ingénierie, RFR and T/E/S/S. The precaster, Bonna Sabla, also received the FIB (Fédération des Industries du Béton/Federation for Structural Concrete) Award for their innovative "MSV" vacuum molding process.
Casablanca - Morocco

Effects of the light in the largest railway station in Morocco

To respect the traditions of Moroccan palaces and public buildings, the architect - AREP - decided to clad the facades of a new railway station in Casablanca with a mashrabiya and sunshades in Ductal®.

The creation of the new Casa-Port railway station had to form part of a traditional neighborhood in Morocco’s largest city. The project is part of a global scheme for urban regeneration and addresses the significant growth in traffic, which is rising to 25 million passengers per year. It also opens up prospects for future urban developments. The “passenger” building consists of a 2,500-m² hall. The facades, which are fully glazed, play with the Mediterranean luminosity: to the west, thanks to an immense mashrabiya (lattice-style wall system), protecting the passenger hall, roof and sides, by a long L-shape sunshade - all created in Ductal®.

“The architects took advantage of all the qualities of Ductal®: mineral content, durability, resistance to sea salt, strength allowing elements to be very slender and thin, taking it further than what we achieved for Rabat-Salé Airport,” explains Salma Ziadi, project manager for Bearch, the precaster of the facade elements.

“For the sunshades, the complexity lay in the architects’ wish for a perfect finish on all surfaces. This requirement meant that we had to pour the elements vertically; a challenge because of their size - 4-m long, 18-cm wide and 2.5-cm thick - but we met the requirement because of Ductal®’s fluidity and self-placing properties. A mounting system enables 3D adjustments on rails that are offset from the walkway, provided for cleaning of the glazing.”

For the mashrabiya which has a void ratio of more than 40%, it was long-term durability that influenced the choice of the material. “Contrasting with neighboring buildings that are just as recent but already suffering from city-center pollution, the brightness of the white Ductal® with organic fibers gives the facade a personality worthy of the grandest Moroccan palaces,” continues Ziadi. “This project heralds others that we are currently working on using Ductal®: the facade of the Rabat Sofitel and the head office of the Land Registry in the capital.”
Warsaw - Poland

Concrete facade renewal

The Foksal Gallery Foundation art gallery, an iconic example of 1960s architecture, has been given a radical renovation, by reducing the weight of the facade, providing thermal insulation and restoring the mineral appearance of exposed concrete.

The twelve panels of gray Ductal® with organic fibers, measuring 7.21 m x 3.46 m, met all the challenges demanded by the project to refurbish the facade of the Foksal Gallery Foundation in Warsaw: a structural requirement to lighten the load borne by the original beams and an esthetic requirement to restore the mineral appearance of exposed concrete to improve architectural continuity with adjacent buildings.

For Laurent Fehr, of Fehr Architecture, the contractor entrusted with manufacturing and installing the panels, “only Ductal® could simultaneously fulfill these two ambitions of the Swiss architects, Diener & Diener. Working with the Ductal® team, the architect could utilize panels of very large dimensions. Each facade panel was made to measure, to incorporate the doors and windows and produced in a range of demanding molded finishes with up to five relief patterns. Ductal® made it possible to work with these exceptional dimensions with a weight that is three times less than traditional precast concrete panels. This is mainly achieved by having a thickness of only 4 cm, which offers the additional advantage of saving space to ensure better thermal insulation.”

As the first application of UHPC in Poland, this project demonstrates how high-tech cladding can enhance the image of a building with strong connotations, and provide a suitable renewal of a mineral facade.
How did you conceive of the idea to incorporate microbeads into a UHPC panel system?
Pascal Dupont: From their beginning, B-ton Design has focused on specifying innovative concrete solutions and esthetic treatments of concrete. A request I have heard repeatedly when visiting architects is to provide a concrete that plays with the light. After a series of successful tests in which we introduced glass during the production of UHPC panels, we were able to envision how glass microbeads on the surface might look on an industrial scale. According to Giovanni Lelli, architect and designer of the R7 reservoir in Villejuif, just outside Paris, he chose this concrete solution with a sparkling facade because, “it’s the best way of evoking sparkling, pure water”.

What motivated the use of this solution for the facade of the Villejuif reservoir?
P. D.: It was the combination of the reflecting and mineral properties. While they have excellent qualities in terms of insulation, these sparkling concrete surfaces can change appearance by playing on all the available light sources without the addition of artificial lighting.

Why is Ductal® particularly suited to this kind of sparkling finish?
P. D.: Ductal® is a very fine-grained UHPC which provides a long-term substrate for the single layer of microbeads, minimizes wear and detachment of this layer, and makes it possible to achieve a homogenous surface aspect. The fact that it is a material with very low porosity accounts for the absence of alkali reaction between the incorporated glass and the concrete matrix.
FACADE

Cladding

All the qualities of Ductal® in a standard offer

With its R&D well proven by numerous tailor-made, high-profile projects, Lafarge is now launching a standard offer of Ductal® panels intended to meet the external thermal insulation needs of offices, apartment blocks, shopping centers and public buildings. This is a revolution for architects seeking a mineral alternative to traditional cladding solutions, with the additional advantage of all the benefits of fiber-reinforced ultra-high performance concrete.

This is what happens when the world leader in building materials and solutions makes excellence available to everyone - at a reasonable cost.
Comfort and energy savings have made external thermal insulation one of the best methods for dealing with the challenges of current energy requirements; even though facades are now required to perform new functions, they must continue to satisfy the creative requirements of designers and architects while satisfying the need for sustainable solutions that are also economical.

Apart from its esthetic properties, Ductal® UHPC has very low porosity, which gives it exceptional durability by comparison with other mineral materials, offering resistance to abrasion, carbonation, chloride-ion penetration and freeze-thaw conditions. This durability is backed up by reduced maintenance, thanks to the possible water-repellent and anti-graffiti surface treatments that strengthen the stability of the facade over time.

The notion of durability is even more meaningful in the context of environmental issues, particularly the need to limit the consumption of resources.

A life-cycle analysis and a life-cycle cost analysis were carried out on three cladding panel solutions: ultra-high performance concrete (UHPC), stratified (layered) laminates (HPL) and aluminum. For a number of criteria - greenhouse gas emissions, water consumption and air acidification - the impact of Ductal® panels is two to six times less than the other two materials, a decisive advantage for buildings striving for environmental excellence as well as HQE, LEED or BREEAM certification.

To meet these challenges, Lafarge is launching a range of cladding products manufactured with Ductal® concrete.

“The challenge, which we have now met, involved the development of a cladding system that would allow us to provide architects with a mineral alternative that combines Ductal® performance with large-dimension panels (up to 3.6 m), classified ‘M0’ for fire resistance and with an incomparable and varied finish, all in the form of a standard offer,” explains Emilie Hergott, Director of Ductal® for France and Export, and project manager for the Ductal® cladding project.

The fineness of the grain in Ductal® concrete makes it possible to reproduce textures with extreme precision, highlighting the regularity of the skin. “In our discussions with architects and project owners, we observed a genuine desire for the authenticity of a mineral material, which is a constituent of the majority of built space today,” continues Emilie Hergott.

“These panels are manufactured thanks to a dedicated production tool suitable for manufacturing thin flat panels. This enables us to obtain similar costs to traditional cladding while maintaining optimal surface quality and; thanks to the possibility of process-coloring; we can offer a varied palette of colors.” This creative freedom is strengthened by the possibility of producing monolithic corner panels, which can be used for corners but also for details like window openings.

TheOutside corner, external thermal insulation system with Ductal® cladding panels.

FACADE

Cladding
All the qualities of Ductal® in a standard offer

Takeaways

> A standard facade solution in Ductal® that is very competitive: from the initial purchase and throughout the lifecycle of the building
> Solid partners in Europe and the United States to provide rapid response to large volumes
> Unique elegance thanks to impressive dimensions, colors, textures and finishes
> Exceptionally robust and very limited environmental impact
The new 4,050-m² building contains a spacious waiting area, offices, meeting rooms, a pharmacy and numerous examination rooms capable of serving about 5,500 clients per year.

For the facade, Saavedra Gehlausen Architects approved the Ductal® cladding solution offered by the precaster as an economical alternative to two options presented by other manufacturers. The external cladding, covering a total area of 280 m², is comprised of about 200 precast Ductal® panels, each approximately 60 cm x 213 cm and just 1.27-cm thick - with an attractive terracotta finish, as required by the architects. The panels were installed by the precaster in November 2014, using a special hidden fastener system.

Chicago - United States
A terracotta finish for a behavioral health services facility

A vacant grocery store in Rockford, Illinois, near Chicago, was transformed into a modern behavioral health services facility, the Rosecrance Ware Center.

The new 4,050-m² building contains a spacious waiting area, offices, meeting rooms, a pharmacy and numerous examination rooms capable of serving about 5,500 clients per year.

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Paris - France
Stone-like cladding for a lightweight facade

A building containing eleven low-energy apartments on the east side of Paris, designed by architects Philippon-Kalt, has been planned to meet all of the environmental requirements set by the City of Paris. “These requirements often go beyond French regulations, particularly with regard to thermal efficiency,” notes Jean Kalt. “This explains our interest in industrial players capable of investing in the development of new materials and new building solutions. Our contribution to this project is a solution for a stone-like cladding applied to a lightweight timber facade; to blend into the existing streetscape and use external thermal insulation of the highest quality. The big advantage of Ductal® lies in the thinness of the panels, which makes it possible maintain reasonable dimensions for the facade (less than 350 mm). As a very fluid material, Ductal® also has a surface quality that is visually superior to traditional concretes while retaining the authenticity of a mineral material. From our point of view, this solution delivers the detailed layout of our design and maintains the personality that we wanted for this small apartment building.”

Paris - France
Stone-like cladding that fits seamlessly into the street facade, Paris, France.
In North America, approximately 70,000 bridges must be rehabilitated or replaced in the next 10 years. About one-quarter of these structures will use a precast concrete deck system.

Lafarge is working with the Federal Highway Administration (FHWA), various U.S. Departments of Transportation, as well as the Ministries of Ontario and Quebec in Canada to determine the best in situ UHPC solutions for each specific situation: interstate and intrastate traffic, areas at risk from earthquakes, extreme climates, etc.

This important research and development, combined with our range of in situ product solutions and services, has led federal and national authorities to recognize Ductal® as the preferred UHPC solution for the sustainable and durable connection of precast bridge elements.
Most bridges in North America were designed in an era when traffic bore no comparison with what it is today. Rehabilitating them is a priority for the Federal Highway Administration (FHWA) which, for many years, has been testing solutions that, in a quest for both technical and economic performance, would address a triple challenge: safety, traffic flow management and infrastructure longevity.

“From very early on, we worked closely with the FHWA to test Ductal® joint fill on pilot projects. The solution met each of these challenges,” explains Dominique Corvez, Head of Ductal® operations for North America. “On the basis of more than 100 completed projects, a large number of states have adopted this solution, requiring Lafarge to develop an industrial-scale service that meets its criteria of reliability, quality and global offer.

The experience gained shows that our solutions are highly appropriate for rehabilitating or replacing the 70,000 bridges declared structurally obsolete. Four major scenarios have already been the subject of successful experimental work.

The first of these scenarios is the sustainable rehabilitation of bridge decks (new design with a lifespan of more than 100 years). For the rehabilitation of the Pulaski Skyway, we were awarded the contract to supply Ductal® for the second phase of work, following the success of the first phase, thereby proving that Lafarge is capable of delivering 10,000+ t of Ductal® onsite. (see www. ductal.com - Ductal® Solutions No. 15)

The specified volume of Ductal® nearly doubled when it was determined to be a suitable, cost effective material by comparison to the non-cementitious product that was originally specified.

Furthermore, this project represents the first time in North America that Ductal® Joint Fill has been placed by pumping, with the material flowing non-stop along a 170-m pipe.”

For bridge owners, this project also confirms the benefits of a “One Lafarge” approach which, beyond the supply of raw materials (premix, fibers, admixtures), also means that we provide on-site, specialized technical assistance, quality assurance and the supply of a variety of special mixers in order to guarantee and simplify the application.

The second scenario is to limit traffic disruption for the users. This is a priority for transportation officials, and a growing number of them are now demanding the use of construction techniques known as “ABC” (Accelerated Bridge Construction). The challenge of an ultra-rapid rehabilitation project was met in Wampum, Pennsylvania (see the interview with Louis J. Ruzzi) and on Interstate 84, a major arterial route linking the states of New York and Pennsylvania. By opting for a solution of precast concrete deck panels with Ductal® joint fill connections instead of a cast-in-place concrete deck, the contractor was able to shave weeks off the schedule, resulting in reduced costs to the owner (New York State Dept. of Transportation) and reduced traffic disruption.

The third scenario is the need to respond to the risk of potential seismic activity. The rehabilitation of the Mission Bridge in British Columbia, Canada demonstrates to what extent Ductal® provides a reliable and highly durable cost-effective solution for use in high-seismic zones. (see page 21)

The fourth and final scenario is part and parcel of extreme climatic conditions across a region the size of a continent. “The Firebag River Bridge, an 80 m, single span structure in northern Alberta, Canada demonstrates Lafarge’s ability to provide on-site Ductal® solutions and services in some of the most remote locations. The project also demonstrates how we can implement casting procedures in temperatures that are way below zero Celsius,” notes Dominique Corvez. In North America, the challenge of working under extreme conditions has been overcome numerous times, in numerous remote locations by Lafarge teams and contractors.

SOLUTIONS ADOPTED BY MULTIPLE STATES IN NORTH AMERICA

It is on the basis of more than 100 completed projects that a large number of North American states have adopted this solution, requiring Lafarge to develop an industrial-scale service that meets its criteria of reliability, quality and global offer.

Dominique Corvez
Located in the Hackettstown Historic District, the Hackettstown Route 46 Bridge is a two-span 39-m structure used by more than 13,200 vehicles each day. In response to traffic and site constraints (including the important historical value), the contractors Greenman-Petersen, Inc. (GPI) of Lebanon chose a Ductal® solution for its renovation. By specifying precast elements and state-of-the-art materials, the bridge reconstruction was completed in just 10 days, thereby minimizing the period of full road closure. The precast concrete substructure and superstructure sections were designed to be rapidly installed and connected Lafarge’s Ductal® UHPC - a first for the New Jersey Department of Transportation.

It was also important for the owner and project team to learn from this project, with a goal to accelerate the renovation of other structures facing similar challenges. It is one of 170 civil engineering projects in the world that the ACEC (American Council of Engineering Companies) has recognized for its preeminent engineering achievements; eligible for one of the top 2015 Engineering Excellence Awards. Criteria included: project uniqueness and originality, complexity, success in meeting goals, technical innovation and economical value.

The ACEC, based in Washington, D.C., includes a membership of more than 5,000 independent engineering firms and more than 325,000 professionals whom are engaged in the development of transportation, water and energy infrastructure, along with environmental, industrial and other public and private facilities across America.
SEISMIC CHALLENGE
The Mission Bridge retrofit project combines performance with economy

Opened to traffic in 1973, the Mission Bridge is a major, four-lane road bridge just over a kilometer long in a high seismic zone that crosses the Fraser River. Its retrofit means that the bridge now complies with today's seismic requirements and can therefore continue to provide an essential road link in the event of natural disaster.

Associated Engineering reviewed the use of compaction piles which was found to be too costly and investigated the use of elliptical steel or traditional reinforced concrete jackets which would need to be massive and alter the profile of the pier and visibility at the site. The British Columbia Ministry of Transportation and Infrastructure opted for a solution that involved Ductal® jacketing of the south bank pier.

In addition to a substantial saving of $1.5 million (CDN), Ductal® also delivers exceptional high seismic deformation capacity using a thin jacket. The project also provided the opportunity to demonstrate the effectiveness of a new Ductal® solution that can be used on similar projects in future.

The retrofit involved two tapered, rectangular columns 2.1 m x 2.6 m on a height of approximately 3.2 m from the base. The design required the use of 25-mm diameter dowels into the existing concrete. Rebars, spaced at 230 mm in both directions, was attached to the dowels. The contractor constructed strong formwork around the columns to withstand the high pressures involved in placing the fluid concrete, and a 225-mm thick Ductal® jacket was cast.

To minimize the number of cold joints, Lafarge utilized its ready-mix concrete plant in Abbotsford, British Columbia to batch and supply a total of 18 m³ of Ductal® using two ready-mix trucks, making two trips each. This solution, which brings together different Lafarge product lines ("One Lafarge" approach), was selected instead of using portable mixers onsite. It was the first time that Ductal® has been batched in ready-mix trucks for a project in British Columbia. The formwork was then filled from the top using a standard hopper, with the casting completed in one day.
After nearly 50 years of service, the Chillon Viaducts in Switzerland have recently undergone a major upgrade to ensure they comply with new earthquake/seismic resistance standards, repair the effects of water ingress, make them more impervious to water, and improve their overall structural properties (following the detection of Alkali-Aggregate Reactions [AAR] in the existing concrete). A new 45-mm Ductal® bridge deck delivers an effective response to these challenges.

Here, we take a close look at this remarkable renovation and discuss what makes it a world first.

Opened to traffic in 1969, the two, 2.2-km long Chillon Viaducts were named for the Château de Chillon, on which they tower above on the eastern slopes of Lake Geneva. As an official Swiss heritage site of national significance, the viaducts are truly one of the most spectacular structures of the Swiss highway system.

Construction of precast elements for this twin structure required the use of post tensioning techniques. Used by more than 50,000 vehicles per day, traffic volumes have increased significantly in recent years.

An inspection conducted in 2009 revealed that significant amounts of water had penetrated the structure in multiple locations and corroded its reinforcing bars. Furthermore, since it no longer complied with current earthquake resistance standards, the structure required major repair work that would involve changing the static system and supports beneath some of the piers. Upon commencement of work on site, hydrodemolition tests were conducted after it was determined that the structure was also affected by Alkali-Aggregate Reactions (AAR) which had compromised the mechanical properties of the concrete. If that discovery had not been made, it would probably have been necessary to completely rebuild the structure within the next 15 years.

“The main goal of taking action was to mitigate the damaging effects of the AAR,” explains Stéphane Cuennet, Structural Technical Specialist from the Office Fédéral des Routes Suisses (OFROU)*, the Federal government agency responsible for Swiss highways. “It involved strengthening and waterproofing the road slab to remove any possibility of water penetrating the concrete and reducing the extent of stresses imposed by road traffic by making the slab more rigid, thereby increasing its ultimate strength, and limiting longitudinal distortion of the bridge decks.”

To meet these objectives, a UHPC solution was chosen by a group of specialists, including engineers from the École Polytechnique Fédérale de Lausanne (EPFL): casting a 45-mm layer of Ductal® on the existing deck in order to weatherproof it and improve the structure’s overall structural behavior.

“This really was the only plausible solution to guarantee a reliable rehabilitation in view of the uncertainties surrounding changes in the mechanical properties of concrete,” argues Cuennet.
With this knowledge, the Ductal® team at Lafarge put into place the technical resources required to define a formulation that would respond to the specific constraints of the project in terms of tensile strength, slope performance (gradients of up to 7% on the existing deck) and ease of implementation. Throughout the project, Damien Jacomo, the Ductal® Business Engineer responsible for Civil Engineering projects, and the Lafarge Ductal® team worked alongside the contractor and project owner to validate the Ductal® solution, its implementation and onsite quality monitoring.

Eugen Brühwiler, a global authority on UHPC, lecturer at EPFL and director of the structures maintenance, construction and safety laboratory, was appointed as expert consultant for the project by the OFROU: “The use of UHPC for the Chillon Viaducts is a world first, not only in terms of the area to be covered, but also the volumes to be produced and installed in such a short period of time”.

One of the remarkable benefits of the ultra-high performance concrete layer cast on the road slab is its ability to strengthen the structure against longitudinal shear forces and provide additional longitudinal rigidity with a thickness of just 45 mm, rather than the 20 cm of traditional reinforced concrete that would otherwise have been required. This UHPC layer also makes the deck more waterproof and therefore stops the ingress of water that could trigger a deterioration of the AAR. “The UHPC provides the perfect response to the weaknesses of ordinary concrete”, continues Brühwiler. “Its composition ensures that all the spaces inside the material are occupied by fine particles. It is an extremely compact material that is very dense and impermeable to water. Thanks to the large quantity of fine steel fibers it contains, it never cracks in service.”

This durable, robust solution considerably reduces the load on existing infrastructures, and is much faster to implement.

Brühwiler also believes that it offers significant financial benefits. “Contrary to what many people think, the cost of using UHPC to reinforce structures is ultimately good value, given the number of requirements it meets. The performance of this technique offers undeniable benefits but, in the end, it was purely for financial reasons that it was adopted in this instance.”

* Source: Kichoff issue 14
** Source: Batimag interview October 2014

### REFERENCE POINTS

- **Length:** 2 x 2.2 km
- **Width:** 2 x 12 m
- **Area of Ductal® poured:** 53,000 m²
- **Increase in traffic:** +10% in 3 years
- **Permitted vehicle weight increased from 24 to 40 metric tons**
- **General contractor:** Walo Bertschinger AG
- **Project owner:** OFROU
- **Project owner support:** EPFL
- **Designers:** MONOD-PIGUET +ASSOCIÉS Ingénieurs Conseils S.A.
Inventing the future

Beyond the progress in both technology and performance that UHPC has offered the world of architecture and engineering for 15+ years, Ductal® reflects Lafarge’s capacity for inventing the future. “Research carried out on Ductal® solutions also opens up opportunities in future energy markets, like wind power and nuclear power, as well as transportation infrastructures, offshore structures, and the security of buildings and people,” says Sébastien Bernardi, Ductal® Technical Director. The R&D efforts by Lafarge engineers and technicians, combined with the proactive commitment to progress by the Groups’ sales teams and our collaborators (architects, engineers, project owners) will help us to continue to develop solutions that enable the construction industry to keep pace with the new, evolving needs of our fast-changing world.

> Energy

Wind power

The durability of UHPC is a major benefit

The development of energy from renewable sources is a major challenge for our planet and that challenge is being spearheaded by wind power solutions. Whether on land or offshore, wind power offers practical solutions that are growing rapidly with installed generating capacities of around 400 GW.

Until now, the majority of existing wind power solutions have used steel masts, but these are now beginning to show signs of limited performance in terms of fatigue, durability and maintenance.

Wind turbines in Ductal®? It seems obvious - if you are open to starting over from scratch, to design a solution that utilizes the full potential of Ductal®, including its exceptional mechanical performances, compressive strengths, tensile capabilities, modulus of elasticity and low creep and shrinkage.

The material’s durability is clearly a major benefit, and one that has been well proven, with a great deal of feedback from its use in aggressive environments over the past two decades.

Over the long term, Ductal® offers a genuine alternative to existing energy solutions, and, with optimized design, it would extend the usage life of a wind turbine to much more than 25 years, currently the upper limit.

Therefore, an extended usage life would certainly be a decisive factor in terms of the investment and complexity required for this type of construction.

Wind turbines: responding to new demands of the energy market.
**Nuclear**

Sealed for the long term

Understandably, the containment vessels of nuclear reactors must meet precise/rigid criteria to ensure that they remain sealed to external air in the event of a nuclear accident. Some reactors, although they meet the appropriate criteria, have leakage rates that are now the subject of a repair program being conducted by EDF in France. The challenge of this program is to extend the operating usage life of these power plants to at least 60 years.

The power plant design most affected by this problem is one that uses double concrete wall containment vessels with no metal liner. In France, this is the case for 1,300/1,400 MW facilities that account for approximately 20% of the country’s nuclear plants.

The current resin-based sealing solutions applied to the inner face do not work for the outer face without an additional treatment to prevent blistering. Resolving this weakness significantly increases the cost of the overall solution.

The use of Ductal® for the outer face appears very promising, since it provides the required level of air seal and significantly reduces the risk of blistering. A solution has therefore been developed and evaluated in collaboration with a civil engineering firm specializing in the nuclear industry.

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**Transportation**

Creating transportation solutions that fit seamlessly into new urban developments - Dubai.

**Urban mobility**

Upgrading and development

The upgrading and development of transportation systems are major challenges for local and regional authorities, especially those in major urban centers where population densities are high.

Many cities around the world are initiating ambitious projects to upgrade and extend existing transportation networks and create new subway lines.

In this context, elevated railways offer a logical technical and economic solution, compared with underground subways.

Designing transportation solutions in Ductal® (for viaducts, bridges, stations, etc.) is a viable response to ensure improved environmental integration in a multitude of ways, such as:

- limiting or reducing noise pollution by effective containment of noise and vibration
- controlling costs in every project phase (durability, reduced maintenance, etc.)
- contributing to the process of building better cities
The phrase ‘security of buildings and people’ refers collectively to all the solutions and services that contribute to the protection of buildings and their occupants against potential threats. It could be industrial (i.e., explosion, chemical pollution, etc.) or even the risk of terrorist attack.

Safety-related projects typically address three specialties:
- hardware in the form of detection, access control, video surveillance and other systems (78%)
- alarm management, systems interface and other software (20%)
- services, such as security and remote surveillance companies (2%)

The hardware specialty covers two distinct families of technology: active devices, such as presence detectors, door and window opening detectors and surveillance cameras, and passive elements, such as building architecture, doors, windows, obstacles, etc.

The relative proportion of active devices to passive elements varies from project to project, but architectural design is becoming increasingly important. The quest to identify and develop bullet-proof and explosion-resistant construction materials then becomes crucial in the design of effective solutions to limit the collateral damage caused by shards and splinters of materials.

Once again, Ductal® can offer multiple, valuable solutions for making civil and military buildings safer. Its superior mechanical performances and essential function of its embedded fibers make it possible to consider customized solutions for both new and existing buildings (i.e., architectural adaptations, major renovations, strengthening projects).

> Security

Protecting buildings and people

Putting very high mechanical performance to the test

Freedom Tower, the first tower to be built on the World Trade Center site - New York, NY, USA.

A SOLUTION FOR GREATER SECURITY
A number of countries, including China, Switzerland, the USA and France, have recently begun to draft National Standards for Ultra-High Performance Concretes (UHPCs).

The first of these draft standards is due for publication this year but they differ, particularly in terms of performance levels and applications.

To ensure consistent regulatory standards across Europe, France will soon ask the European Committee for Standardization to set up a working group to begin the process of drafting a European standard. This request is a logical next step when France publishes Europe’s first National Standards for UHPCs in September this year.

Until now, the reference document for France has been the “Ultra-High Performance Concrete Recommendations”, published by the French Civil Engineering Association (AFGC) in June 2013. However, this document does not have the status of a regulatory standard, and its scope of application is limited to UHPCs with metal fibers and characteristic compressive strengths of greater than 150 MPa. Therefore, the decision was made to begin the process of creating a regulatory standard for France so that UHPCs can be integrated to the traditional construction sector and contribute to the facilitation of project design.

As a result, 2 standards have been drafted with significant input from Lafarge:
- 1 materials standard (NF P 18-470) entitled Ultra-High Performance Concrete: specification, performance, production and conformity
- 1 design standard (NF P 18-710) entitled National Supplement to Eurocode 2. Calculations for Concrete Structures: rules specific to Ultra-High Performance Concretes.

The materials standard applies to UHPCs with characteristic compressive strengths greater than 130 MPa, intended for use in buildings and engineered structures such as:
- precast structures and structural elements
- structures and structural elements cast on-site
- sections of structures with UHPC being cast on-site, particularly for use in joints, coatings or repairs.

The design standard applies to structural calculations for buildings and engineered structures in non-reinforced UHPC, reinforced UHPC and prestressed UHPC applications. It defines the mechanical strength, capability for service, durability and fire resistance requirements, but covers only UHPCs with metal fibers and a characteristic compressive strengths greater than 150 MPa. A third standard for the construction of UHPC structures will be published in the near future to cover all aspects of UHPC onsite usage.

It also applies to precast, non-structural or architectural elements cast on-site.

The Ductal® range of products and solutions has been developed over more than 10 years by Lafarge. These options are the outcome of major R&D input from the LCR (Lafarge Research Center) and its industry-recognized expertise in formulation, hydration, flow characteristics, microstructure and materials/process interactions.

This research also has led to the registration of many patents for new Ductal® inventions which currently total around 30, along with more than 244 patents worldwide. The development of Ductal® relies heavily on these patents, which are defended vigorously in the event of counterfeiting.

This patent strategy is a permanent feature of Lafarge’s R&D, whereby the innovations developed continue to result in the regular filing of patents for one or two new inventions each year.