Ductal® Solutions

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LAFARGE
bringing materials to life™

EDITORIAL

Ductal® : A Material at the Heart of Sustainable Construction

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Laurent Machet's project
REHA-PUCA award winner

After years of research and development which gave rise to a range of applications benefiting from the thousand and one innovative aspects of its characteristics and use in prestigious projects throughout the world, Ductal® now finds itself in a new period of growth.

The partnerships established by Lafarge to respond to architects' creative expectations, structural engineers' demands for performance, precasters' deployment issues, and also clients' economic requirements have all contributed towards the fact that Ductal® now bears the weight of the greatest ambitions for sustainable construction – ambitions to which we all aspire.

By giving substance to this societal ambition, which the construction and civil engineering sectors must react to, Ductal® has now taken up position as the standard industry alternative that responds to all sustainability issues.
A material which, thanks to you, is a reality and now paving the way for sustainable construction.

Jean Martin-Saint-Léon
Managing Director for Ductal®
Lafarge Group

PERSPECTIVE

Sustainable Construction and Life Cycle

The claim that a structure is sustainable is all too frequently based solely on the environmental impact of its materials at the time of their production. But, environmental impact and life cycle cannot be dissociated. Only by considering the entire life cycle of the building – from the production of the materials and their transport, to its maintenance and what happens at the end of its life – can we get a true picture of its "sustainability". A house that lasts 20 years must therefore have its environmental impact multiplied five-fold to achieve a fair comparison with a house that was going to last 100 years.

Likewise, there is no such thing as a "natural" material. Some have a low environmental impact at the time of production, but only have short-term usability. Others require a great deal of energy for their production, but their durability considerably reduces their actual environmental impact. We also need to consider what is included in the notion of "life-time". Can we compare the durability required of the Channel Tunnel with that of an office building? Do we take umbrage today at the forests that were decimated to create the foundations of Venice and which are still holding up the city centuries later? Producing Ductal® requires on average three times less energy than required to produce a ton of conventional concrete. Furthermore, its extrapolated field tested life span of 1000 years, the material savings that it enables (between three and six times less than conventional concrete) and the virtual lack of maintenance required can reduce the environmental impact of Ductal® structures by more than 30% compared with equivalent structures made out of conventional materials. We can see, then, that actual environmental impact depends on this essential balance between the purpose of the building and the most suitable material, so that the structure is… sustainable.

Jean-François Batoz
Director of Development for Ductal®
Director of Marketing for Precasting

Which Materials for Which Sustainable Construction?

The world's top 300 specialists in the design and use of ultra-high performance fiber-reinforced concrete (UHPC) came together for a conference on November 17 and 18 in Marseilles.

Among other things, it was a good opportunity to confirm the surprising environmental performance of Ductal®, based on a life cycle assessment (LCA) carried out in real situations in civil engineering works and residential structures. Here is a summary of that conference.

"UHPC is to conventional concrete what the jet engine is to the propeller engine"

Rudy Ricciotti

Seven years after the recommendations of AFGC- SETRA regarding UHPC were published, the aim of the Marseilles conference was to take stock of the expertise and experience in the field of UHPCs and analyze prospects for development. Jean-François Batoz and Mathieu Rivallain, Director of Development for Ductal® and Engineer respectively, were invited to speak about the specific contribution of UHPC to sustainable development. Presented for analysis were the results of the recent comparative studies between traditional construction methods and Ductal® structures.

Looking Beyond a Simplistic Concept of "Sustainable Construction"

After warning against a misguided vision of sustainable construction, which is "often difficult to grasp and sometimes leads to comparisons that are simply not correct," Jean-François Batoz defined the concept as a "vision of construction which, through a well-thought-out combination of materials and building products and their intelligent use, seeks to limit its environmental impact, taking into consideration the consumption of finite resources and emissions into the air, water or ground."

Only LCA, which is established on the basis of scientific methods and now subject to international standardization, allows us to draw up a balance sheet of materials and energy for all the phases in the life cycle of a building or structure – from production of the materials to the end of its life, dismantling, and disposal or recycling of constituent parts.

If we take into account the environmental performance of the structure or building throughout its life cycle, Ductal® now appears to be an "environmentally efficient" material, in contrast to environmentally-friendly products for which environmental impact is calculated purely as a function of the quantity or volume of material used.

In-Situ Results in Favor of Ductal®

In fact, when applied to a material in a real situation, this method demonstrates the environmental efficiency of Ductal®. In the civil engineering sector, the first example structure studied was a standard bridge with a span of 30 m – with no intermediate supports – and two road-traffic lanes (the type of structure that represents more than two-thirds of bridges built every year in France).
When compared, the LCAs of a composite bridge (steel structure with concrete deck) and a Ductal® bridge (deck girder structure) show that Ductal® consumes on average 50% less energy (total primary energy, contribution to the greenhouse effect and depletion of abiotic resources).
"When placed in the context of realistic hypotheses regarding extraction, production of materials, transport, construction, maintenance and end of life, the conclusions of the LCA are emphatic.
The Ductal® bridge is shown to have a much better performance in terms of its environmental impact than a composite bridge, in particular through the great reduction in the quantities of materials used," concludes Jean-François Batoz.

FOCUS
Life Cycle Analysis: the End of Preconceived Ideas?

Based on the LCA method, the scientific comparison of materials that are considered to be "green" and ordinary materials casts doubt on a great deal of false evidence. In the construction sector, the environmental balance sheet for hemp fiber or duck feather insulation – assumed to be more environmentally-friendly than other insulation types – proves to be worse than glass wool. In the same way, a scientific comparison between a breeze (cinder) block wall and a brick wall, which is typically considered "natural", is unequivocal. The former is shown to have the smaller environmental impact in 8 cases out of 9!

If this is then applied to a prefabricated 100 m^2 house, the comparison (also taking air acidification into account) reveals a significant difference of around 18 to 30% in favor of Ductal®.
This solution appears even more significant in the context of sustainable construction when we also consider how easy precast Ductal® elements are to assemble on site. "By using modules that are precast in the factory and assembled on site with a very limited number of operations, we introduce a considerable degree of efficiency to the construction site and an improvement not only in the environmental impact, but also in the quality of construction."

"Mozart" house

Concrete, the Best Solution for the Low-Energy House

When it was presented at Batimat 2009, the new multiple-material study *Qualité Environnementale des Bâtiments – QEB* (environmental quality of buildings) shook up perceived ideas about the sustainable house. Based on the analysis of various life cycle stages, it effectively demonstrated that concrete products are the best solution for reconciling environmental performance, comfort, resistance and construction costs.
Below is a description of the methodology and details of the conclusions of the QEB study.

Buildings are responsible for 18% of direct greenhouse-gas emissions and 43% of energy consumption. The construction industry has long been attempting to reduce these percentages. This ambition is in line with the objectives of the Grenelle Environment Conference, which clearly expressed the willingness of the authorities to conduct an effective campaign to reduce greenhouse gases. Against this background, the cement/ concrete industry must demonstrate, for the detached house and small residential block in particular, that its solutions represent an excellent response to the need to build houses that consume less energy (not exceeding 50 kWh/m²a and known as "low-energy houses"), so that by 2050 we have arrived at the "Passive House". This has already been demonstrated.

A Scientific Method, by Independent Experts

Carried out in 2009 on the initiative of Cimbéton, in collaboration with all of the construction material sectors (cement, concrete, brick, wood, insulation, etc.), this study was a first in France. Its aim was to compare the environmental impact linked to the construction and occupation of low energy buildings in three regions (continental, temperate and southern) with six construction system variants: concrete blocks, shuttered concrete, aerated concrete, Monomur bricks, bricks and timber frame. By analyzing the various life cycle stages, from extraction of the primary materials to the end of life, through all the intermediate phases (production, transport, consumption), the study measured 10 environmental impacts. It was carried out by consultants Tribu Energie, for the thermal aspects, and by the company Ecobilan, for the environmental impact, based on the environmental product declarations (FDES) supplied by all the industries. This gave rise to a critical review carried out by independent experts, including the CSTB. One-hundred cases based on two types of single-dwelling housing and one small multiple-dwelling building were studied over a period of 100 years.

"MOZART" HOUSE: **"concrete" results**

Among the hundred or so construction systems studied, the "Mozart" house refers to a street-level dwelling with a habitable surface area of 100 m² (119.4 m² NFA). The results presented here focus primarily on the major indicators of the Grenelle Environment Conference:

• **Environmental consumption:** For all of the materials studied, the energy required for the construction and deconstruction of a low-energy house is relatively marginal in comparison to the energy required to run it. Depending on the climatic zone, the energy required may be two to three times more significant than the "construction site" energy. In the material classification, concrete solutions are ranked at the same level as the other construction systems in terms of energy.

• **Greenhouse gases:** In regards to CO_2 emissions, i.e., the impact on climate change; the overriding factor to be taken into consideration is the type of climatic zone. The more the extreme temperatures (at the installation site) require significant insulation, the greater the differences between various materials. Nevertheless, the difference between the "best" and "worst" solutions over a year, is equivalent to no more than a car journey from Paris to Marseilles and back. So, for example, the difference in the "climate change" impact between concrete block and timber is less than 10%.

• **Air quality:** Since concrete is inorganic and inert, it guarantees extremely healthy internal air (pollution, dust, bacteria).

• **Acoustic and thermal comfort:** Thanks to its mass, concrete actively contributes to acoustic insulation while its thermal inertia allows it to accumulate coolness overnight and redistribute it during the day. A concrete house therefore requires less heating energy and can do without air conditioning.

• **Cost:** In contrast to certain other materials, the constituent parts of concrete are locally available (in France) and consistent throughout the country. The cost of a low-energy house made from concrete can be reduced to 1100 euros per square meter (excluding land), which was in fact the most competitive cost of all the materials. Armed with these results, concrete – whether conventional or aerated – seems more than ever to be a major ally in the quest for sustainable construction.

The Ductal® Thermal Breaker: Reducing the Energy Consumption of New Buildings

TESTIMONIAL
Vincent Brossy Architect - Brossy & Associates

An entire generation of architects has shaped architecture by imagining that the architectural form is linked to construction methods. At a certain point, the material used gives the building its appearance. The thermal breaker obviously gives the option of continuing to build, in particular, with exposed reinforced concrete. Quite apart from the economic aspect and the thermal performance aspect, it really is a question of architectural choice.

This is a rather elegant solution of continuing to use a traditional, familiar and cost-effective construction method which responds to the demands of future regulations.

Optimization of the energy consumption of buildings is a major issue at both national and international levels.
In France, 30% of energy is used for heating in the residential and service sectors alone. This is a concern, when you consider that thermal bridges may be responsible for up to 30% of the total energy lost from a building.

The French government has set ambitious targets for reducing energy consumption in housing by 2013. The goal is to improve on current performance by more than 60% - and all the more so, because 90% of current new builds are still insulated on the inside and therefore only rarely deal with the problem of thermal bridges.
In particular, these thermal bridges occur in buildings with concrete façades, where the slabs, walls and roof meet. Heat passes through the floor to form a link to the façade and is diffused towards the outside. To find a solution for this problem, in 2007 Lafarge set up a working collaboration with, among others, Bouygues Bâtiment Ile-de-France, Fehr-Technologies, Pouget Consultants and the Centre Scientifique et Technique du Bâtiment (CSTB). The outcome of this project, which benefited from the support of ADEME (French Environment & Energy Management Agency), was an innovative component: the Ductal® Thermal Breaker. “A thermal breaker is able to reduce thermal bridges by 70%,” explains Alain Birault, Head of the Ductal® thermal breaker project for Lafarge, “and therefore achieves a Psi-value of 0.3, in line with the specifications or a low-energy house.
This performance level was made possible by integrating Ductal® at a mechanical level in order to achieve a continuous link between the slab and roof, using the thinnest ribs possible, surrounding the structural steels. The concrete link was therefore continuous. We are using precast elements, 1.20 m long, with ribs every 60 cm - which makes them very easy to fit in place. In addition, this continuity is combined with insulation and thermal lining systems to ensure compliance with acoustic regulations.

Mechanical trials and resistance to fire

The Ductal® thermal breaker has undergone several rounds of mechanical testing at the CSTB. It can support a load greater than 8 t. and, in practical terms, it can take the strain of floors with spans of up to 6.5 m, which means that it is able to meet the requirements for the majority of layouts encountered in the residential sector. Furthermore, a fire test in CSTB’s large furnace demonstrated a resistance of more than 2h20, which is exceptional for this type of component. The thermal breaker can also be used in buildings up to 50 m in height, in accordance with the French code.

THIRD INTERNATIONAL FIB CONGRESS IN WASHINGTON:
“Think Globally, Build Locally”

The *fib* Congress is the most prestigious international event in the concrete sector. The theme for the “Third International Congress and Exhibition” (Washington, D.C., May 29-June 2, 2010), was “Think Globally, Build Locally”; a unifying message at the heart of concerns about sustainable construction. Concrete structures provide benefits in terms of sustainability that designers and engineers are continuing to develop. With this in mind, the technical program presented the latest concepts and experiences in the field of sustainable design. Six papers on practical applications utilizing Ductal® were presented and published.
The event was organized by a fib partnership involving the International Federation for Structural Concrete and the PCI (Precast/Prestressed Concrete Institute), both who share a common objective concerning development at an international level and of scientific and field studies that enable progress in the technical, economic, aesthetic and environmental performance of concrete constructions.
On May 30, Jury chairman Hans Rudolf Ganz presented Vic Perry, Vice President & General Manager, Ductal® (North America) with a special certificate of merit for the Glenmore/Legsby Pedestrian Bridge – recognizing this innovative Ductal® project as a “Nominated Structure” in the 2010 fib Awards for Outstanding Concrete Structures.

BRIDGE AWARDS

- HAWK LAKE BRIDGE, Ontario, Canada – PCA Concrete Bridge Award - 2010
- JAKWAY PARK BRIDGE, Iowa, USA – (1) Iowa Quality Initiative Structures Research Merit Award - 2009 & (2) PCI Design Award - 2009
- THE GLENMORE/LEGSBY PEDESTRIAN BRIDGE, Alberta, Canada – (1) ACI Awards of Excellence in Concrete - for "Bridges" and "Advanced Concrete Construction" - 2009 – (2) PCI Special Jury Award for Innovative Technology - 2008 & (3) fib Congress - "Nominated Structure" for the 2010 "fib Awards for Outstanding Concrete Structures"
- THE WAPELLO COUNTY MARS HILL BRIDGE, Iowa, USA – PCA Concrete Bridge Award - 2006
- THE SHERBROOKE PEDESTRIAN OVERPASS, Quebec, Canada - PCI (Precast/Prestressed Concrete Institute) Design Award (Honorable Mention) - 1998

Ductal® Girder: Sanderling Drive Pedestrian Overpass, Alberta, Canada

Ductal® Bridge Solutions
Gaining Acceptance in North America

US : 156,000 bridges to restore

According to the Federal Highway Administration (FHWA) National Bridge Inventory (NBI) Study, approximately 156,000 bridges in the USA are structurally deficient or functionally obsolete. State, provincial and municipal engineers are seeking new ways to build better bridges, thereby reducing maintenance costs that are diverted from capital budgets required for building much needed highways and bridges. Therefore, the FHWA launched "The Bridge of the Future"; intended to be a bridge that can last for 100 years or more and require minimal maintenance and repair, while being adaptable to changing conditions such as increasing loads or traffic volumes.

How is Ductal® used in bridges?
Since completion of the first Ductal® footbridge in Sherbrooke, Quebec (1997), numerous innovative Ductal® bridge solutions have been completed around the world – with projects completed in France, Canada, USA, Australia, New Zealand, Japan, and South-Korea. Across North America, 15 Ductal® Bridge projects have been completed: six in 2009, 10 more are scheduled for 2010.
In these projects, Ductal® has been used for beams, girders, decks, piles, and joint fill for precast deck systems. Thanks to its outstanding properties, the freedom to design innovative, optimized shapes is now possible – and with additional benefits such as: superior freeze/thaw resistance, extremely low porosity, improved flexural strength and superior toughness – all relating to improved resistance to mechanical solicitations as severe climatic conditions.

Our valued clients, such as the Federal Highway Administration (FHWA), the New York State Department of Transportation, the Iowa Dept. of Transportation, the Ministry of Transportation of Ontario and the City of Calgary have been heavily involved in the development of their own Ductal® bridge projects.

Ben Graybeal, Ph.D., P.E., Research Structural Engineer, Federal Highway Administration, Virginia, USA

How do you see Ultra-High Performance Concrete (UHPC) helping to solve or address the needs of the "Bridge of the Future"?

B. G. : Given the ever increasing demands on our bridge structures and resources, it is clear that conventional construction techniques of the 20th century are not in themselves sufficient to meet 21st century needs. There is a strong demand for new solutions to existing problems, whether the solutions emanate from materials or structural configurations or construction techniques. The advanced properties of UHPC open many new avenues toward these solutions. The Federal Highway Administration's "Bridge of the Future" Research Program is developing robust solutions that increase durability and reduce construction time. UHPC has allowed for the development of new structural components and component-joining technologies which directly address immediate needs in the highway sector.

What obstacles prevent state DOTs from implementing the use of UHPC for future projects?

B. G. : The following was adapted from a Public Roads article titled "UHPC Making Strides" that I authored for the Jan-Feb 2009 issue.
As is frequently the case with established industries serving the public works sector, implementation of innovations occurs rather methodically. FHWA has identified five specific obstacles hindering widespread UHPC deployment.

Unless industry sees a clear financial benefit, manufacturers are unlikely to invest in innovative technologies. Manufacturers who see a risk in using a new material are hesitant to modify current operations so that they can produce the innovative product efficiently. As would be expected, the costs of fabricating UHPC components thus are significantly higher than the costs of manufacturing conventional concrete components.
The lack of design code provisions relevant to the advanced properties of these innovations is a clear hindrance. This gap effectively requires that all UHPC structural designs proceed along one of two paths. The designer can choose to make limited use of UHPC, in effect using the advanced properties of UHPC simply as an added safety factor. Alternatively, the designer can rely on research results, effectively requiring some level of demonstration testing prior to implementation.

The limited number of applications of UHPC to date necessarily means that limited experience is available with regard to inspection, maintenance, and repair of UHPC structures. Although FHWA researchers and others expect these structures to perform well once deployed into the highway system, UHPC is not immune to damage from over-height or wayward vehicles, or unanticipated structural loadings. Methods for inspecting UHPC for damage and for repairing UHPC components will need to be developed prior to widespread acceptance of this material by the highway industry.

Finally, the higher cost of the constituent materials in UHPC necessarily means that it will have a higher per-unit volume cost than conventional and high-performance concretes. This increase is unlikely to be offset entirely through the use of more efficient structural designs. To compensate for the greater cost, designers need to use a life cycle costing approach that takes into account the enhanced durability of UHPC.

Ray Krisciunas, P.Eng., Head of Structural Transportation for the Ministry of Transportation of Ontario

How do you see Ductal® solving challenges for bridge owners in terms of construction and maintenance?

R. K. : Ductal® has provided us with an entire new way of constructing bridges quickly and with guaranteed long term performance. Its extreme high strength, durability and ductility have opened up to applications that simply would not be possible with other materials. Most notable has been its use in field joints for prefabricated components. Lafarge has been extremely helpful in providing technical support concerning the use of Ductal®.

Dean Bierwagen, P.E., Iowa Dept. of Transportation (Bridges and Structures), Iowa, USA

What design challenges does Ductal® solve for you and; how do you see it used in the future?

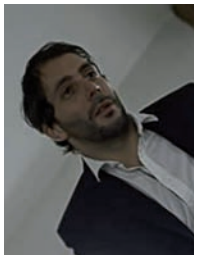
D. B. :

1. Applications in repair such as deck replacement (using a reduced section such as a waffle slab), where reduce weight could increase bridge capacity.
2. Increased durability; could be used in areas where normal concrete does not perform well (joint locations).
3. Consider using as an overlay in precast panels for new bridges to improve durability and reduce permeability of decks.
4. Consider using in areas where a reduced cross section or reduced weight is required.

Ductal® Joint Fill: Hawk Lake Bridge, Ontario, Canada; PCA Concrete Bridge Award, 2010

Transformation of 68 apartments in a residential block
Recognized low-energy house - Val de Reuil (27)

Interview with Laurent Machet, REHA-PUCA award winner



Ductal® Solutions: Describe your project in a few words...
Laurent Machet :
The transformation that we proposed for the 68 dwellings in the residential block in Val de Reuil (Ed.: Normandy, France) consists of removing all the façades from the building in order to streamline it considerably and fitting a loggia, conceived as a new skin for the building and providing 1.80 m of additional floor space to each apartment.
Acting alternately as a conservatory in the winter and an open veranda in the summer, these extra square meters clearly fulfill their function as a thermal buffer, increase convenience of use for the inhabitant and allow more light to enter.

Ductal® Solutions: In what way does Ductal® provide a new and distinctive solution?
Laurent Machet : Ductal® enables a very light, self-supporting solution. Its principal asset over all other conceivable materials in the creation of this double-skin structure is that the whole can be achieved with only three parts:
- a sub-frame supporting the glazed frames. This also enclosed the construction site, allowing us to work on an occupied site,
- a 3 cm waffle floor,
- the peripheral posts supporting the floor.

These three elements are extremely easy to put in place and, at the same time, guarantee resistance to air, water and fire. The work is carried out with the site occupied and there is no need for displacing residents during rehabilitation. But above all this project, supported enthusiastically by the Val de Reuil town council within the parameters of the ANRU, is allowing us to test a new functionality of Ductal®: the extension of a façade to bring each of the apartments into line with thermal standards using a light system of enclosed balconies that can be dry-fitted.
By the same means, the increase in surface area allows the usability of the apartments to be brought up to date, as well as increasing the financial and communicative value of the housing stock.

FOCUS

REHA-PUCA or the redevelopment of multiple-dwelling buildings for high energy performance

The panel for the REHA (Redevelopment of Multiple-Dwelling Buildings for High Energy Performance) consultation process selected 17 winners from the 69 submissions aiming to apply innovative technical and architectural solutions to the redevelopment of residential blocks for a high level of energy performance. The objective was to gather specific proposals that bring about a real increase in value of the buildings, both on the outside and the inside, to showcase interesting schemes for entire buildings or parts of buildings, to put together a great range of innovative architectural and technical solutions with a strong energy-based constituent.
The challenge is to propose operational responses that address the issues of urban integration, architectural quality, quality of use, excellence in terms of energy efficiency, environmental performance, security, and economic and social effectiveness. In a nutshell, specific, adaptable and repeatable responses that can be employed in similar situations. It is against this background that Laurent Machet, a young, independent architect and urban planner, formed an association with Ductal® and ranked among the 17 award winners in this consultation process, carried out in partnership with the ANAH (National Agency for Housing Improvement), ANRU (National Agency for Urban Renewal), USH (Social Housing Union), UNHAJ (National Union for Youth Housing), CNOUS (National Centre for University and Student Welfare), ADOMA and ARC (co-owner's association).

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