

# Infrastructure

— ductal® —



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## Ductal®

For more than 25 years, we've been producing the most advanced range of Ultra High Performance Concrete technologies and services. Born from the desire to minimize inputs while maximizing performance, Ductal® stands for optimal strength, ductility and durability. Decades of global practice, research and development have allowed us to acquire the technology and expertise needed to bring the most ambitious projects to life —without a hitch, anywhere in the world. Our team consists of a diverse collective of licensed engineers, architects, construction consultants and field technicians — all working directly with our clients to develop tailored but pragmatic answers to some of the most important questions in the construction industry today. By inventing construction materials that use less and last longer, we're enabling more responsible built environments that lift up communities while being more respectful to their natural environment. For the sake of people and the planet we all depend on, we're bringing concrete solutions to tomorrow's challenges.

## Ductal® for civil engineering

Combining the revolutionary technologies of a high-performance cementitious matrix and high strength fibres, Ductal® provides superior performances in mechanical properties, durability, and aesthetics. Compressive, tensile, and flexural strengths combined with high abrasion resistance and low permeability allows Ductal® to be used in a wide range of applications. Common applications include some of the most demanding structures: bridges, roads, hydraulic structures, industrial slabs and any type of structure with stringent requirements. Contractors, precasters, and owners can now expand their business by relying on our solutions that facilitate the ability of design and execution of highly demanding applications that are difficult or impossible to achieve with traditional concrete elements.

Ductal® owes its innovative character to its exceptional composition characterized by:

-Optimization of the granular skeleton: the superior performance of Ductal® is the result of improved microstructural properties. The optimization of granular provides a very low porosity in a cement-based matrix. Thanks to the use of micro-particles, SCMs, silica fume and optimized sand gradations, dense composition and very low void ratio are the main characteristics of this composition.

-Reduced w/c ratio: for a comparable mixing water volume, Ductal® has a significantly higher cement content than normal and high strength concrete. Typically, this results in a significantly lower w / c ratio of less than 0.25.

-High fiber content: the high fiber content of 1 to 5% by volume gives the structure high ductility as well as strain-hardening behavior depending on the variety/ formulation of Ductal®. The elements are reinforced both inside and on the surface thanks to the homogeneous distribution of fibers. The efficiency of fibers in Ductal® depends on material, content, geometry, distribution, and orientation.

## Technical characteristics and performances

Exceptional resistance in compression, tensile strength, ductility and durability, Ductal® is clearly distinguished from normal and high-strength concrete both in terms of its mechanical properties and its durability.

### Compression

Ductal® exhibits excellent performance in compression: it is 4 to 8 times higher than conventional concretes. Compression behaviour is linear up to the maximum stress and exhibits no damage to the material during this phase, up to a maximum deformation of 4,5‰. As for all concretes, after the peak, the strain is no longer uniform; although the presence of fibres prevents brittle failure of the material. This is a very good advantage compared to conventional UHPC that tend to be brittle in compression so are unsafe. Thanks to its metallic fibers, Ductal® is safer.

### Tension

The tensile behavior of Ductal® is divided into three phases:

- In the elastic phase, the deformation increases linearly with the load and is completely absorbed during unloading
- In the strain-hardening phase, the deformation increases with the load with the appearance of the finely distributed micro-cracking. The deformation is permanent. The strain hardening behavior only takes place if the fiber content is high enough to take over from the cement matrix after cracking occurs and therefore resist the tensile force. With insufficient fiber content, the material shows a softening response directly after the elastic phase.
- In the softening phase, the tensile stresses decrease but the deformations increase and get concentrated into a crack opening where more and more fibers are pulled out. The maximum crack opening in the event of a failure is approximately half the length of the fibers.



## Bending behavior:

The fibers give the material a ductile behavior during bending (when loaded in flexure beyond the elastic limit, micro-cracks occur and the fibers hold the cracks tightly closed, providing a ductile performance rather than a sudden or brittle failure). The ductility behavior observed during bending is characterized by multiple cracks before the stress peaks, without localization and without the presence of any macro cracks.

## Creep and shrinkage

Since the water to cement ratio is very low, Ductal® can exhibit a relatively high final shrinkage of up to 1‰ in the form of autogenous shrinkage and does not exhibit much drying shrinkage.

Due to the low water content of the material and use of silica fume, deformation under permanent loads (creep) is strongly scaled down. The specific properties in terms of creep (very small) allow mastering all the difficulties of design related to defer deformations. This is particularly interesting for the construction of prestressed structures by post-tensioning or pre-tensioning because the prestressing losses are strongly reduced.

## Durability properties:

Low porosity-Freeze-thaw resistance-Abrasion resistance-Marine exposure-Fire resistance-Resistance to aggressive agents.

In addition to having much better mechanical strength than that of ordinary concrete, Ductal® as an UHPFRC has remarkable characteristics in terms of durability witnessed by the experimental results. The dense composition of Ductal® prevents aggressive solutions from penetrating into the matrix, and so the mechanisms that can deteriorate conventional concrete are not present. Consequently, durability properties, as measured by permeability tests, freeze-thaw tests, abrasion tests, are significantly better than those of conventional concrete. The very low voids ratio protects the fibers, which means that the mechanical properties are maintained when the concrete is subjected to tensile stresses. These properties make UHPFRC suitable for special applications such as highly aggressive environments.





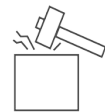
## The main advantages of using Ductal®



Reduce the material quantities



Save time and site works



Ensure a high level of durability and longevity



Reduce the maintenance of the structure



Ensure the accuracy of construction schedule/planning

Ductal® is typically provided/delivered as a kit with all necessary components:

Dry premix (pre blended powder), admixtures, and fibres.



## Implementation

When placing layers of Ductal® on existing concrete, substances and/or particles susceptible to affect the material bond must be completely removed and the support surface must be saturated with water beforehand. The same requirements apply as for the rehabilitation of concrete with hydraulically bound materials. Depending on the project requirements, Ductal® can be placed manually or mechanically. Its workability is guaranteed for one to two hours depending on ambient conditions and mixture formulation. The fluid Ductal® is poured into the formwork and spreads out easily thanks to its self-leveling behavior. If material cast is interrupted, the previously placed layer of Ductal® must be vigorously agitated before placing subsequent fresh material to ensure a homogenous fiber content throughout the full element. Thixotropic Ductal® in thin layers can be successfully consolidating with concrete pavers and vibratory truss screeds for horizontal applications. Ductal® Shotcrete solution is sprayed as wet cast with concrete piston pumps in thin layers for vertical or vaults applications.





Nipigon Cable, Canada, 2017 - Ferovial/BOT JV

### Formworks

A self-consolidating Ductal® solution is prone to induce large pressures on the formwork. Due to Ductal®'s high fluidity, the formwork must be very impermeable to its fine particulation and fluid characteristics. A self-consolidating Ductal® mixture® will precisely reproduce formwork textures.

### Curing/heat treatment

Due to the low water to cement ratio, the curing of UHPC is of particular importance. It's imperative to avoid any loss of water. Freshly placed Ductal® must be covered with plastic sheets immediately after installation and must be protected from external weather agents (wind, sun, rain, cold.). The duration of standard curing is generally from 4 to 7 days. When utilizing heat treatment (controlled intake of heat and humidity), the material resistance can be improved and shrinkage can be stabilized/reached in a shorter time period.



Kanderviadukt, Switzerland, 2018 - Walo Bertschinger SA

### Prefabrication

The material's combination of superior properties facilitates the ability to design thin, complex shapes, curvatures, and highly customized textures – applications that are difficult or impossible to achieve with traditional reinforced concrete elements. Therefore, endless possibilities of improved aesthetics are possible.

Prefabrication allows for very small dimensions and optimized use of the material's mechanical properties, even in traditional concrete construction. Ductal® greatly increases these opportunities as it allows much smaller dimensions. Therefore, unthinkable shapes and geometries are now possible when designing with Ductal®.

### Dead load and construction time

Studies prove that strengthening techniques using UHPC with steel reinforcement greatly increase ultimate capacity. Ductal® allows for retrofitting/strengthening with considerably thin layers. Preliminary tests have shown that the ultimate strength of a bridge deck can be increased by more than 50% with the application of a layer of reinforced Ductal® with a thickness of only 40 mm. Moreover, this strengthening measure is extremely effective because it reduces the added dead weight and the construction time.





# **Solutions**

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# Ductal<sup>®</sup> Infrastructure

Optimal strength, ductility  
and durability.

**Address the most challenging structural and durability challenges with high-strength, ductile and self-compacting solutions. Whether precast or poured in-situ, these can meet the most demanding requirements – regardless of complexity.**

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Ductal<sup>®</sup> Infrastructure solution is specifically engineered to fundamentally enhance the performance of new and existing structures. Superior performances in compressive, tensile and flexural strengths, combined with high abrasion resistance, crack control, and high impermeability makes it perfect for strengthening, waterproofing and protecting structures, extending their service life while reducing maintenance costs.

## Optimization

The material's high mechanical properties combined with exceptional ductility allow for the construction of lightweight yet enduring prefabricated bridges, strengthening bridge decks and repairing vertical structures that display the best in innovative techniques and durability requirements – along with endless possibilities for improved aesthetics.

The high prefabrication potential of Ductal® accommodates projects at different scales, reducing the size and complexity of structural connections and rebar detailing. This allows for a better exploitation of mechanical resistances, even in the context of existing traditional concrete construction.

Ductal® is ideally combined with prestressing (pre or post tensioned) as it allows to go thinner for the same bearing capacity due to its very high compressive strength. The solutions offered avoid or limit the use of complex shape anchoring rebars due to the use of fibers while saving on cables due to very low creep coefficient especially when heat treated.

## Implementation

Whether cast in place or precast, Ductal®'s flexural and durability advantages, as well as its self-compacting consistency, offer a great potential to explore for rehabilitation projects, and provide a reliable, durable solution to extend the lifespan of structures such as bridges, piers, girders, and joints. Its fluid, self-consolidating consistency makes it ideal for casting in congested areas, without the need for vibration. Typical design strength can be reached in a short amount of time. Its innate strength allows for the creation of thinner structural elements, and just about any new shape or geometry imaginable can be brought to life. The fibers enable also to avoid the use of trusses (shear resisting) rebars which allows to build thinner element, creating "steel like" structures.

Available in North America	<p><b>Ductal® Accelerated</b> Enhanced performance at a fraction of the time.</p> <ul style="list-style-type: none"> <li>- Fast track your construction process and meet your performance objectives in no time with our accelerated infrastructural solution.</li> </ul>
Available in EMEA & Asia	<p><b>Ductal® Infrastructure T1/T2/T3</b> Advanced ductility for more durable and water-resistant performance.</p> <ul style="list-style-type: none"> <li>- Increase your structure's resistance to highly aggressive environments with our advanced infrastructural solution designed to refrain macro-cracks from forming and to guarantee water resistance.</li> </ul>

## Advantages

Ductal® Infrastructure marks a clear departure from conventional and high-strength concretes both in terms of its mechanical properties and behaviour, providing long-term durability and protection even in the most aggressive of environments. The solution satisfies necessary requirements of the technical specifications while providing a cost-efficient solution for projects.

### Application Joint fill / Closure pours

- Link slabs and expansion joint headers
- Beam end and bearing encasements
- Column and pile jacketing
- Protection of hydraulic and marine structures
- Slender precast elements



Mauves sur Loire bridge, France, 2020- Bouygues TPRF





Mauves sur Loire bridge, France, 2020 - Bouygues TPRF



Pulaski Skyway, USA, 2018 - CCA Civil



Zurich Airport railway station, Switzerland, 2019/2020 - ARGE FF Flughafen



# Ductal® Overlay

Withstand the test of time.

**Fast track your construction process and reduce the amount of material needed for your structure with this thixotropic technology — guaranteeing maximized life span and minimized maintenance over time.**

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This cast-in-place dense UHPC composition presents a cement-based matrix with a very low void ratio, making it impermeable to carbonation and alkali reactivity, and preventing the penetration of aggressive chemical agents into the applied layers (preventing rebar corrosion), even under heavy stress from road traffic and deicing chemicals. Ductal® Overlay provides a durable and impermeable layer against chlorides and can also structurally strengthen an existing bridge deck. It is an efficient rehabilitation method to extend the service life and to enhance the long-term durability performance in a cost-effective way. Ductal® Overlay offers an optimized solution that protects, strengthens and waterproofs at the same time while saving considerable time during construction.



## Implementation

Ductal® Overlay includes thixotropic consistency that increases the range of applications (slopes up to 15% and horizontal surfaces applications) while providing speed of construction. The solution's implementation can be performed easily with reduced minimal down time, which diminishes risks related to planning and execution deadlines.

## Advantages

Add a highly protective, durable, low maintenance layer to new and existing concrete surfaces with Ductal® Overlay, adding protection, strength, durability, waterproofing and resistance to chemicals to any project.

The solution's implementation can be performed easily with reduced minimal down time, which diminishes risks related to planning and execution deadlines.

## Application

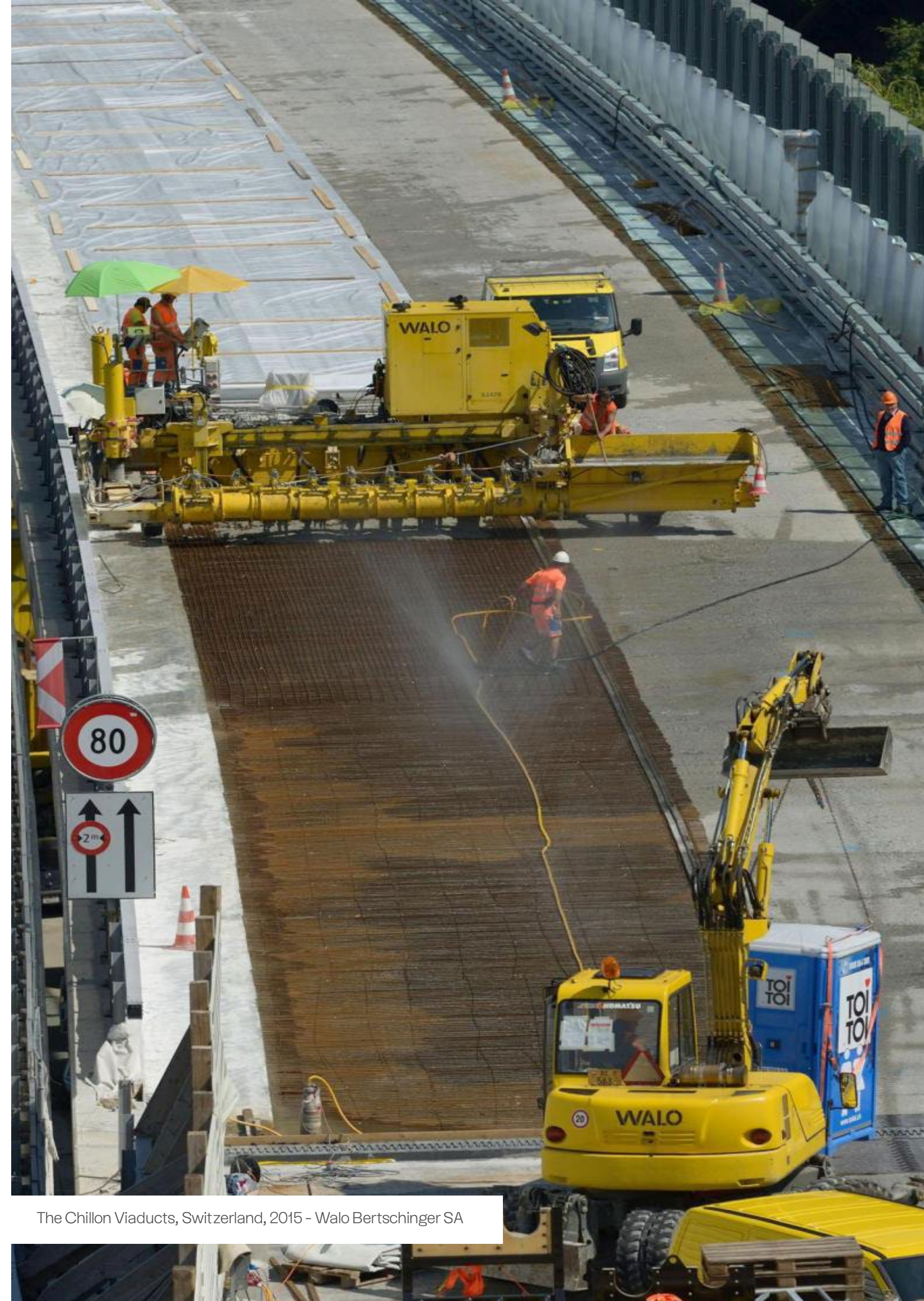
Add a highly protective, durable, low maintenance layer to new and existing concrete surfaces with Ductal® Overlay, adding protection, strength, durability, waterproofing and resistance to chemicals to any project:

- New overlay
- Bridge deck rehabilitation and protection
- Industrial/warehouse floor slab protection
- Building slab strengthening and repair

Available in EMEA & Asia

### Ductal® Overlay T1/T2/T3

Unrivalled ductility and durability for advanced protection.  
- Waterproof and optimize your structure's resistance with this solution boasting remarkable durability and mechanical performances. An ideal solution for ambitious projects that need robust protection.



The Chillon Viaducts, Switzerland, 2015 - Walo Bertschinger SA





Yunnan Bridge, China, 2020 - Sinohydro Bureau 8



Des Fenils bridge, Switzerland, 2021 - Grisoni - Zaugg SA



IA 163, USA, 2020 - UHPC Solutions



# Ductal<sup>®</sup> Shotcrete

Projected strength for any geometries.

**Overcome the barriers to traditional forming and pouring methods with our highly adaptive Shotcrete – a time- and cost-efficient solution that extends the service life of any structure and surface.**

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Ductal<sup>®</sup> Shotcrete is a wet-mix formulation that can help strengthen, stiffen and protect new and existing structures, improving their performance along the way. Its steel micro-fiber reinforcement procures its high compressive and flexural strengths from the early-age stages, resulting in the elimination or reduction of traditional mesh or rebar reinforcement, and improved structural capacity overall. As a real breakthrough in the field of UHPC technology, Ductal<sup>®</sup> Shotcrete represents a global, competitive solution to meet the various requirements of engineers across all types of projects.



## Optimization

Ductal® Shotcrete is the ideal material for applications where forming and pouring methods are either cost prohibitive or impossible. It is specifically engineered to enhance structural performance, provide long-term durability, and reduce the maintenance costs of new and existing structures. The Shotcrete solution offers a reduced thickness of necessary material and the ability to remove the wire mesh used in some secondary reinforcing applications while creating maximum lifespan. The restoration can also be performed with minimal down time due to the short cure time of the product.

## Implementation

Thin layers of Ductal® Shotcrete (less than 10 cm) applied in direct projection ensure the durable repair and protection of infrastructures, while reducing on-site intervention times – up to 3 times faster than conventional shotcrete.

Its wet-mix application process means it can be conveyed and shotcrete with standard mechanized shotcrete equipment and nozzles – even for overhead applications.

## Application

Ductal® Shotcrete is a very efficient onsite solution due to the minimum needs for surface preparation, no need of formwork and low rebound rate which shortens the operation time while maintaining the initial geometry that is a critical condition.

Common applications include:

- Repair and protection of existing structures
- Strengthening of steel drainage culverts
- Structural strengthening
- Tunnelling and mining
- Difficult-access applications
- Protection of hydraulic and marine structures
- Waterproofing



Sevenans metallic culvert, France, 2020 - Freyssinet





Sevenans metallic culvert, France, 2020 - Freyssinet



Barbazan metallic culvert, France - 2020, Freyssinet



Sevenans metallic culvert, France, 2020 - Freyssinet



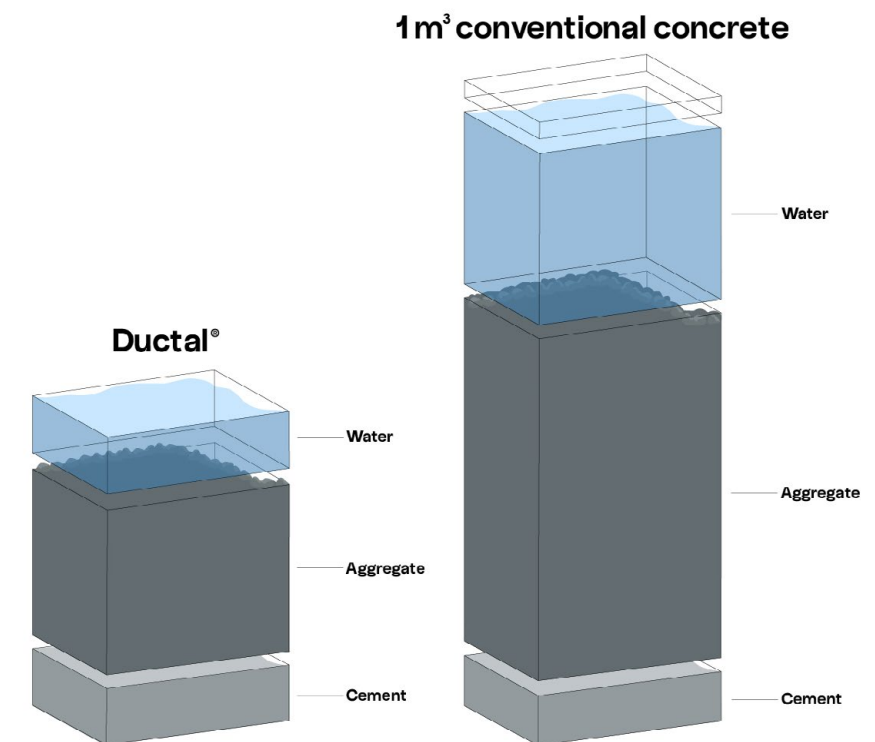
At Holcim, we started asking ourselves hard questions about the sustainability of concrete over 25 years ago. Having already spearheaded the transition towards low-carbon construction and led the way to promoting circular economy (from alternative fuel use to our research into concrete recycling), developing solutions that allowed architects, engineers, contractors and owners to design and build greener projects was only natural.

Because concrete does have good fundamentals: it's durable, resistant, adaptable, versatile. It is by dialling up these properties and adding new ones that we reduced concrete's negative impact on the environment.

## Exceptional durability

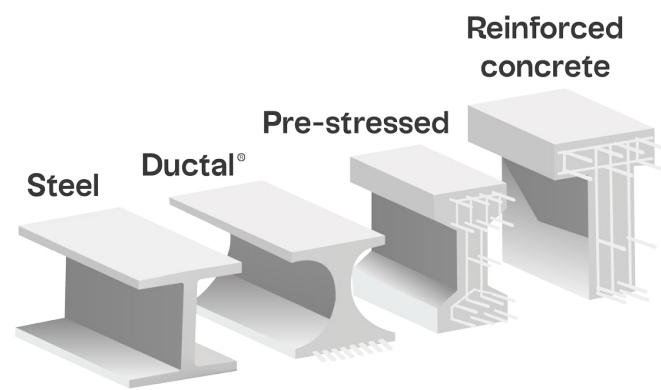
Ductal® UHPC is a proven construction material for all situations requiring very high mechanical properties, exceptional durability, or efficient solutions. The targeted modification of the constitution and isolated components allows to obtain much higher mechanical strengths and a significantly increased durability compared to traditional concrete. The particular interest here is the deformation behavior of the building material under tensile stresses in which a hardening action occurs due to the high fiber content.

The dense structure of Ductal® prevents the penetration of gases and liquids. Therefore, the building material exhibits high resistance to carbonation, chlorides, sulphates and de-icing salts, as well as high chemical resistance to acid attacks.





Ductal® solutions are a revolutionary way to make less with more: our ultra-high mechanical performances, low transport requirement, combined with the partial or full replacement of rebars by micro steel fibres, enable us to design structures with one-third to half of the usual amount of material for equivalent functionality. And, whether sprayed or poured on-site or even in precast form, it's easy to see how the reduction of material usage reduces carbon emissions from manufacturing to transportation.



Beams of Equal Load Carrying Capacity





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