



Ductal[®]

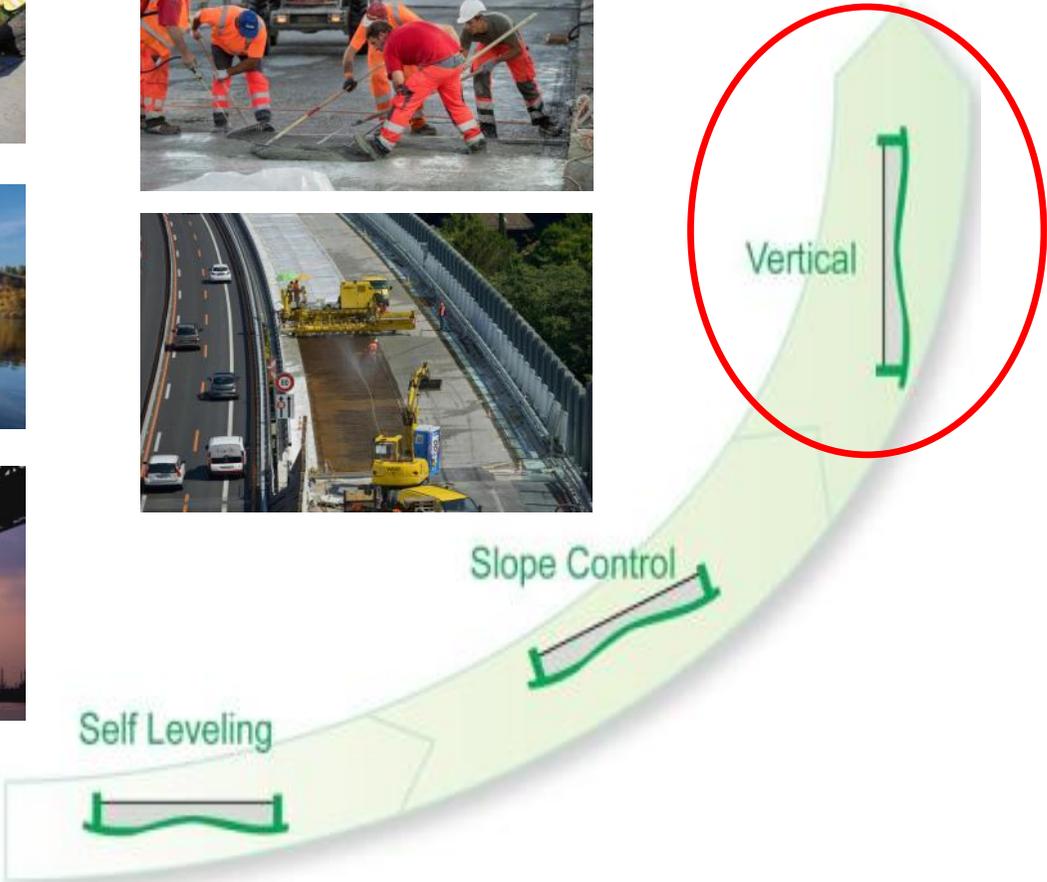
UHPC Shotcrete – A New Way to Install UHPC

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LafargeHolcim

Evolution of UHPC applications



Why do we need UHPC shotcrete?

- Structural strengthening (not just a protective coating)
- Thinner walls (taking advantage of UHPC properties, a thinner wall will take less time to shoot)
- Target applications where forms are no longer required to use UHPC (which is normally fluid) for complicated shapes
- UHPC tensile properties will allow for a reduction and/or elimination of rebar and/or mesh for some applications
- Wet UHPC shotcrete has a much lower rate of rebound compared to normal shotcrete, hence less batching and clean up
- UHPC properties will provide very low permeable surface, eliminating the need for additional coatings

Mix design goals

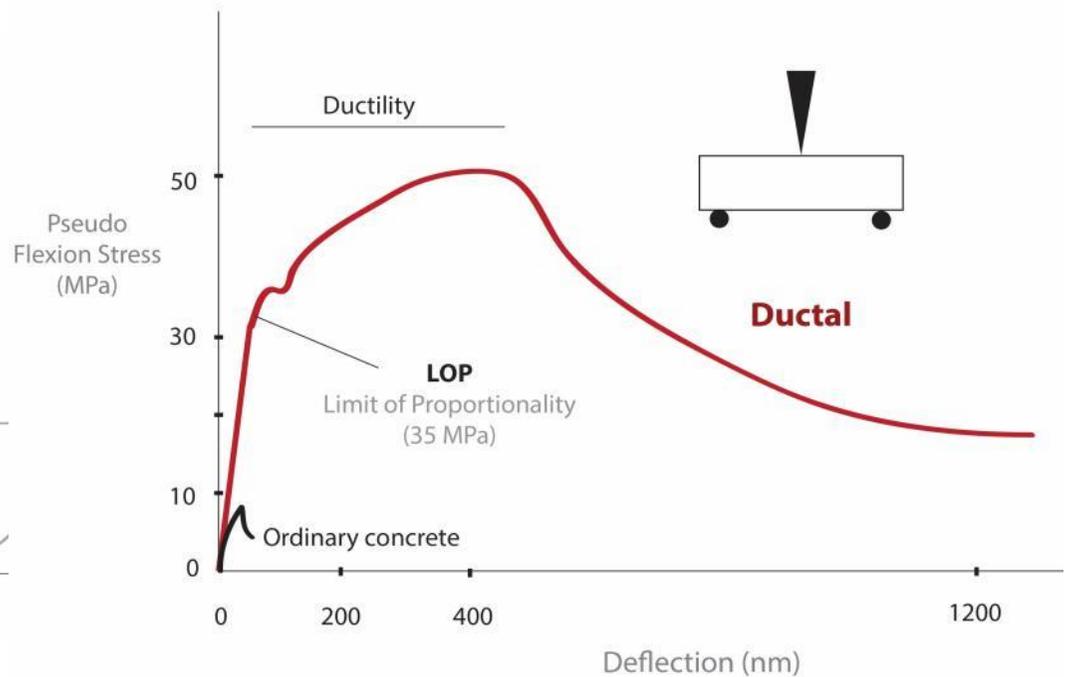
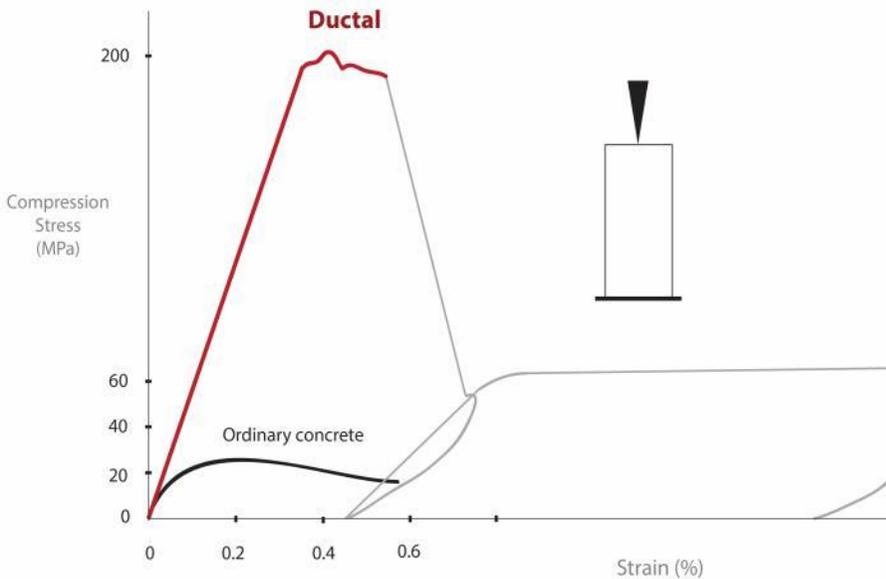
- wet mix
- viscous mix without the need for an accelerator at the nozzle
- 2% to 3% of steel fibers
- less than 10% lost
- for ambient temps between 5°C (40°F) and 45°C (113°F)
- pumping distance at least 60 m (200 ft)
- useable for vertical and over head applications
- random orientation of fibers in 2D
- finish possible with towel

Wet mix used for UHPC shotcrete

- Batching UHPC normally takes time because we use a very water to cement ratio. We also have to ensure that the steel fibers are well dispersed in the mix.
- A wet mix allows for the proper batching of the product.
- A wet mix also produces less rebound and a UHPC shotcrete rebound is about $\frac{1}{2}$ compared to normal shotcrete.

Mechanical Performances

Strain hardening due to using approx. 150 kg/m³ (250 lbs/yd³) of short steel fibers to the wet mix.



Ductal® UHPC shotcrete properties

- working time 1.5 hr (at 20°C / 68°F)
- air content (after placing) 1%
- Characteristic compressive strength f_{ck} 130 MPa (19 ksi)
- Characteristic value of limit of elasticity under tension $f_{ctk,el}$ 6 MPa (870 psi)
- Characteristic value of post-cracking strength f_{ctfk} 5 MPa (726 psi)
- Mean value of Young's modulus E_{cm} 40 GPa (5,800 ksi)

Mixers / Pumps

- Batching UHPC shotcrete normally requires a high shear mixer.
- Commercially available piston pumps are used to shoot UHPC shotcrete.
 - Ø of the piston cylinders needs to be larger or equal to 150 mm (6 in)
 - reduction from the pump to the hose has to be progressive, for instance if outlet is 125 mm (5 in) in Ø, you need a metal transition pipe of approx. 3.5 m (12 ft) long to reduce this to the hose size of 50 mm (2 in).
 - a engine power of 55 Kw (75 hp) pump should be able to pump UHPC shotcrete over 40 m (130 ft).
- Priming the line – use UHPC without steel fibers.
- To clean the line – once placement is done, pump a mortar without steel fibers and clean the hose with water. If the operation is stopped with UHPC in the hose, it will be very difficult to clean.

Example of shotcrete pump for UHPC formulations



Schwing SP-500

Specifications

Concrete Output Per Hour	45 cu yds	34 cu m
Maximum Pressure on Concrete	1100 psi	76 bar
Concrete Cylinder Diameter	6 in	150 mm
Concrete Cylinder Stroke Length	39 in	1000 mm
Outlet Diameter	5 in	125 mm
Shifting Cylinders	2	
Max. Pump Strokes Per Minute	32.5	
Hydraulic Pressure	3867 psi	266 bar
Engine Power	74.5 hp	55.6 kW

UHPC Shotcrete Trials

May 2016
first projection tests



November 2017
2nd series of validation tests



UHPC Shotcrete Trials



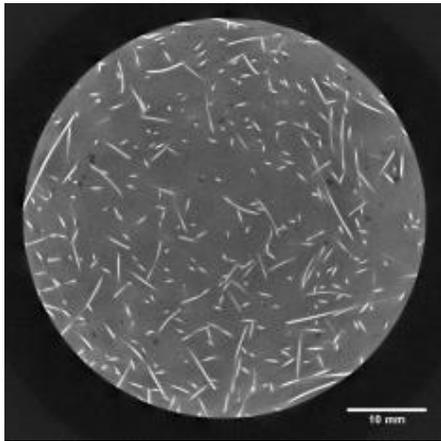
Mechanical properties testing

Application by a certified nozzleman and similar tests used compared to regular shotcrete to confirm the mechanical properties of the new mix.

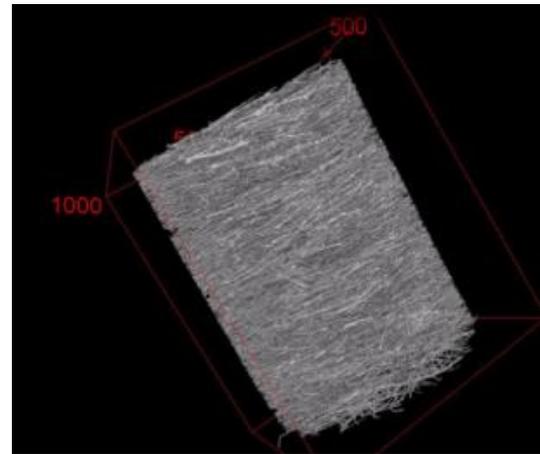


Fiber orientation

Fibers alignment is random perpendicular to the projection direction



View from the top



Side view

Finish

Testing of the workability of the mix once installed.

Trowels or rulers need to be used as soon as possible.

A curing compound needs to be applied to allow proper curing.



Testing the integrity of the solution

A section of metal culvert was coated with UHPC shotcrete and the element was loaded. Analysis done with the collaboration of CETU (French tunnels study center) and IFSTTAR (French institute of science and technology for transport, development and networks).



Why start with metal culverts rehab?

In France, metal culverts with a diameter of 2 m (6.5 ft) and higher represent about 10% of all culvert applications.

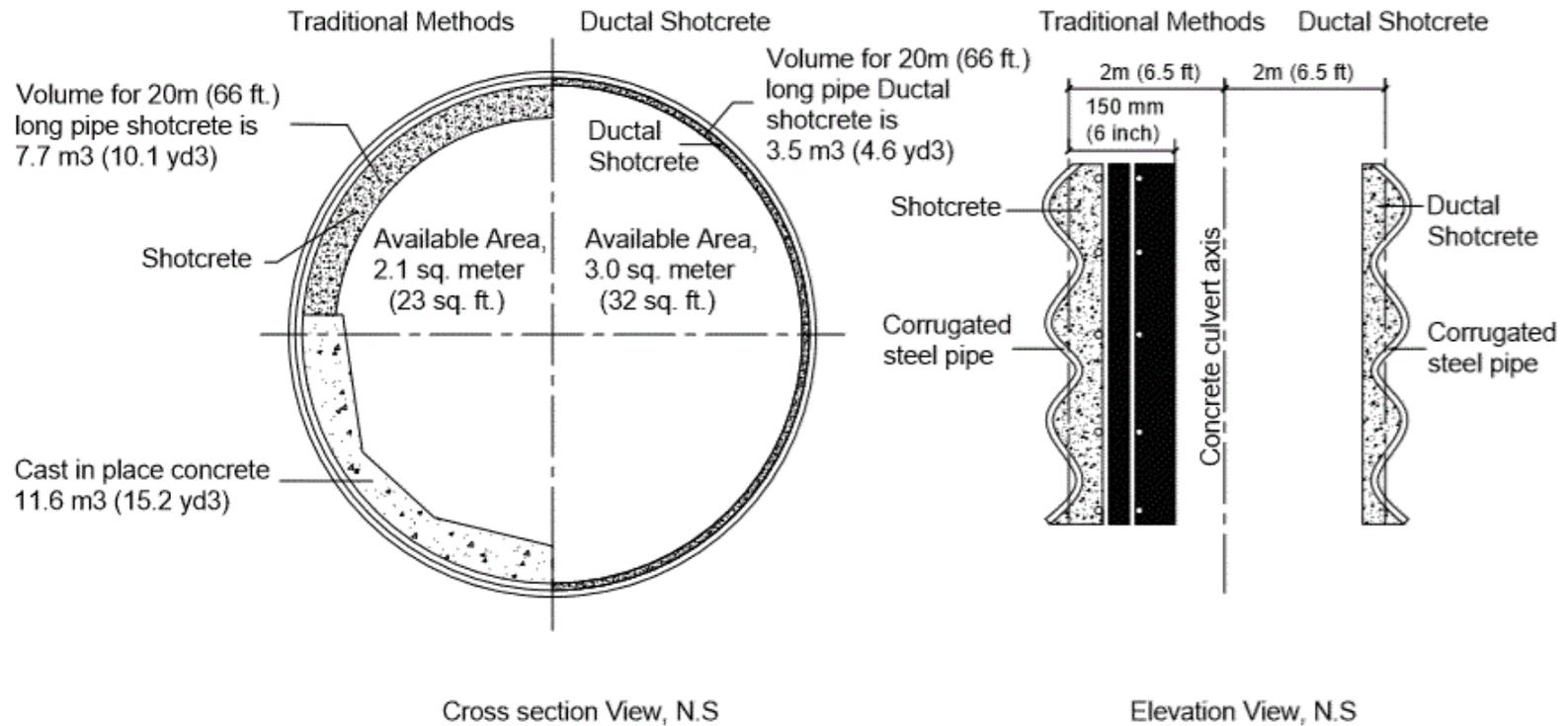
60% are used to control water flows, hence many have corrosion and erosion issues.

50% are over 35 years old, hence at the end of life.



Concept developed by Freyssinet

In this specific example, less than ½ the quantity of material is required when using UHPC



1st UHPC shotcrete project – completed at the end of 2018

Route N70 about 500 km south/east of Paris.

Freyssinet is our partner for the design and installation.



Ductal® shotcrete



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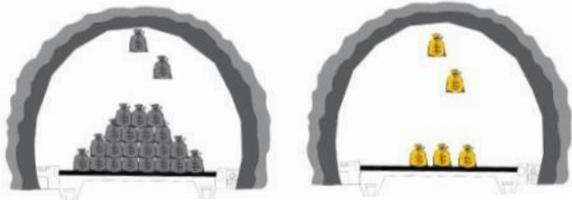
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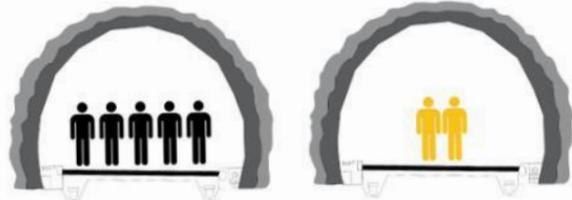


Shotcrete vs UHPC Shotcrete

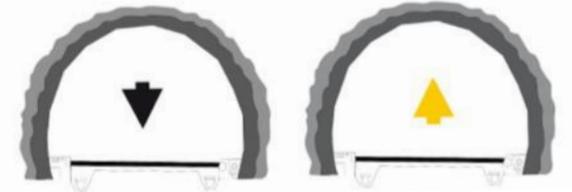


Less rebound

Corrugated metal culverts solution



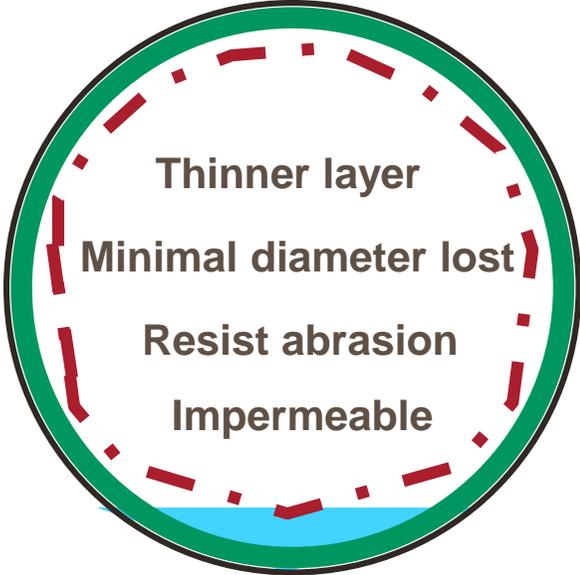
Less manpower/time



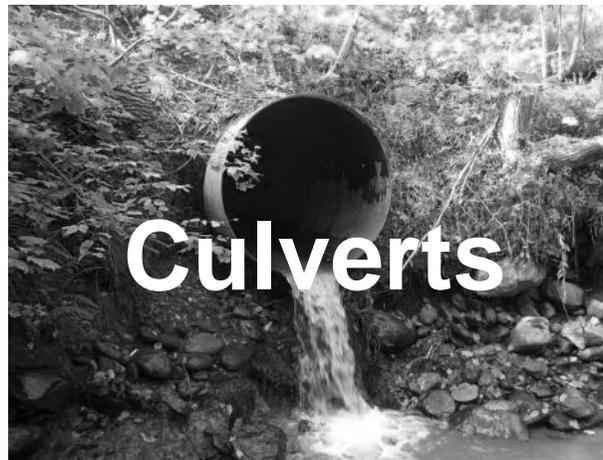
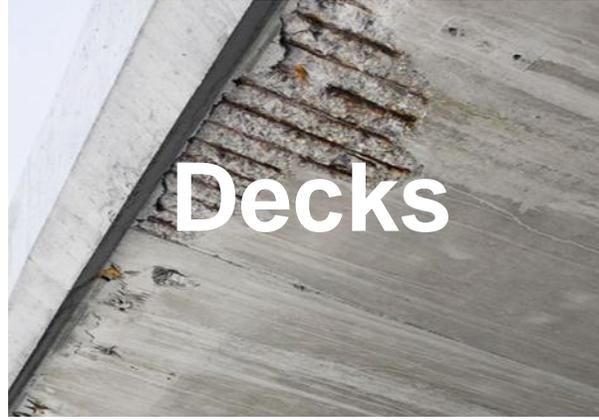
More structural support



Less material



Where to use UHPC shotcrete?



Final comments

UHPC is an ideal material for infrastructure projects

- Last 5 years have seen a marked increased in use across North America.
- Cost effective under the right conditions and when all benefits are taken into account.
- Formulation development continues to improve characteristics and ease of placement.
- Numerous resources available to guide consultants and owners in the development of specifications for their projects.

Contact

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