Sustainability and unique construction properties: two major trends in modern concrete technology

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LafargeHolcim

The LafargeHolcim Group – A short introduction

- A world leader in building materials
- From the merger of Lafarge and Holcim (in 2015)
- Products
  - Cement (No. 1 out of China)
  - Aggregate
  - Ready-mix concrete
  - Other products (mortars, asphalt, precast products etc.)
- Active over the 5 continents
- Turnover ≈ 28,5 B CHF
- Employees ≈ 80,000

LafargeHolcim R&D

The LafargeHolcim global Research Center in Lyon (France)

is the most sophisticated R&D facility in our industry.

A network of local Construction Development Labs and technical centers, close to our markets:

Algeria, Argentina, China, France, India, Malaysia, Mexico, Morocco

We partner with leading academics, customers, start-ups and suppliers

to jointly develop new technology-driven construction solutions for our customers.

Main missions

Creating value for our end users and customers with innovative solutions

Anticipating trends and new technologies

Transferring innovation to local markets

1,500 patents*

*Granted patents or patent applications

Outline

- **Introduction**
- **Unique Engineering properties**
  - Ease of placement
  - Strength at early age
  - Ultra high-performance (strength and durability)
- **Sustainability**
  - Resource preservation
  - Climate change mitigation
  - Water management, air quality, well-being
  - Life-cycle cost management through specified durability
- **Conclusion**

Introduction

- Concrete is the first construction material worldwide (in volume). Also the first material for bridges
- Invented by the Roman ancients, constantly evolving since the beginning of industrial era (late XIXth century)
- The problem we are facing as producers: **how to better address the construction needs while taking care of sides effects on people and environment ?**
- A short review of solutions either commercially available or at a development stage

Unique engineering properties

Ease of placement

- Self compacting concrete invented in the late ’80 in Japan
- With SCC
  - no more vibration
  - no consolidation flaws
  - better concrete facings
  - $20 \leq fc_{28} \leq 80$ MPa and more
- For bridges, suitable for piles, pylons etc.
- Lafarge among the first companies to industrialise and widely distribute robust self-compacting concrete mixes (Agilia™)

"Marilyn Monroe" towers in Toronto, Canada

Strength at early age

- Accelerated mixes to remove forms as early as 8h or even **4h after batching**
- Management of workability window according to transportation and placement constraints (1 to 2 hours)
- For structural concrete, Portland cement (not CAC = calcium-aluminate cements)
- No increase of heat of hydration nor further risk of cracking

The Port Mann bridge, British Colombia, Canada incorporates Chronolia™

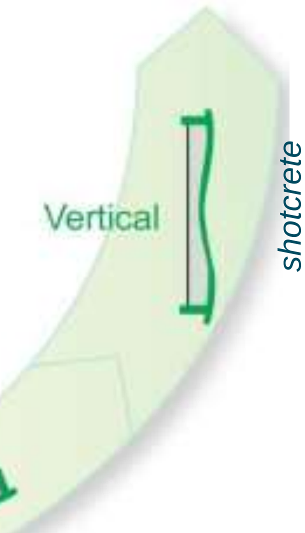
Ultra-high performance concrete (UHPC) : mix-design basics

- Selected constituents
  - Fine sand (< 1 mm)
  - Cement
  - Mineral and organic admixtures
  - (steel) fibres
- Optimisation of packing density
- Ultra-low water/binder ratio
- Long mixing
- For precast applications: possible thermal treatment to foster final strength

UHPC : fresh concrete properties

Can be self-placeable…

or can be sprayed !



can be stable on a slope of 6%

Ultra-high performance concrete : hardened concrete properties

Mechanical properties

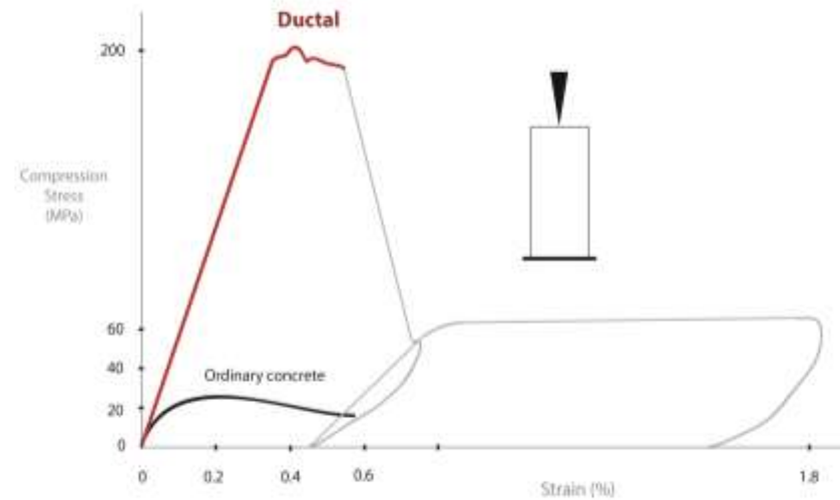
- 100 ≤ fc_{28} ≤ 200 MPa

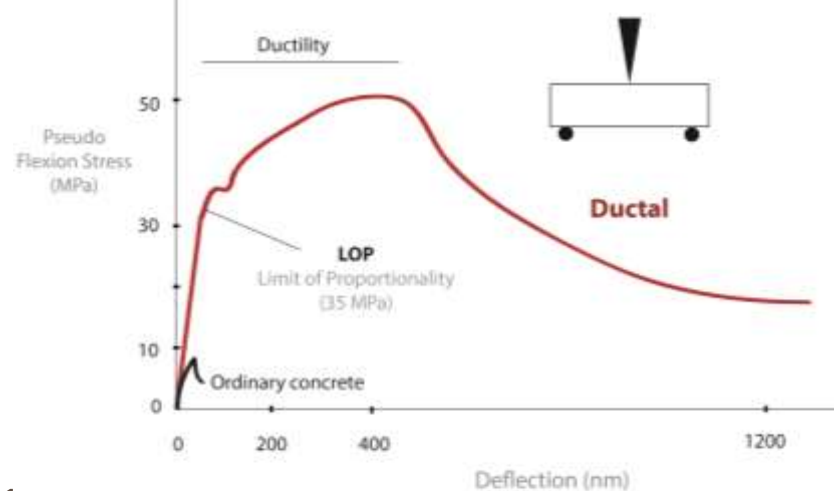
  (with thermal treatement)

- Flexural strength up to 50 MPa
- Design tensile strength ≈ 10 MPa

Durability-related properties (as compared to normal-strength structural concrete)

- Gas permeability /100
- Chloride diffusivity /50
- ~~Carbonation~~
- ~~Freeze-thaw degradations~~

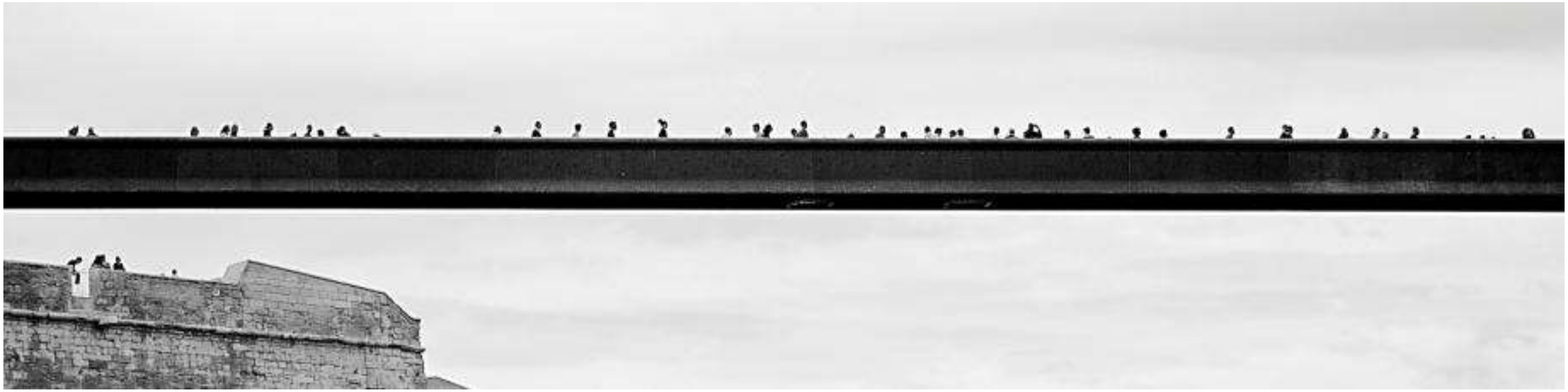


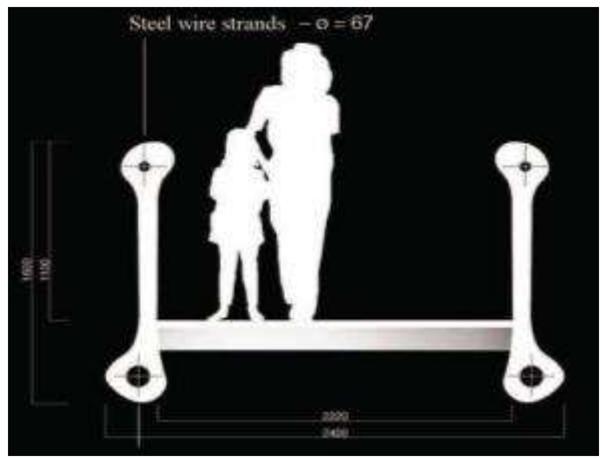


UHPC : application to bridge engineering

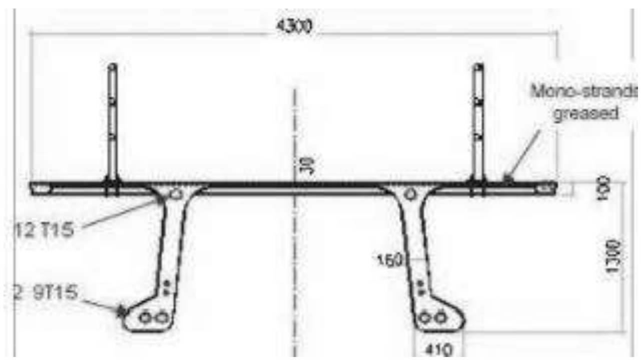
- Long-span prestressed beams
- Thin arches
- Connection of precast slabs
- Overlays for deck reinforcement and protection
- Precast slabs for widening
- Blisters for added external prestressing
- Piles jacketing to increase bearing capacity or to protect against corrosion
- …

MuCEM- Marseille - France

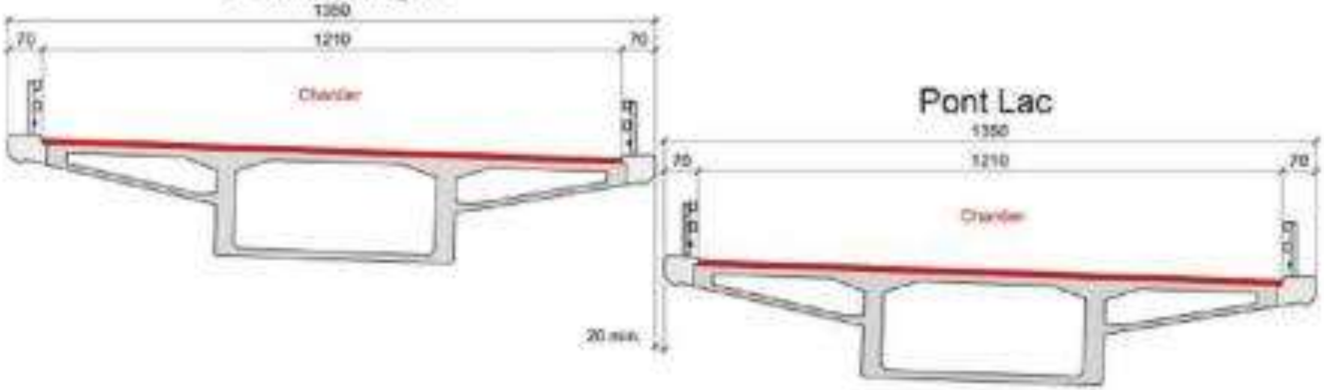




Peace Footbridge - Seoul



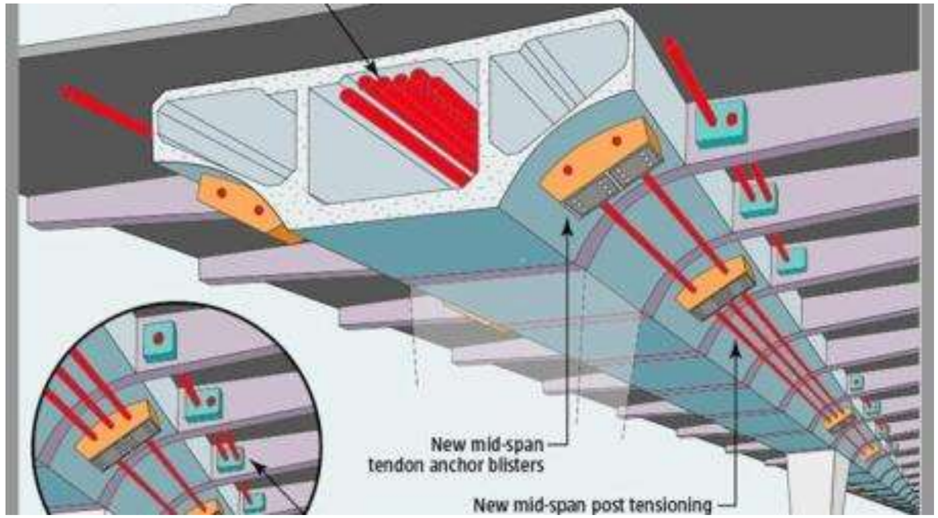
Chillon Viaducts : Overlay



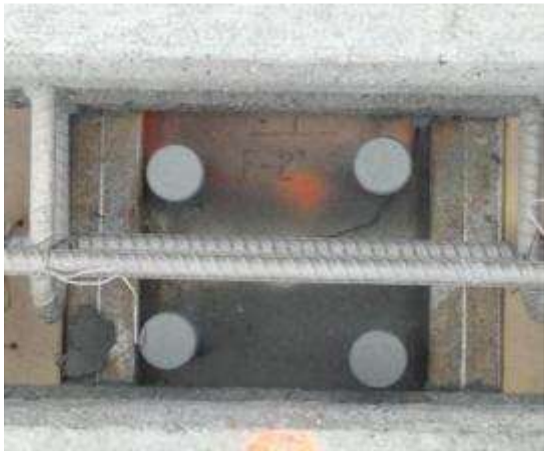
Bridge Extension : Precast UHPC slabs

Piles jacketing to increase bearing capacity

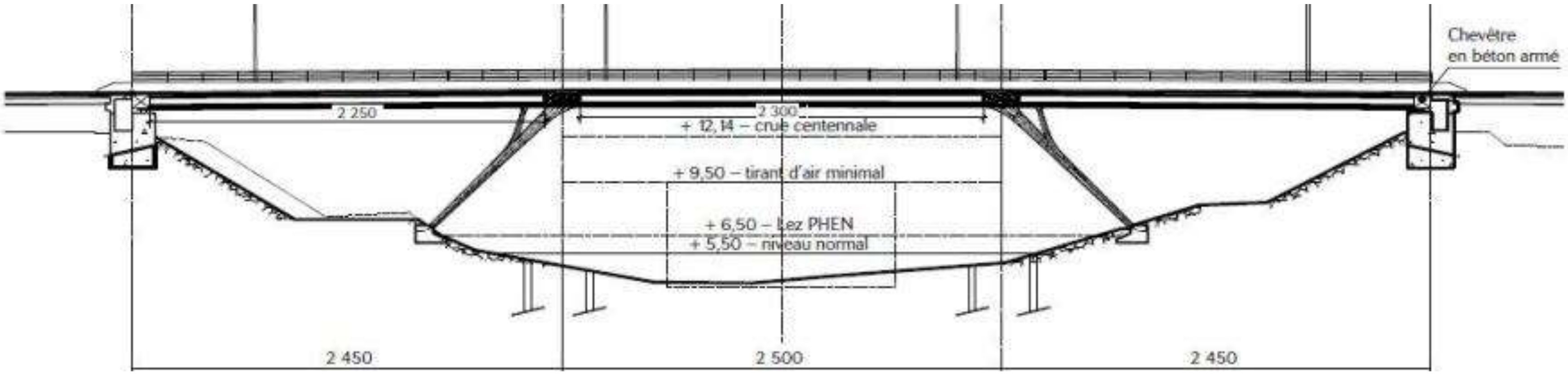
Hammersmith Flyover – London



Joint Fill/Shear Pocket



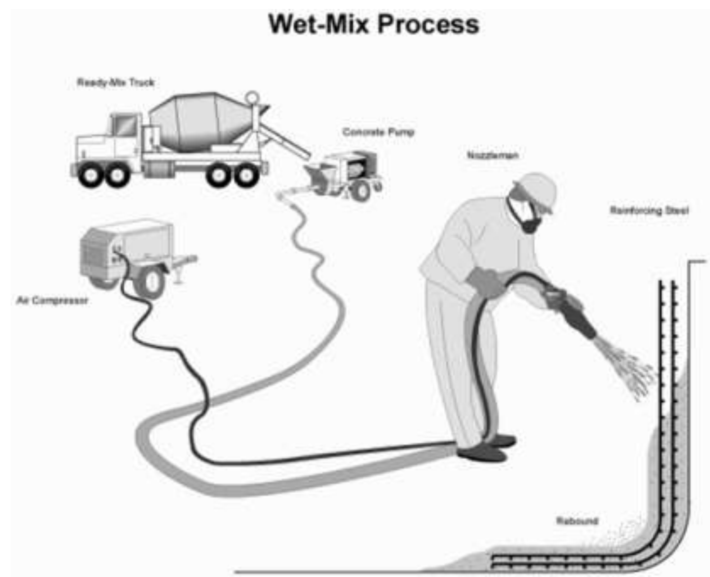
Pont de la République - France



Mars Hill Bridge – Ohio - USA

LH / Freyssinet partnership – On-site tests

Ductal Shotcrete



Sustainability

Ressource preservation in cement manufacturing

- Saving raw materials and energy using alternative raw/fuel materials to produce clinker: biomass, industrial wastes, tyres etc.
- Partial replacement of clinker by supplementary cementitious materials: fly ash, blastfurnace slag, limestone, metakaolins etc.
- Current data for LafargeHolcim:
  - Rate of alternative fuels: 15%
  - % of clinker substitution in cement : 28 %

Resource preservation : recycling concrete into concrete

- Need to save natural aggregates + to avoid landfilling in many parts of the world + to reduce transportation distances for aggregates
- Recycling: crushing end-of-life reinforced-concrete pieces and using obtained aggregate either in a new concrete or in cement manufacturing
- Technically, replacement rate can range from 0 to 100 % (0-30 % of coarse aggr. according to European Standard EN 206)
- At low %, marginal effect on concrete properties. Most impacted ones: E-modulus, shrinkage and creep
- Can be envisaged in some parts of the bridges (foundations, massive piles etc.) subject to acceptance by authorities

aggneo™

Climate change mitigation : low CO_2 cement

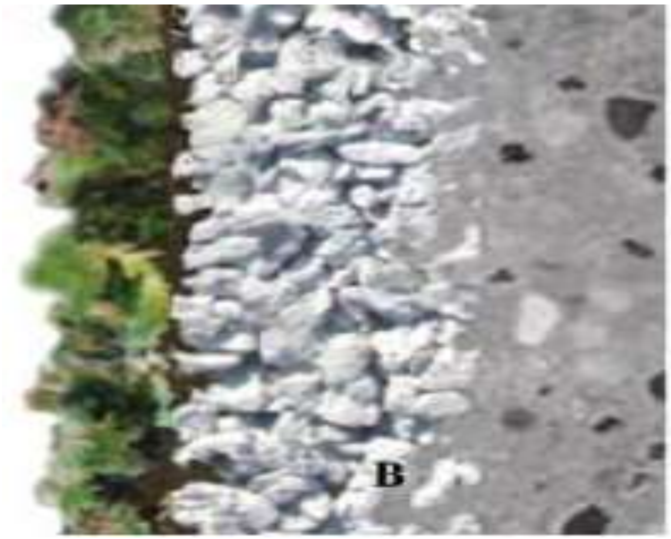
- Yes cement bears 5-8 % of anthropogenic CO_2
- 1st strategy:
  - to combine alternative fuel with supplementary cementitious materials
  - **LH commitment: to reach 490 kg/t of CO_2 in 2030** (1990: 770; 2016: 580)
- 2nd strategy: to develop non-Portland cement.
  - Aether™ is a belite-ye'elemite-ferrite (BYF) cement with a carbon footprint reduced by 30% *(development stage at LH)*
  - Axel is a calcium-sulfo-aluminate (CSA) cement *(id.)*
  - Solidia™ : a cement which hardens through carbonation, not hydration. **More than 60 % saving in CO_2** *(first commercial applications in the range of thin precast products)*

Climate change mitigation: low CO2 concrete and structures

- Concrete with low cement dosage at controlled engineering properties through
  - Mix optimisation: best packing, superplasticizers, SCM
  - High level QC
  - Low workability + intense vibration (prefabrication)
- Smart structural design
  - Use of HPC/UHPC
  - Less matter, more stresses

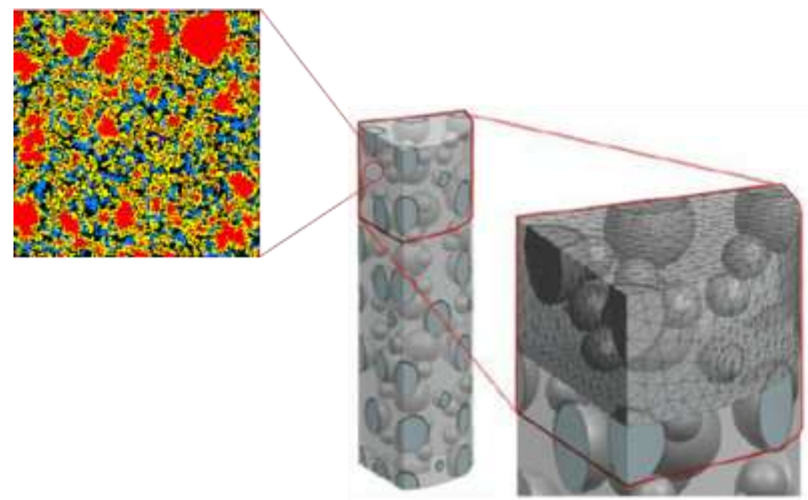
Water management, air quality, well-being

- Water management: need to reduce the concrete water footprint (currently ≈ 400 l/m^3 of concrete)
  - Substitute water curing by other techniques
  - Use of non-potable water in critical areas
- Air quality: existing technologies to decrease NOx/VOC
  - Photocatalysis (TiO_2). Works but needs UV radiations
  - **LH Depolluting technology based on active charcoal into concrete** *(under development)*
- Biophilly: **new LH vegetalized concrete**
  - Double-layer concrete with a porous external layer
  - Plants growing in it, watered by concrete porosity
  - An affordable way to bring nature into cities *(under development)*



Life-cycle cost management through specified durability

- From prescriptive to performance-based approach
- Focus on key material properties (permeability, Cl- diffusivity, carbonation) to predict reinforcement corrosion
- Three complementary approaches by LH:
  - Material testing
  - Mix-optimisation to match durability specifications
  - Modeling of corrosion initiation time



Conclusion

- More than ever, concrete is the key material for infrastructures
- It has evolved for a century, preceding or following the progress in structural design
- Workability, strength and durability can be fully tuned within a wide range to fit the construction needs
- However, the contemporary engineer must take not only the final goal into account, but also environmental and social aspects
- This challenge can only be addressed through a cooperation of all involved stakeholders (owners, builders, and material providers)

Thank you for your kind attention !

¡Muchas gracias por su atención !