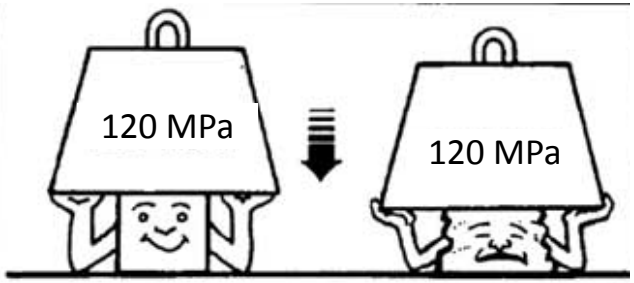
CBI day, Stockholm 2016-03-16

ULTRA HIGH PERFORMANCE CONCRETE (UHPC) – DEVELOPMENT, APPLICATION, SUSTAINABILITY

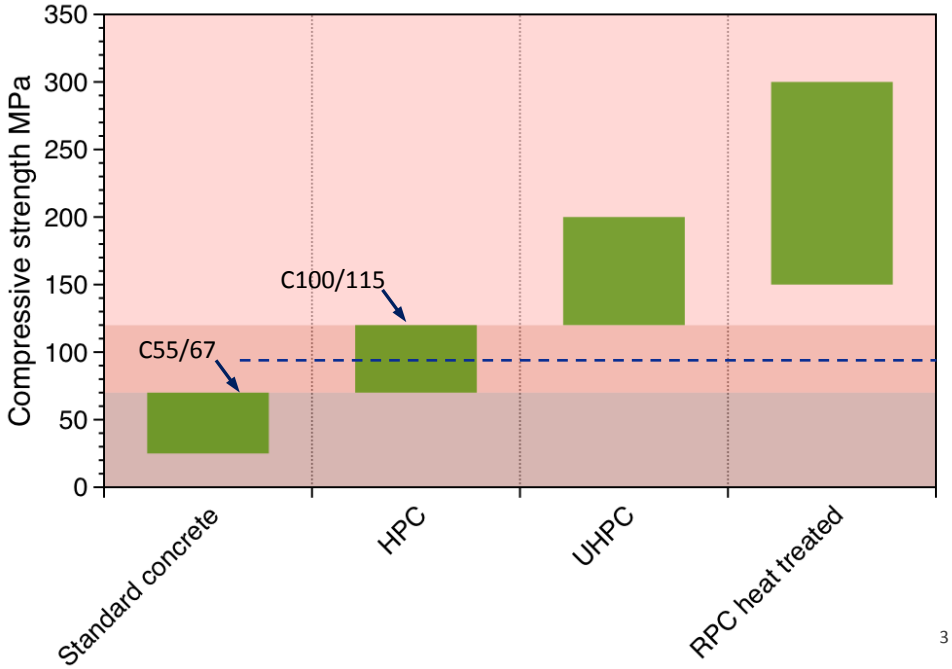
What is UHPC?

- Compressive strength



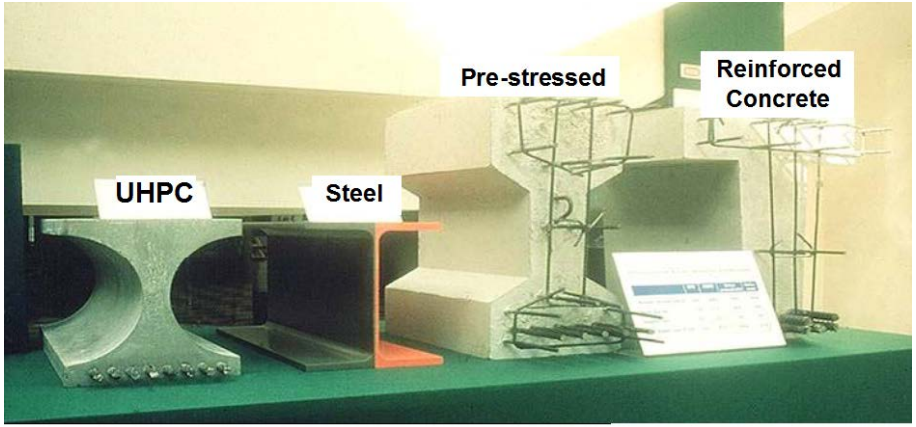
UHPC

Standard concrete



What is UHPC?

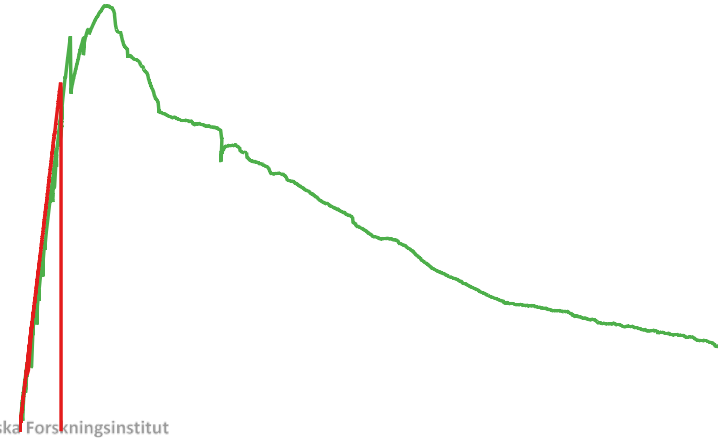
- → Reduction in cross section or material thickness

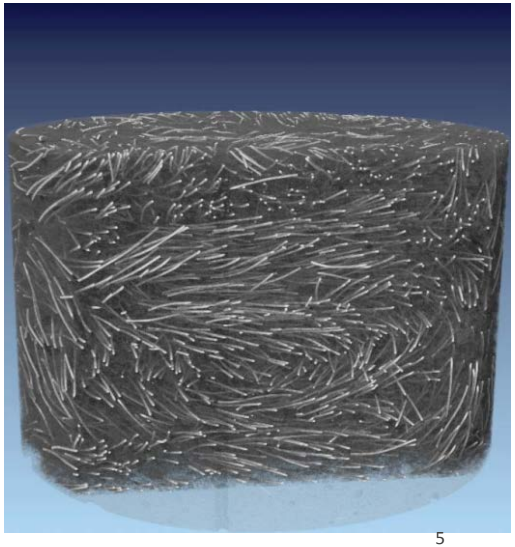


Source: Internet

What is UHPC?

- Compressive strength ≥ 120 MPa
- Ductile behavior due to fibers or textile reinforcement (FRUHPC, TRUHPC)



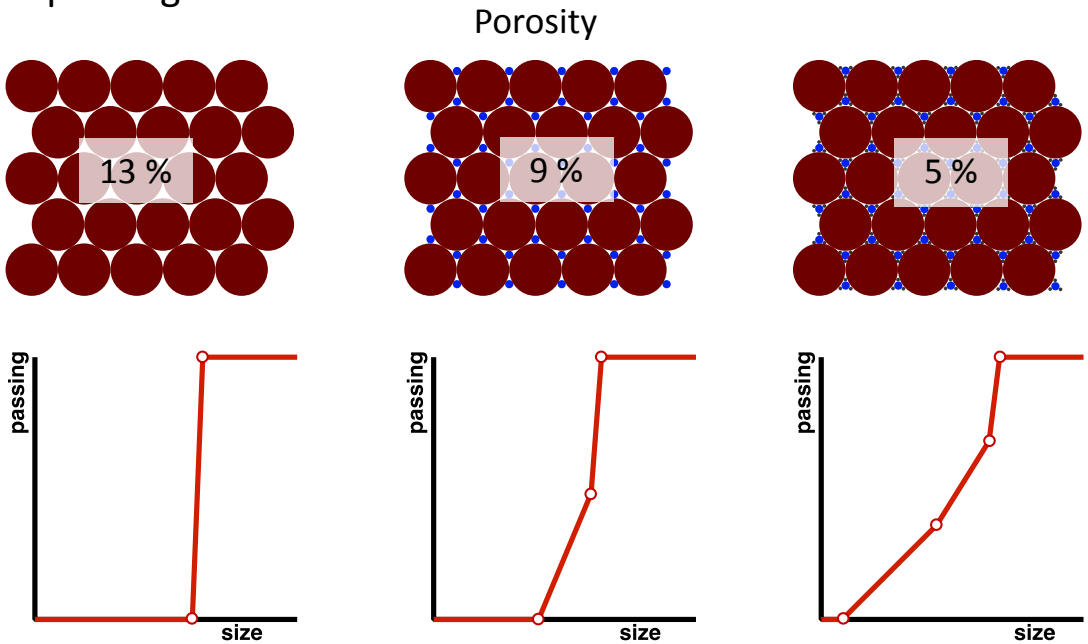


What is UHPC?

- Compressive strength ≥ 120 MPa
- Ductile behavior due to fibers or textile reinforcement
- Very low w/b ratios → High density → low porosity → tight microstructure
- Very durable
  - Low permeability for chlorides
  - High freeze-thaw resistance
  - High resistance towards acid and sulfate attack
- Reactive Powder Concrete (RPC) = UHPC with max aggregate size < 1-2 mm

Principles of mix formulation

- Particle packing

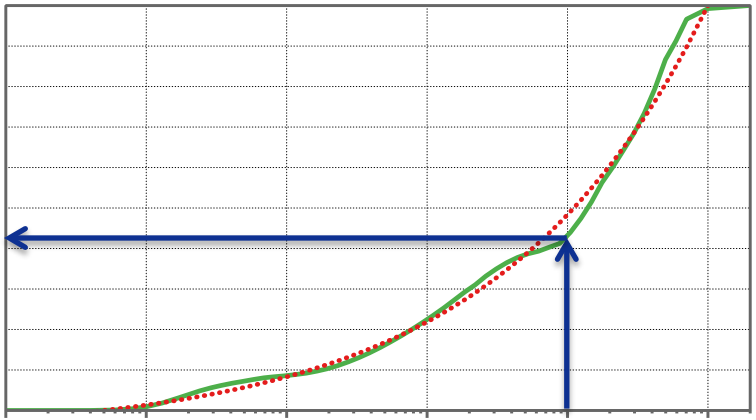


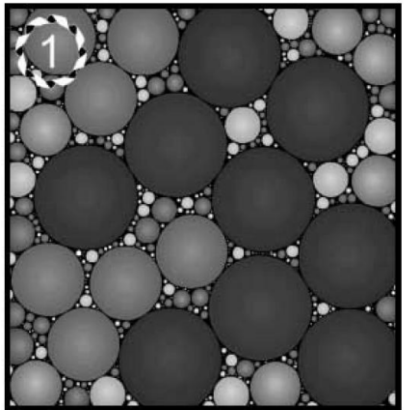
Principles of mix formulation

- Raw materials
  - Cement
  - Filler/SCM (e.g. quartz, fly ash, slag)
  - Finest filler/SCM (silica fume)
  - Sand (e.g. 0/1, 0/2 or 0/4)
  - Water
  - Super plasticizer
- Low water/binder, water/cement ratio
- High dosage of super plasticizer
- Self-compacting

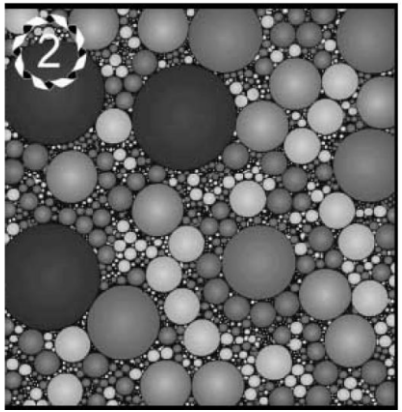
Principles of mix formulation

- Particle packing – Compared to standard concrete → high powder content!





standard concrete



UHPC

Fresh concrete properties

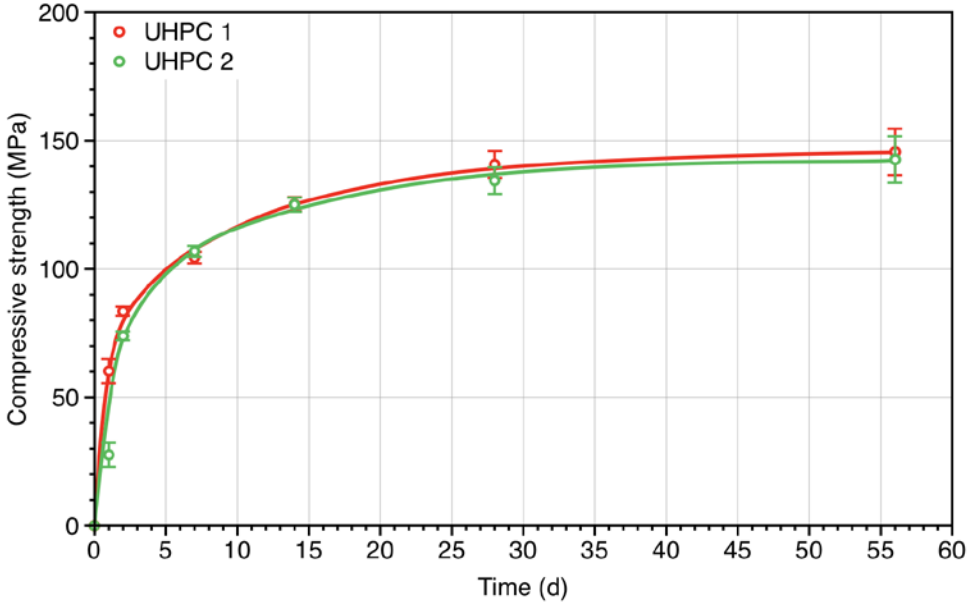
- Mixing of UHPC
  - In early days often high shear mixer were propagated
  - However, it should be possible to use low energy mixer as well

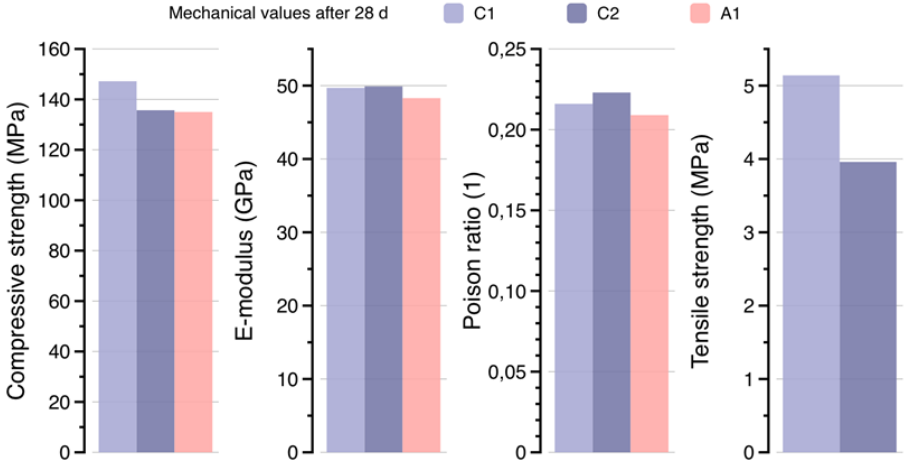
Fresh concrete properties

- Mixing of UHPC in the lab and in the plant

Hardened concrete properties

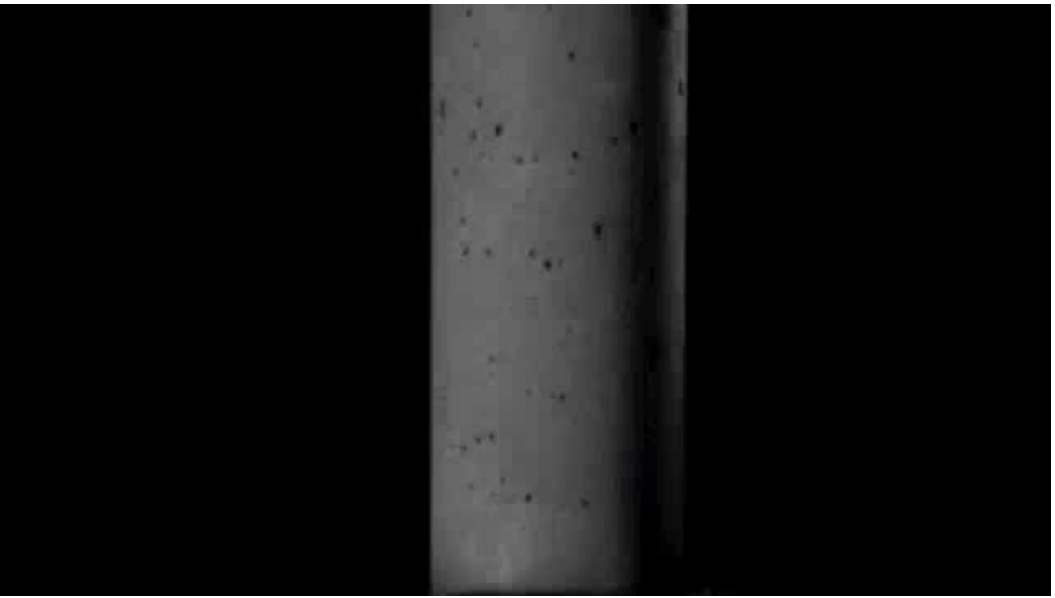
- Strength and strength development

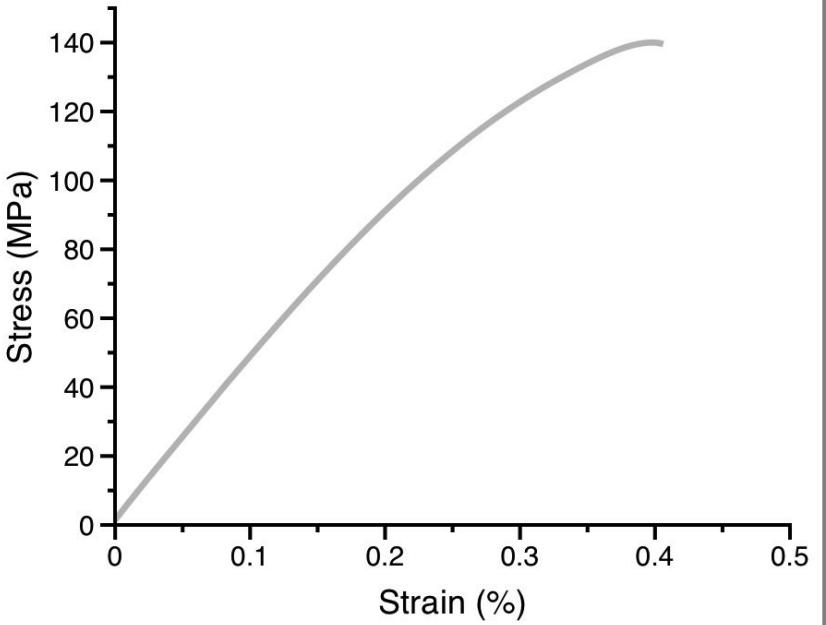




Hardened concrete properties

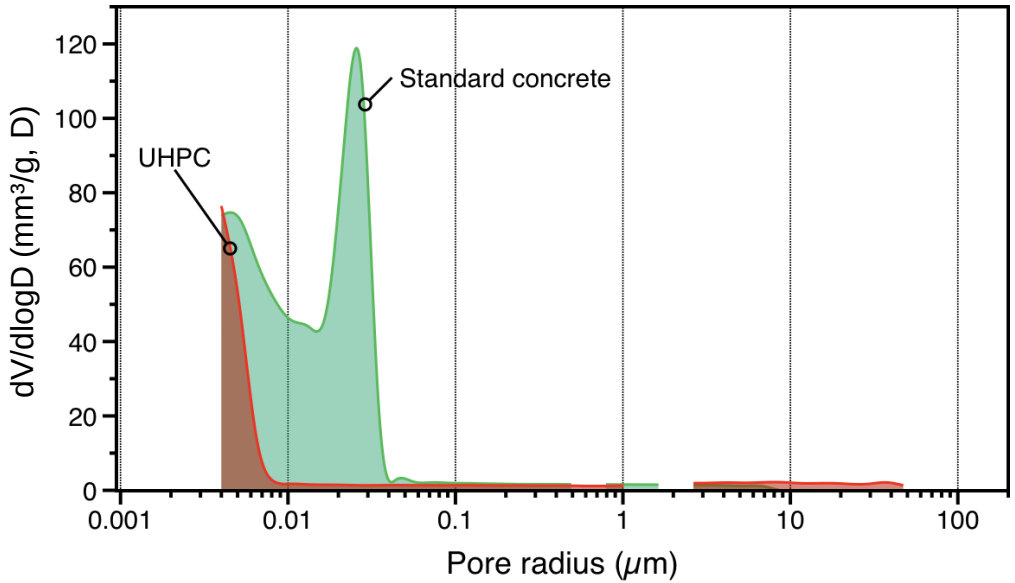
- Strength and strength development





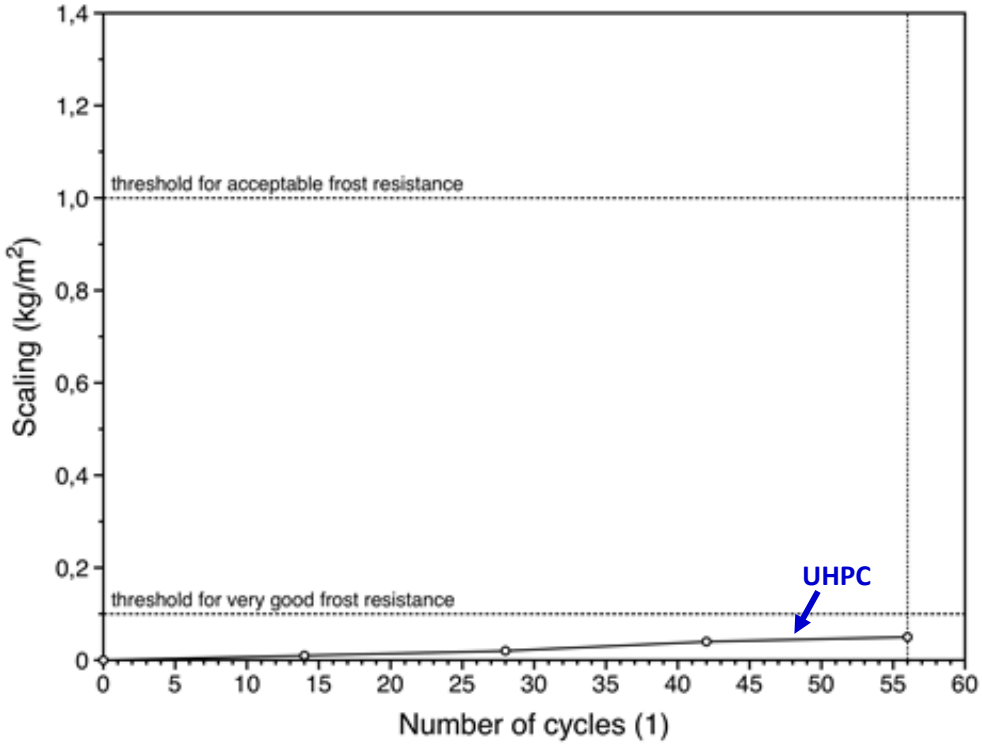
Hardened concrete properties

- Microstructure
  - Shows low porosity with many pores smaller 0.01 µm



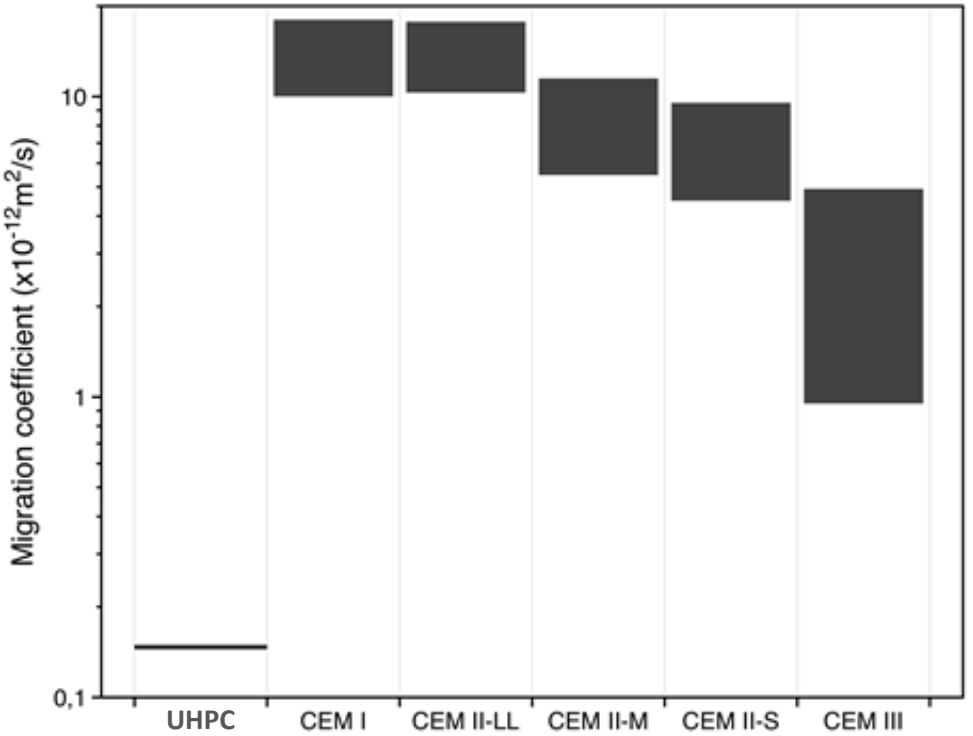
Durability

- Frost resistance (SS 137244)



Durability

- Chloride migration (NT BUILD 492)



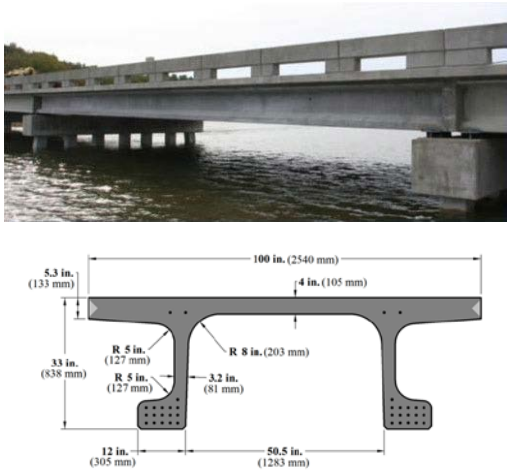
Application examples – Bridge in Carinthia, Austria

- Traffic bridge, 157 m long
- Made of fiber reinforced UHPC

Source: Internet

Application examples – Various bridges

Source: Internet



Route 64 over Cat Point Creek, Richmond County, VA

Footbridge of Peace, Seoul, South Korea

Sakata-Mirai bridge, Sakata, Japan

Application examples – Façade applications

Source: Internet

The RATP Bus Depot, Thiais, France

Office Building VR-Bank Krefeld

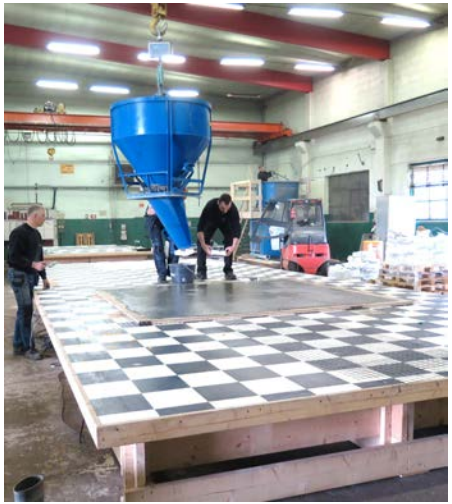
Application examples – Façade applications

Source: Internet

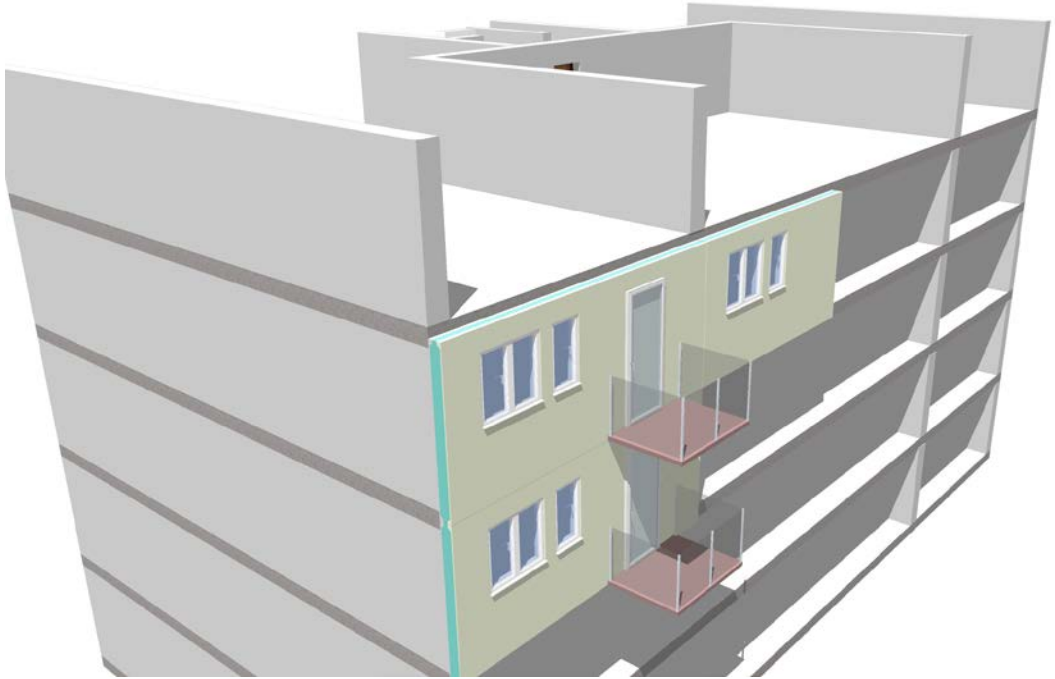
Lille Metropole Modern Art Museum, France

Jean Bouin stadium, Paris, France

Application examples – Façade applications



Sandwich elements: SESBE



Application examples – Other applications

Source: Internet

Machine beds

Furniture

Application examples – Potential applications

- Sewage pipes
- Shelters
- Blast barriers
- Connections for precast elements

Costs and sustainability

- Material costs compared to standard concrete (plant mixing, transport not included)

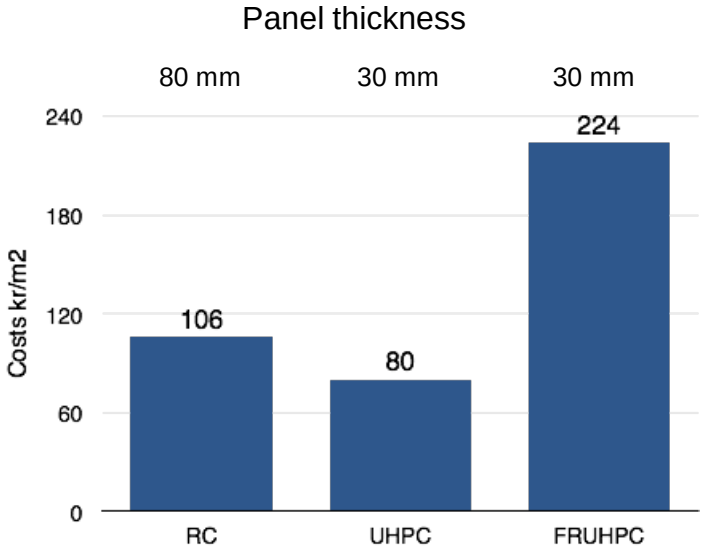
s

5100

2700

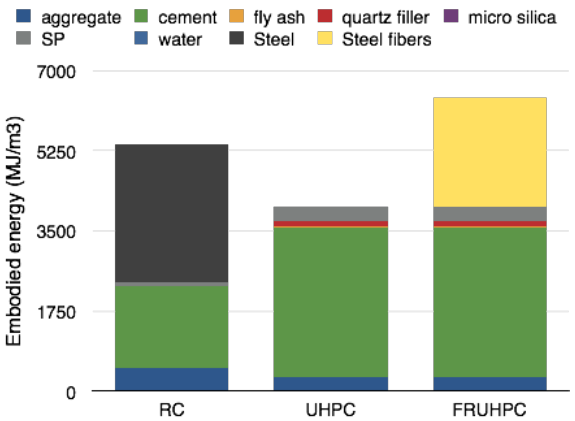
1300

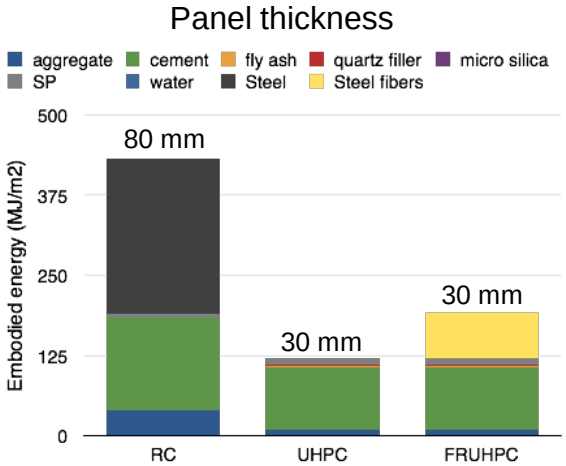
550



Costs and sustainability

- Sustainability –Example embodied energy of façade panels





Summary

- Advantages
  - Ultra high performance concrete (UHPC) has applications ranging from engineering structures to furniture
  - It is particular dense in microstructure, therefore it shows a high strength and durability
  - By combining it with fibers or textile grids it behaves ductile
  - Applied at the right place it can be more sustainable as reinforced concrete
- Optimization
  - Heat treatment at 90 degree can reduce curing times and increase early strength
  - UHPC optimal for precast concrete plants, less for in-situ casting
  - Can be formed in complex forms and easily be functionalized

Summary

- Difficulties
  - Complex composition makes it more prone to mixing errors → better in form of ready mixed material
  - The optimal mix proportion of **UHPC is based on the particle size distribution** of its components → **components needs to be kept the same and in same quality**!
  - UHPC is more expensive per m^3 as reinforced concrete; however UHPC can complement concrete solutions when more lightweight and thin structural elements are required
- Conclusion
  - UHPC will eventually **not** replace standard concrete but will enlarge the area of sustainable construction in the future!

Tack för er uppmärksamhet!