Ultrahigh performance concrete for repairs, strengthening and new structures

Is there really a need for a stronger/better concrete ?

Stronger concrete
(UHPC>150MPa)

Higher production costs

Low material/structure volume ratio

Excellent durability

Low maintenance costs

Long life-span >100 years?

Weaker concrete
(OPC or HPC 40-100MPa)

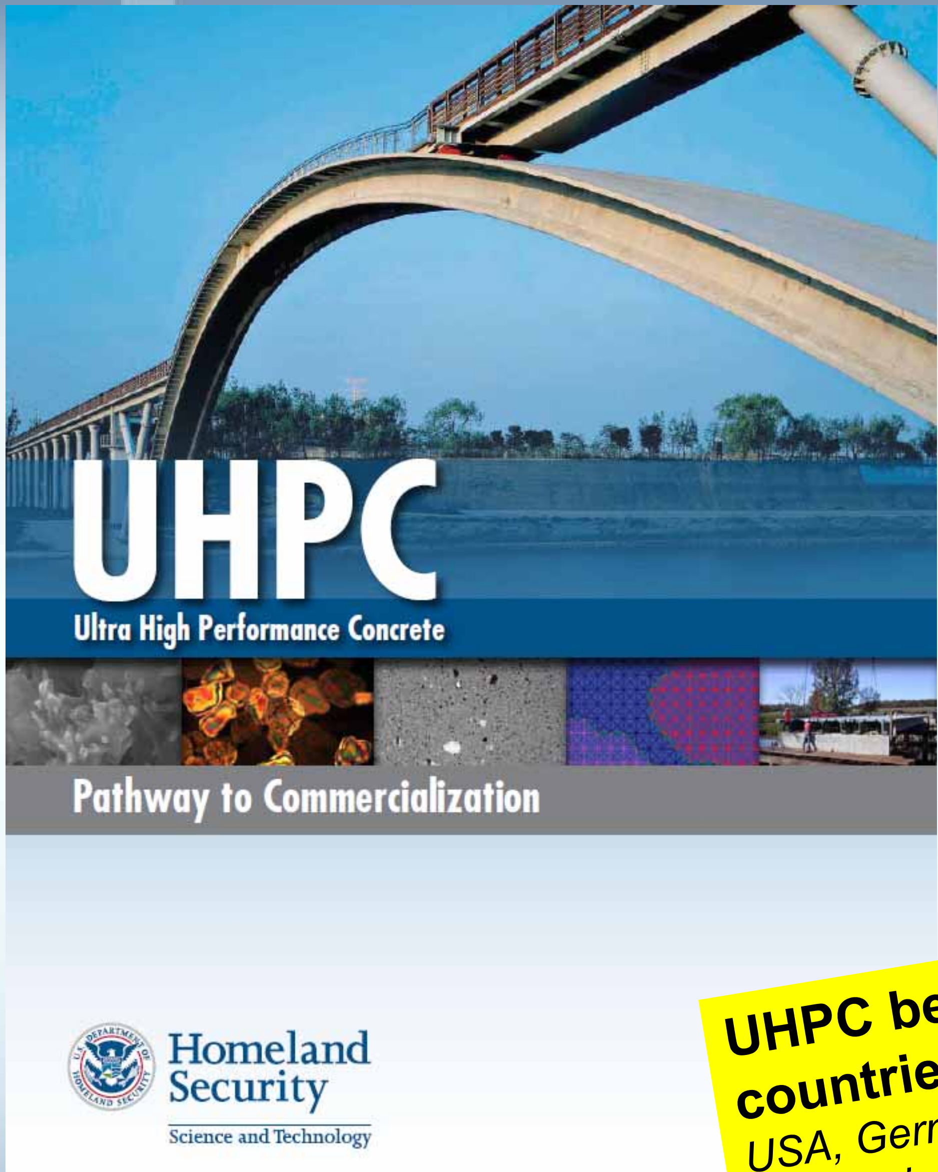
Lower production costs

Higher material/structure volume ratio

Average durability

Average/high maintenance costs

Short life-span



(…) UHPC materials may offer unique advantages and higher performance (…) include: strength, ductility, flexibility and toughness, impact resistance, dimensional stability, durability / increased useful life, impermeability / freeze/thaw resistance, corrosion resistance, abrasion resistance, aggressive environment resistance, and chemical resistance.
(…) Other advantages may include: ability to construct thin sections and use complex structural forms, elimination of passive reinforcement (reinforcement bars), precise replication, use of conventional concrete equipment, ability to cast by pouring, injection or extrusion techniques, self-consolidation, off-site manufacturing, fast construction, and reduced maintenance. (…)

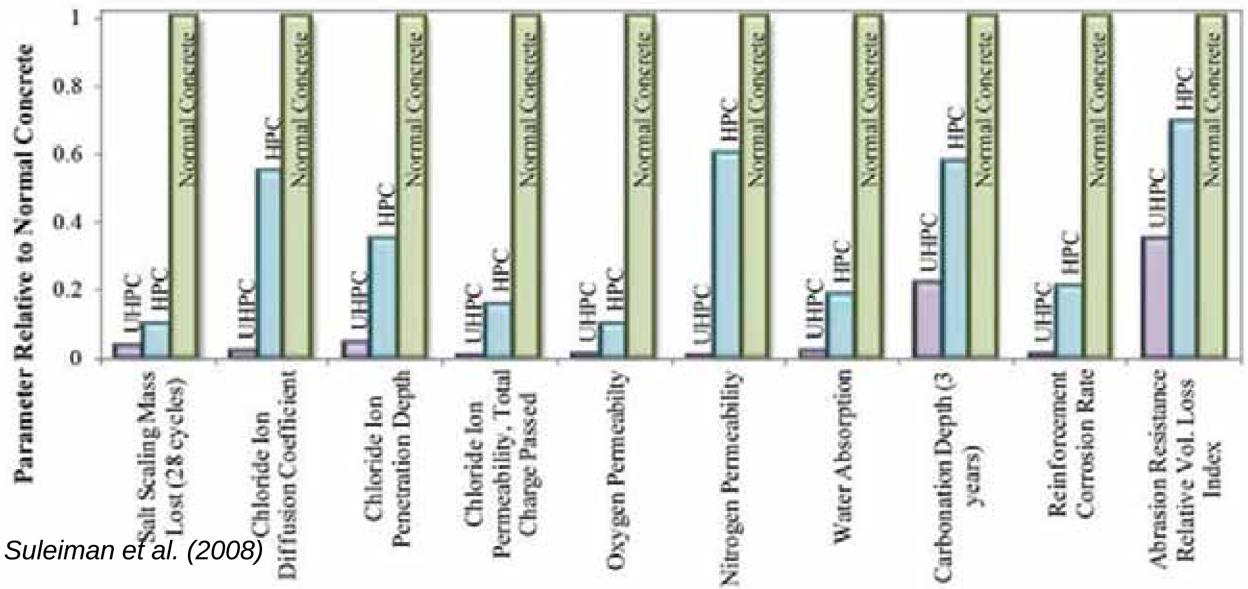
UHPC becomes hot topic in many countries around the world
USA, Germany, France, Switzerland, Czech, Finland, Indonesia, Australia, Netherlands, Canada etc…

UHPC

Ultra High Performance Concrete

Compressive strength 200 MPa and more

e.g. Durability

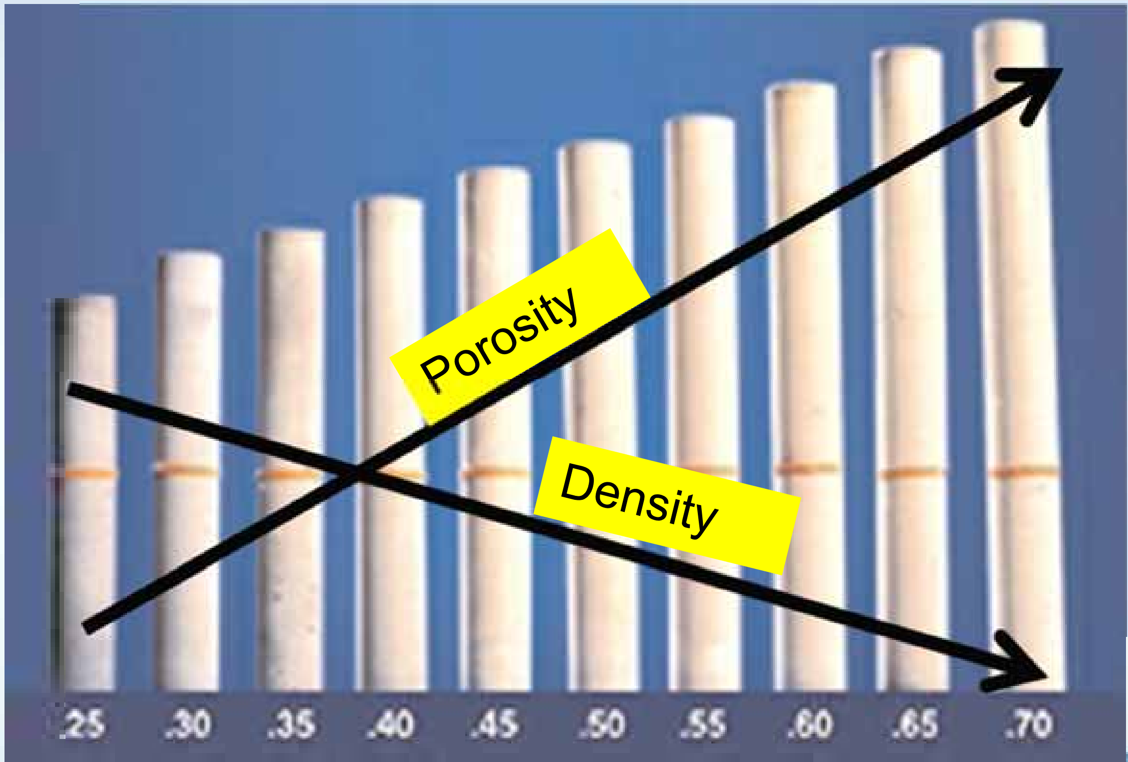


Suleiman et al. (2008)

Sustainability

From where comes the strength and durability?

Effect of Water to binder ratio on paste volume



Increased water dilutes the effect of the cement paste, increasing volume, reducing density, and lowering strength

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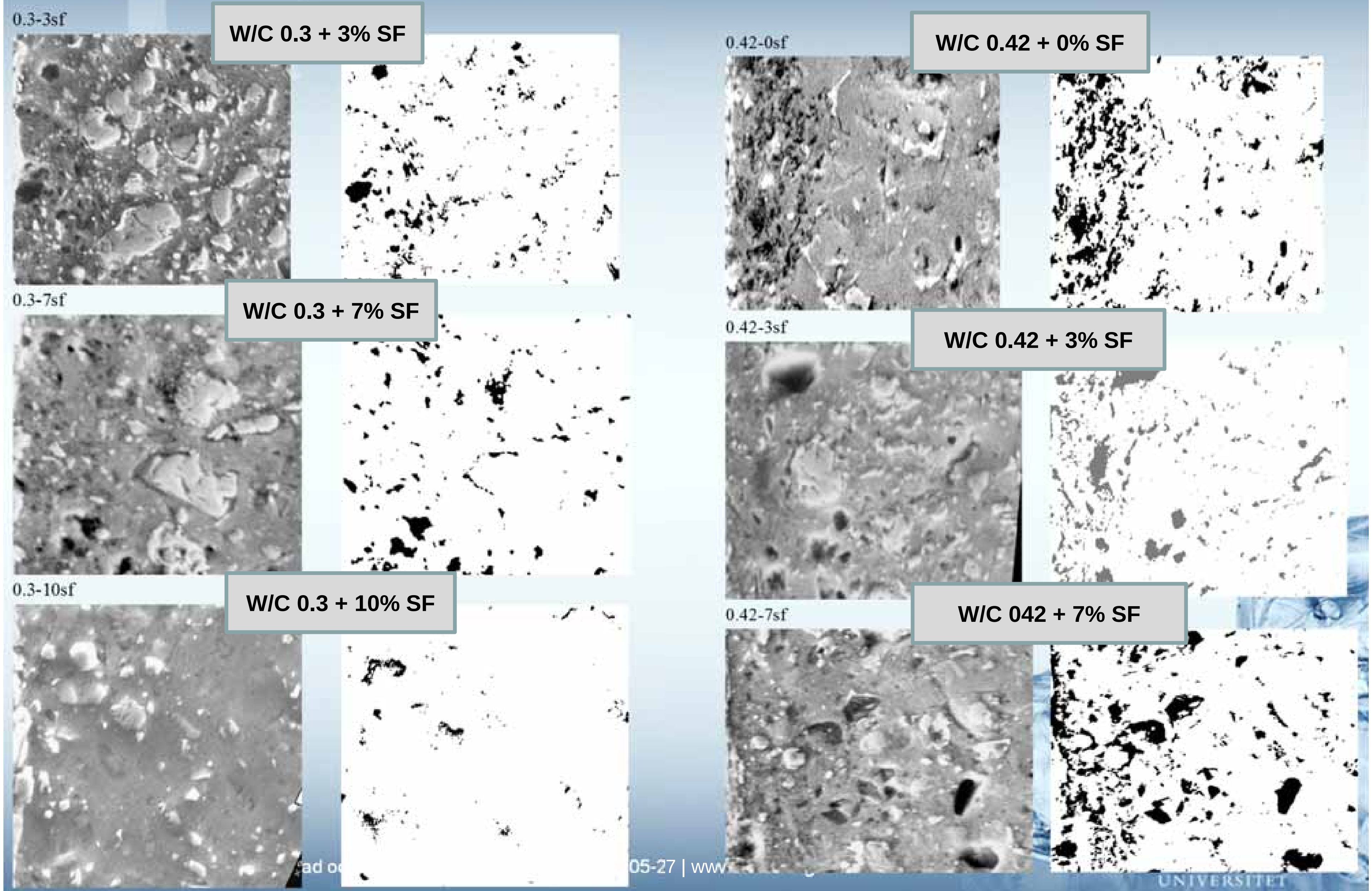
Effect of W/B ratio and SF amount of ITZ porosity



How to improve concrete ?

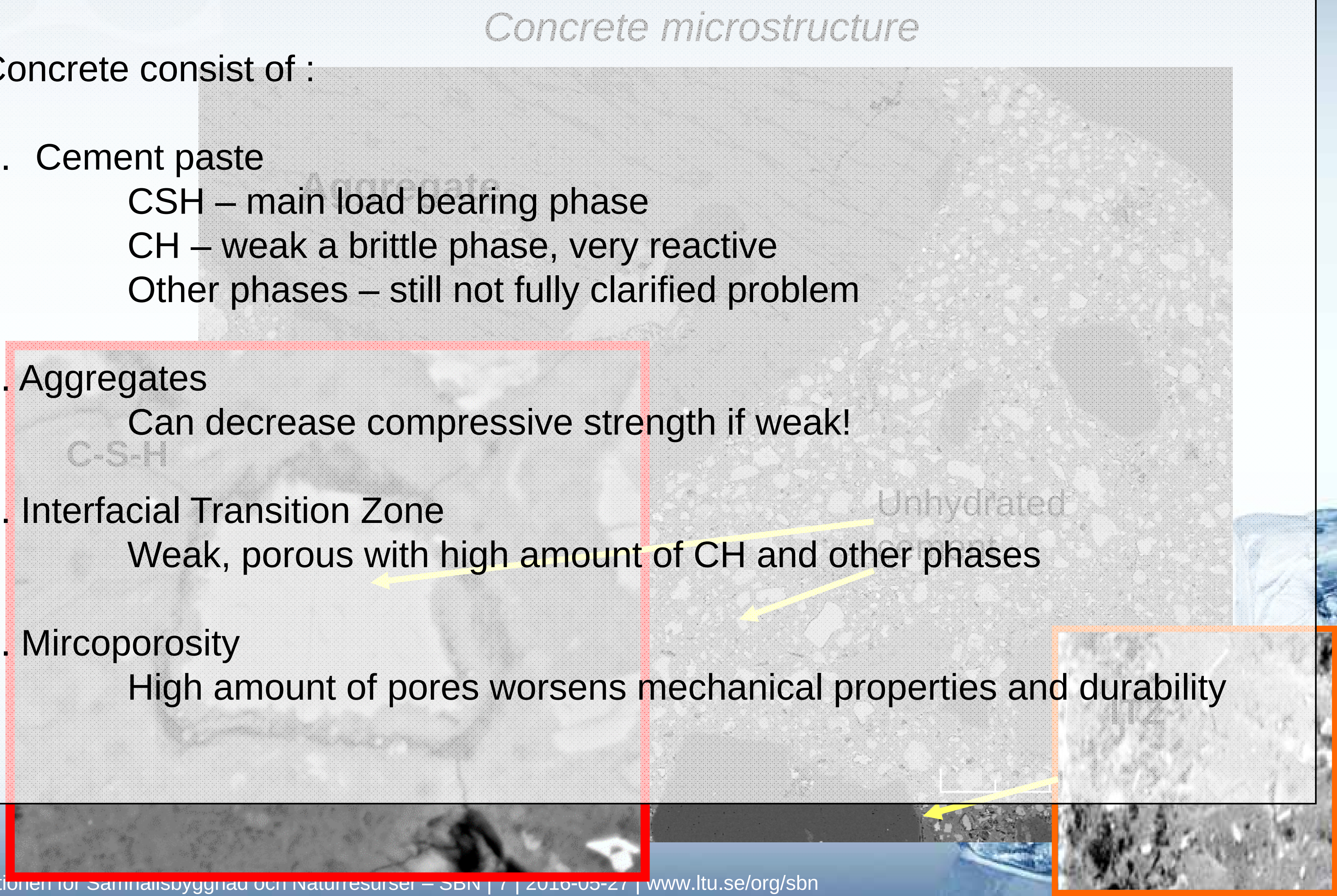
Concrete consist of :

1. Cement paste
   - CSH – main load bearing phase
   - CH – weak a brittle phase, very reactive
   - Other phases – still not fully clarified problem

2. Aggregates
   - Can decrease compressive strength if weak!

3. Interfacial Transition Zone
   - Weak, porous with high amount of CH and other phases

4. Mircoporosity
   - High amount of pores worsens mechanical properties and durability



How to improve concrete ?

Eliminate the weak phases

Less CH

Less other phases (AFt, AFm)

Smaller or not existing ITZ

Lower porosity

Strengthen the main load bearing phases

Stronger CSH

Stronger aggregates

Better particle packing (less water required)

Fillers (decrease of porosity, additional reaction)

Secondary binders (consuming CH, decreasing porosity, decreasing ITZ

Smaller aggregates (smaller is stronger! and no ITZ)

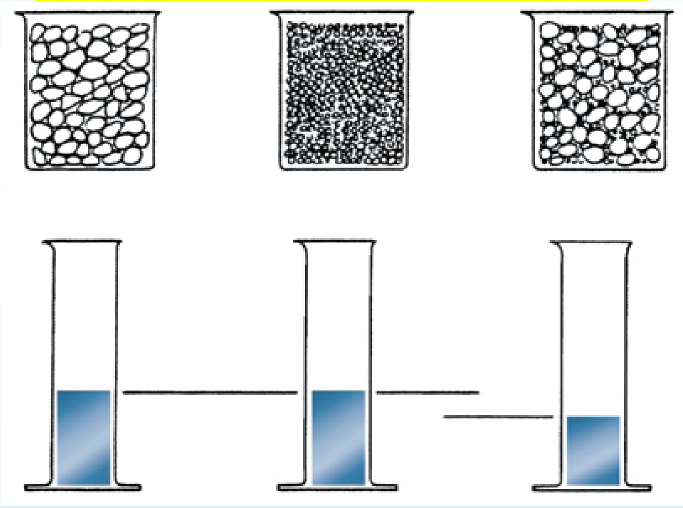
Heat treatments (to improve the hydration of cement)

How to produce UHPC?

Very simple…

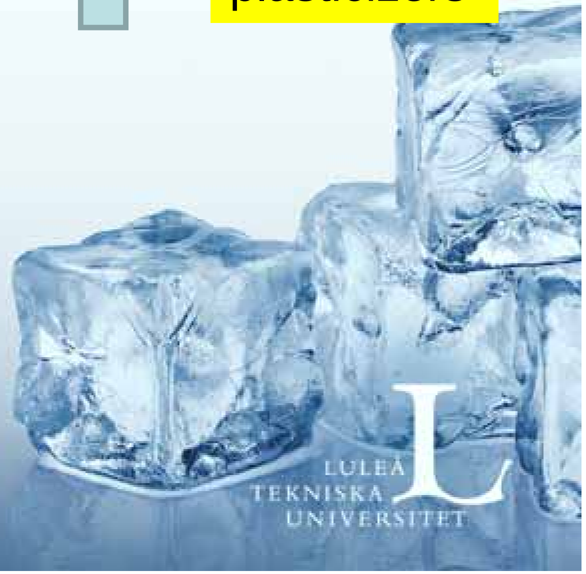
Just optimize the current (known) concrete technology

Maximum packing density



+ W/C ratio <0.25

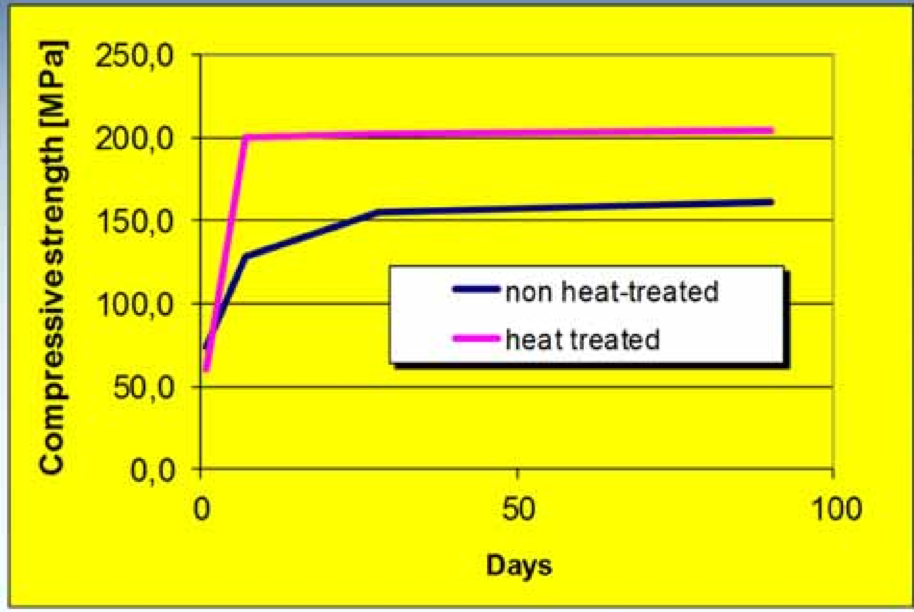
+ Super plasticizers

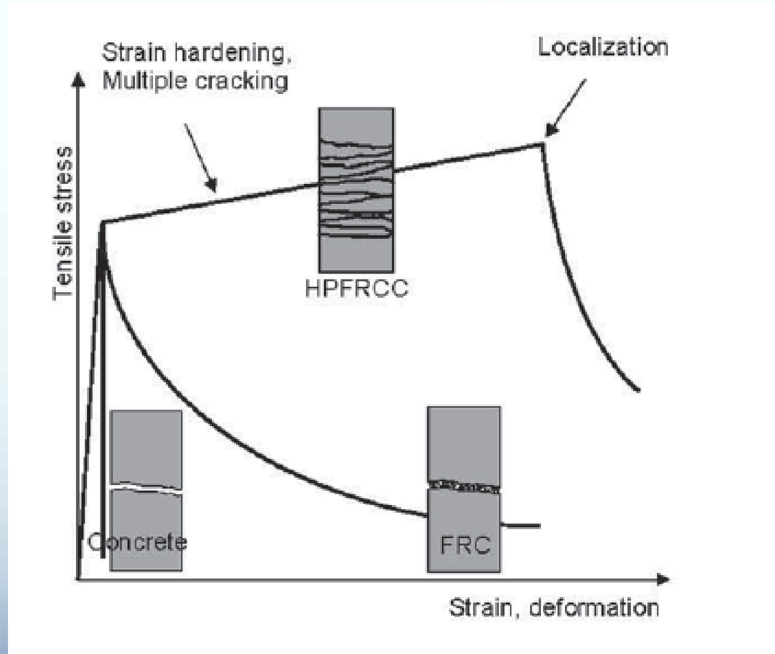


Typical composition:

Cement: 1
Silica fume: 0.25
Fine sand: 0.8 – 2
Fillers (quartz): 0.2 – 0.6
Fibers (12 mm long)
W/B ratio <0.18

Fresh concrete properties
(fluid like consistency)





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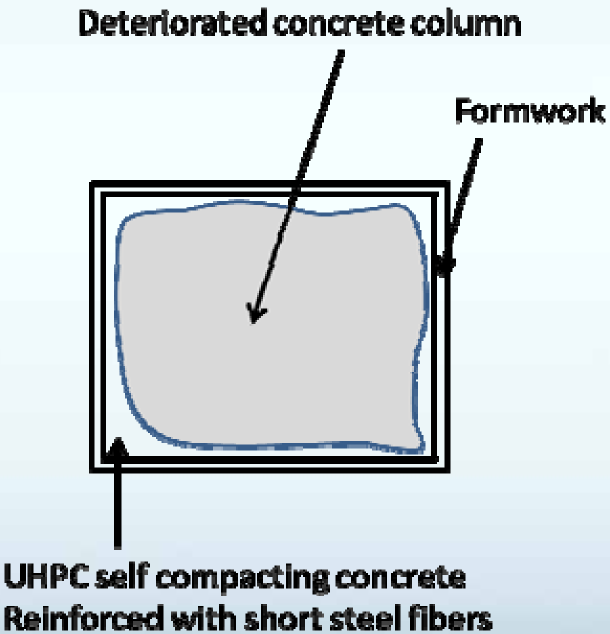
Applications of UHPC - Repairs

Repair of deteriorated bridge columns



Dam repair with injection of UHPC(P) grouts

Old technology

New material (UHPC-P)

Applications of UHPC in new structures

- Bridges
- Multi-storey parking garages
- Noise barriers
- High rise buildings

Structural engineering