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Corporate Solutions

Concrete: Trends, Opportunities and Risks

Pascal Schappes - October 5th, 2022

Definition – What is concrete?

- Concrete is a building material generally made of broken stone, gravel, sand, cement, water and usually adhesives
- Concrete hardening is caused through a chemical reaction named hydration
- Earliest recordings date back to 6500BC, potentially invented by the Egyptians
- Concrete does have a considerable compressive strength but very low tensile force
- Structural concrete is therefore usually combined with structural steel (reinforcement steel)

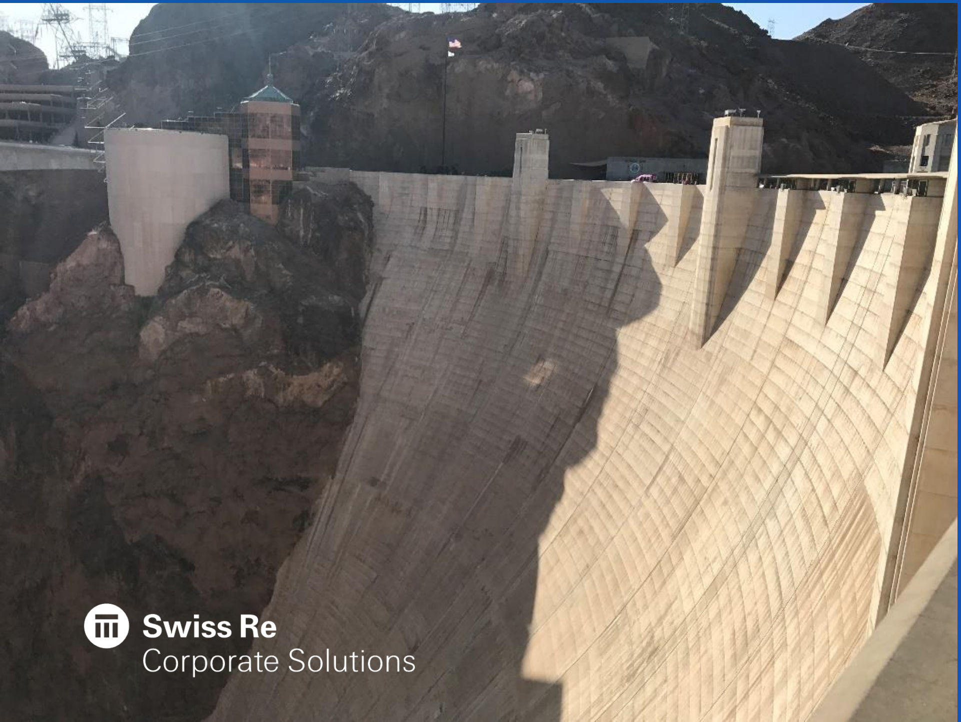
Great Wall of China (220 BC)

Colosseum, Rome (80 AD)

Pantheon, Rome (126 AD)

Where is concrete inevitable or potentially without alternative?

• Foundations	e. g. baseplate, deep foundations
• Retention walls for excavation pits	e. g. slurry walls, secant bored pile wall
• Tunnels	e. g. shotcrete, tubbing rings
• High-span bridges	(depending on location and geometry, structural steel can be an alternative)
• Massive constructions	e. g. dam structures, gravity walls, stiffening core of high-rise buildings



Hoover Dam (1936)

and

Mike O'Callaghan –Pat Tillman Memorial Bridge (2010)

DC Tower 1 (2013)

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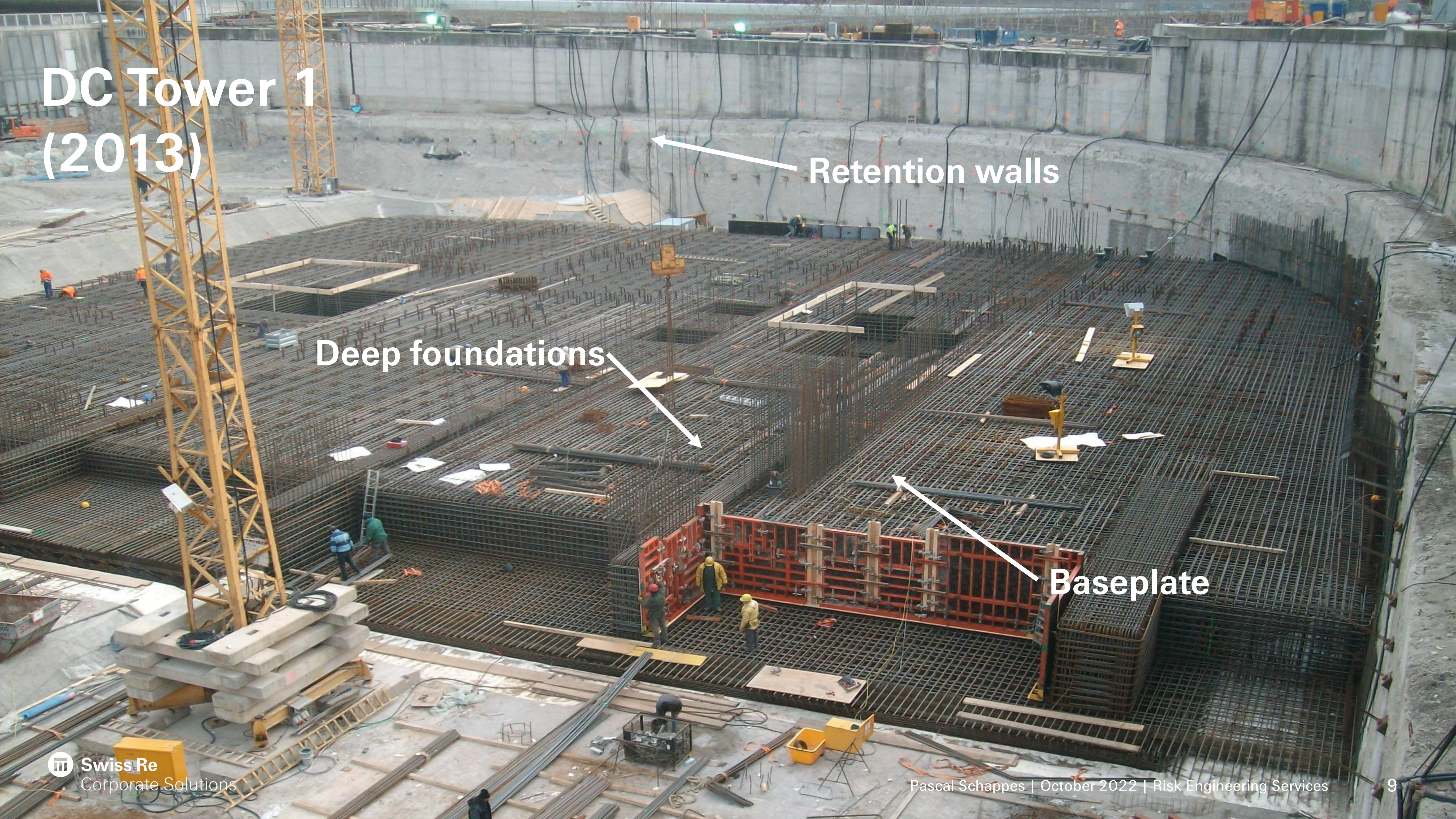

Loss examples

Genova Morandi Bridge, Italy

- Structural system of a cable-stayed bridge
- Failure of one of the pre-stressed major tension beams, causing a chain reaction
- Supposed root cause: complex maintenance due to unique design

Source: eurotopics.net

Loss examples

Chirajara Bridge Collapse, Colombia

- Failure of horizontal pre-stressed concrete beam in one of the main pillars
- Supposed root cause: potentially design failure

Source: bbc.com

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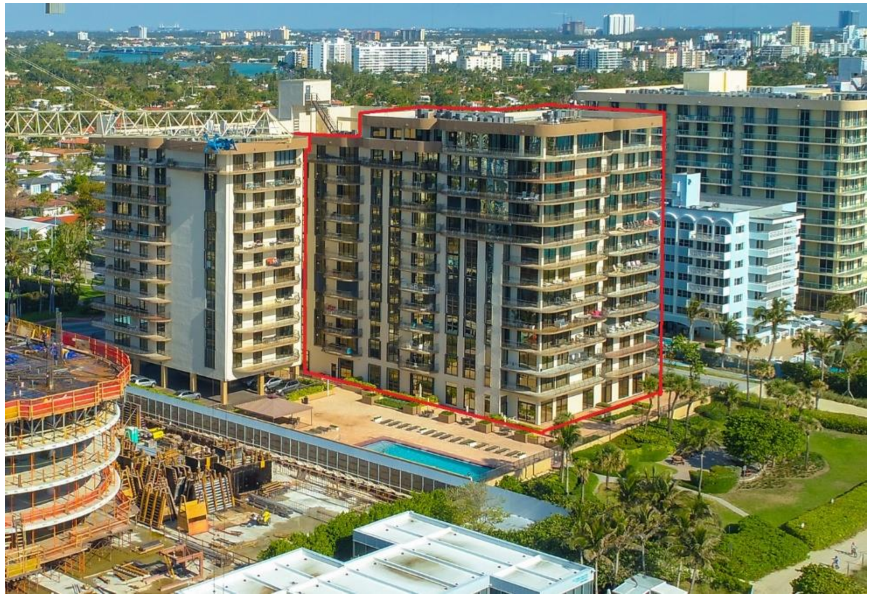
Loss examples



Source: www.architectsjournal.co.uk

Miami Surfside Condominium Collapse

- Failure in a single element results in the failure of adjoining structural elements, which in turn lead to the failure of additional structural elements
- Supposed root cause: lack of maintenance

Source: abcnews.go.com

Advantages of concrete

- Strength — Concrete with a compressive strength of more than 100 N/mm^2 is available on the market
- Flexibility — Concrete can be poured into nearly every imaginable shape
- Reliability — Being an artificial product (made of mainly natural ingredients), concrete is consistent and therefore reliable
- Experience — Concrete has been used for thousands of years
- Lifespan — Lifespan of concrete is between 50 and 100 years, depending on maintenance
- Combustibility — Concrete can be considered as non-combustible

Disadvantages of concrete

Disadvantages from a technical standpoint:

- Concrete is prone to environmental influences, e. g. chlorides
- With approx. 2,5 – 2,8 to/m^3, concrete must be considered heavy

Disadvantages from a sustainability standpoint

- CO_2-footprint (clinker production, 1to CO_2 for 1to of clinker), steel production
- gravel pits
- chemical adhesives

Trends and opportunities (1)

Following the three principles of sustainability can help to decrease the environmental impact of concrete:

- Reduce – see next slides
- Reuse – e. g. refurbishment of an existing concrete structure/ building
- Recycle – see next slides

Trends and opportunities (2)

- Recycling (recycle)
  - using concrete from dismantled/demolished concrete structures

- Increase of lifespan (reduce)
  - cathodic protection against corrosion
  - use of bacteria to heal cracks (self-healing concrete)
  - use alternative material like basalt fibers (better substance resistance of water, salts, alkalis and acids)

- Reduction of CO2-footprint (reduce)
  - decrease the clinker factor of cement by using supplementary cementitious materials (SCMs)
  - use of CO2 mineralization (conversion of gaseous CO2 into solid mineral carbonates) to produce concrete

Trends and opportunities (3)

- Reduction of reinforcements and other non-renewable materials (reduce)
  - use of 3D-printing (only for small buildings at the moment) to reduce amount of reinforcement steel and formwork material
  - replacement of reinforcement steel by carbon fibers (nature-friendly, recyclable)

- Optimization of technical characteristics (reduce)
  - reduction of weight, increase of strength
  - replacement of reinforcement steel by carbon fibers
    - 3 times lighter than steel,
    - good fire resistance,
    - 2,5 times stronger (tensile strength) than steel

Risks (1)

- Recycling of concrete
  - Recycled aggregate concrete shows an increased cracking risk compared to standard aggregates.
  - In the past, use of recycled aggregate concrete should not exceed 25-35%. Today a share of 80% is possible under certain circumstances

- Cathodic protection against corrosion
  - still a small-scale solution
  - costly
  - limited lifespan

- Self-healing concrete
  - expensive
  - limited experience on the market
  - no code available to standardize self-healing concrete

Risks (2)

- Basalt fibers
  - negative impact on workability
  - more expensive than steel reinforcements
  - breakable and low in withstanding bending force
  - lack of specific design guidance

- Use of supplementary cementitious materials (SCMs)
  - slower production
  - reduced strength
  - reduced freeze–thaw durability
  - more expensive

Concrete – Conclusions

Concrete will remain the most relevant building material in the future.

Therefore, it is essential to keep up our efforts in finding new ways to make concrete more sustainable.

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Thank you!

Contact us

Pascal Schappes
Senior Risk Engineer
pascal_schappes@swissre.com
+49 89 3844 1599

Marc Schmassmann
Senior Risk Engineer
marc_schmassmann@swissre.com
+41 43 285 27 24

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