Concrete

- Most used construction material worldwide!
- Relatively cheap
- Basic ingredients (sand / gravel / water) readily available
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Concrete, the problem:

1. Cement, main ingredient = ‘Non-sustainable’

Yearly consumption in The Netherlands:

- 6 million tons cement
- 12 million tons sand
- 15 million tons gravel

Environmental impact:

10% of world CO₂ production due to cement production
Concrete, the problem:

2. Liable to early-age crack formation / degradation

1. Loss of strength

2. Increased permeability: ingress of aggressive chemicals
   → Degradation of concrete matrix
   → Risk of reinforcement corrosion

- Acid sulfate soils
- Spalling, e.g. freeze/thaw cycles
- Ettringite formation / sulfate
The Corrosion Society (USA) estimates the **annual** direct cost of corrosion in construction and other applications to be **$276 billion** (of which **$4 billion** due to reinforcement corrosion of highway bridges)
Possible strategies to deal with crack-formation:

1. Manual inspection and repair
   - Time consuming / costly
   - Traffic delay / costly
   - Not always possible (accessibility)
Possible strategies to deal with crack-formation:

2. Application of self-healing concrete!!!

→ Chemically-based
  
  e.g. formation of expansive hydration products

→ Biologically-based
  
  e.g. incorporation of bio-cement producing bacteria
Bacteria as self-healing agent:
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Bio-mineral production: reduces permeability
Bacteria as self-healing agent:

\[ 2 \text{Ca}(\text{CHO}_2)_2 + 2 \text{O}_2 \rightarrow 2 \text{CaCO}_3 + 2 \text{CO}_2 + 2 \text{H}_2\text{O} \]

Convert food to minerals (bio-cement)

Two-component self-healing agent,

‘Green inside’:

→ 1. Bacteria (catalyst)

→ 2. Mineral precursor compound (chemical / ‘food’)
Needed: ‘Concrete-compatible’ bacteria

11 species:

Alkali-resistant spore-forming bacteria

1. > 50 years viable
2. Concrete compatible

Endolithic communities

Playa, rock

Soda-lake communities

Wadi Natrun, Egypt  pH ~ 10
Will incorporated bacteria and food impede concrete quality?

High number of incorporated bacteria:
- Acceptable (~5%) strength loss

Incorporation of CaLactate:
- No strength loss

Organics: 1% of cement weight
Crack-healing: bacterial bio-cement production

Products influenced by bacteria / food combination:

Isolate 2 + NaGlutamate:

Larger, 0.1 - 1 mm-sized, plate-like precipitates
Crack-healing: bacterial bio-cement production

Products influenced by bacteria / food combination:

Isolate 3 + CaLactate:

Robust, 20 - 100 µm-sized, calcite-like precipitates
Results permeability testing

Control (no bacteria, no ‘food’)
Results permeability testing

Bacterium C2C21A + CaLactate
Conclusions

Bio-based self-healing concrete ‘Green inside’:

1. High crack-sealing capacity:
   - Less maintenance + repair
   - Prolonged service life constructions

2. Healing agent bio-based = ‘Sustainable’

→ Self-healing bio-concrete:
   good for both economy and environment!