Mimic Nature: Full material cycling / Self-healing materials

Bio-inspiration for developing durable and sustainable materials:

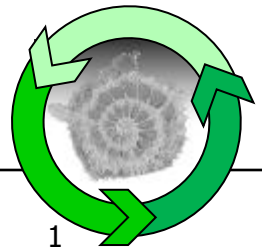
STW BioGeoCivil Engineering program

(www.biogeocivil.nl)

Goals:

1) Use bio-based processes for improving sustainability performance of geo- and civil engineering practices

2) Develop (novel) bio-based materials with superior service life performance



STW BioGeoCivil Engineering program

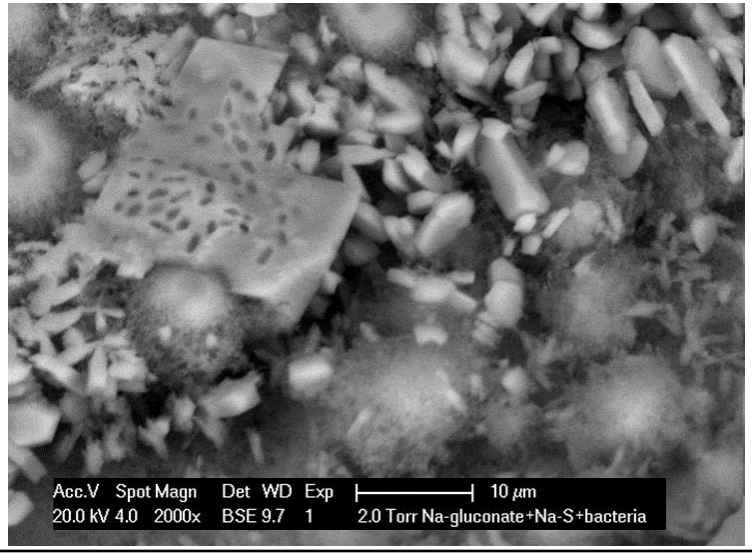
Biologists ⟷ **Civil Engineers**

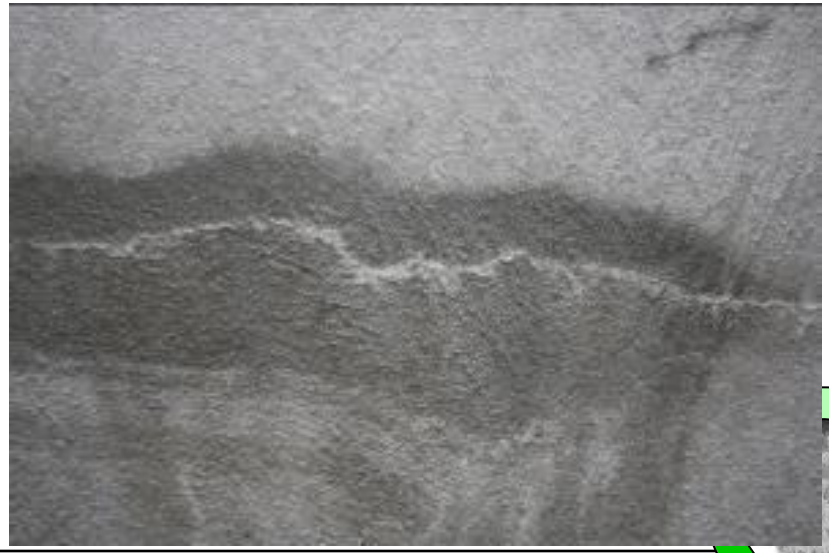
2. Bacteria-based repair and performance improvements of aged concrete structures (BioRetrofit)

(Wiktor, Beltran, Jonkers TUD)

→ Development of bacteria-based concrete compatible and sustainable repair systems

→ Reduced aging / increased service life





3. Limestone-producing bacteria

Endolithic communities

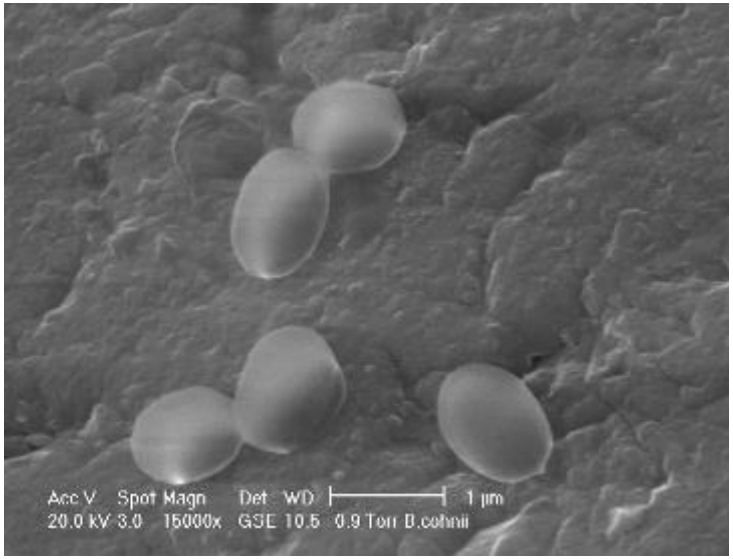
Playa, rock

Alkali-resistant

spore-forming bacteria

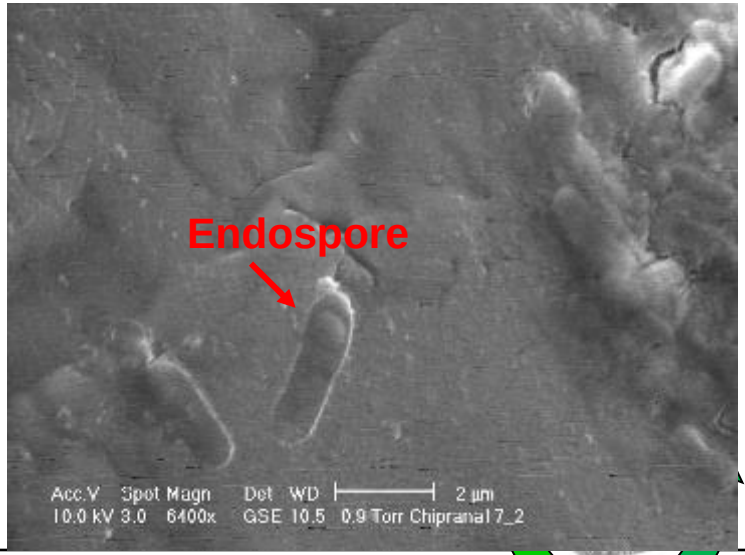
1. > 50 years viable

2. Concrete compatible



Soda-lake communities

Wadi Natrun, Egypt pH ~ 10

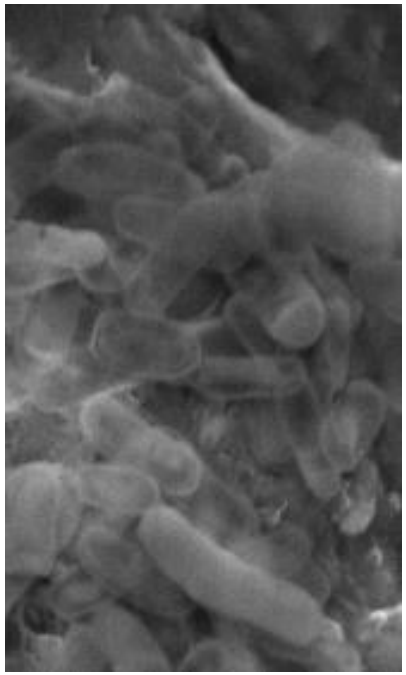


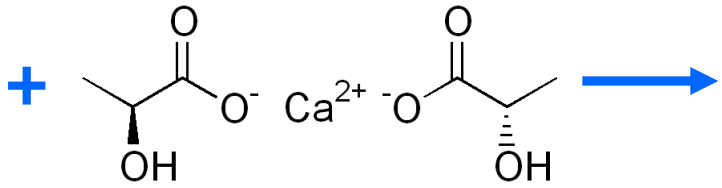
3. Limestone-producing bacteria

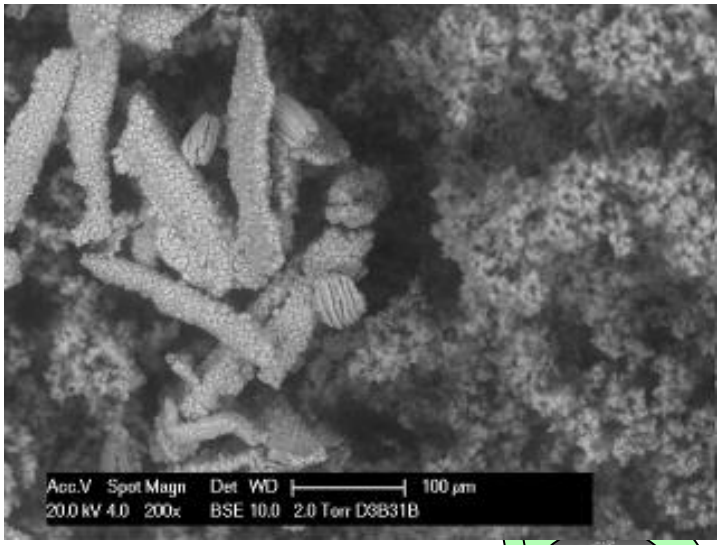
$$Ca(C_3H_5O_3)_2 + 6\ O_2 \quad >>> \quad CaCO_3 + 5\ CO_2 + 5\ H_2O$$

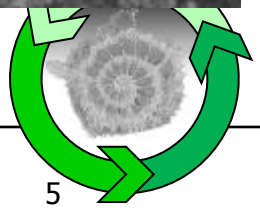
(Increased calcite production from concrete matrix Portlandite:)

$Ca(OH)_2$









6. Towards the development of carbon dioxide neutral renewable cement (BioCement)

(Carr, Jonkers et al. TUD/WUR)

→ **Replace Portland cement for biomass-derived ash**

→ **Sustainable / increased service life**

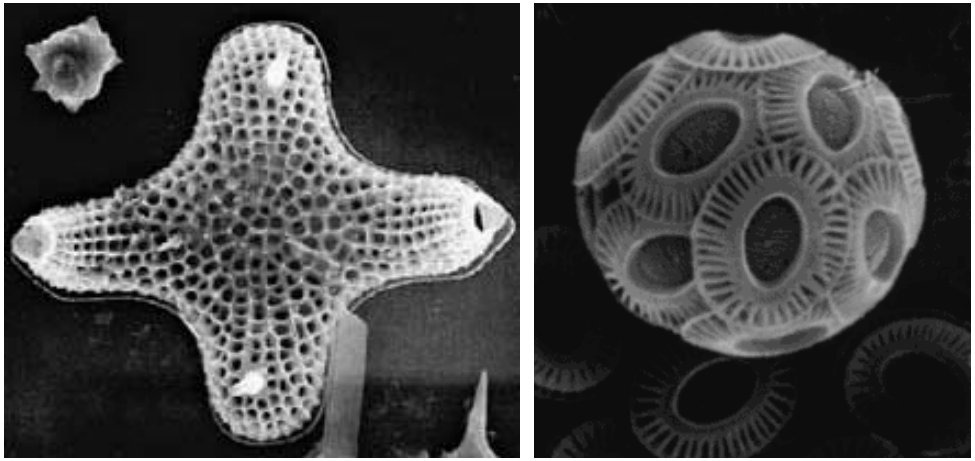
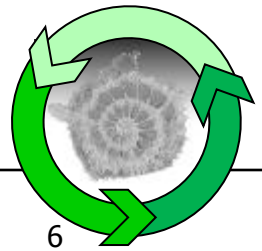


Fig 3. Diatom (left, size ca. 20 µm) and Coccolithophorid (right, ca. 2 µm) algae which produce silicate- and calcium carbonate-based skeletons respectively. Source: www. ucmp.berkeley.edu and www.mbari.org



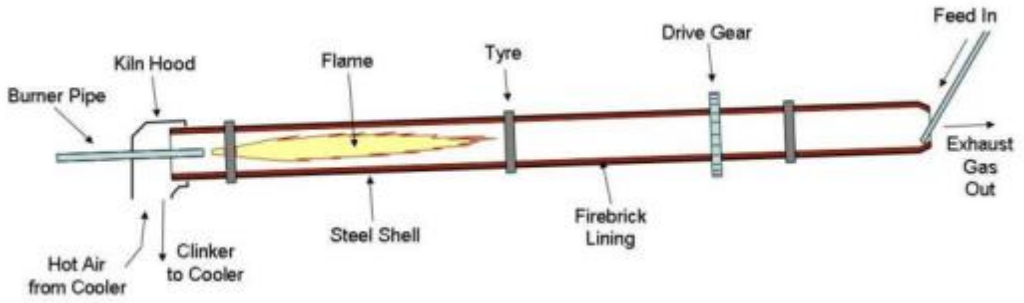
Traditional Portland cement production:
High energy consumption and CO_2 emission!

Limestone and clay burned at 1500ºC produces clinker composed of:

Short:		Mineral:	Composition:
C_3S	tricalcium silicate	**(Alite)**	Ca_3SiO_5 $(3CaO + SiO_2)$
C_2S	dicalcium silicate	**(Belite)**	Ca_2SiO_4 $(2CaO + SiO_2)$
C_3A	tricalcium aluminate	**(Aluminate)**	$Ca_3Al_2O_6$ $(3CaO + Al_2O_3)$
C_4AF	tetracalcium aluminoferrite	**(Ferrite)**	$Ca_4Al_2Fe_2O_{10}$ $(4CaO + Al_2O_3 + Fe_2O_3)$

Average mineral composition in weight:

CaO	65-70 %
SiO_2	18-24 %
Fe_2O_3	3-8 %
Al_2O_3	3-8 %



Traditional Portland cement production:

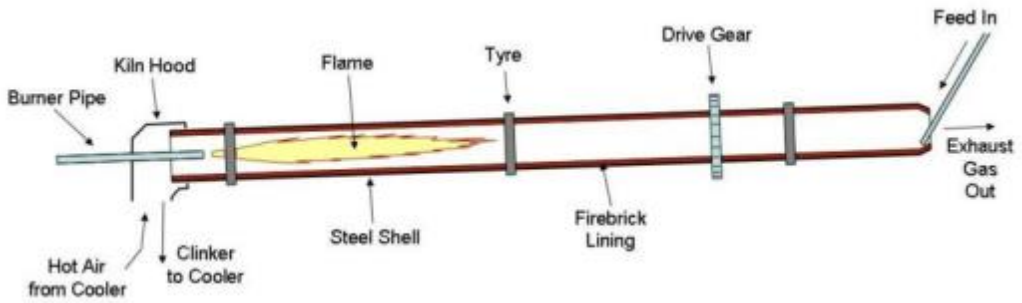
High energy consum… … CO_2 emission!

Limestone and clay burned at 1500ºC produces cl… …mposed of:

Short:		Mineral:	Composition:
C_3S	tricalcium silicate	**(Al…**	Ca_3SiO_5 $(3CaO + SiO_2)$
C_2S	dicalcium silicate		Ca_2SiO_4 $(2CaO + SiO_2)$
C_3A	tricalcium aluminate	**…minate)**	$Ca_3Al_2O_6$ $(3CaO + Al_2O_3)$
C_4AF	tetracalcium aluminof…	**…errite)**	$Ca_4Al_2Fe_2O_{10}$ $(4CaO + Al_2O_3 + Fe_2O_3)$

Average mineral com… …n weight:

CaO	…%
SiO…	…24 %
…	3-8 %
…3	3-8 %



Possible to produce from biomass-derived ashes?

Hypotheses:

1) (Residual) biomass contains energy + raw 'cement' minerals

(SiO_2 + CaO + Al_2O_3 + Fe_2O_3)

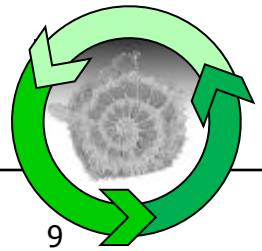
2) Biomass-derived minerals need less activation energy

(either lower temperatures or shorter calcination time)

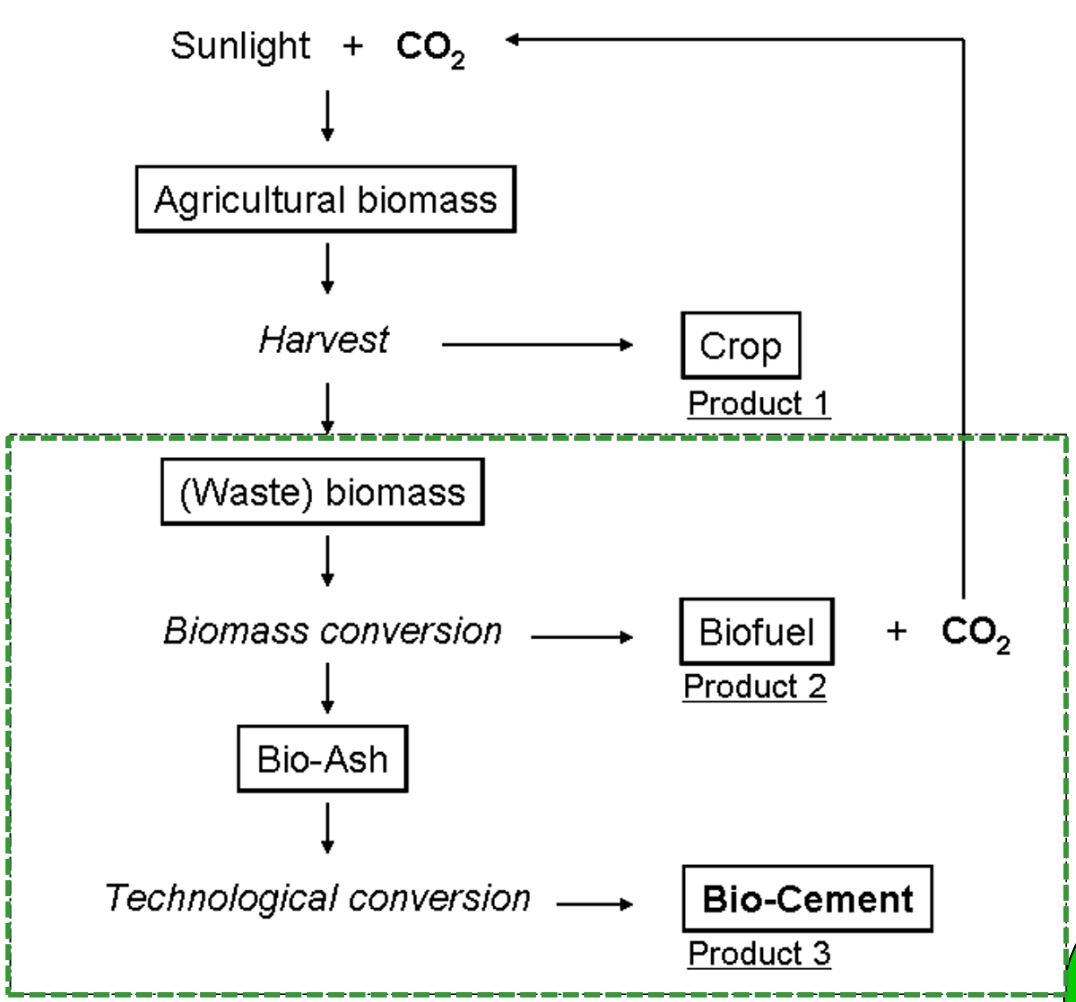
than clay/limestone-derived minerals to form hydraulic cement minerals

(Alite, Belite, Aluminate, Ferrite)

⟶ Saves energy and reduces CO_2 emissions



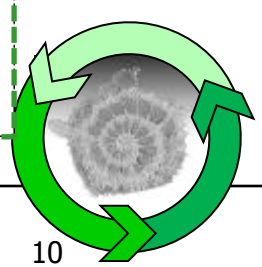
Project aim biomass flow:



WUR

WUR/ECN

TUD



STW BioGeoCivil Engineering program