

Eco-concrete

Methods to improve the environmental impact of concrete

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M2i conference

11.-12.12.2017

TU **e**

Technische Universiteit
Eindhoven
University of Technology

Where innovation starts



Composition

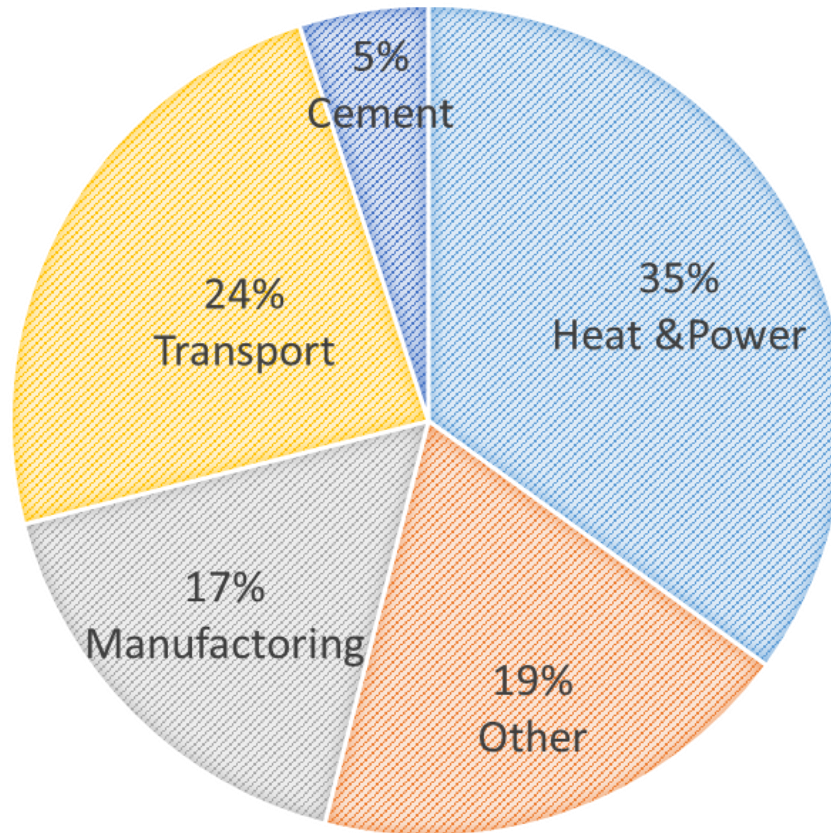


10%	Cement	
15%	Water	
2%	Air	
73%	Aggregate:	30% Sand 43% Gravel

$w:c:s:g = 0.5:1:2:3$

21 billion tons in 2011

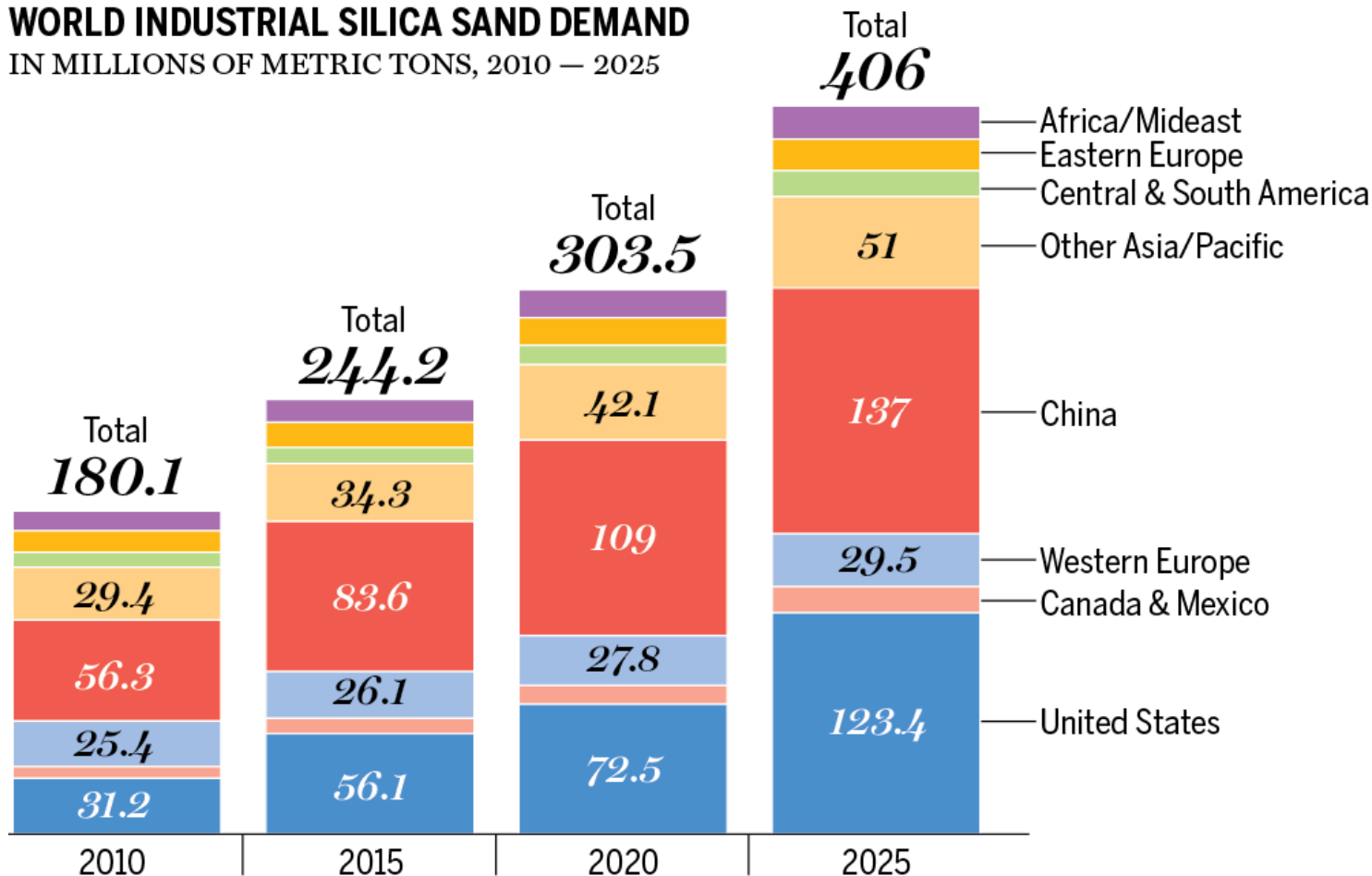
CO₂ PRODUCTION BY SECTOR



Problems

WORLD DEVOURING SAND

WORLD INDUSTRIAL SILICA SAND DEMAND
IN MILLIONS OF METRIC TONS, 2010 — 2025



SOURCE: THE FREEDONIA GROUP

NATIONAL POST

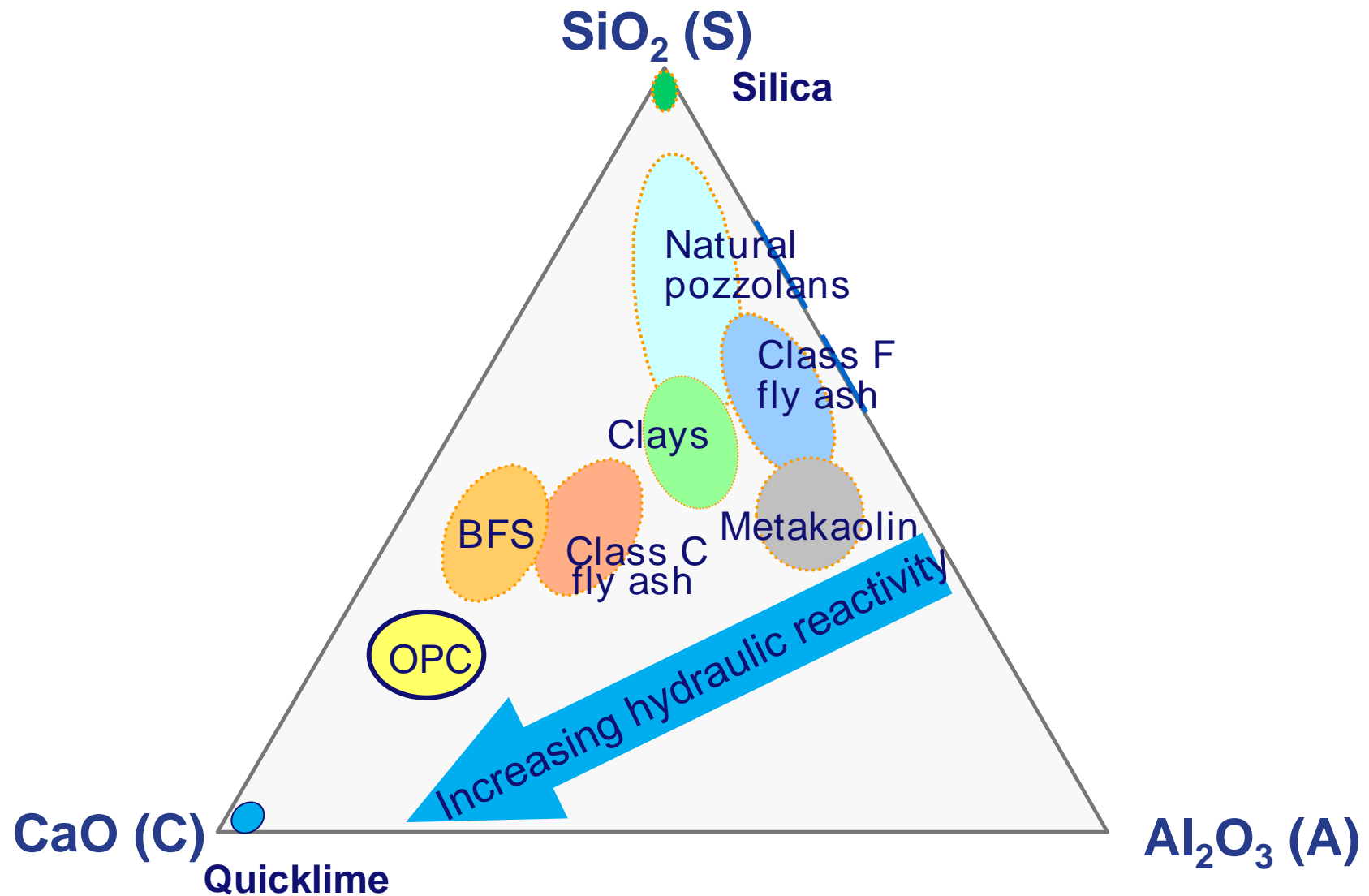
Problems



Source: Tommy Trenchard / IRIN

- **Supplementary cementitious materials**
- **Alternative binders**
- **Alternative aggregates**
- **Recycling of concrete**
- **Green additives**
- **Functionalizing concrete**

Supplementary Cementitious Materials

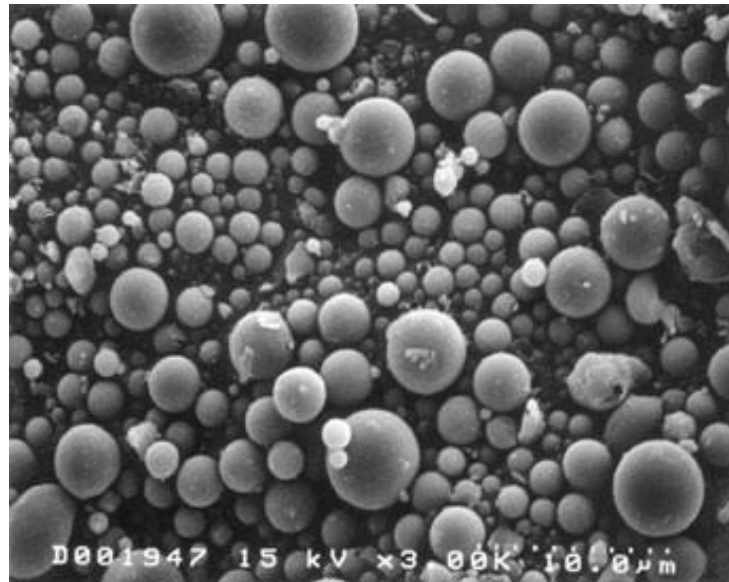


Supplementary Cementitious Materials

CEM III

40-90% of cement replaced with SCM

Fly ash from coal combustion (for how long?)



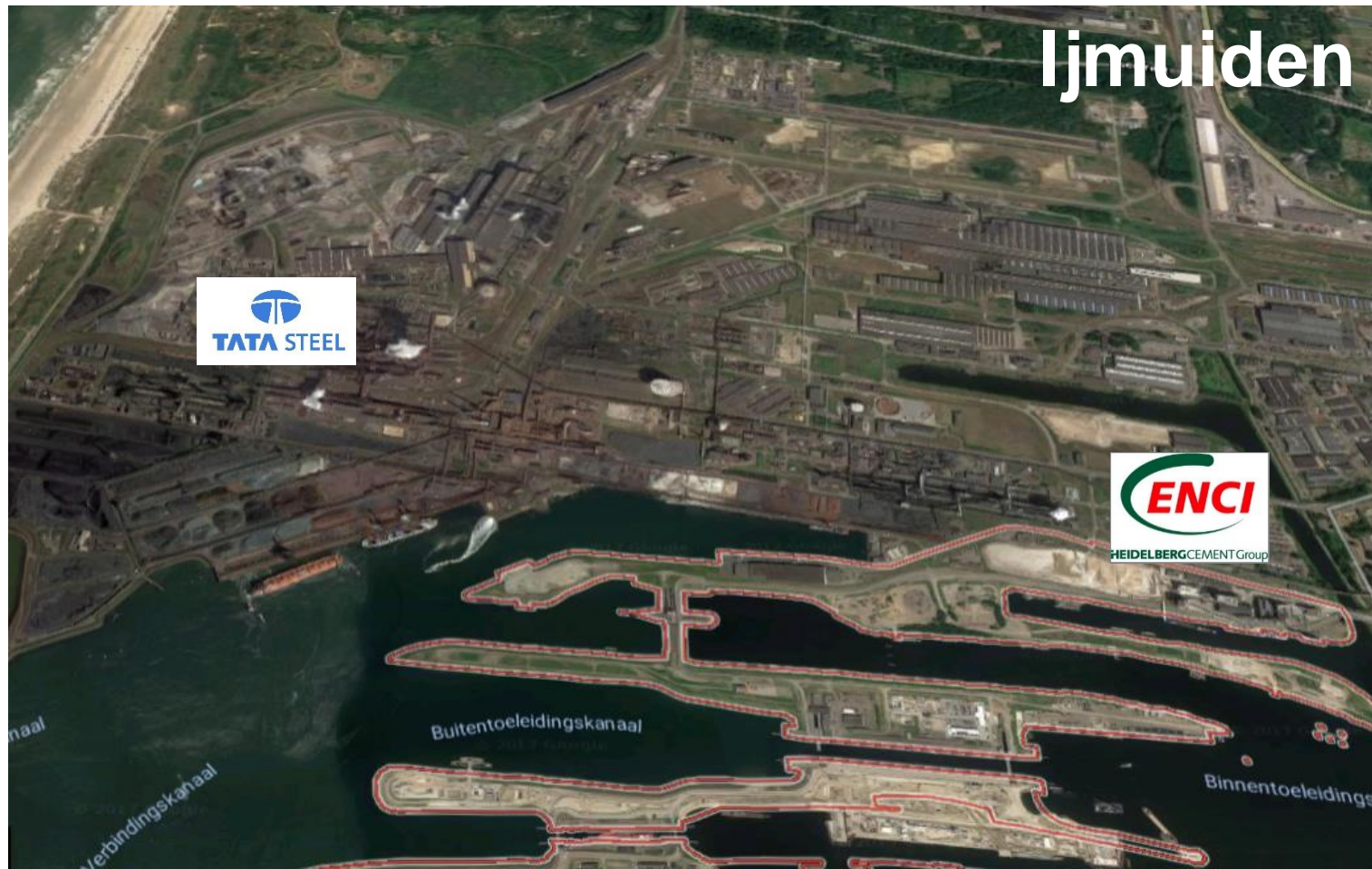
CEM III

40-90% of cement replaced with SCM

Blast furnace slag from iron production



Source: Euroslag



- other types of slag are currently unused
- Converter slag ~600kton a year
- C_2S , $Ca_2Fe_2O_5$, FeO , CaO
- not reactive

HTM-STW-M2i 4-year project:  materials
innovation
institute

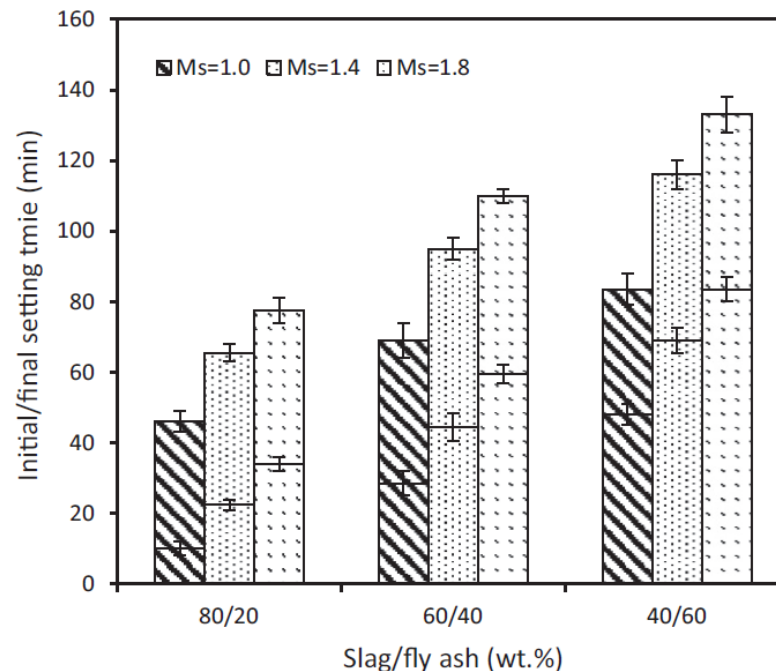
"High-end application of converter steel slag in sustainable building materials"



Alternative Binders

Alkali Activated Binders/Geopolymers

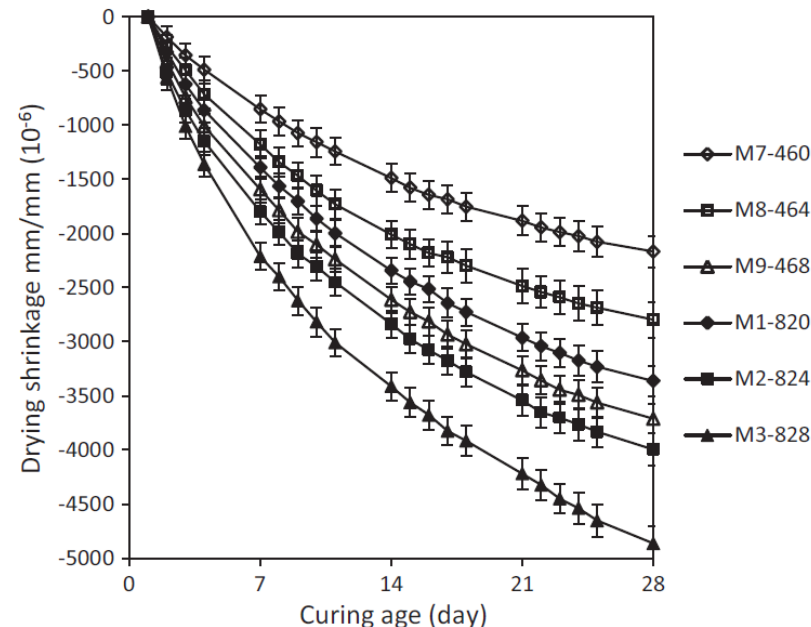
- Alkaline activator: NaOH , Na_2SiO_3 , Na_2CO_3 , Na_2SO_4
- Activated material: Blast furnace slag, fly ash
- Formation of C-(A)-S-H and N-A-S-H type gels



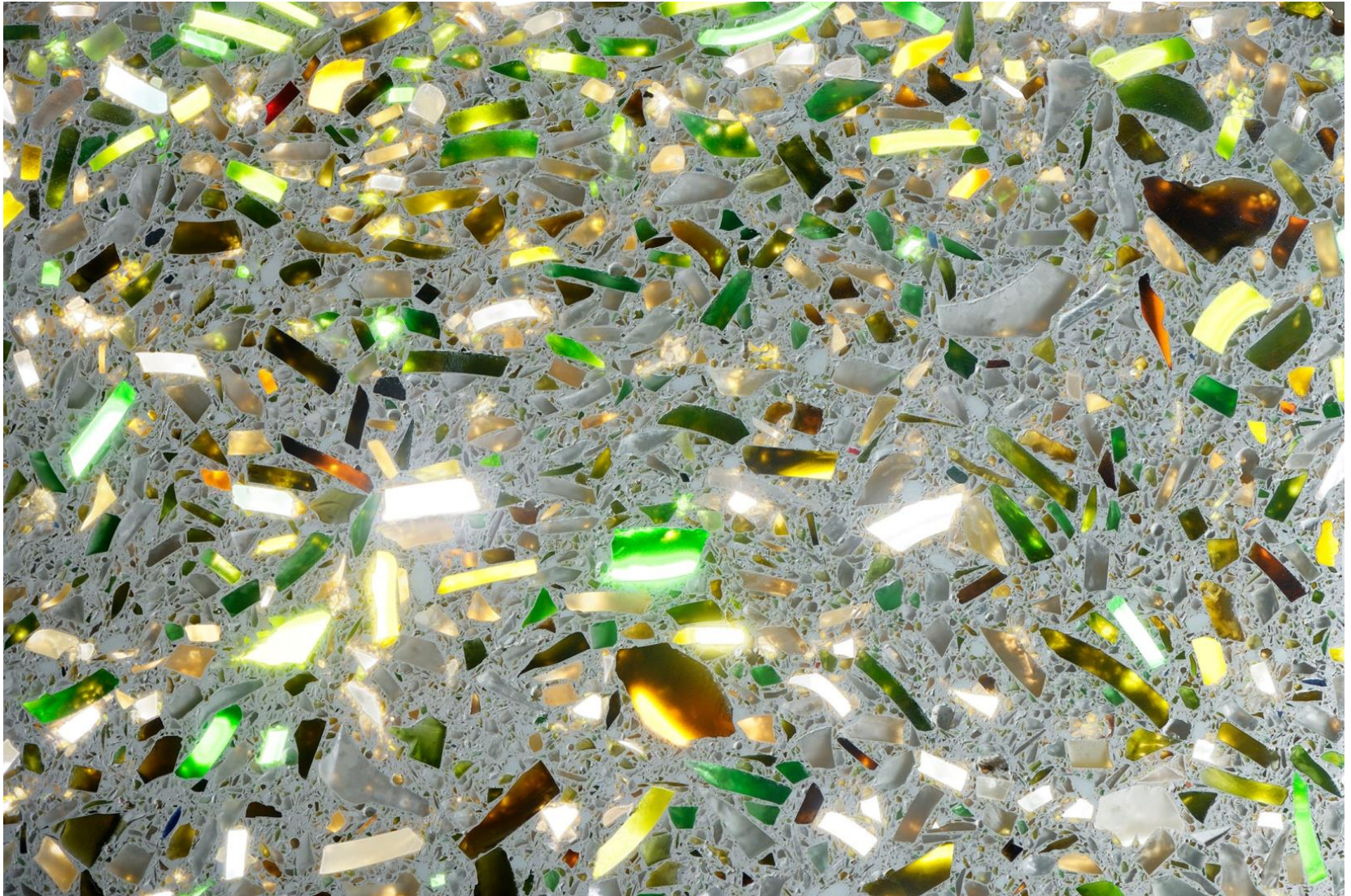
Alternative Binders

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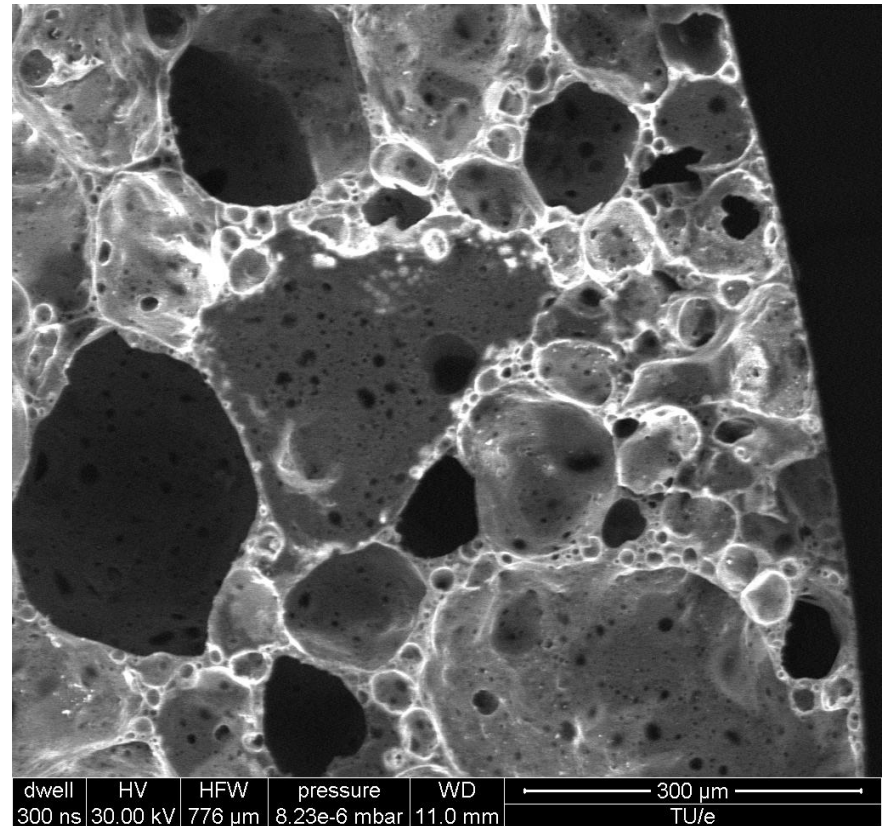
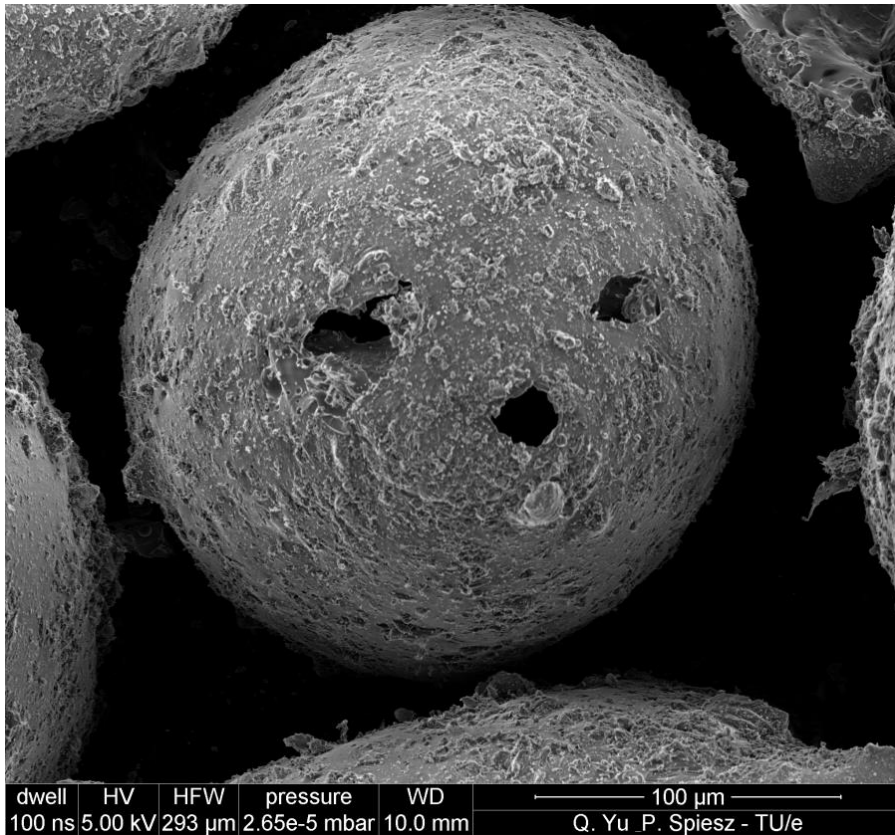


Alternative Aggregates

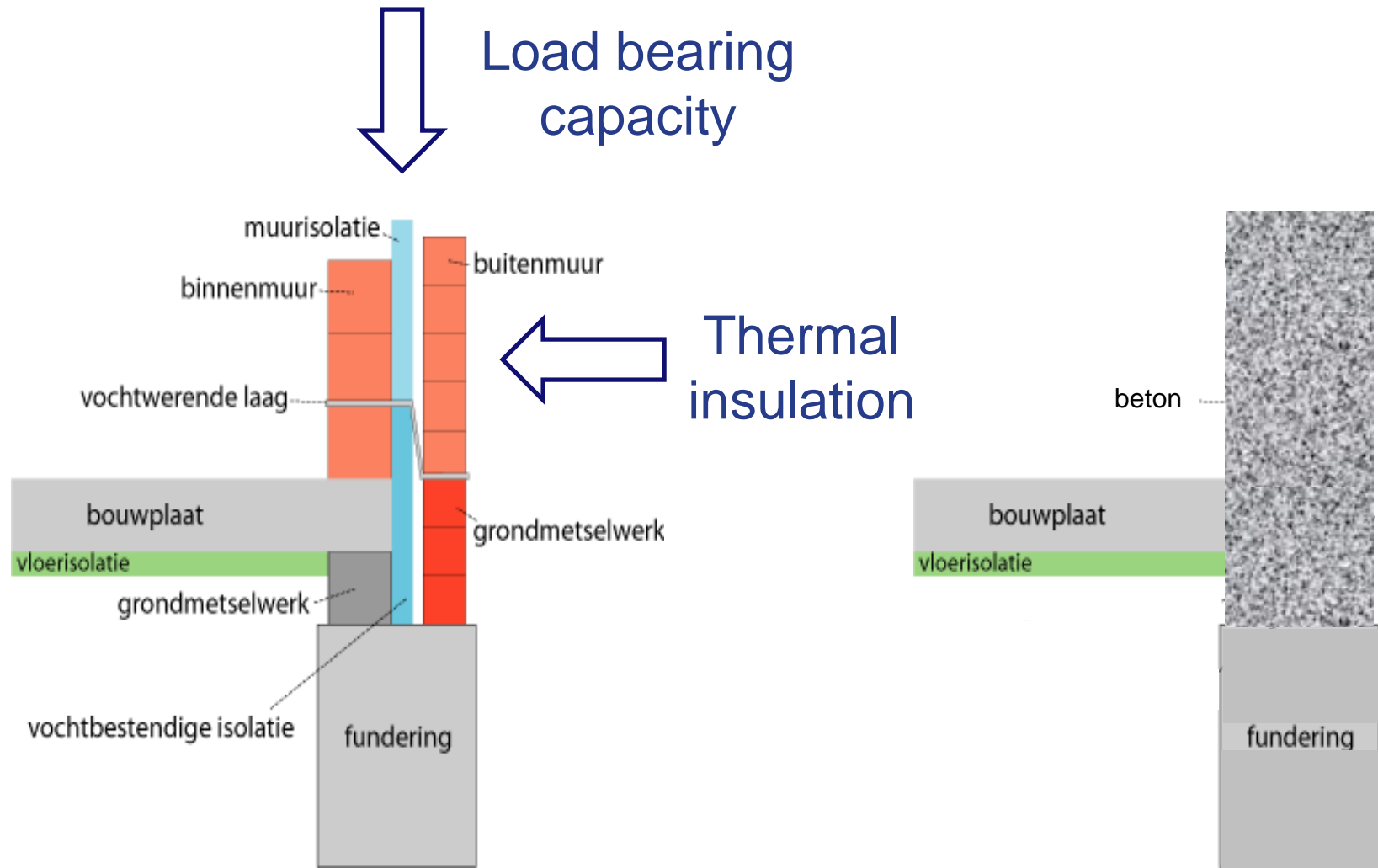


Alternative Aggregates

Lightweight Aggregate



Alternative Aggregates



Cavity wall and monolithic wall

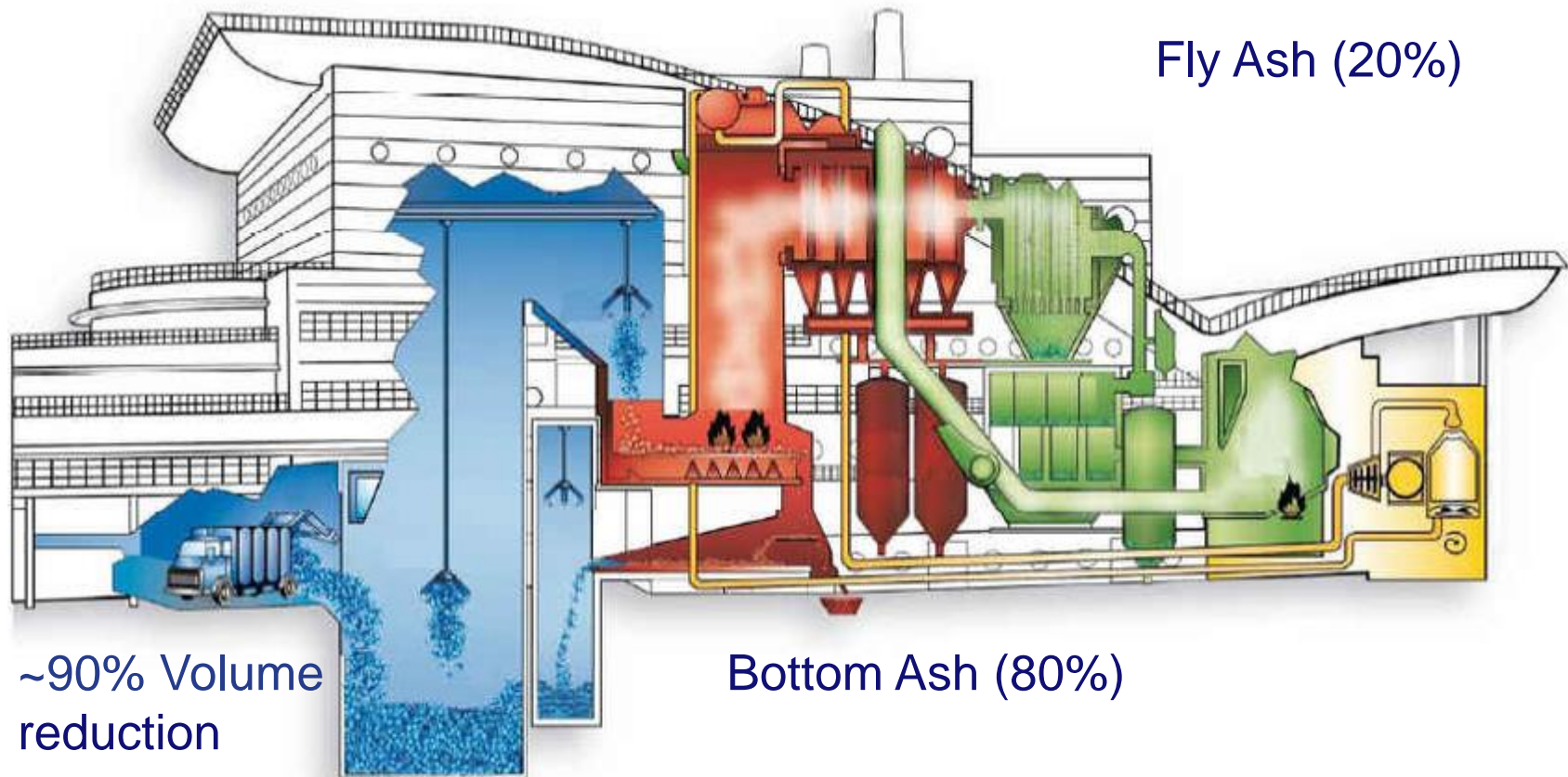
Alternative Aggregate

Monolithic concrete Germany and Switzerland



Alternative Aggregates

MSW Incineration /Waste to Energy plant



Alternative Aggregate



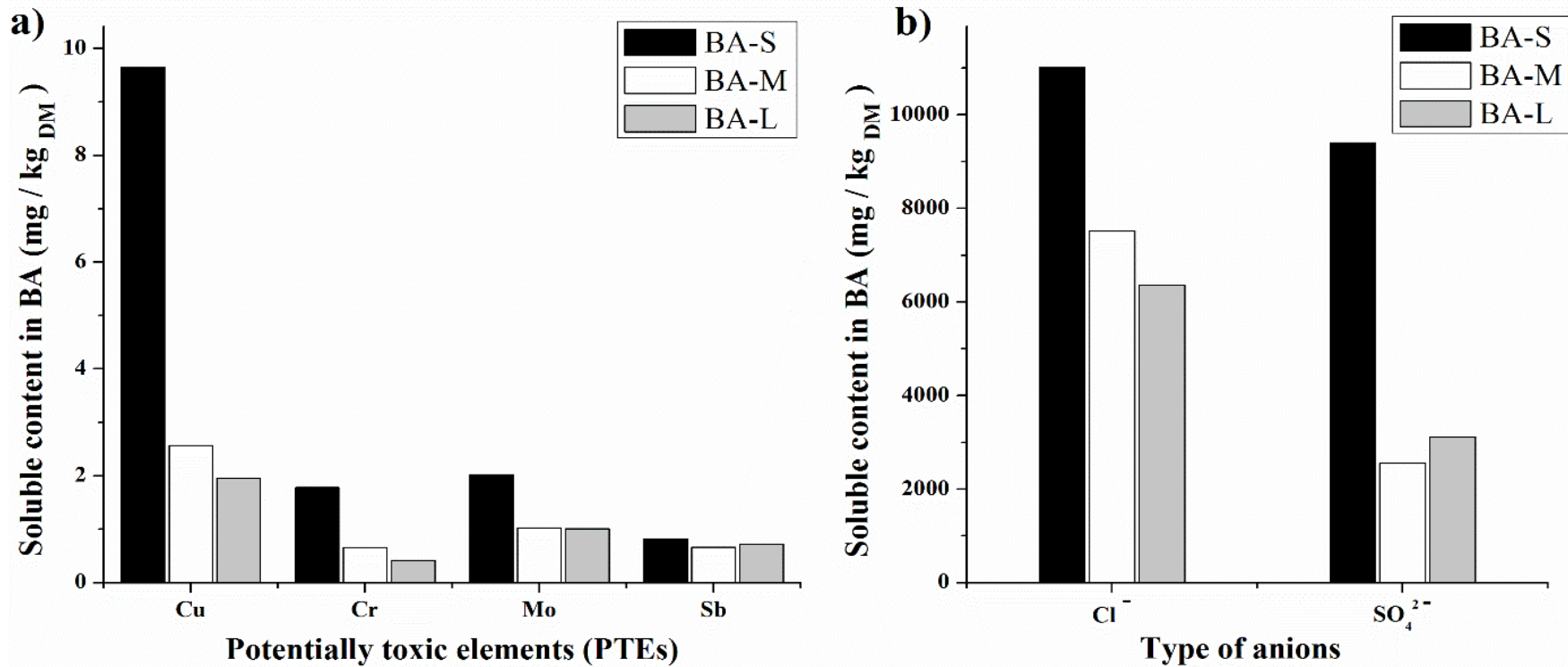
Alternative Aggregate

Environmental legislation:
Soil Quality Decree

Contaminant	Shaped building materials [mg/m ²]	Non-shaped building materials [mg/kg]
Sb	8.7	0.32
As	260	0.9
Ba	1500	22
Cd	3.8	0.04
Cr	120	0.63
Co	60	0.54
Cu	98	0.9
Hg	1.5	0.02
Pb	81	2.3
Mo	144	1
Ni	400	0.44
Se	4.8	0.15
Sn	50	0.4
V	320	1.8
Zn	800	4.5
Br ⁻	670	20
Cl ⁻	110000	616
F ⁻	2500	55
SO ₄ ²⁻	165000	1730

Alternative Aggregates

Size dependency of bottom ash leaching



Fine fractions (< 0.125mm) are the most contaminated

Alternative Aggregates

Washing



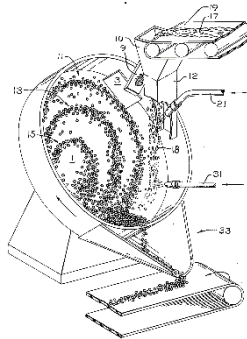
It reduces the level of contaminants by dissolution of soluble phases

Crushing
& milling



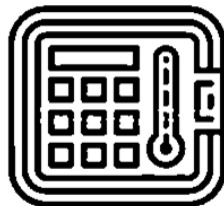
It provides an optimization of physical and chemical properties of the by-products

Pelletization



It creates an external core around by-products particles, fixing inside the harmful compounds

(Hydro)thermal
treatment



It provides different temperature and pressure conditions, increasing the immobilization within the crystals

Recycling of Concrete

Recycled Concrete Aggregates → Liberated original aggregates



Recycling of Concrete

Abrasion Comminution / Smart Crushing



Virgin aggregates



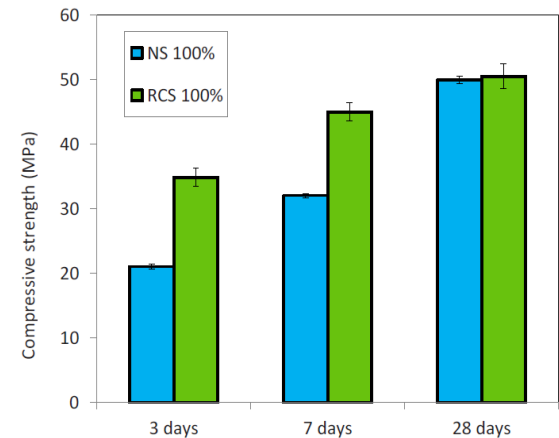
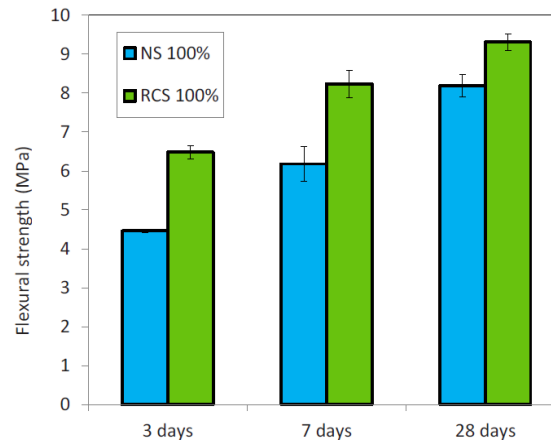
Regular crushed concrete



Liberated aggregates



Research Prototype

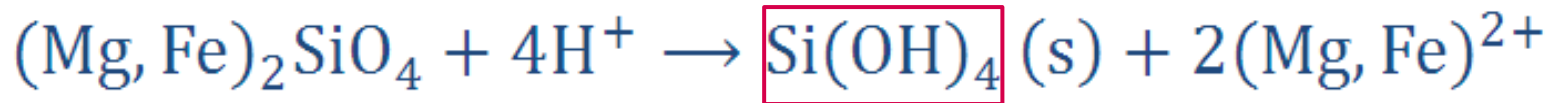


Flexural & compressive strength
(Florea et al, 2014)

Green additives

Nano-silica:

- current production processes with high energy requirements ($T > 1000\text{ }^{\circ}\text{C}$).
- olivine nano-silica $T < 100\text{ }^{\circ}\text{C}$



Olivine

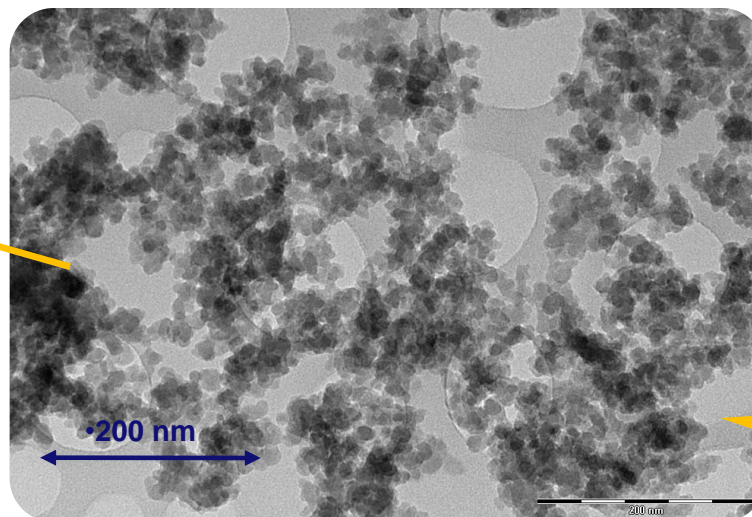
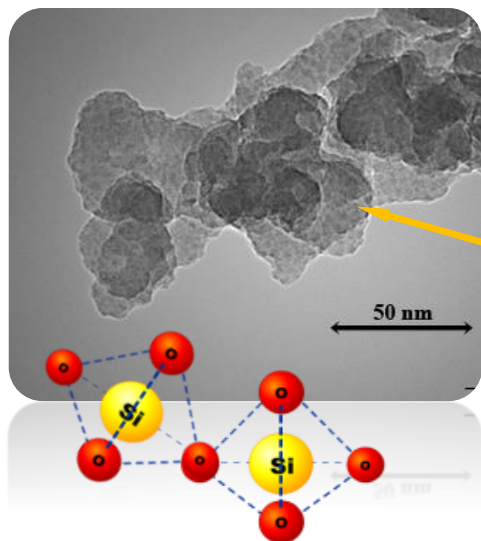


Acid



Nano-silica

Green additives



Min. 98.9% SiO_2

Amorphous

$\text{SSA}_{\text{BET}} = 200 - 400 \text{ m}^2/\text{g}$

$d_{\text{BET}} = 8 - 15 \text{ nm}$

Small silica particles (clustered) containing high amount of surface hydroxyl groups (Si-OH).

Green additives

- **Treatment Methodology**



- **Acid pretreatment**

- I. **Removal of undesirable constituents (e.g. iron oxide, calcium carbonate and trace metals)**
- II. **Reduction silicates**
- III. **Loosen the silica**
- IV. **Increase in surface area**

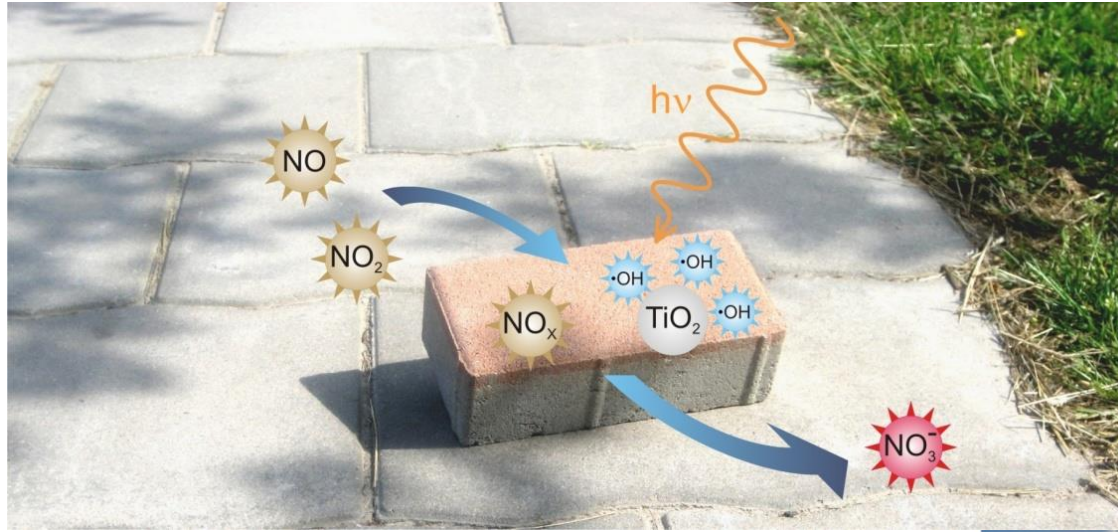
Green additives

Trace elements in water glass

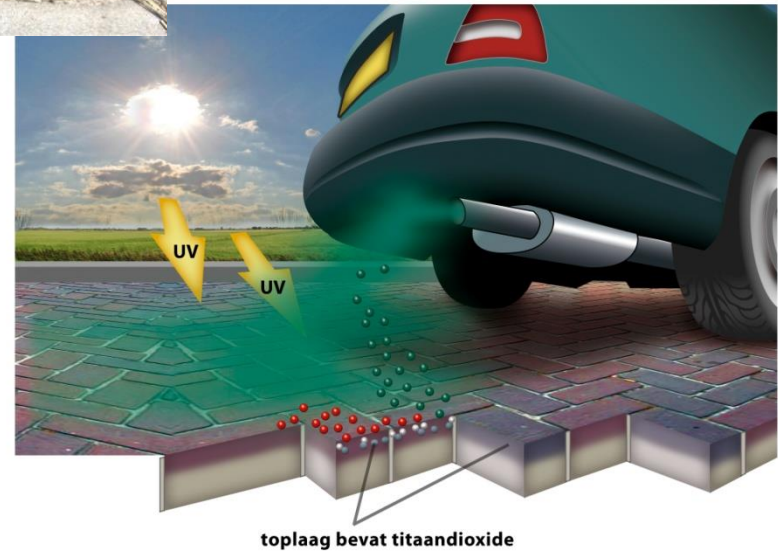
Element	Conc. (mg/L)
Fe	0.02
Cu	0.019
Mo	0.006
Ni	0.006
P	1.11
Pb	0.03
Sb	0.07
S	1
Sn	0.02
Zn	0.021

Modulus of water-glass
 $\text{SiO}_2/\text{Na}_2\text{O}$: 0.25

Functionalizing Concrete



Air purification/
Self cleaning

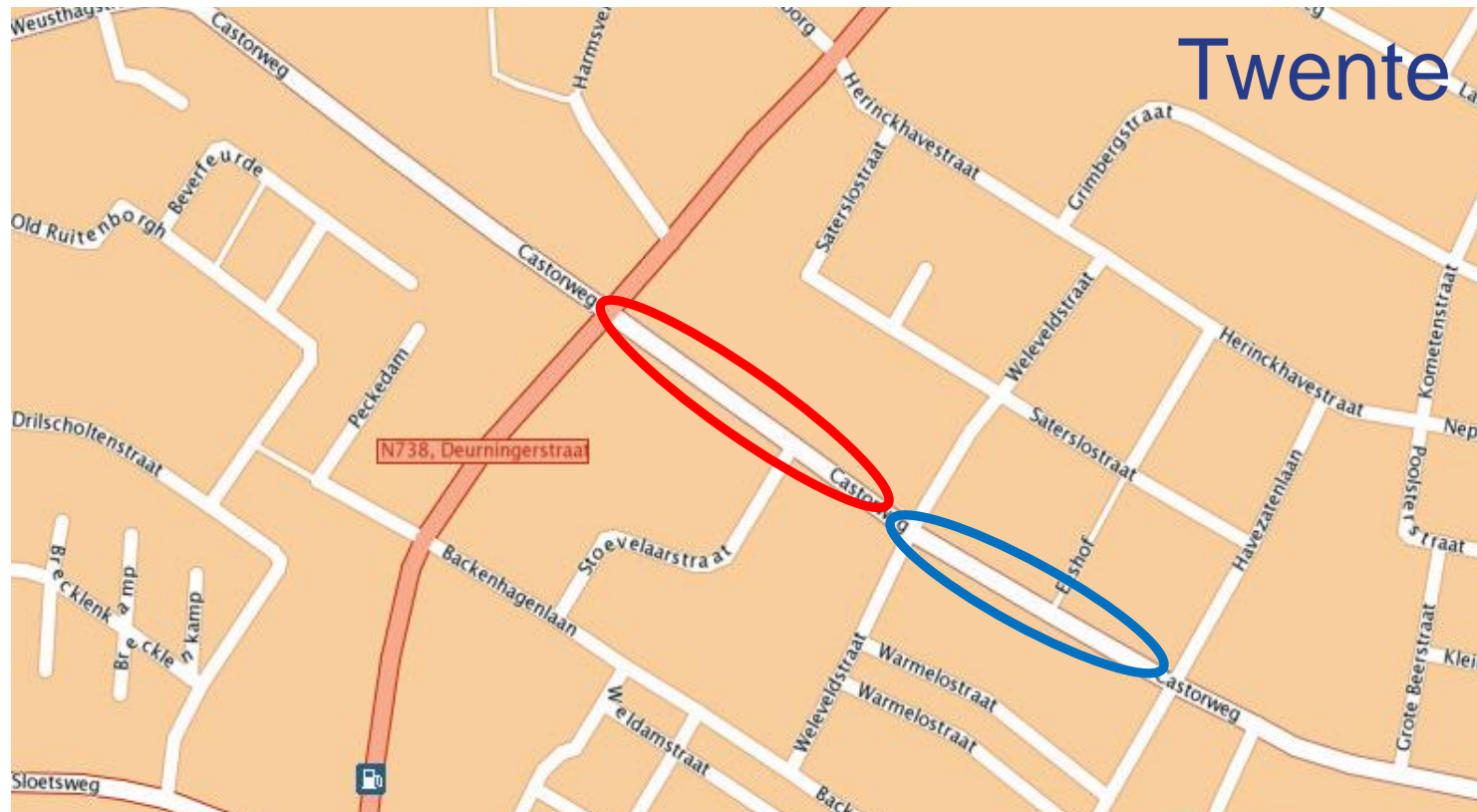


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Functionalizing Concrete



Real-scale application



- Modified street with photocatalytic pavement
- Unmodified or control street

Real-scale application

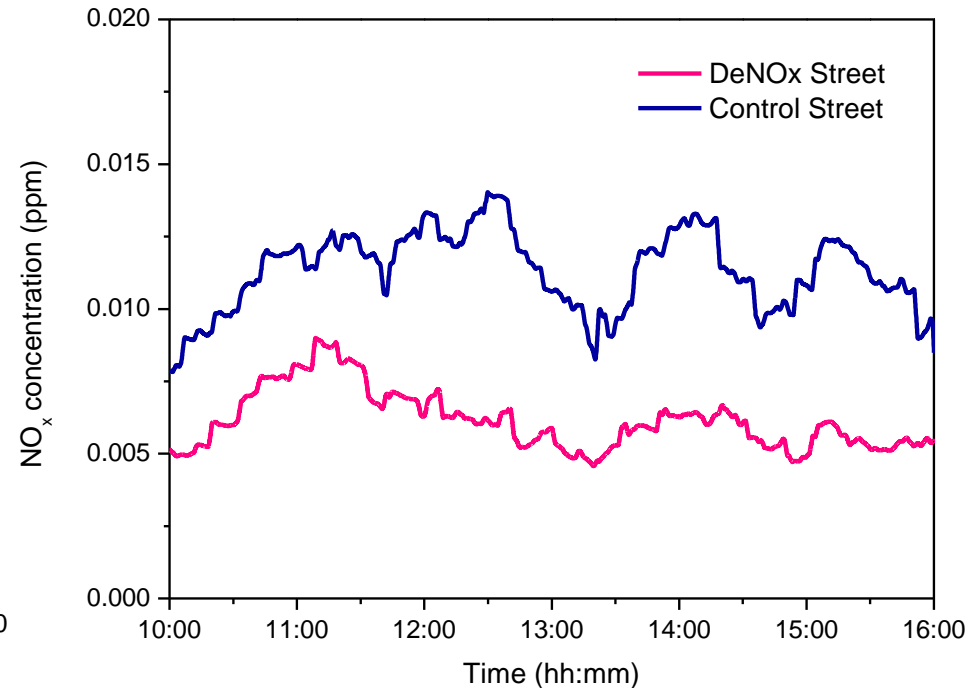
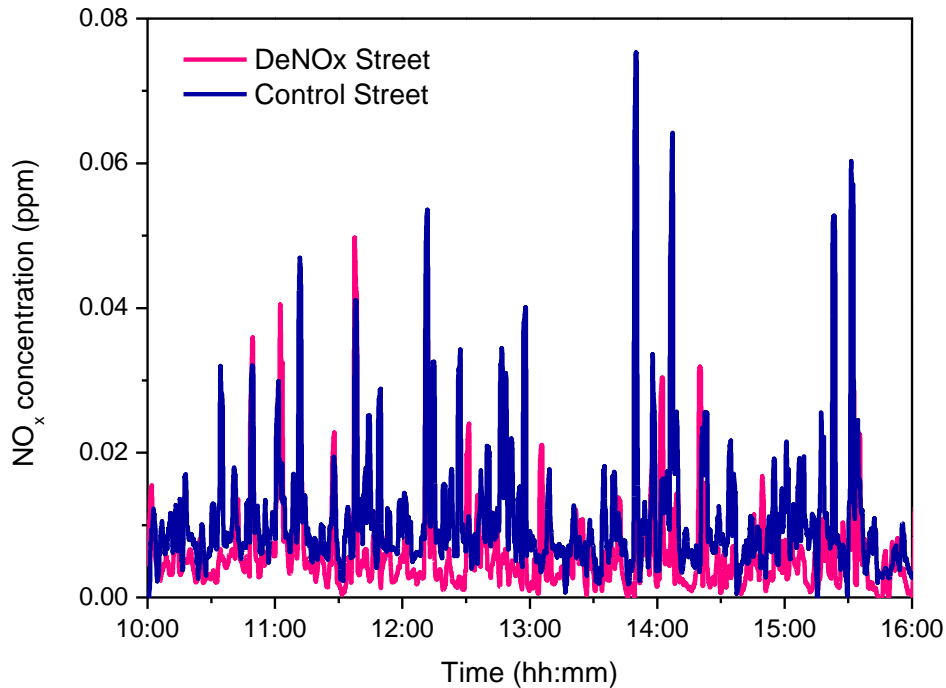


Before modification

After modification (Nov 2009)



Outdoor Measurement 03-06-2010



Average NO_x reduction: 45 %

Acknowledgments



SEVENTH FRAMEWORK
PROGRAMME
NMP
–
Nanosciences,
Nanotechnologies,
Materials and
New Production
Technologies



Part-financed by the
European Union



Rijkswaterstaat Directie Zeeland



Rijkswaterstaat
Ministerie van Verkeer en Waterstaat



Dr.Ir. Cornelis Lely Stichting



Agentschap NL
Ministerie van Economische Zaken



Thank you for your attention.

