Innovatieve betonmengsels: labo-piloot-implementatie

28/03/2025 – living labs event


Enabling low impact building materials,
shoulder to shoulder with our customers.
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Agenda

- **Waarom ecologische beton?**
- **Hoe pakken we dat aan, van labo naar piloot naar implementatie?**
  - **Koperslak: van reststroom naar 250 m^3 kwalitatieve beton**
  - **Nog meer voorbeelden**
- **Conclusie**

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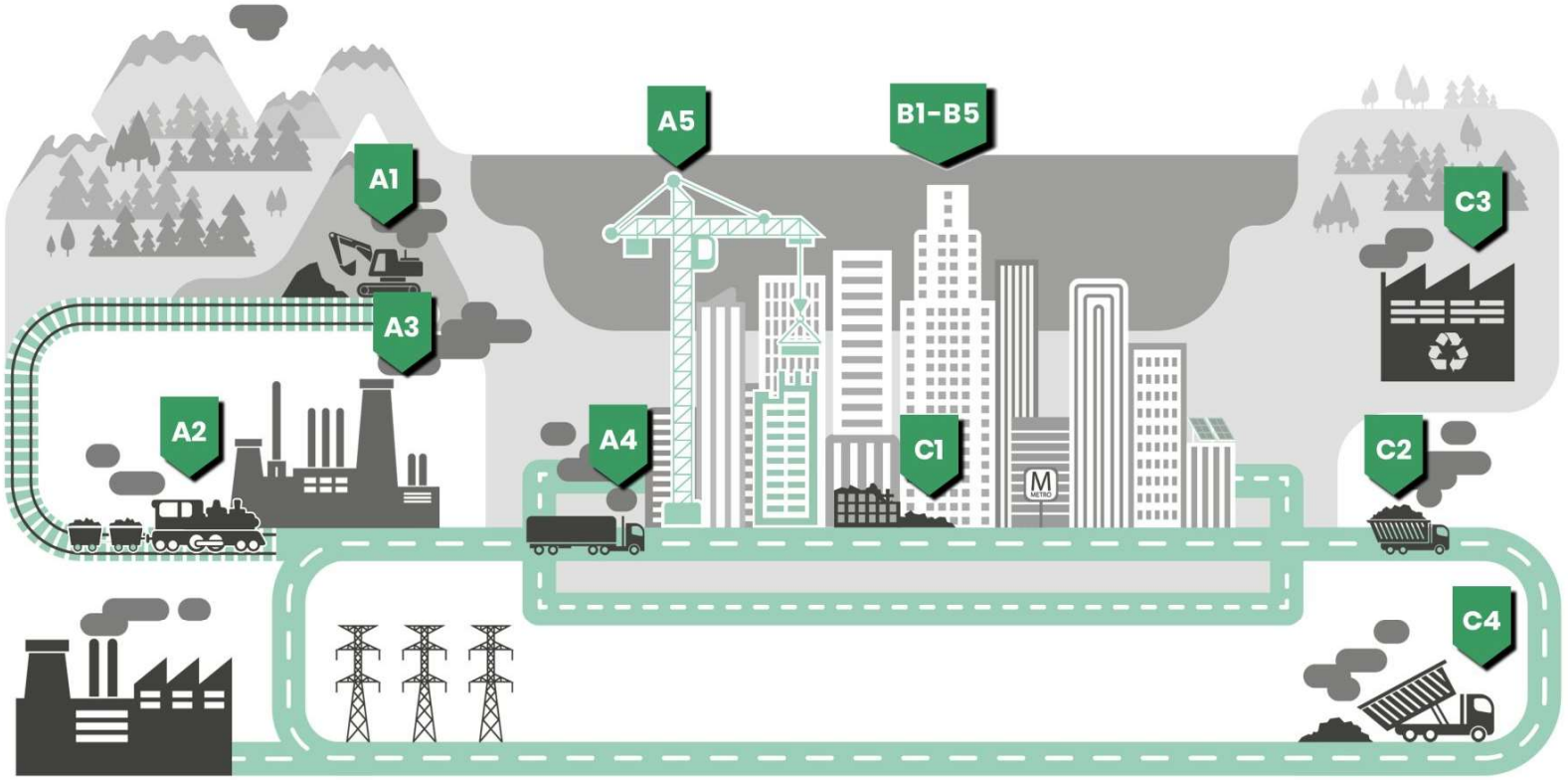
Sources of embodied carbon across the construction lifecycle



A1 - A3 Product stage

A1 Raw material extraction
A2 Transport to manufacturing site
A3 Manufacturing

A4 - A5 Construction stage

A4 Transport to construction site
A5 Installation / Assembly

B1-B5 Use stage

B1 Use
B2 Maintenance
B3 Repair
B4 Replacement
B5 Refurbishment

C1 - C4 End of life stage

C1 Deconstruction & demolition
C2 Transport
C3 Waste processing
C4 Disposal

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ECO-footprint: concrete element

ENVIRONMENTAL IMPACT DATA

CORE ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
GWP – total[1]	kg CO_2e	2,23E+02	1,82E+01	3,02E+00	2,44E+02	2,26E+01	1,22E+01	MND	MND	MND	MND	MND	MND	MND	7,98E+00	7,36E+00	1,29E+01	6,36E-01	3,04E+00
GWP – fossil	kg CO_2e	2,23E+02	1,82E+01	3,02E+00	2,44E+02	2,26E+01	1,22E+01	MND	MND	MND	MND	MND	MND	MND	7,98E+00	7,35E+00	1,29E+01	6,35E-01	2,84E+00
GWP – biogenic	kg CO_2e	2,38E-02	8,16E-03	1,06E-03	3,30E-02	8,75E-03	2,23E-03	MND	MND	MND	MND	MND	MND	MND	1,46E-03	2,84E-03	2,36E-03	4,13E-04	2,07E-01
GWP – LULUC	kg CO_2e	1,52E-02	1,35E-02	4,95E-04	2,92E-02	8,34E-03	1,21E-03	MND	MND	MND	MND	MND	MND	MND	7,94E-04	2,71E-03	1,28E-03	5,99E-04	-2,37E-03
Ozone depletion pot.	kg CFC_{11}e	8,45E-06	4,00E-06	5,20E-07	1,30E-05	5,20E-06	2,60E-06	MND	MND	MND	MND	MND	MND	MND	1,70E-06	1,69E-06	2,75E-06	2,57E-07	-3,19E-07
Acidification potential	mol H^+e	1,15E+00	9,96E-02	1,83E-02	1,27E+00	9,58E-02	1,27E-01	MND	MND	MND	MND	MND	MND	MND	8,29E-02	3,11E-02	1,34E-01	5,97E-03	-4,88E-02
EP-freshwater[2]	kg Pe	5,05E-03	1,62E-04	1,72E-05	5,23E-03	1,85E-04	4,04E-05	MND	MND	MND	MND	MND	MND	MND	2,64E-05	6,02E-05	4,27E-05	6,65E-06	-8,37E-05
EP-marine	kg Ne	4,03E-02	3,49E-02	7,49E-03	8,27E-02	2,85E-02	5,60E-02	MND	MND	MND	MND	MND	MND	MND	3,67E-02	9,25E-03	5,92E-02	2,07E-03	-2,81E-02
EP-terrestrial	mol Ne	3,13E+00	3,84E-01	8,19E-02	3,60E+00	3,14E-01	6,14E-01	MND	MND	MND	MND	MND	MND	MND	4,02E-01	1,02E-01	6,50E-01	2,27E-02	-4,28E-01
POCP ("smog")[3]	kg NMVOCe	7,34E-01	1,11E-01	2,30E-02	8,68E-01	1,00E-01	1,69E-01	MND	MND	MND	MND	MND	MND	MND	1,11E-01	3,26E-02	1,79E-01	6,61E-03	-8,47E-02
ADP-minerals & metals[4]	kg Sbe	1,02E-04	4,12E-05	1,51E-05	1,59E-04	5,30E-05	6,17E-06	MND	MND	MND	MND	MND	MND	MND	4,04E-06	1,72E-05	6,53E-06	1,46E-06	-6,44E-06
ADP-fossil resources	MJ	1,37E+03	2,64E+02	4,42E+01	1,68E+03	3,40E+02	1,64E+02	MND	MND	MND	MND	MND	MND	MND	1,07E+02	1,10E+02	1,73E+02	1,74E+01	5,45E+01
Water use[5]	m^3e depr.	1,81E+01	1,30E+00	2,14E-01	1,96E+01	1,52E+00	4,40E-01	MND	MND	MND	MND	MND	MND	MND	2,88E-01	4,94E-01	4,66E-01	5,52E-02	-1,49E+00

1) GWP = Global Warming Potential; 2) EP = Eutrophication potential. Required characterisation method and data are in kg P-eq. Multiply by 3,07 to get PO4e; 3) POCP = Photochemical ozone formation; 4) ADP = Abiotic depletion potential; 5) EN 15804+A2 disclaimer for Abiotic depletion and Water use and optional indicators except Particulate matter and Ionizing radiation, human health. The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.

Ecologische voetafdruk: grondstoffen

water

1
kg CO_2 / ton

aggregates

10
kg CO_2 / ton

SCM

30 - 100
kg CO_2 / ton

CEM I 52,5 R

1000
kg CO_2 / ton

steel

2000
kg CO_2 / ton

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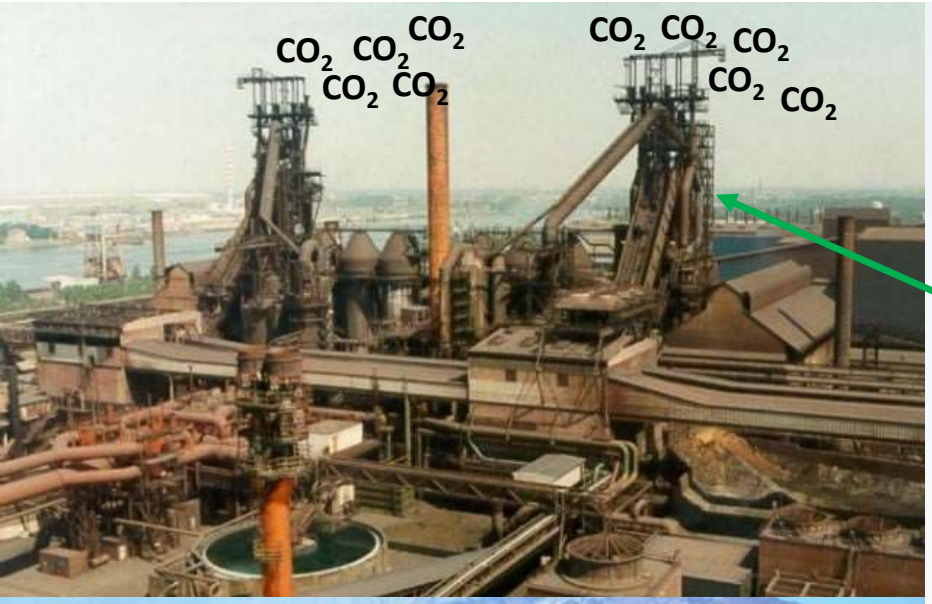

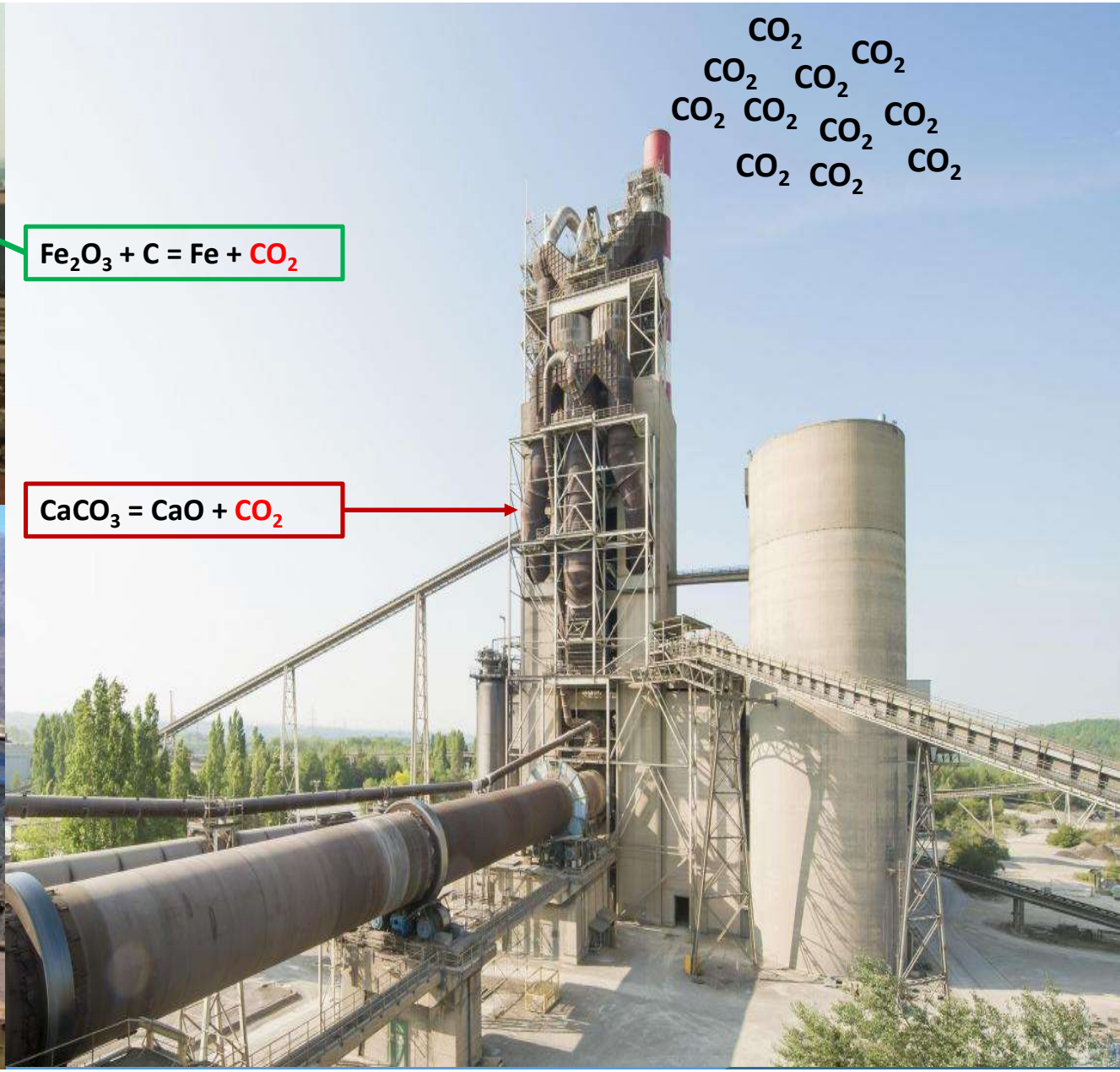

$Fe_2O_3 + C = Fe + CO_2$

$CaCO_3 = CaO + CO_2$

Concrete is the most used man-made material in the world

12.500.000.000 m^3 per year

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Most used man-made material in the world

12.500.000.000 m^3 per year

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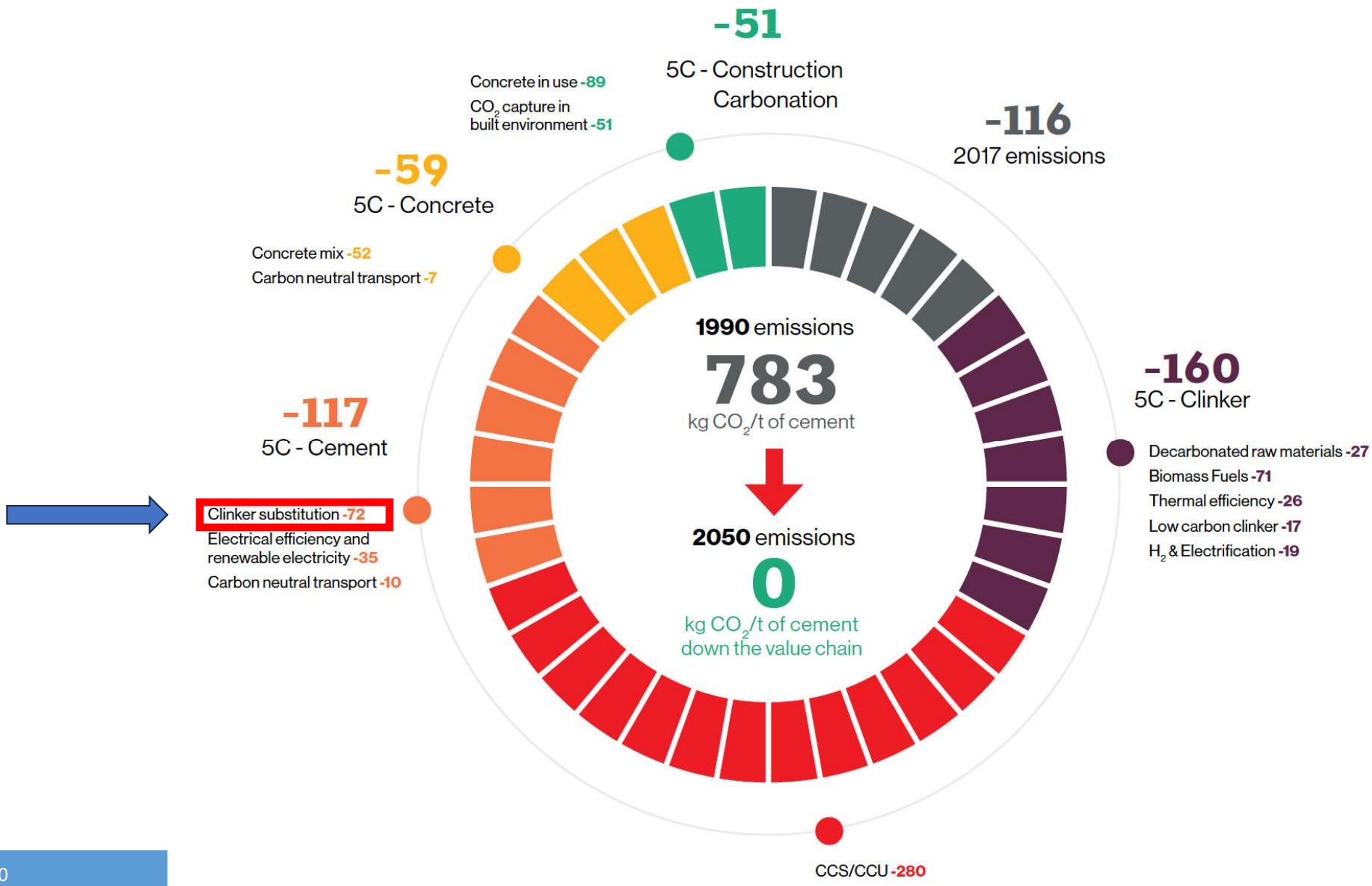

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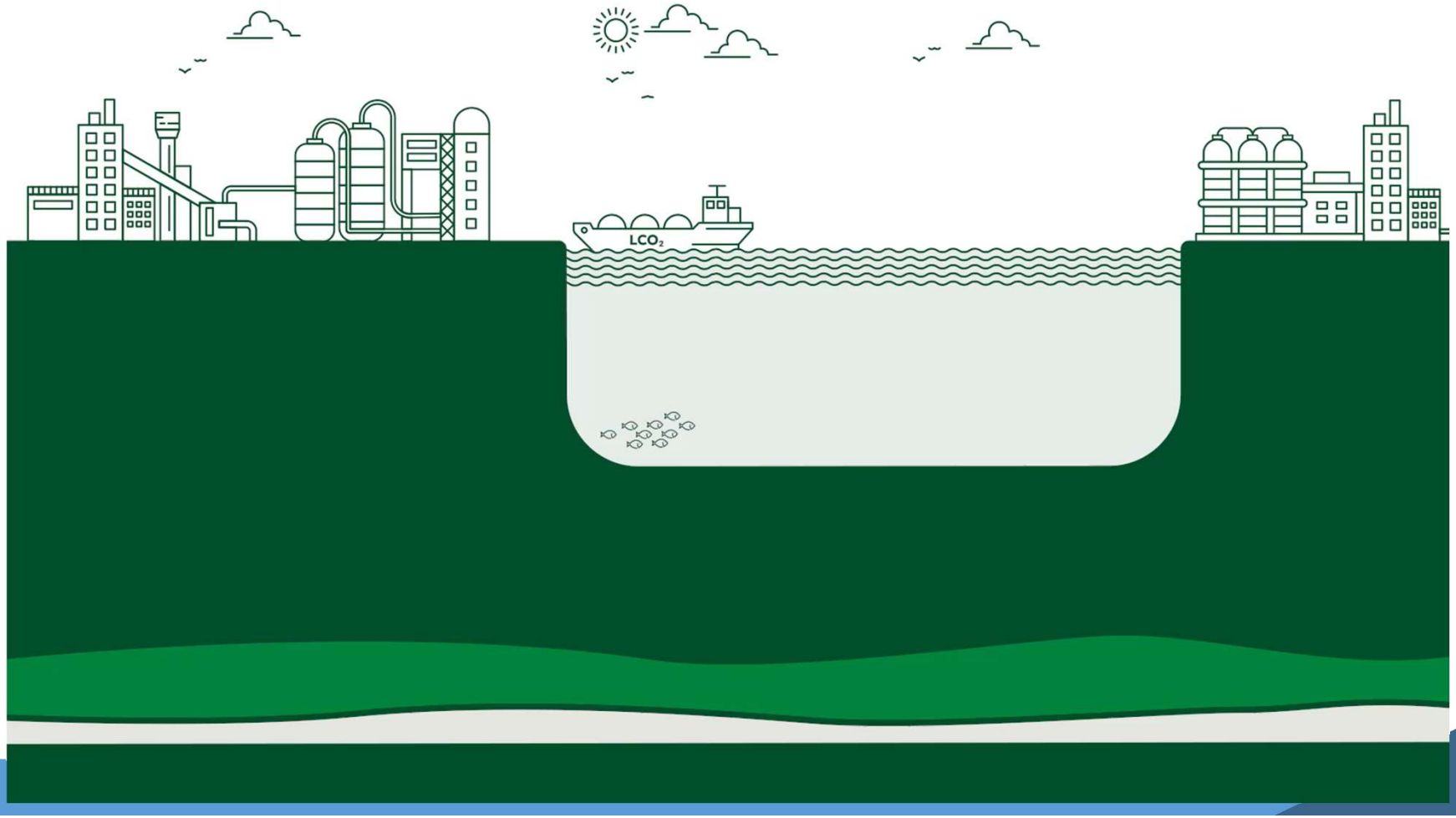
CO_2-free cement: carbon capture



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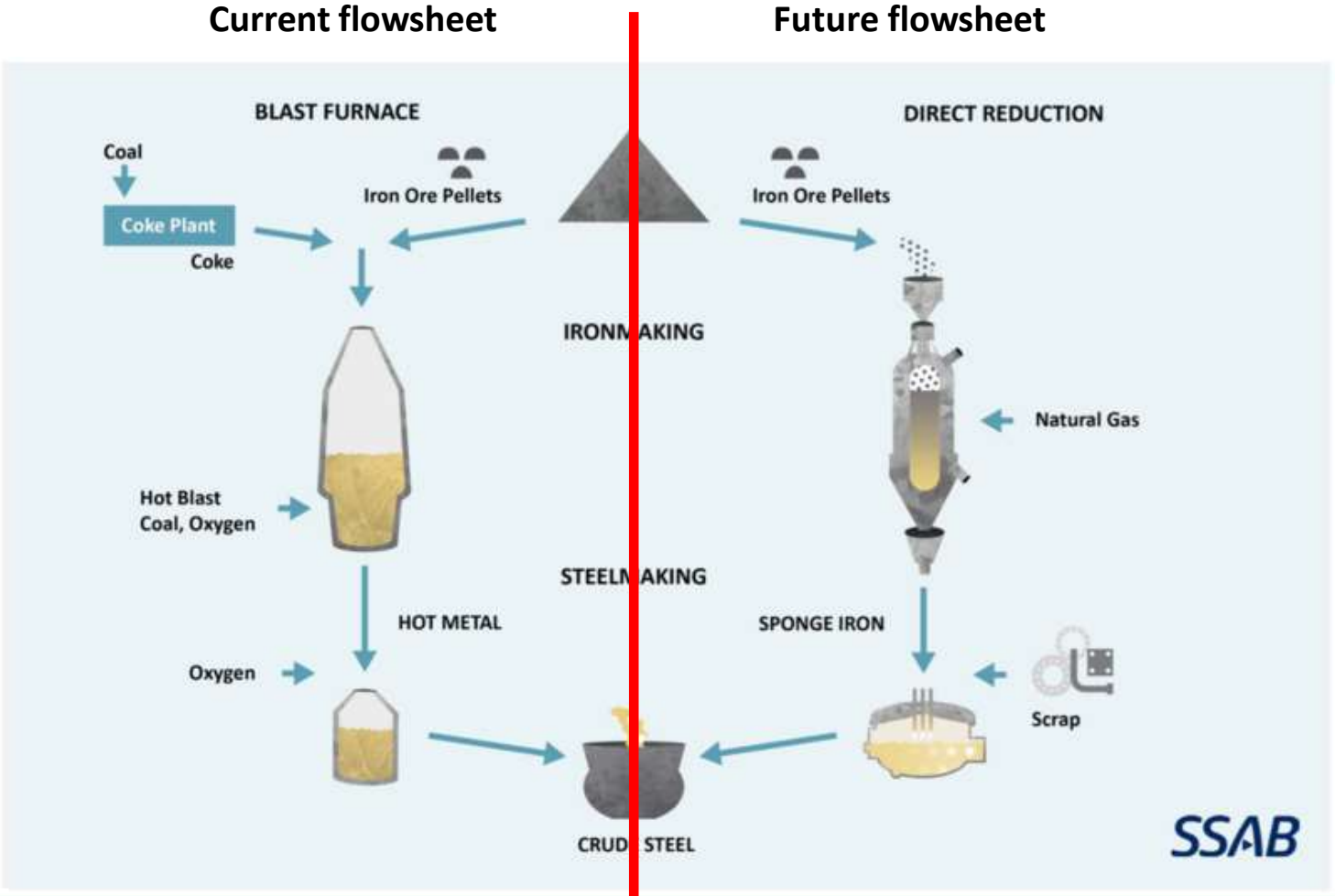
CO_2-free steel: electrical and with hydrogen

$Fe_2O_3 + C = Fe + CO_2$



$Fe_2O_3 + H_2 = Fe + H_2O$

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ECO-footprint: raw materials

water

1
kg CO_2 / ton

aggregates

10
kg CO_2 / ton

SCM

30 - 100
kg CO_2 / ton

CEM I 52,5 R

1000
kg CO_2 / ton

steel

2000
kg CO_2 / ton

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Residue waste piles

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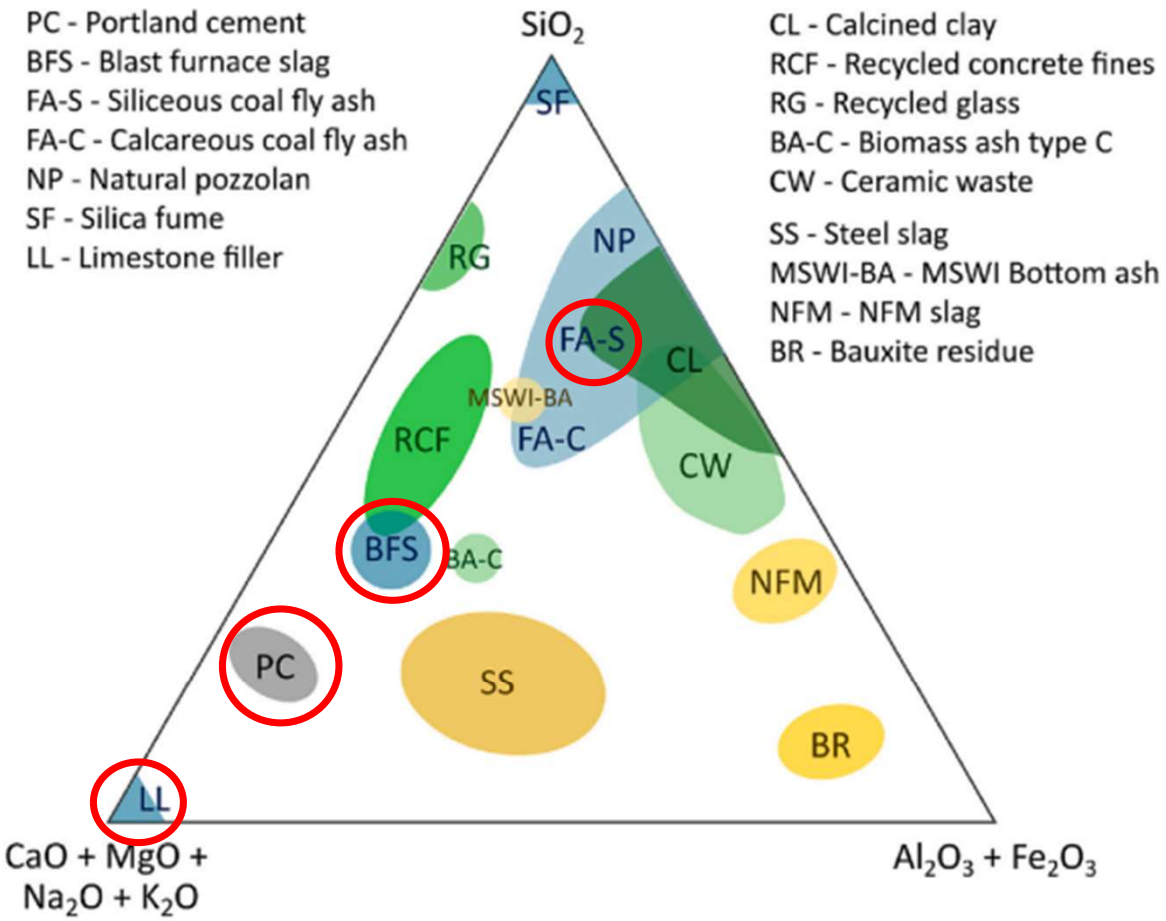

Fig. 1. The chemical composition ranges of common, emerging and future SCMs in a ternary diagram of (earth)alkalis–silica–alumina/iron oxide (in wt%). NFM stands for "non-ferrous metallurgical", MSWI for "municipal solid waste incineration". Commonly used SCMs and fillers are in green shades and emerging SCM sources are in yellow shades. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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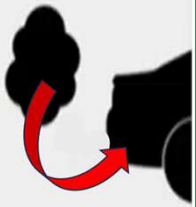
Binders vs. Auto's

	 CONVENTIONAL	 CNG	 PLUG-IN HYBRID	 ALL-ELECTRIC	 ALL-ELECTRIC	
EMISSIONS				 NO EMISSION	 NO EMISSION	
	Traditional Concrete (CEM I)	Conventional Concrete Technolgy	Hybrid binder technology	Alkali-silicate binder technology	Steel Slag binder technology	Carbon Capture and Usage

Labo – piloot - implementatie

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The story of the copperslag

Your engineering partner for low carbon concrete

1

Pre-treatment and analysis

Chemical analysis
Mineral analysis
Crushing/grinding
Sizing and seperation
Thermal processing

2

Binder development

Alkali activation
Cement replacement
Acid activation
Carbonatation
Mg-cement
Ceramics

3

Product development

3D-printing mortar
Acid resistant mortar
Floor screed
Ready-mix concrete
UHPC

4

Performance testing

Aggregate testing
Workability
Strength testing
Freeze-Thaw
Carbonatation

5

Scale - up

Industrial implementation
LCA
Waste legislation
Building legislation

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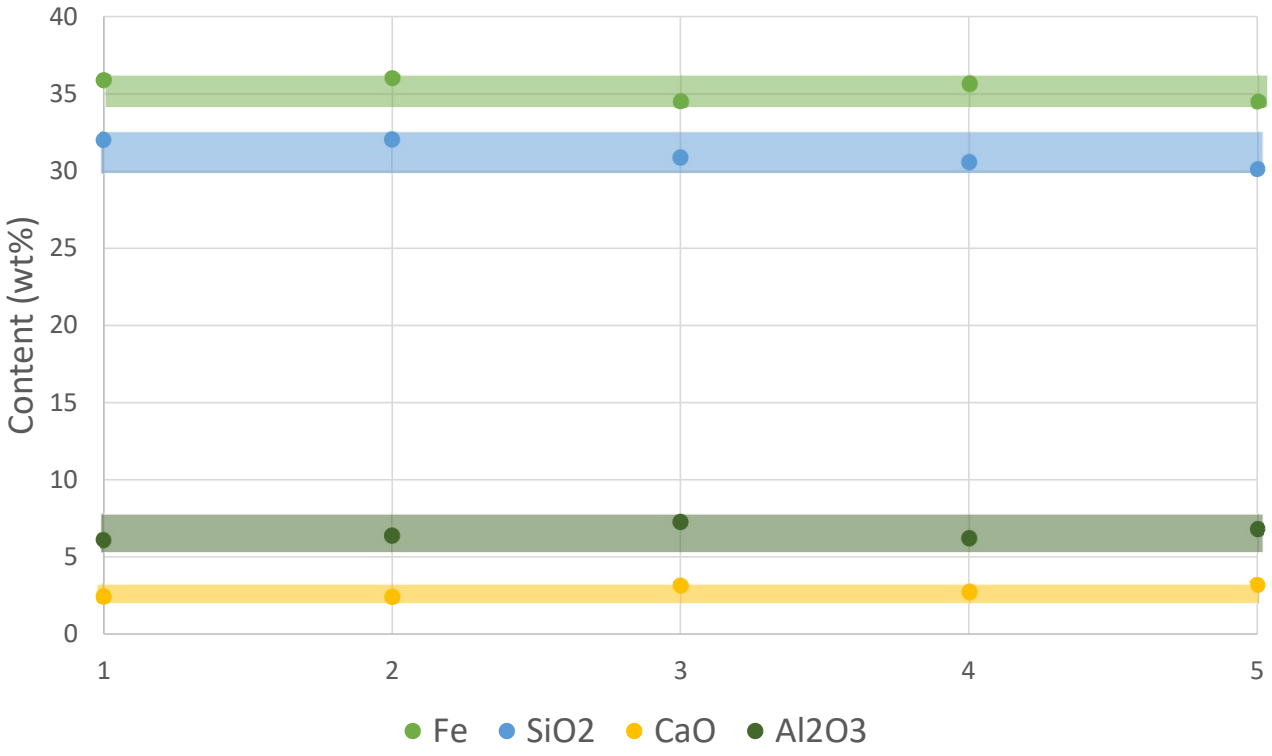
Copper slag

Monitoring gedurende 3 maanden:

- Chemical variabiliteit
- Mineralogie
- Fe-oxidatie staat



	Koranel	Blast Furnace Slag	Fly Ash
FeO	45,3%	0,6%	5,6%
SiO_2	32,2%	33,9%	54,3%
CaO	3,8%	46,5%	1,9%
Al_2O_3	7,7%	10,3%	28,2%
MgO	1,3%	6,9%	1,6%

	Koranel	Blast Furnace Slag	Fly Ash
Amorphous	94 ± 3 %	95%	80%
FeO/Fe_2O_3	97 ± 2%	/	/

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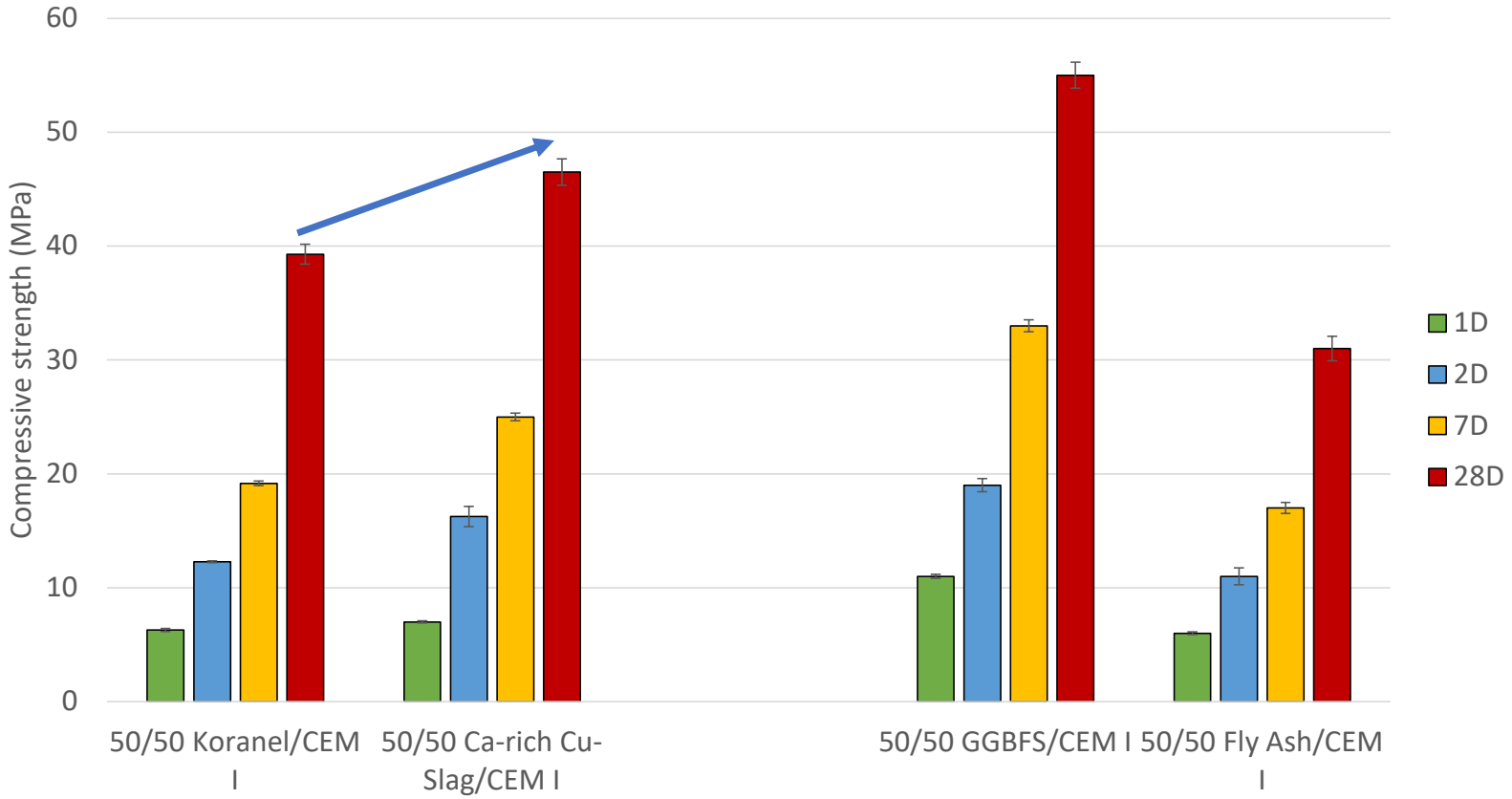
Water granulation of slag + adaptation chemistry

Comparison on mortar level according to EN 196-1:

- 50 wt% replacement of CEM I 52,5R by copper slag, Fly ash and GGBFS



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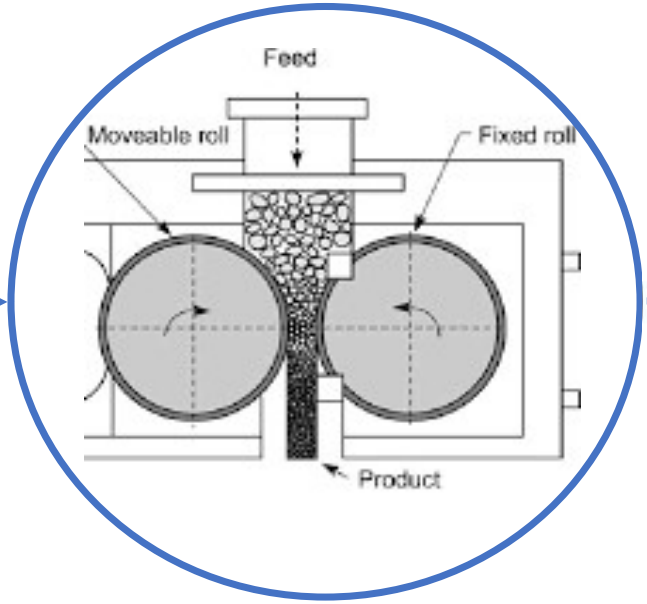
Grindability?

Water gegranuleerde slak

High pressure roller mill
Vertical roller mill
Ball mill



Ground Granulated
Copper Slag

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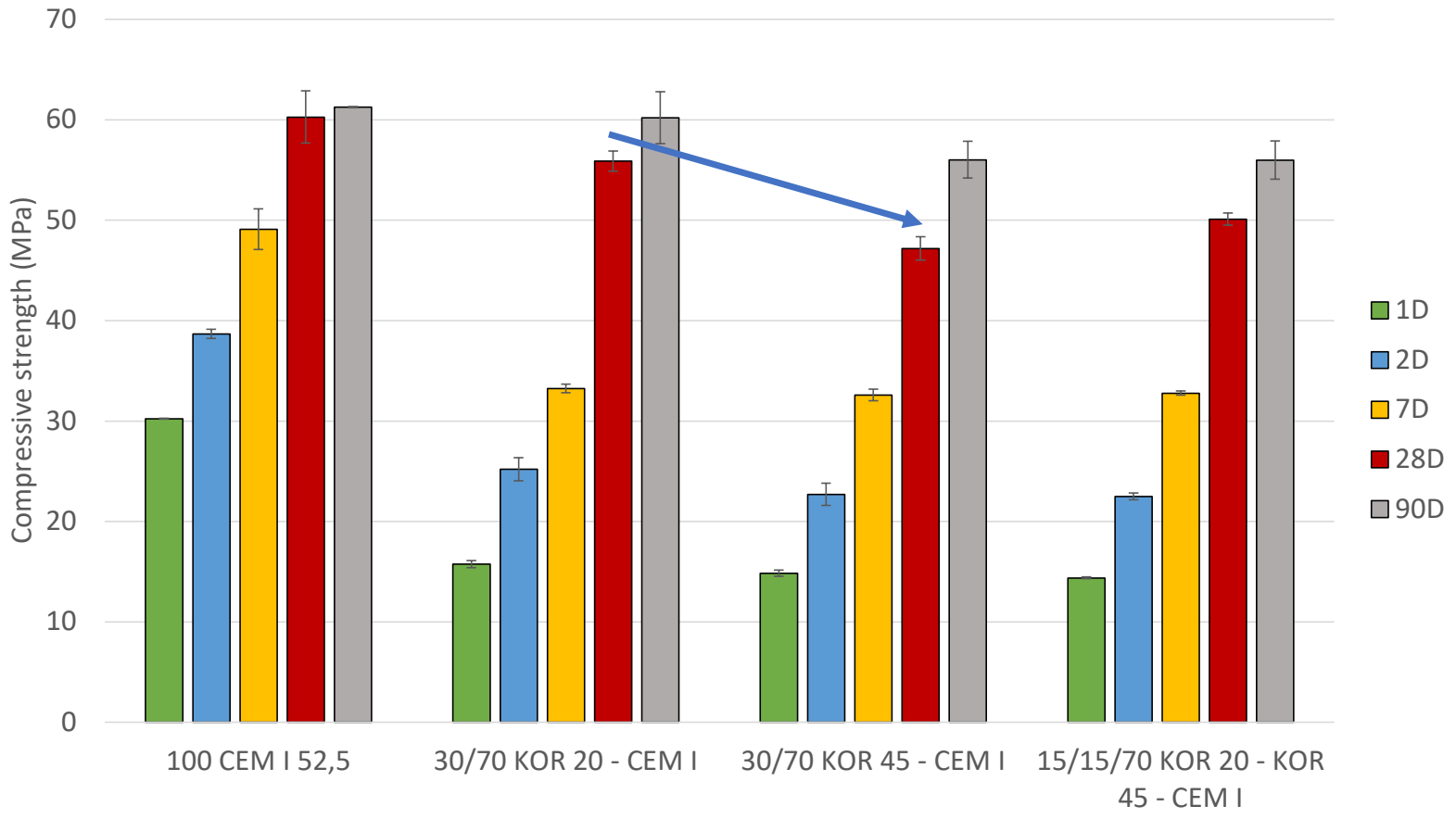
Effect of fineness: 30 wt% cement replacement



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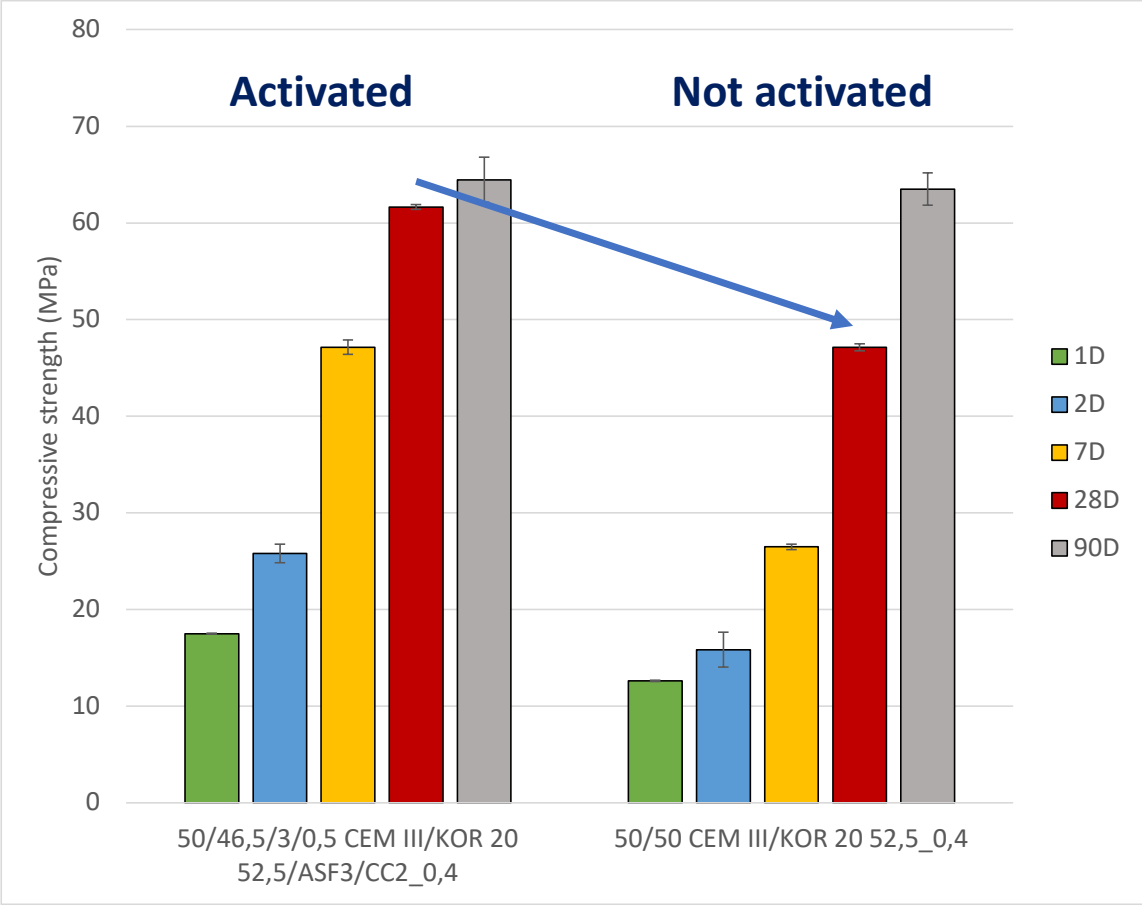
Effect of activation



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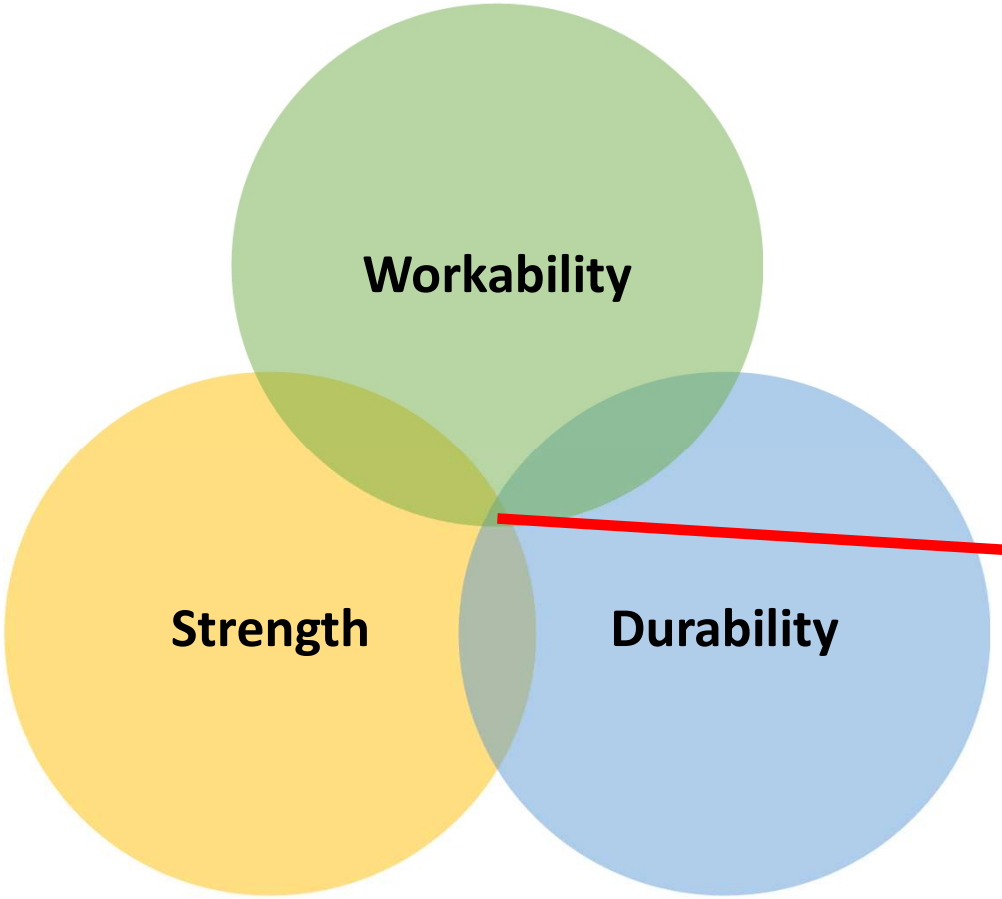
Holy trinity of concrete theology



Good concrete is here

*credits to Geert De Schutter

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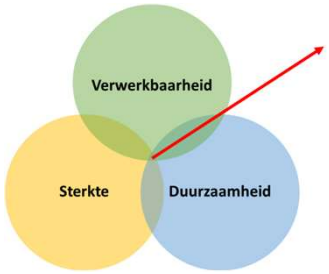
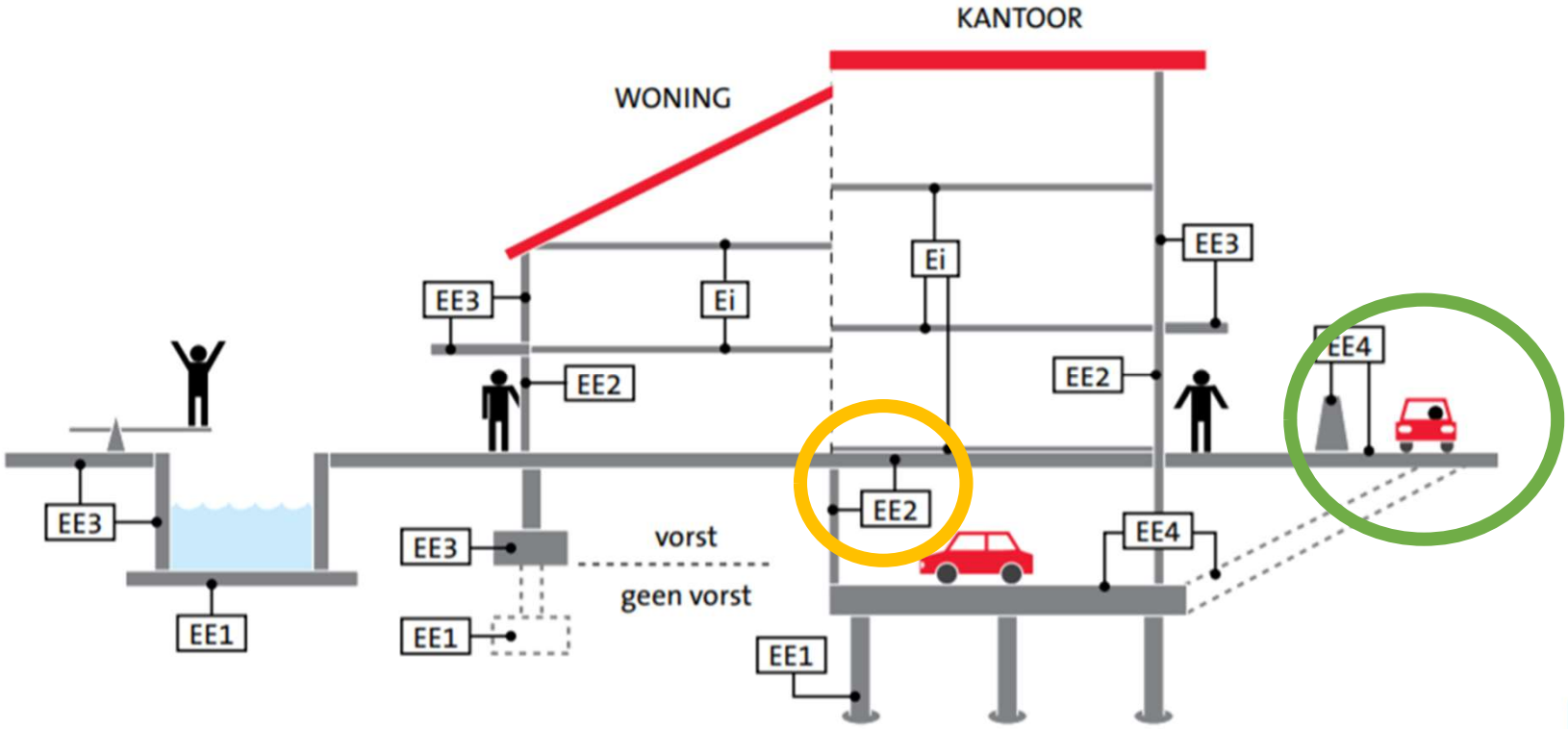


Test	standard	status	
Slump stability	EN 12350-2	Done	Fresh properties
Fresh density	EN 12350-6	Done	
Air content	EN 12350-7	Done	
Compressive strength	EN 12390-3	Done	Mechanical properties
Flexural strength	EN 12390-5	Done	
Splitting tensile strength	EN 12390-6	Done	
Elastic modulus	EN 12390-13	Done	
Chloride Migration	NT Build 492	Done	Durability properties
Carbonation	EN 12390-12	Done	
Water absorption		Done	
Freeze and thaw - salt	EN 12390-9	Done	
Reinforcement corrosion		Ongoing	
Creep and shrinkage	EN 12390-17	Ongoing	Structural Properties
Pull out (steel rebars)	EN 10080	Done	
Flexural strength - slab	Labo Magnel	Done	
Shear capacity - slab	Labo Magnel	Done	

Environmental classes

- Concrete composition based on requirements needed in certain environment: Ei< EE1 < **EE2** < EE3 < **EE4**
- EE2 and EE3 represent the largest part of concrete produced in Belgium



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Slump class

	Kg/m³ binder	w/b	SP (l)	Slump (mm)
(1) 50% CEM III/A 52,5 + 47,5% **KOR20** + 2,5 % PC 95	400	0,42	2	220
(2) 50% CEM III/A 52,5 + 47,5% **KOR45** + 2,5 % PC 95	400	0,42	2	215

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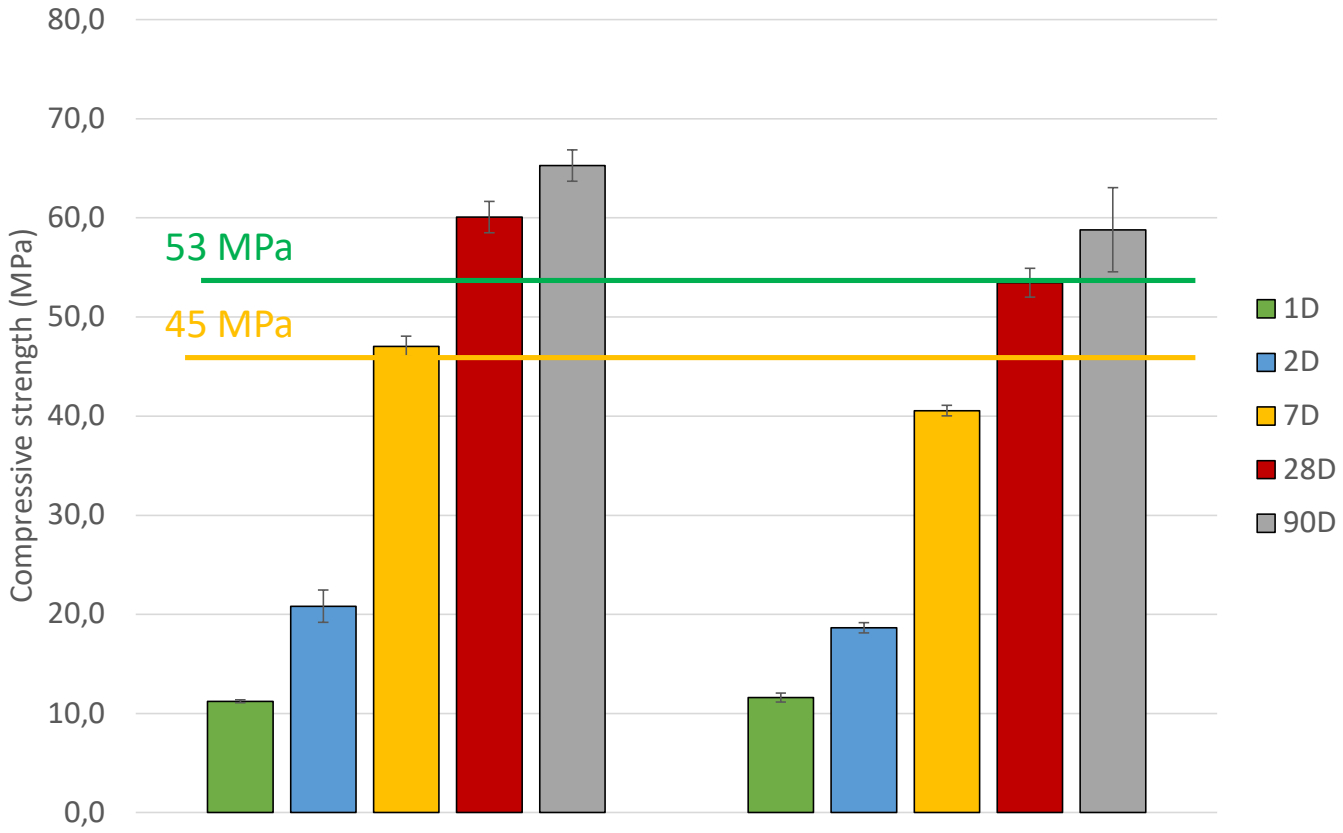
Good strength development



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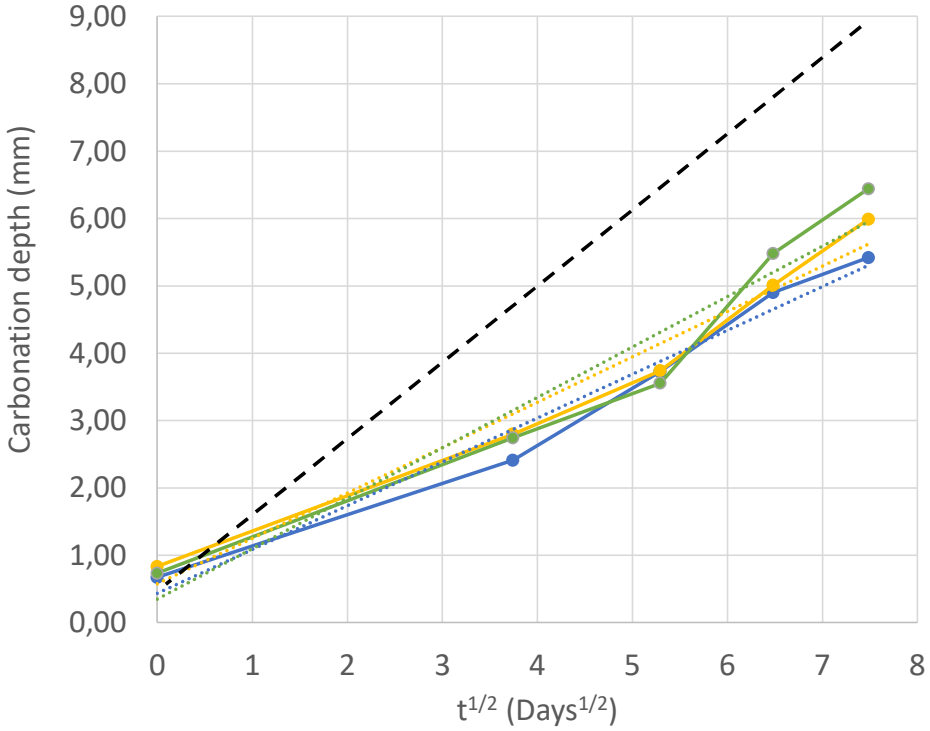
Carbonatation



CEM III/A ref EE2

Hybride KOR 45

Hybride KOR 20

CEM III/B ref EE2

- Hybride mengsels hebben gelijkaardige weerstand tegen carbonatatie als CEM III/A

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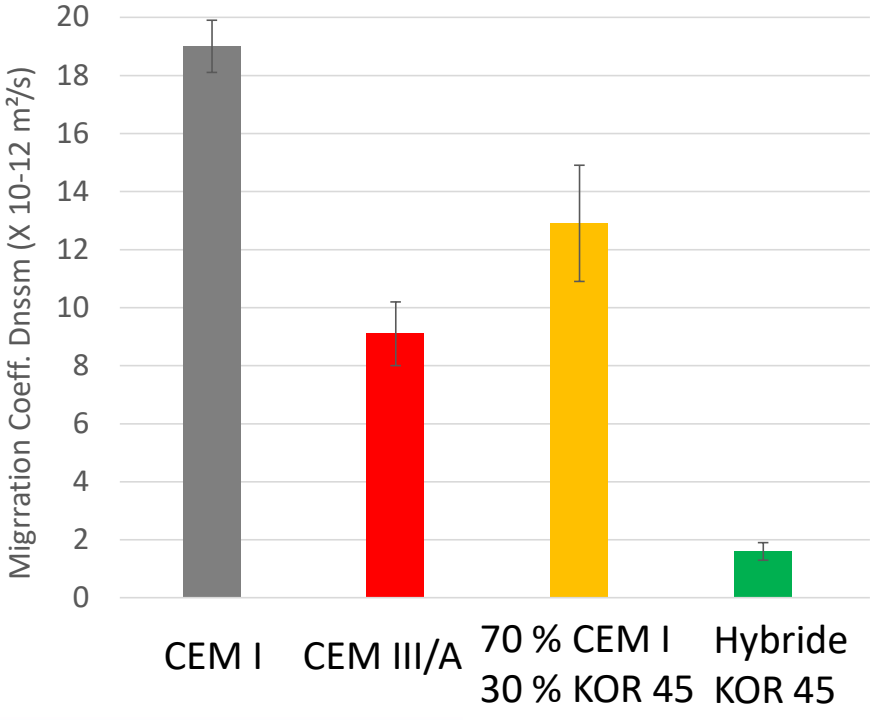
Chloride migration

- Evaluation of resistance to Cl-migration (NT-Build 492):
- Hybride mengsels hebben lagere chloride migratie coëfficient



$$D_{nssm} = \frac{RT}{zFE} \cdot \frac{x_d - \alpha\sqrt{x_d}}{t}$$

where:

$$E = \frac{U - 2}{L}$$

$$\alpha = 2\sqrt{\frac{RT}{zFE}} \cdot \mathrm{erf}^{-1}\left(1 - \frac{2c_d}{c_0}\right)$$

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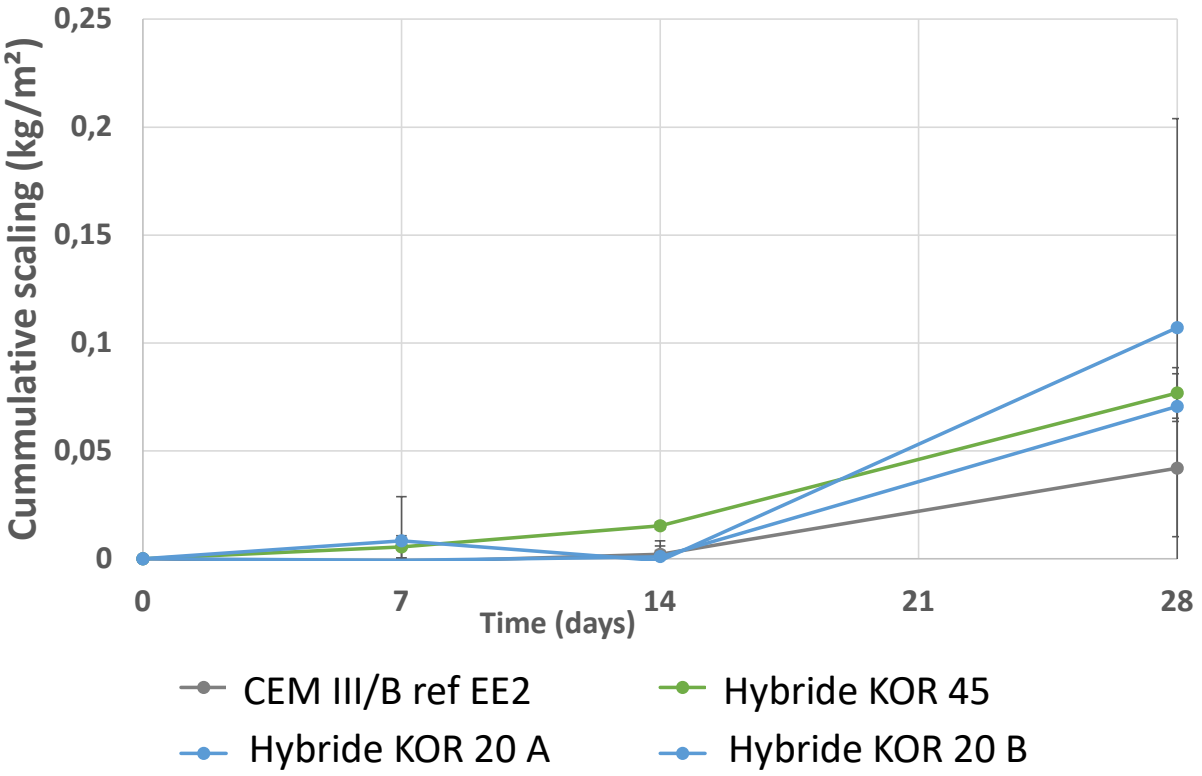
Freeze thaw without salts:



- Geen criterium voor EE2
- Alle stalen voldoen aan eis voor EE3

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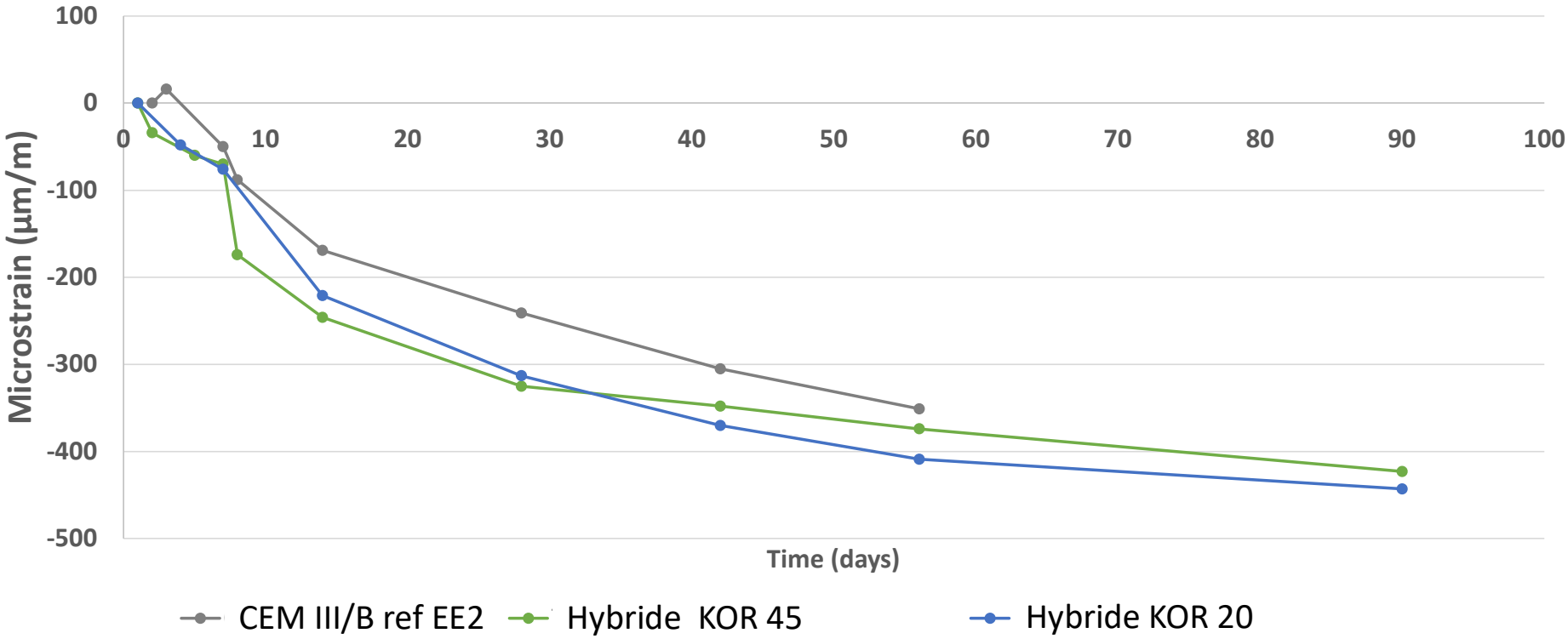
Shrinkage:



- Beton krimp EE2 moet lager zijn dan 570 µm/m op 90 D

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Field testing

J. JANSSENS & ZONEN NV

Field testing

Field testing

Validation durability

Validatie van versnelde carbonatie test

- Live-monitoring van natuurlijke carbonatie
- 10 mm & 20 mm dekking om wapeningscorrosie te onderzoeken

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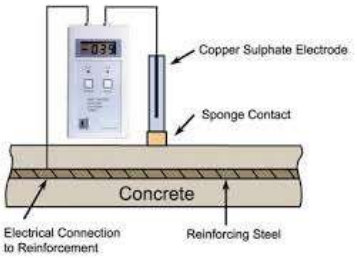
Validation durability

- Live-monitoring van Chloride migratie



1 day wet / 6 days dry cycle with 3% NaCl

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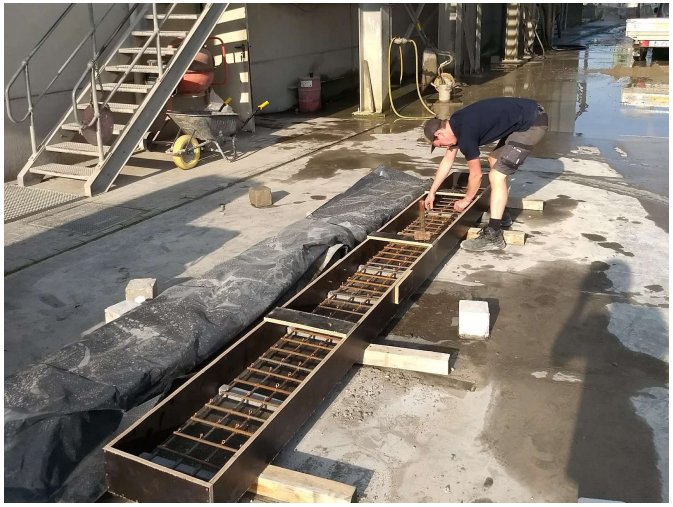
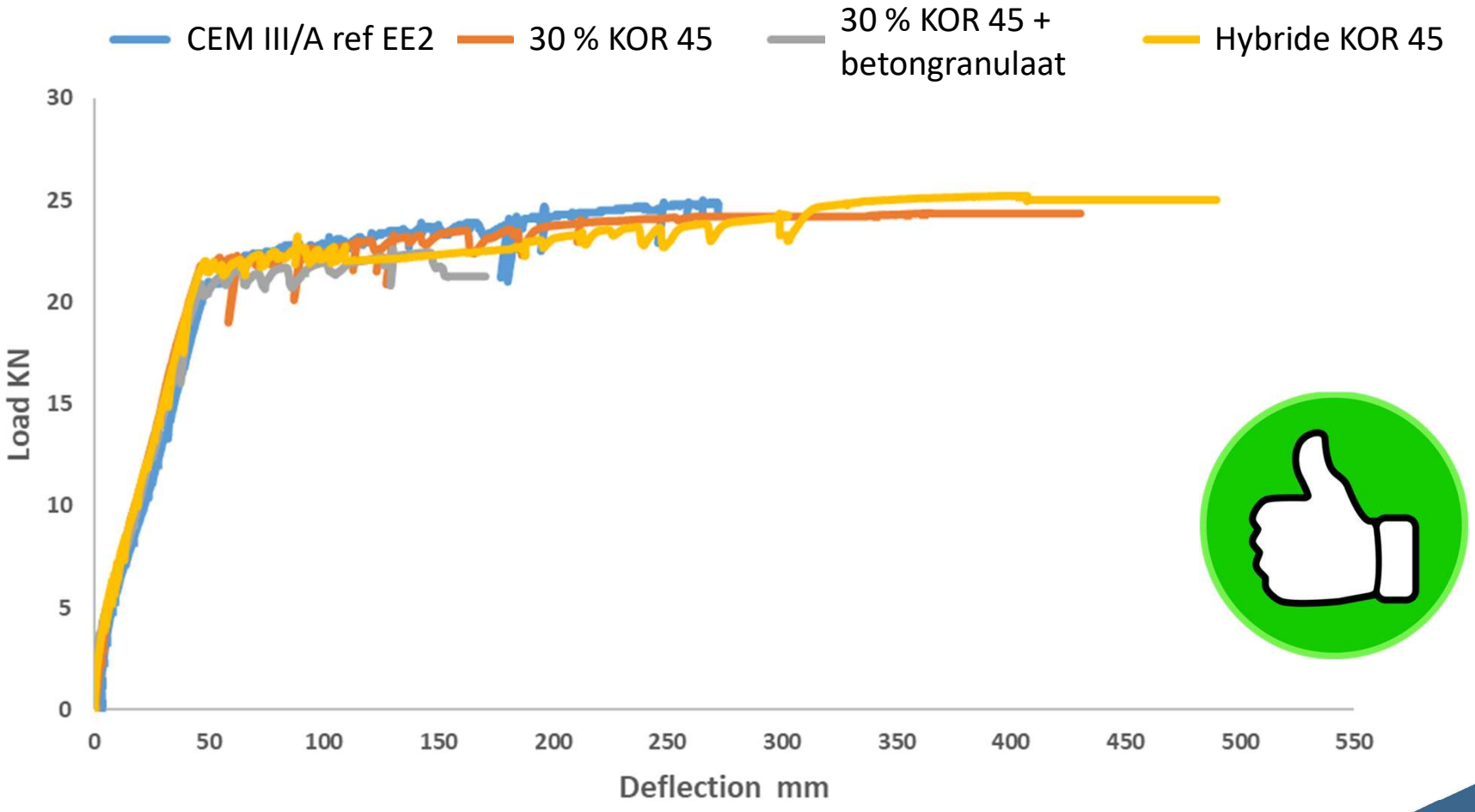
Structural properties

- Structurele eigenschappen worden getest op gewapende balken van 4,3 meter lang
- Verplaatsing en kracht worden gemeten en vergeleken met de berekeningen
- Design compliance: zijn de modellen van de EUROCODE 2 valide?



Structural properties

Structural properties



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The real deal!

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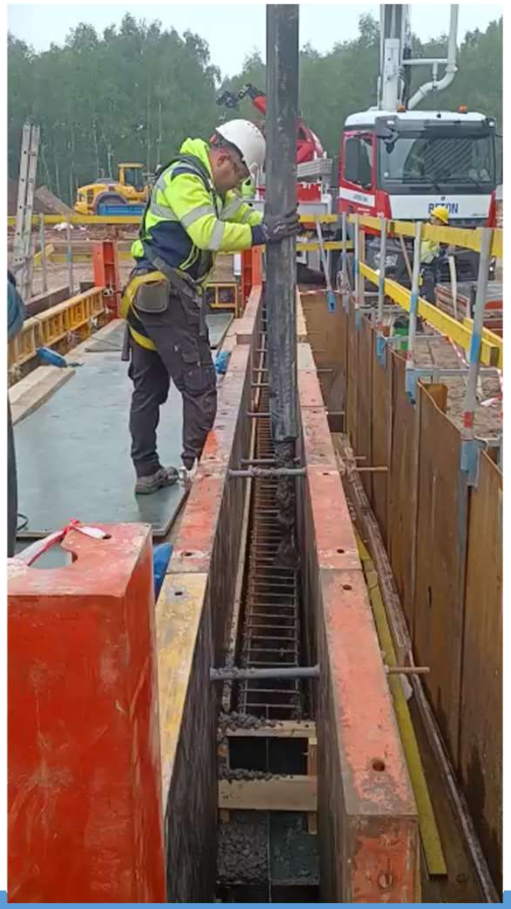
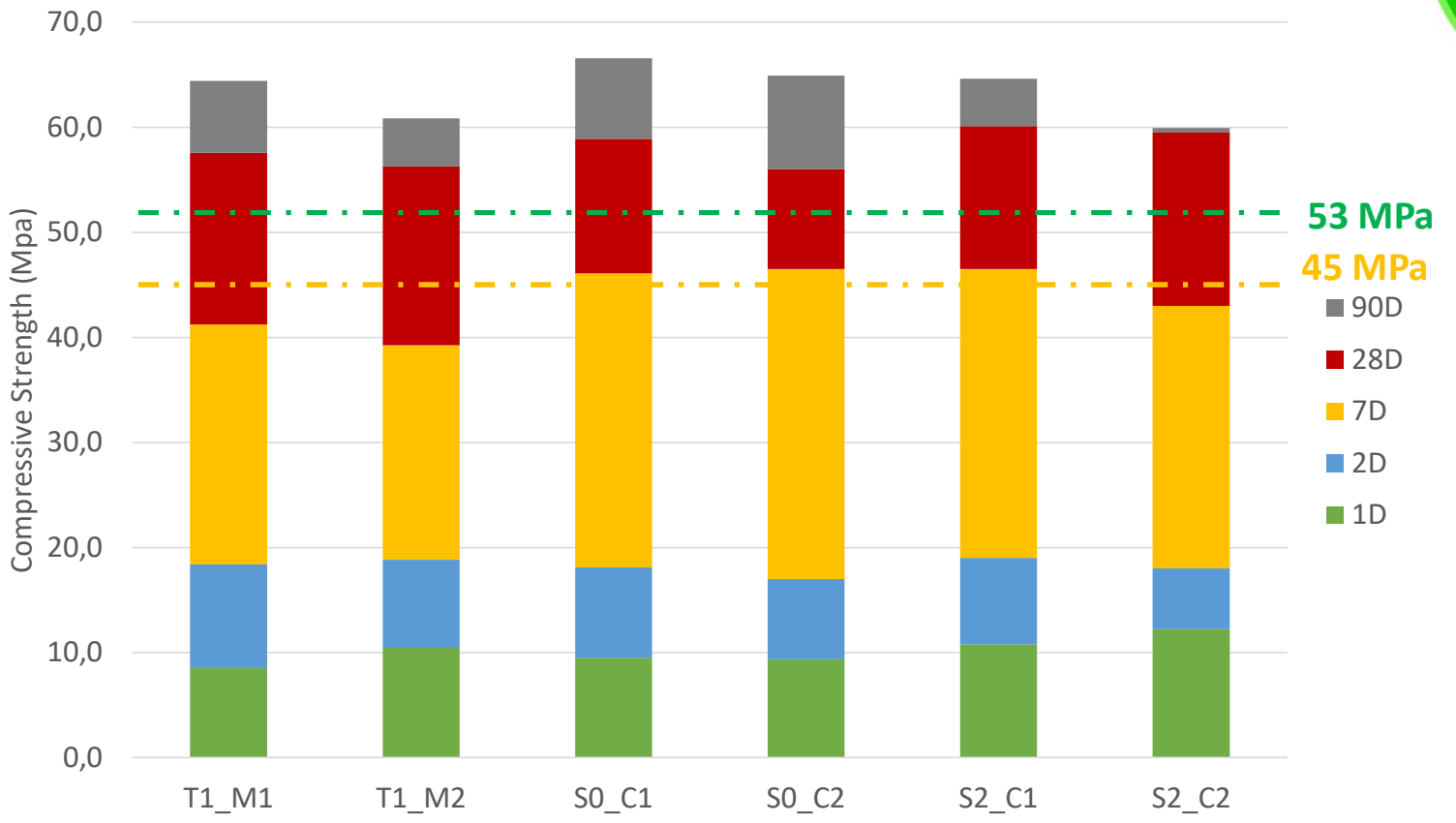
Pumpability



Beautiful

Statistics per truck



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RMX based on copperslag for floors

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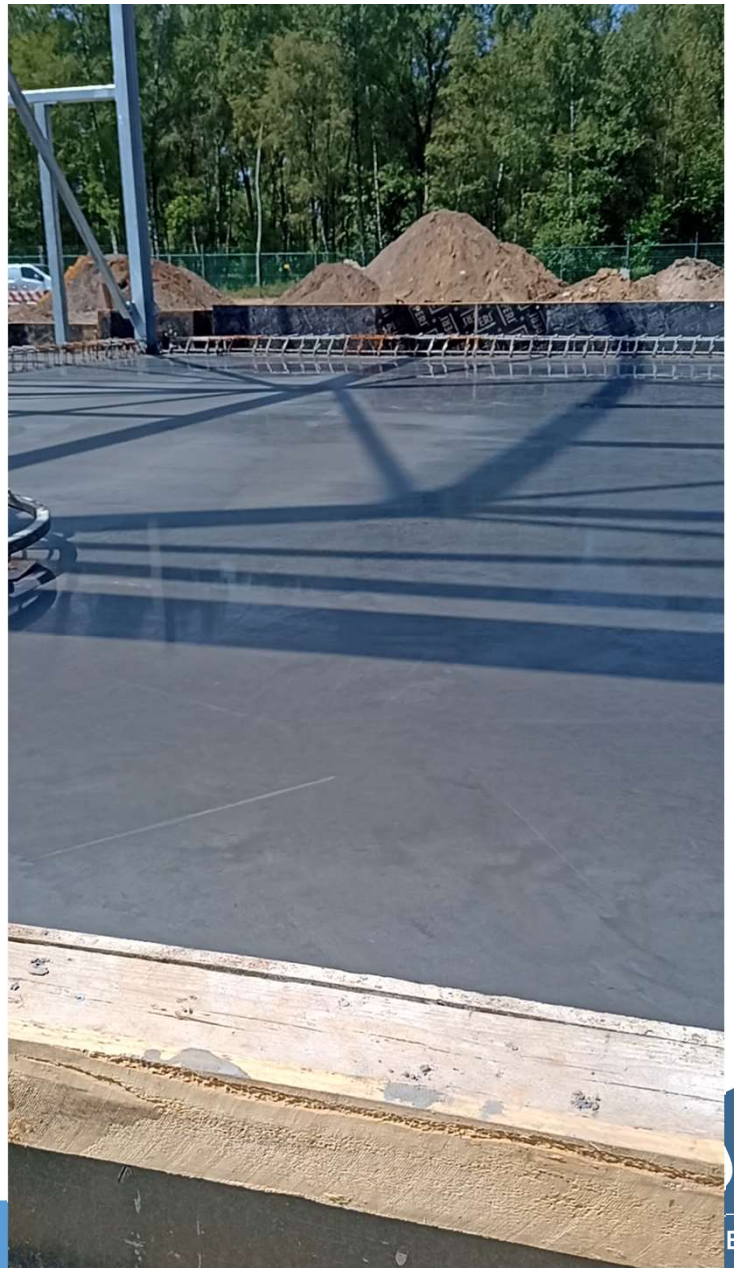
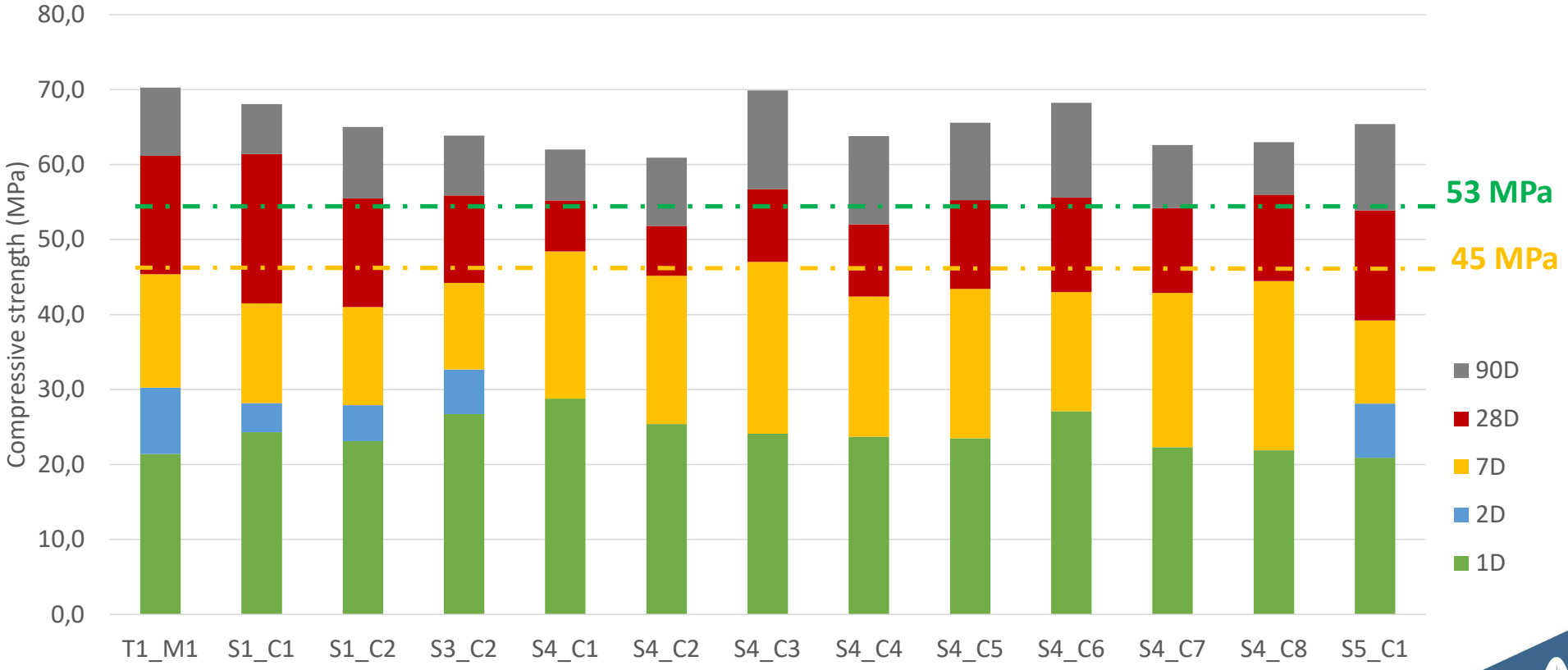
RMX based on copperslag for floors

Polishing



Statistics per truck



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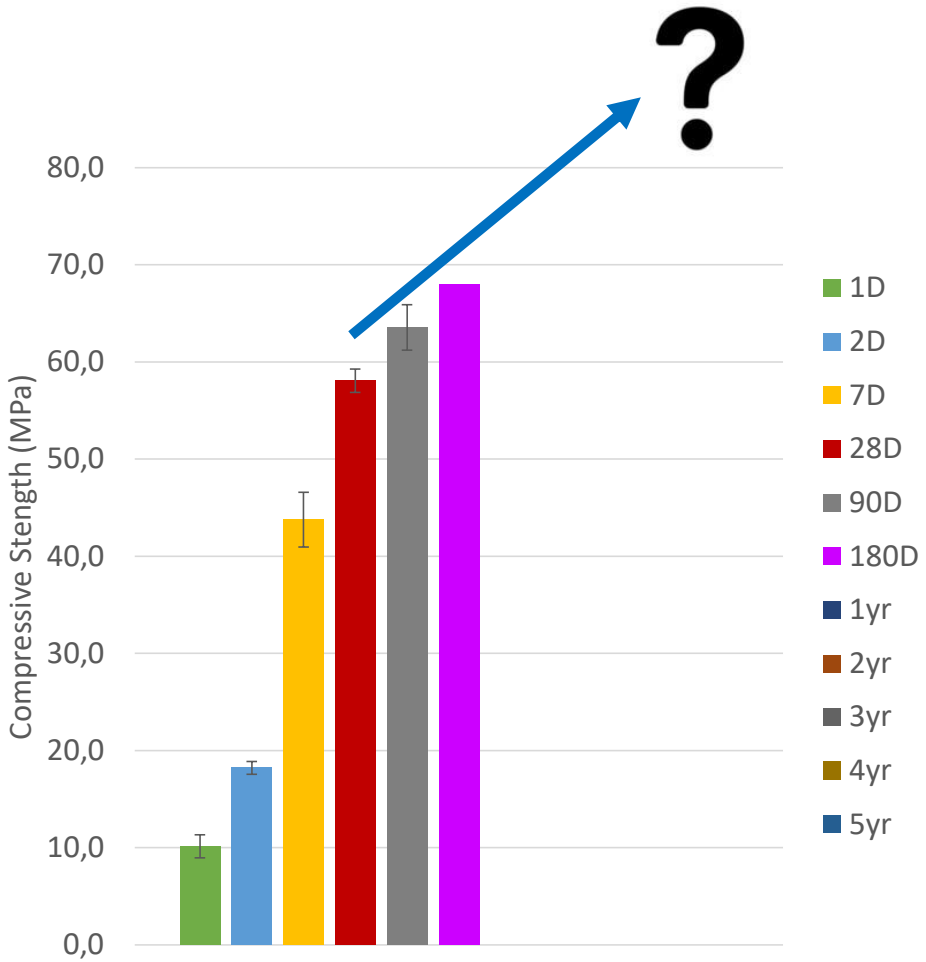
Follow up assured



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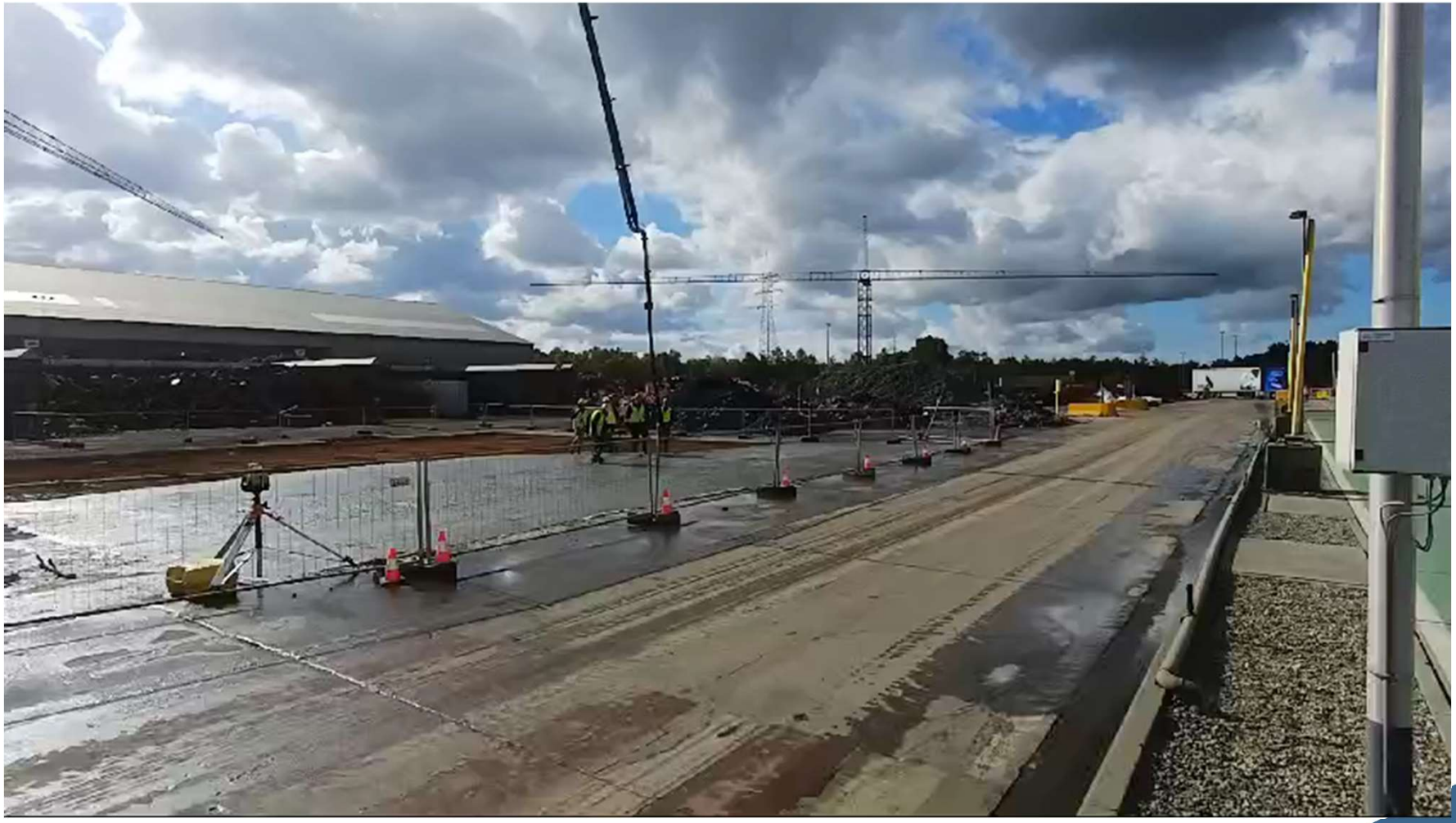
Yes yes, EE4 as well!



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Nog veel meer producten onder weg!

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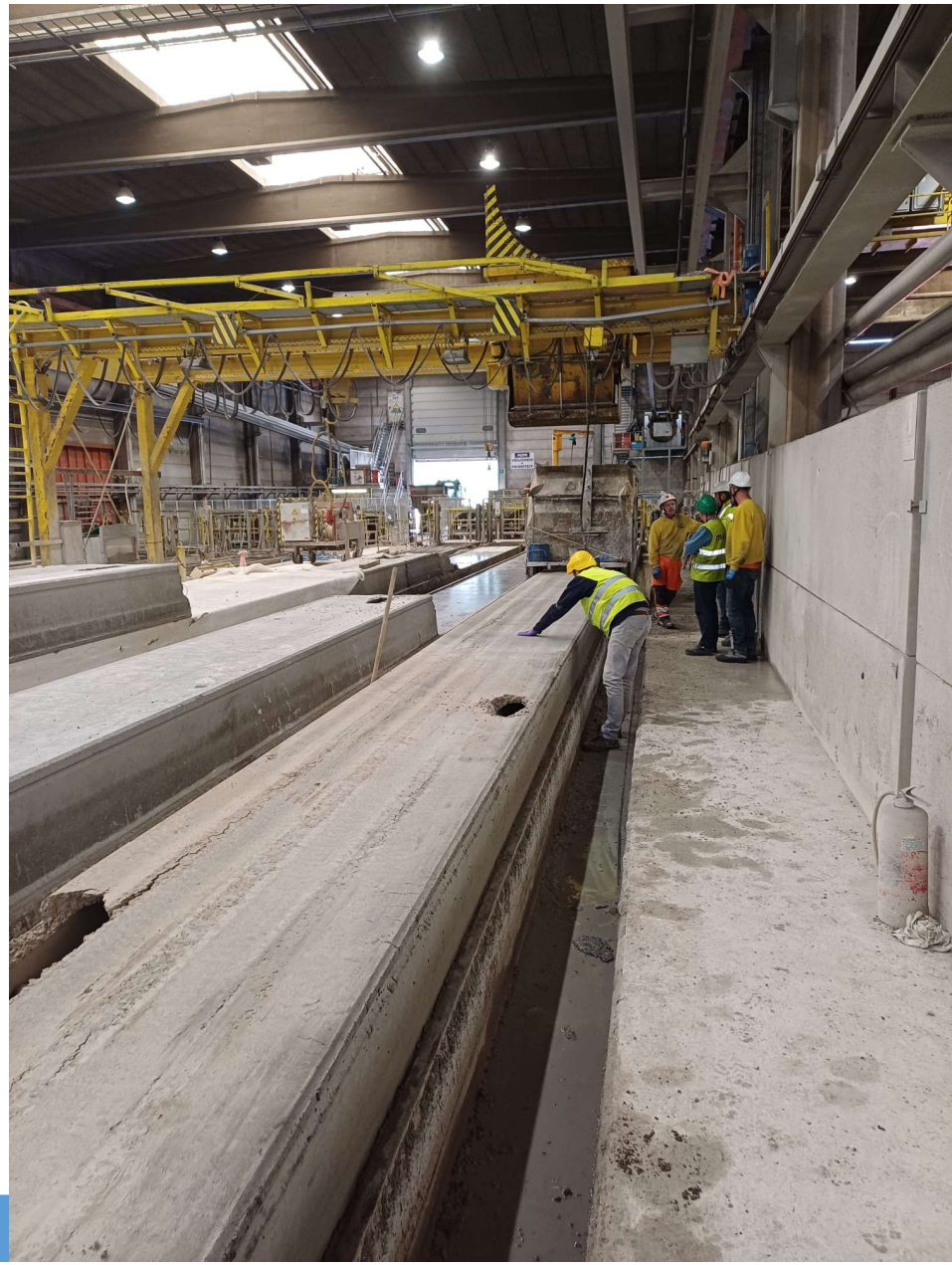
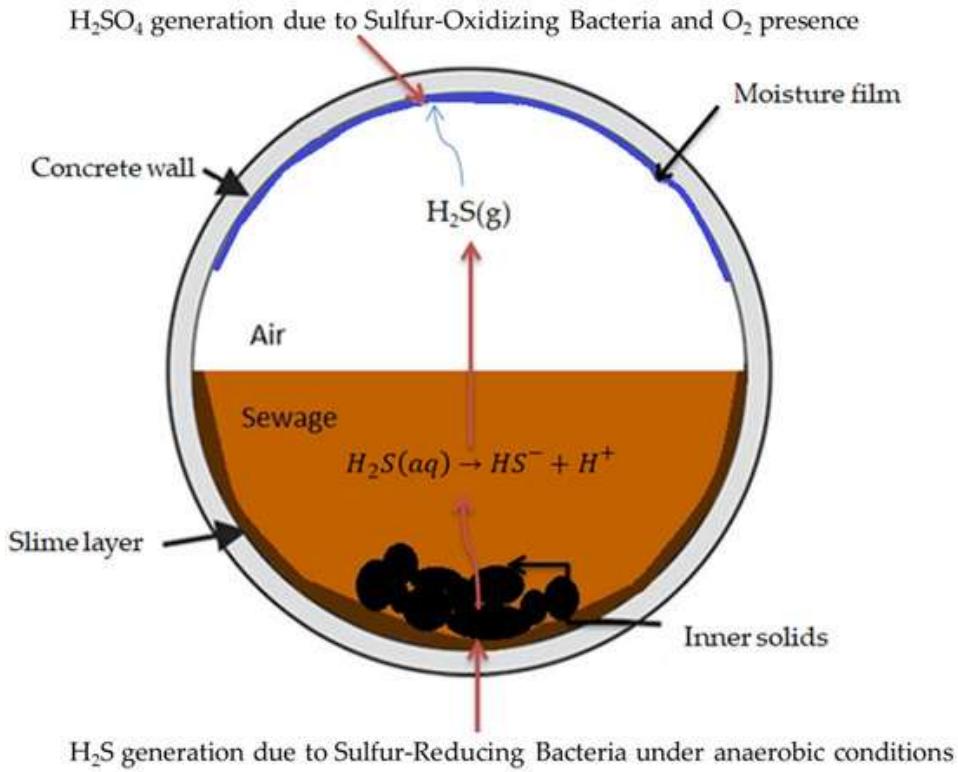
Eco-beton klinkers – grasdallen - metselblokken

Kanaalplaten op basis van hoogovenslak



Buizen: geopolymeer op basis van slak en vliegas



Funderingen uit zerocem - GGBFS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Slenk Tondelier: zerocem GGBFS

Slenk Tondelier: AC Materials

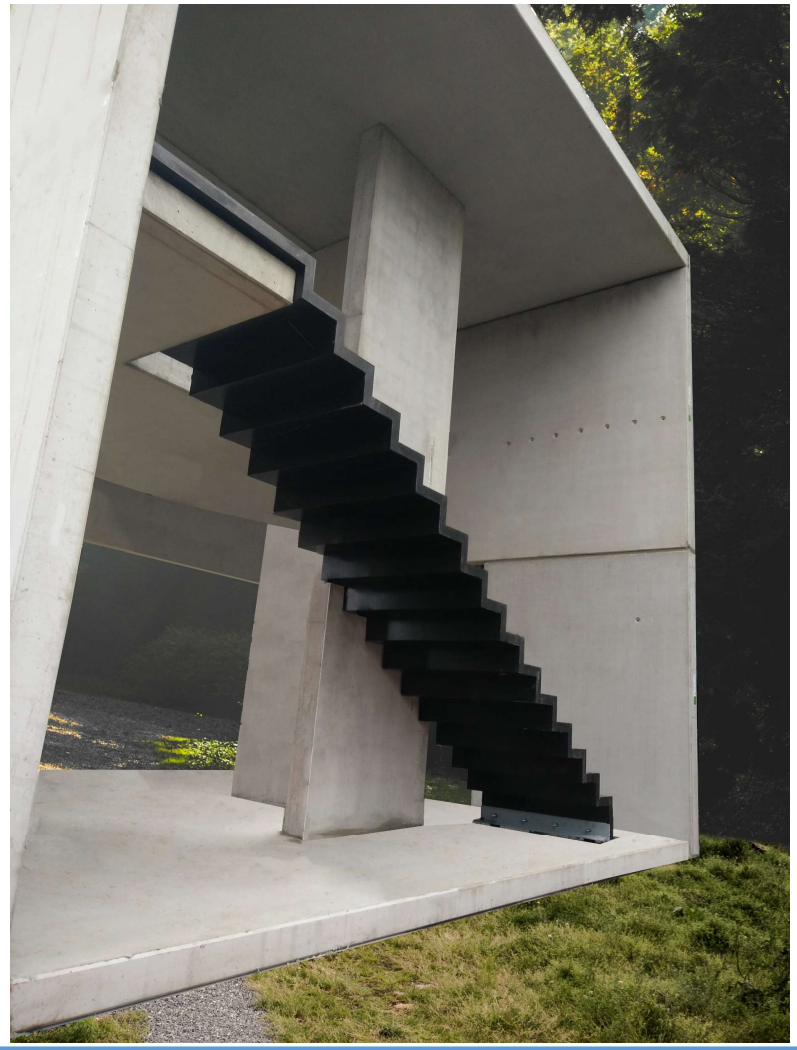
Sandwich Panelen:

Trap uit ecobeton

- Zelfverdichtend beton C45/55
- Hybride Klinker-GGBFS-Fillinox
- 20 u ontkistingstijd (22 Mpa)

ENJOY CONCRETE
PREFABULOUS

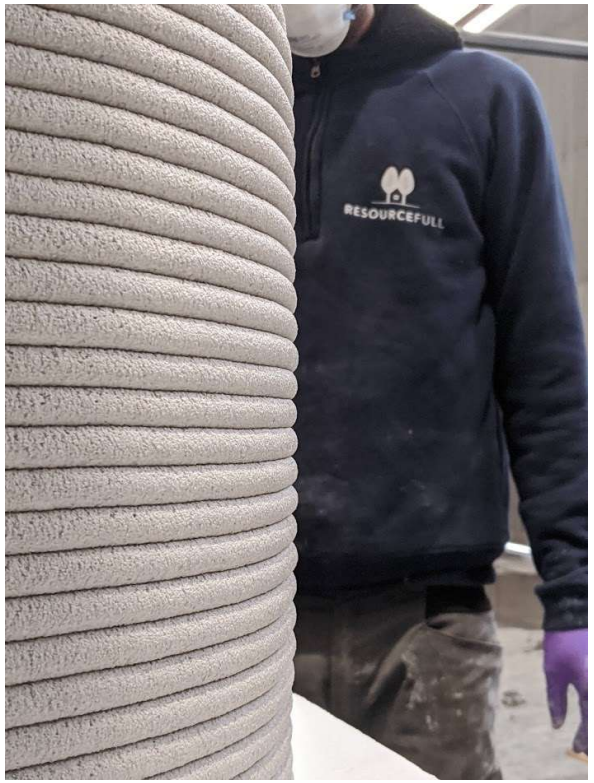
High strength concrete based on steel slag



Marine concrete

Development of 3D printed sea dike reinforcement and water breaking elements.

Zero Cement mortars that are sea water resistant.

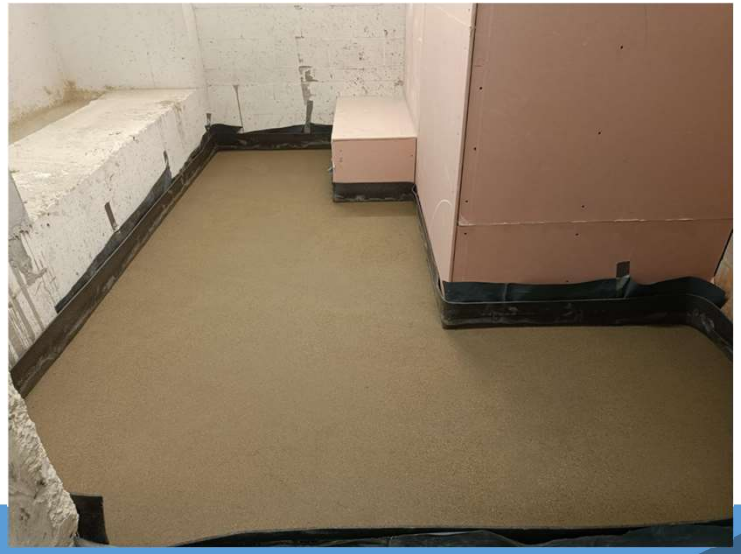


Ceramics made with steel slag and red mud

Self levelling floors based on steelslag

Self levelling floors based on steelslag

Chape op het Martelaarsplein



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Street furniture

URBASTYLE
CONCRETE STREET FURNITURE

RESOURCEFULL

Conclusie

Conclusie

- Kwalitatieve beton met een lage voetafdruk kan in het labo en in het echt!

- Welke hordes komen we tegen op weg naar grootschalige commercialisering?
  - Supply chain van nieuwe grondstoffen
  - Normering/certificering

- Maar deze hordes zijn zeer product en technologie afhankelijk

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Building a greener future, together