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Plasmastone: a novel raw material for geopolymers

Lieven Machiels, Lukas Arnout, Yiannis Pontikes

Geopolymer camp Saint-Quentin, July 8, 2014

Secondary raw materials for geopolymer cements in Flandres, Belgium

Vitreous materials

Slag (metal production), glass, ash (incineration)

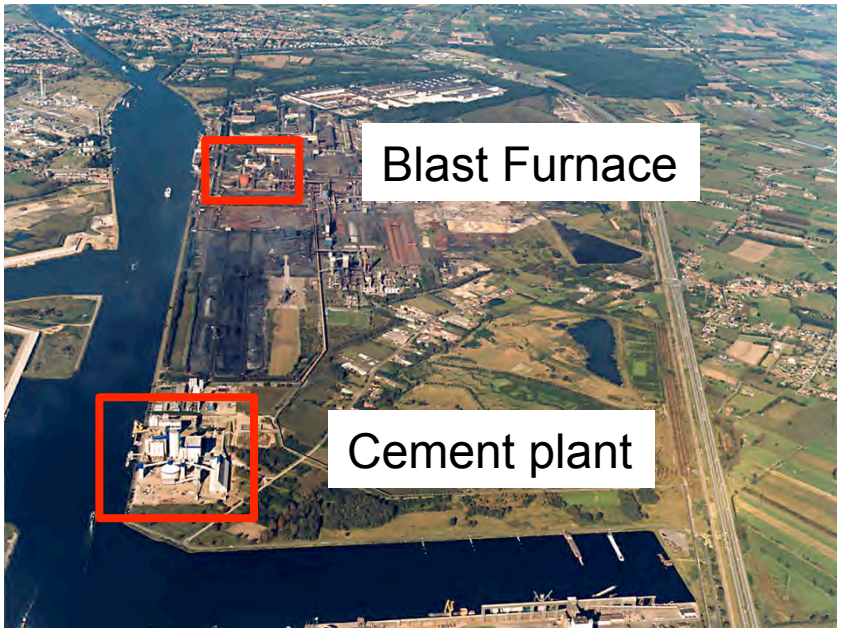
natural equivalent: basalt

Most commonly known example:

Ground Granulated Blast Furnace slag (**GGBFS**), by-product of steel production

Highly glassy (>95%) & interesting chemistry, resulting in high reactivity, clean material (no heavy metals, etc.)

Success story, waste becomes a by-product as soon as it is valorised (now 55€/ton)



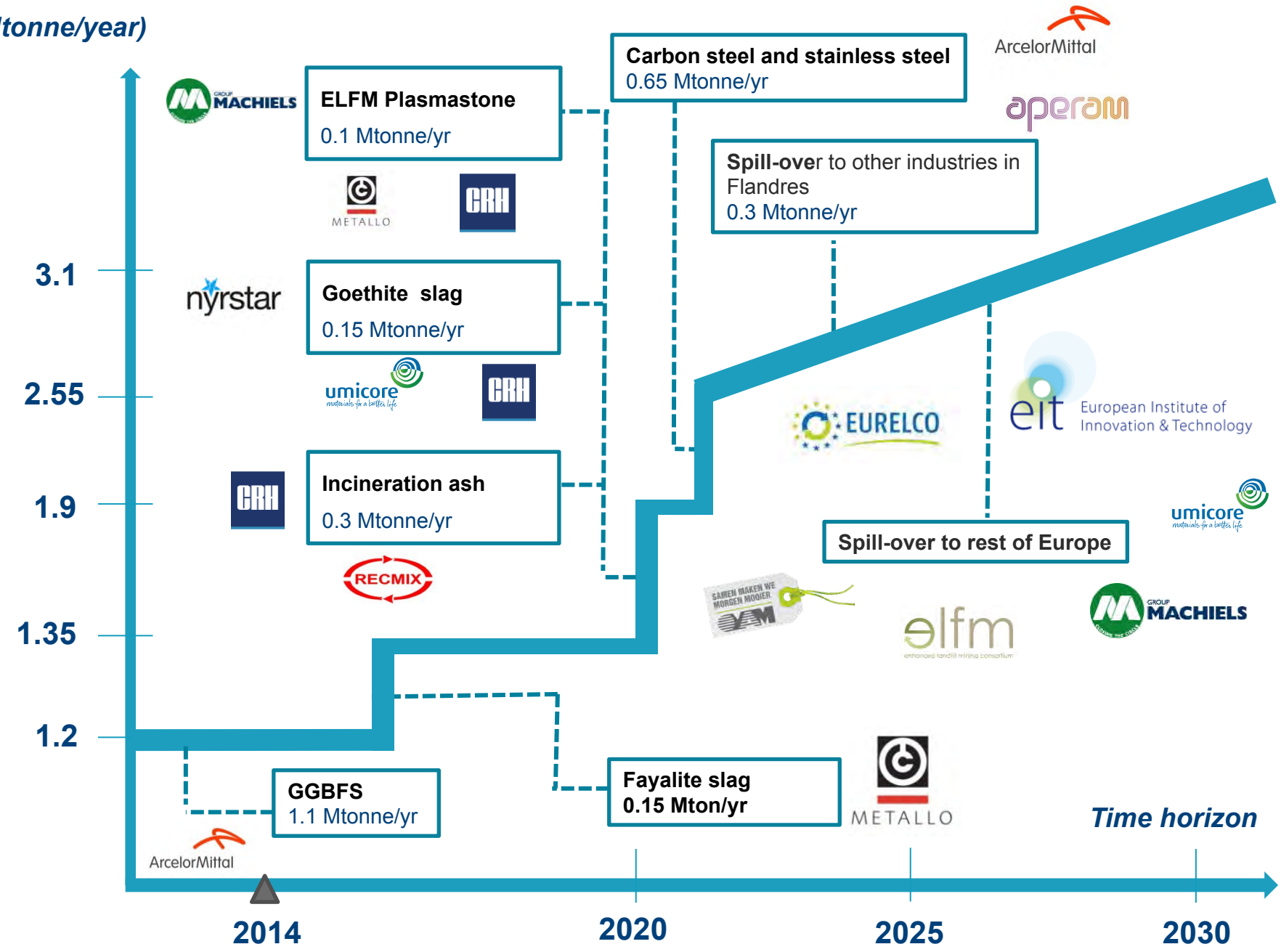
Source: Arcelormittal Gent

Availability in Flandres: 1.2 Mton (2013)

Compare:

- Cement production: 6 Mton/yr;
- Cement import: 3 Mton/yr

But there is more:



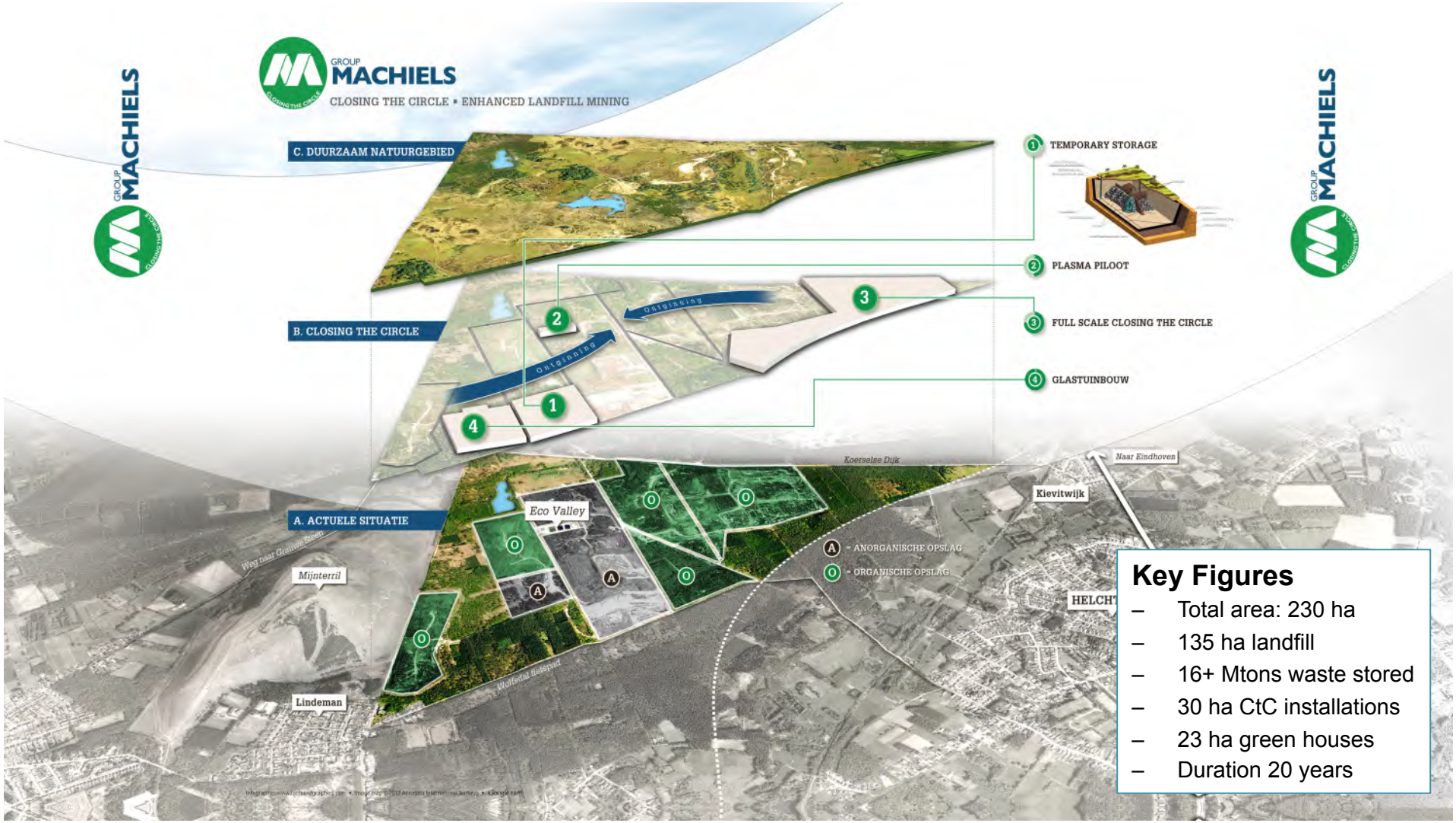
Plasmastone, from Municipal Solid Waste to high-added value products

Closing the Circle project, Limburg, Belgium

Remo landfill, Houthalen-Helchteren, Belgium. Site where the Closing the Circle project will be implemented,.

Source: www.canvas.be/programmas/dockview%3A-alles-kan-schoner/

Closing the Circle project, Limburg, Belgium

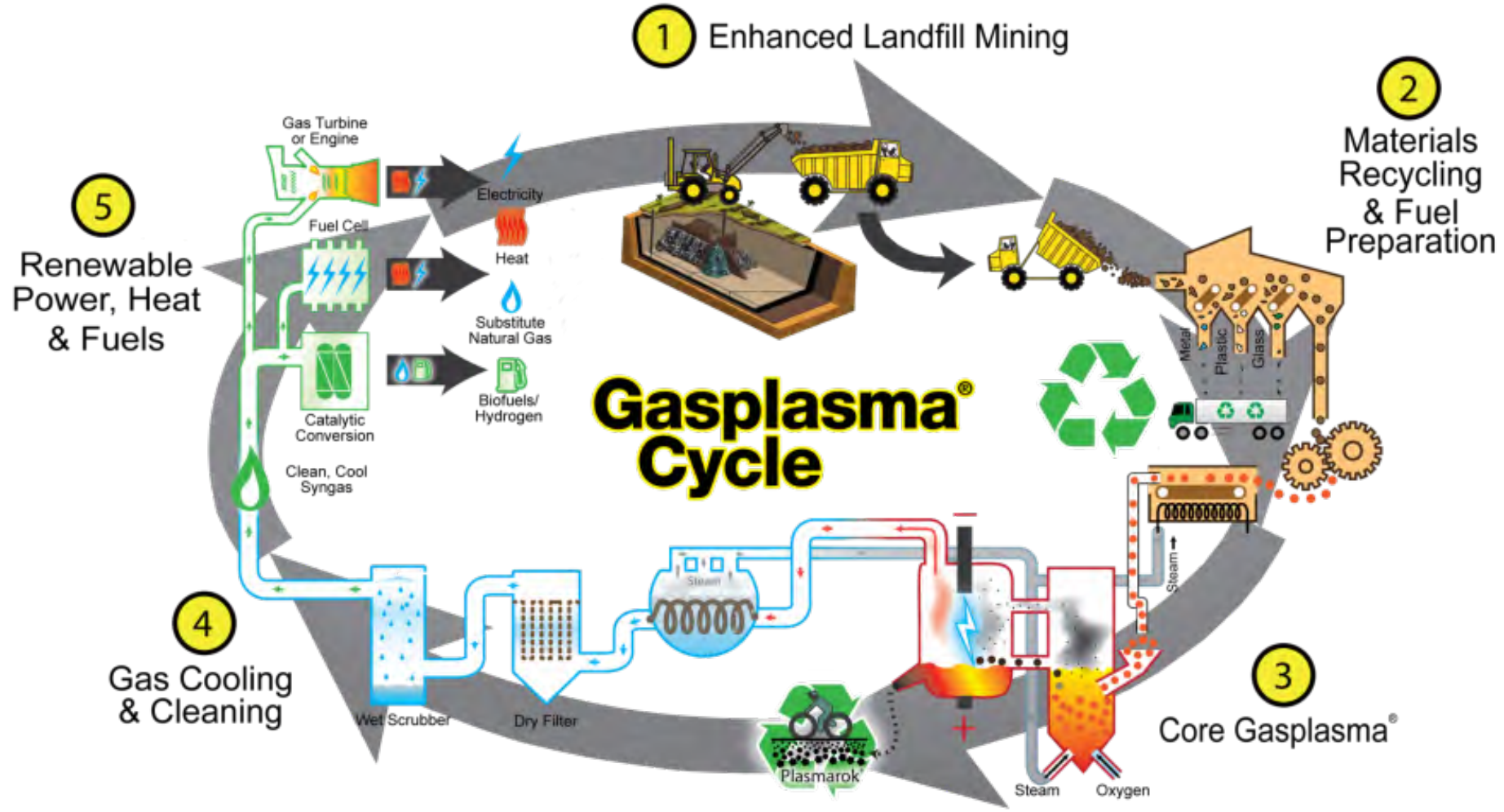


Key Figures

- Total area: 230 ha
- 135 ha landfill
- 16+ Mtons waste stored
- 30 ha CtC installations
- 23 ha green houses
- Duration 20 years

Source: Group Machiels, www.elfm.eu

Closing the Circle project, Limburg, Belgium



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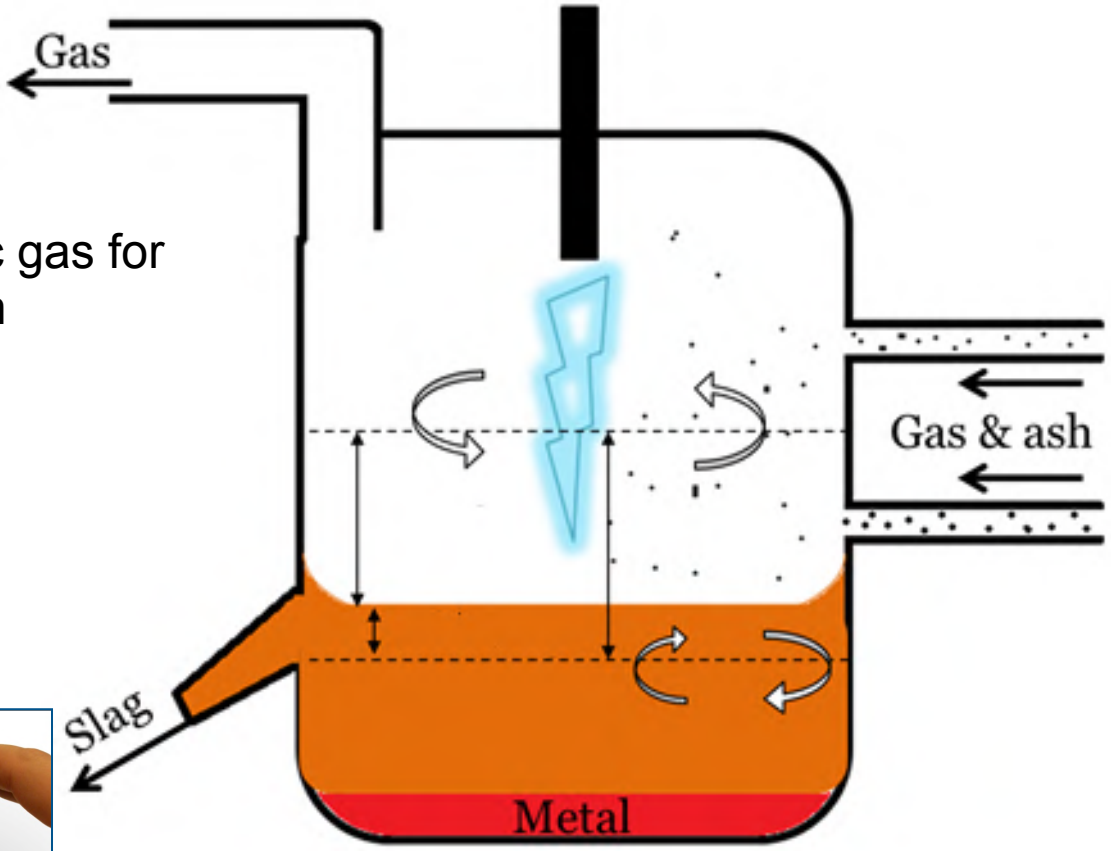


Synthetic gas for hydrogen

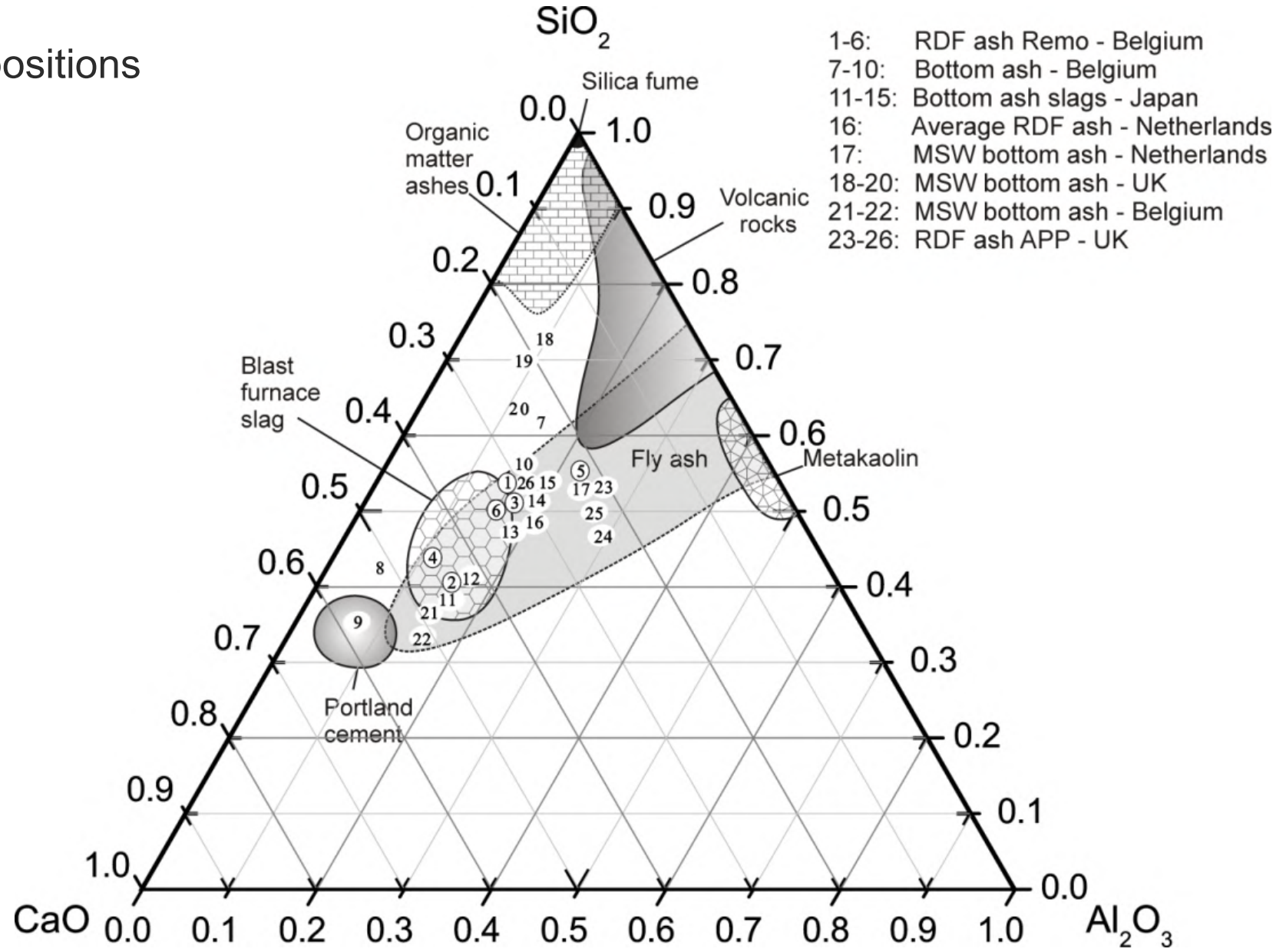
Light ELFM fraction

Plasmastone for novel cement & building materials

etals

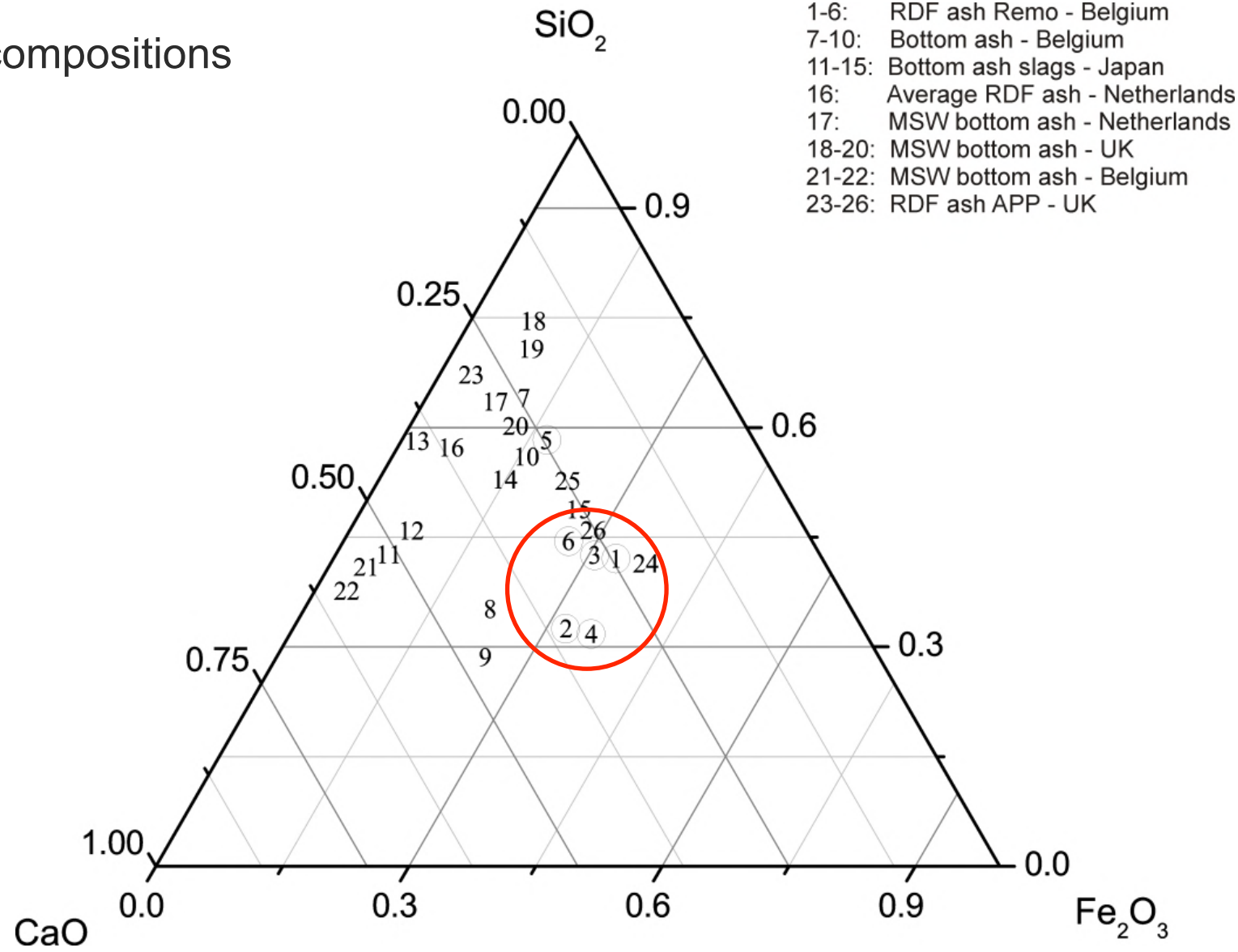
Plasmastone for geopolymer cements?

Compositions



Plasmastone for geopolymer cements?

Waste compositions

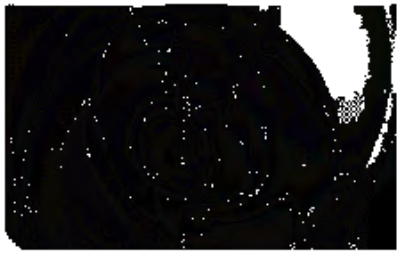


Development of a plasmastone based geopolymer

Plasmastone based geopolymer cements

Plasmastone based geopolymer

Plasmastone + Na-silicate + Sand = Plasmastone based geopolymer mortar



Geopolymer cement synthesis

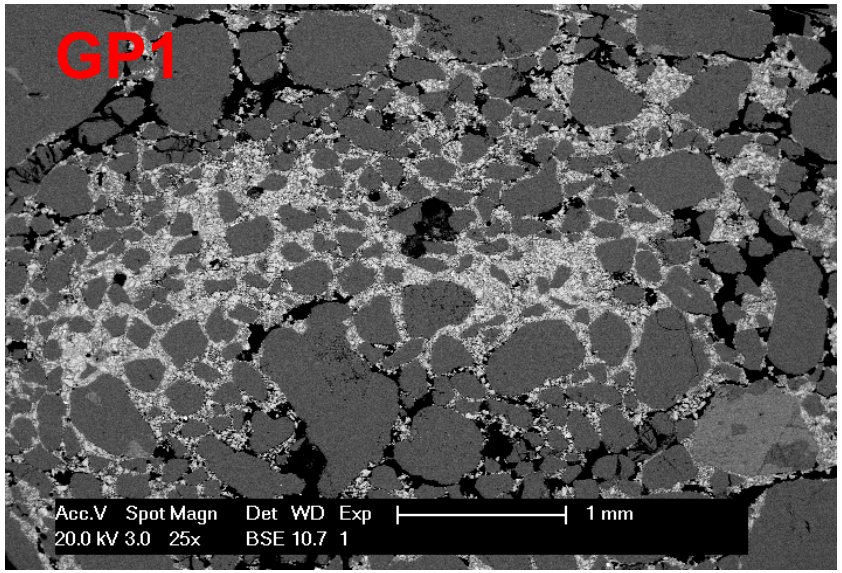
Sample	Glass/Sand (g/g)	S/L	Activation solution (g)
GP1	10/30	13.3	3.0
GP2	10/30	8.9	4.5
GP3	10/30	6.7	6.0
GP4	10/30	4.0	10.0

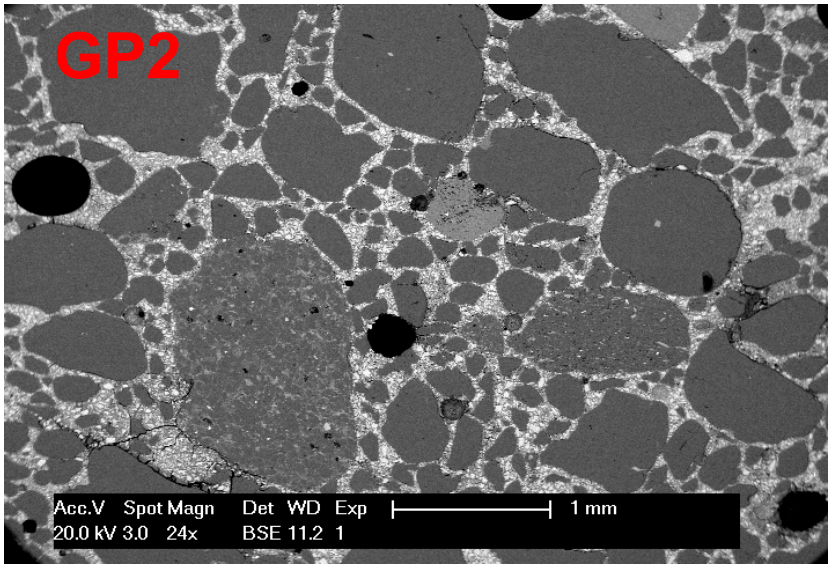
- Activation solution:
50/50 NaOH 10M
+ Na-silicate
(26 wt% SiO_2; 8 wt% Na_2O)

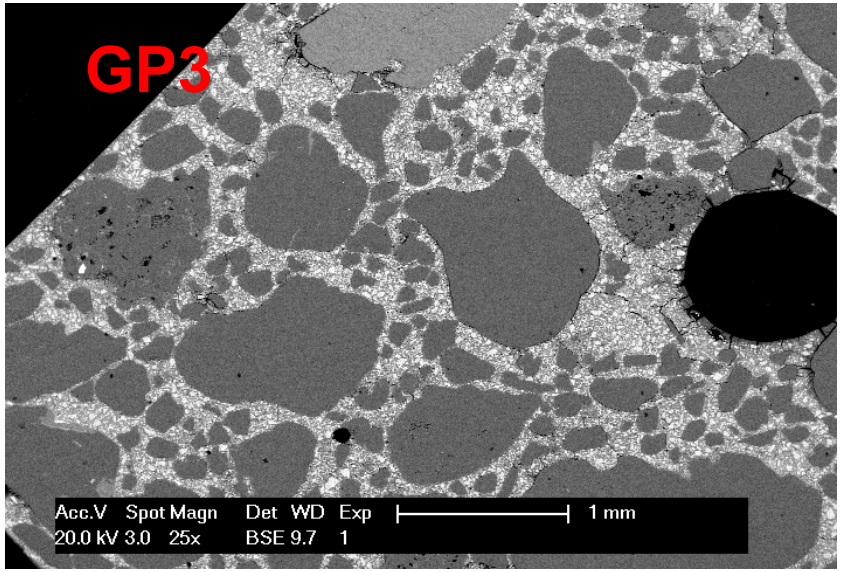
Sample	Curing t	Curing T	Conditions
GP2a		25°C	In plastic foil
GP2b		25°C	In plastic foil
GP2c	24h	60°C	In plastic bottle
GP2d	24h	180°C	In pressure vessel
GP2e	96h	180°C	In pressure vessel with extra water

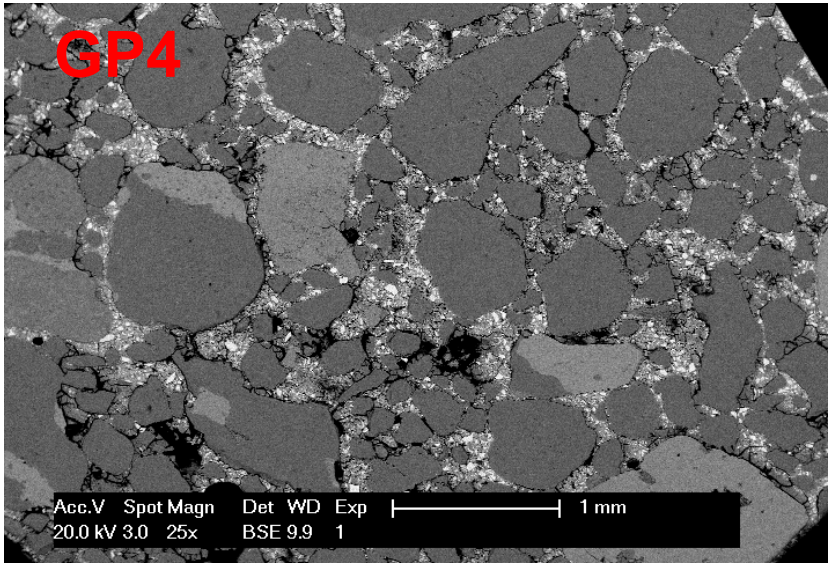
Machiels, L., Arnout, L., Jones, P., Blanpain, B., Pontikes, Y. (2014). Inorganic polymer cement from Fe-Silicate glasses: *Waste and Biomass Valorization, 5* (1), 12-29.

Microstructure: SEM-BSE









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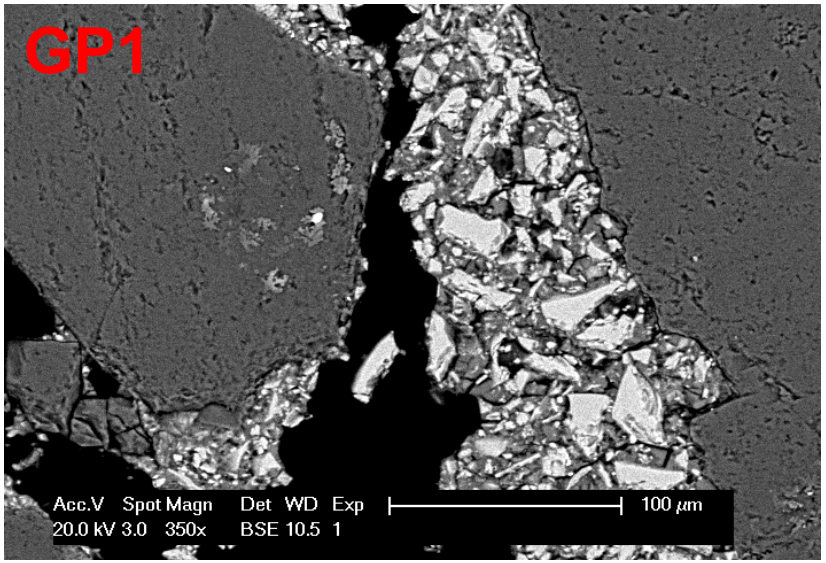

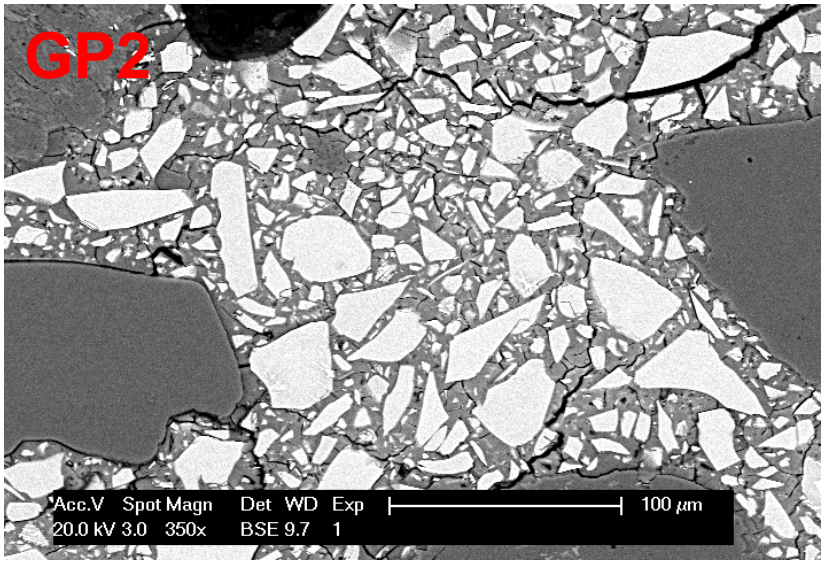

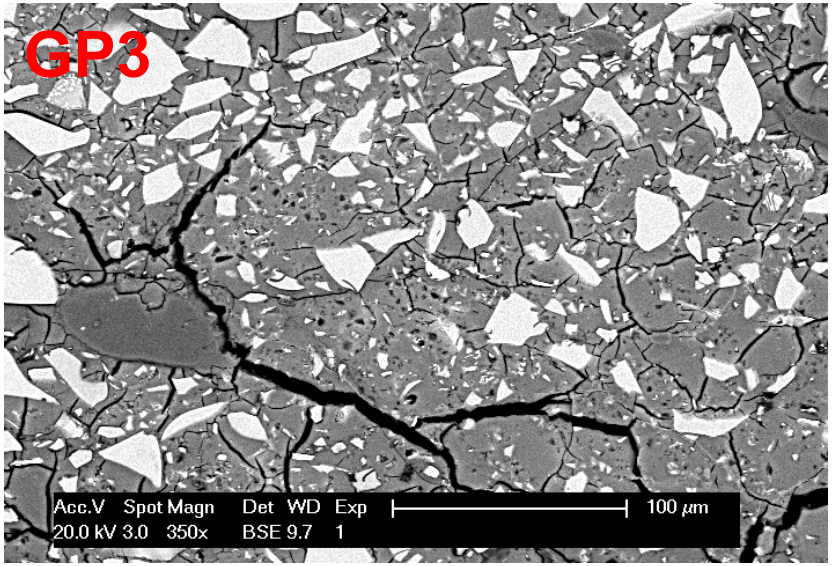

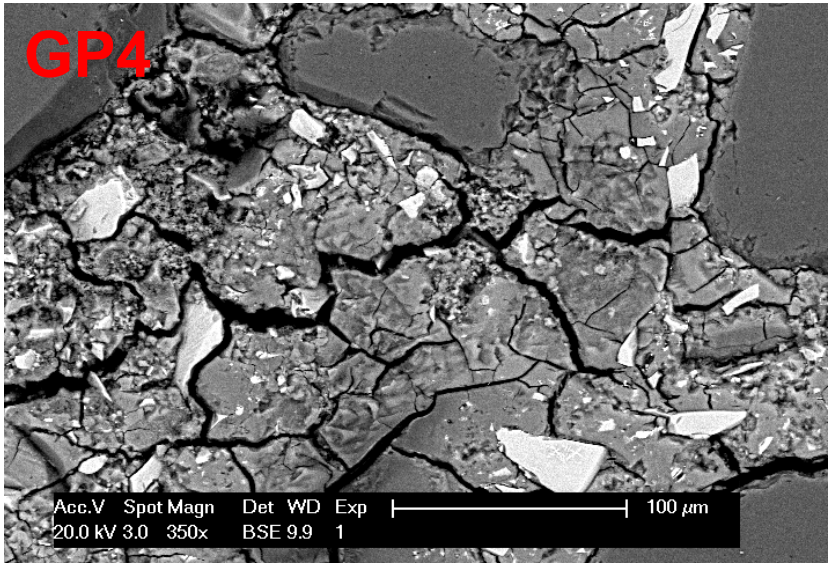

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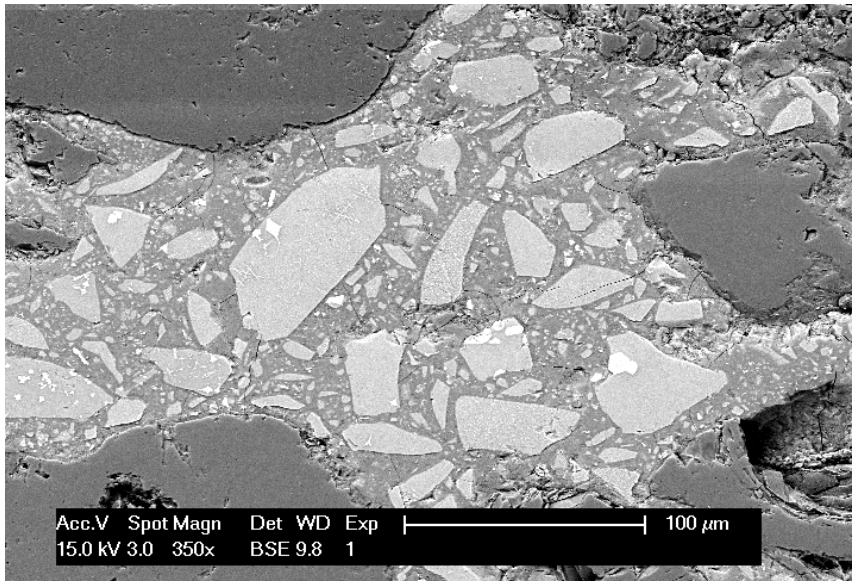
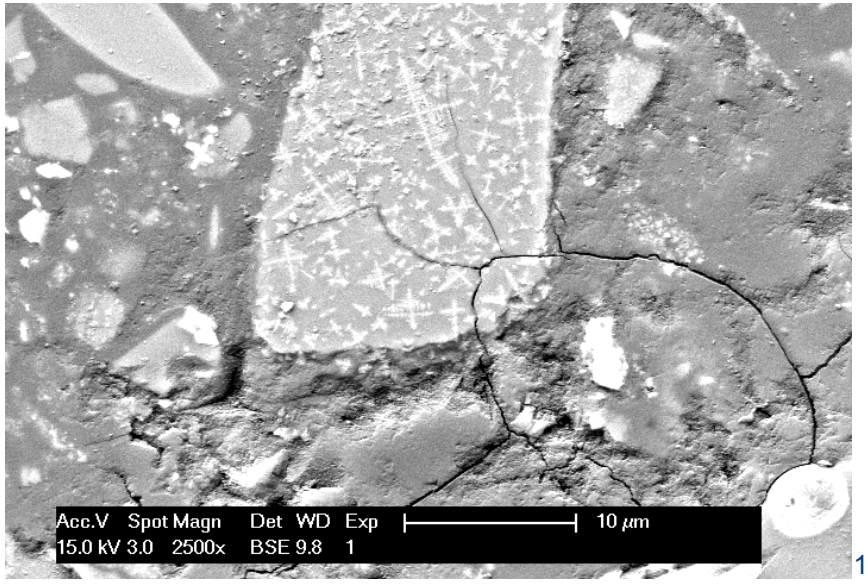




Steam cured sample **GP2e**

- Almost no cracks visible
- Cracks: very small, penetrate plasmastone & sand grains
- Indication that matrix had hardened before cracks originated

Mechanical Properties: Compressive Strength

Sample	28 days (MPa)	100 days (MPa)
GP1	14	15
GP2	33	56
GP3	35	54
GP4	15	47

- GP2 & GP3 best at 28 and 100 days, GP4 needs more time
- Curing: strong positive influence on compressive strength
- Addition of water in pressure vessel: also positive effect on compressive strength

Sample	28 days (MPa)
GP2a	56
GP2b	72
GP2c	106
GP2d	120
GP2e	138

Curing t	With extra water (MPa)	Without extra water (MPa)
24h	92	80
96h	103	90

Machiels, L., Arnout, L., Jones, P., Blanpain, B., Pontikes, Y. (2014). Inorganic polymer cement from Fe-Silicate glasses: *Waste and Biomass Valorization, 5* (1), 12-29.

Physical Properties: Porosity

Sample	Apparent porosity
GP1	18 %
GP2	**12 %**
GP3	14 %
GP4	17 %

Sample	Apparent porosity
GP2a	12 %
GP2b	14 %
GP2c	12 %
GP2d	11 %
GP2e	**10 %**

- Pressing: negative influence on porosity, see GP2b (pressed) > GP2a (moulded)

Machiels, L., Arnout, L., Jones, P., Blanpain, B., Pontikes, Y. (2014). Inorganic polymer cement from Fe-Silicate glasses: *Waste and Biomass Valorization, 5* (1), 12-29.

Heavy metal leaching: 24h at natural pH

Sample	Cr	Cu	Ni	Pb	Zn
GP1	1.50	0.93	0.73	0.11	*<0.02*
GP2	1.92	0.51	0.18	0.12	0.07
GP3	1.73	0.37	0.08	0.04	*<0.02*
GP4	1.76	1.64	0.31	0.10	*<0.02*
VLAREA standard	**0.50**	**0.50**	**0.75**	**1.30**	**2.80**

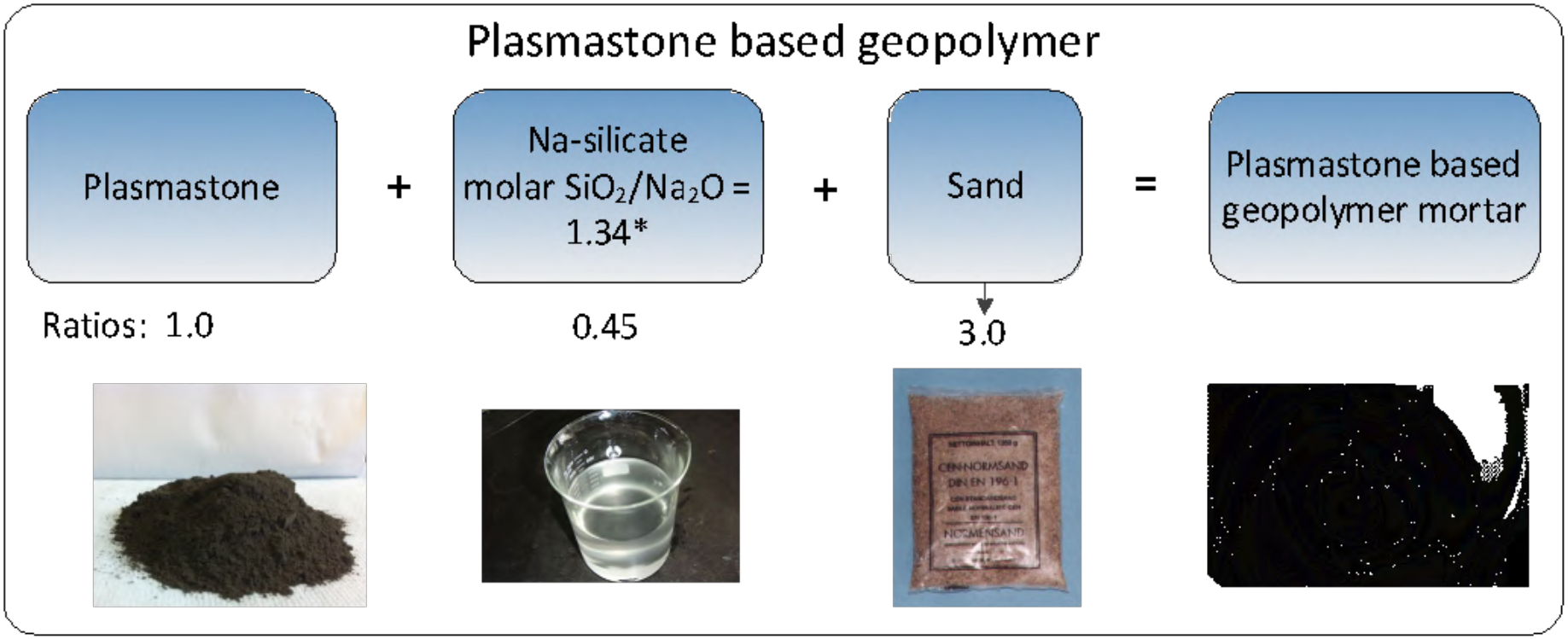
Sample	Cr	Cu	Ni	Pb	Zn
GP2a	1.64	1.04	0.28	0.06	0.26
GP2b	1.50	0.79	0.18	0.06	0.14
GP2c	1.07	0.99	0.18	0.06	0.12
GP2d	0.42	0.45	0.11	0.09	0.08
GP2e	0.36	0.37	0.11	0.06	0.06
VLAREA standard	**0.50**	**0.50**	**0.75**	**1.30**	**2.80**

All values in mg/ (kg.ds)

Leaching tests performed on artificial plasmastone polluted with 1 wt% of heavy metal ions

Recipe optimisation at room temperature

Pourable cement, room T curing



* Activating solution	
Na_2O (wt%)	10.19
SiO_2 (wt%)	13.25
H_2O (wt%)	76.56

- Using standard CEN sand
- ratio plasmastone / activating solution / sand: 1 / 0.45 / 3

L. Kriskova, L. Machiels, P. T. Jones, B. Blanpain, Y. Pontikes. Synthesis of inorganic polymers using a CaO-Al_2O_3-FeO-SiO_2 slag. Proceedings of the CIMTEC Conference, June8-13, 2014.

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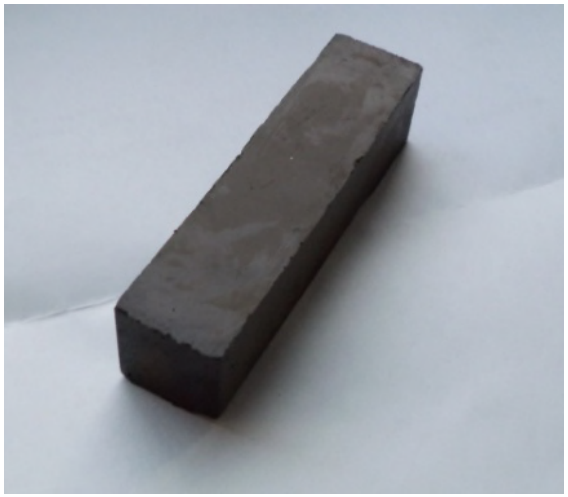
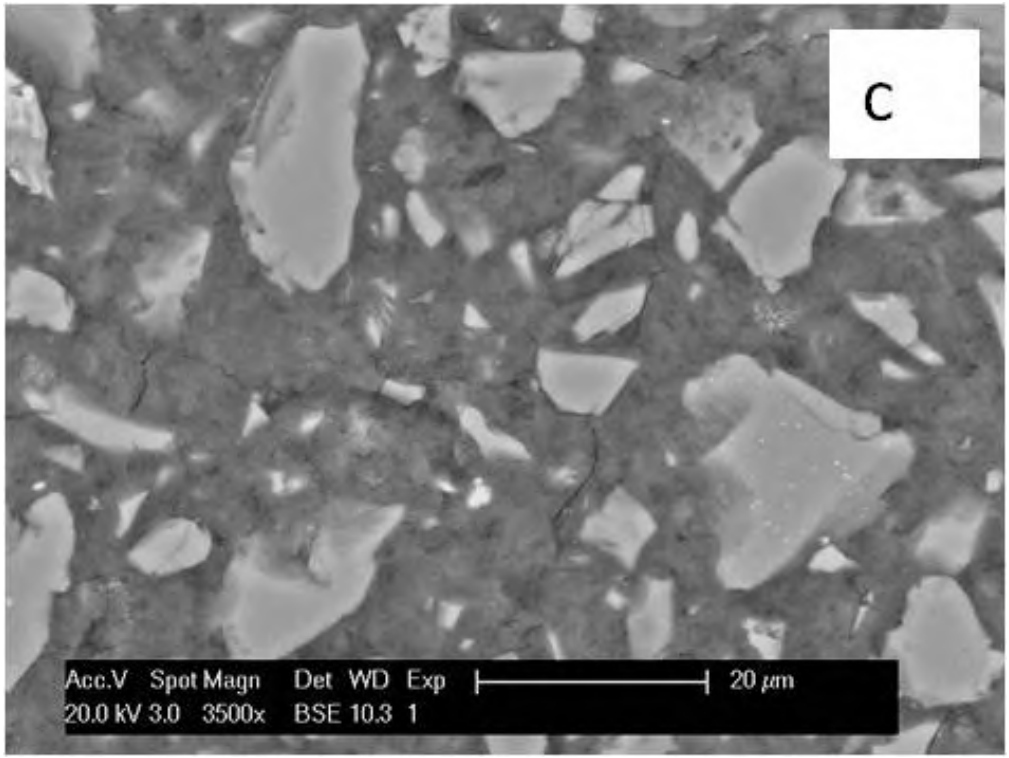




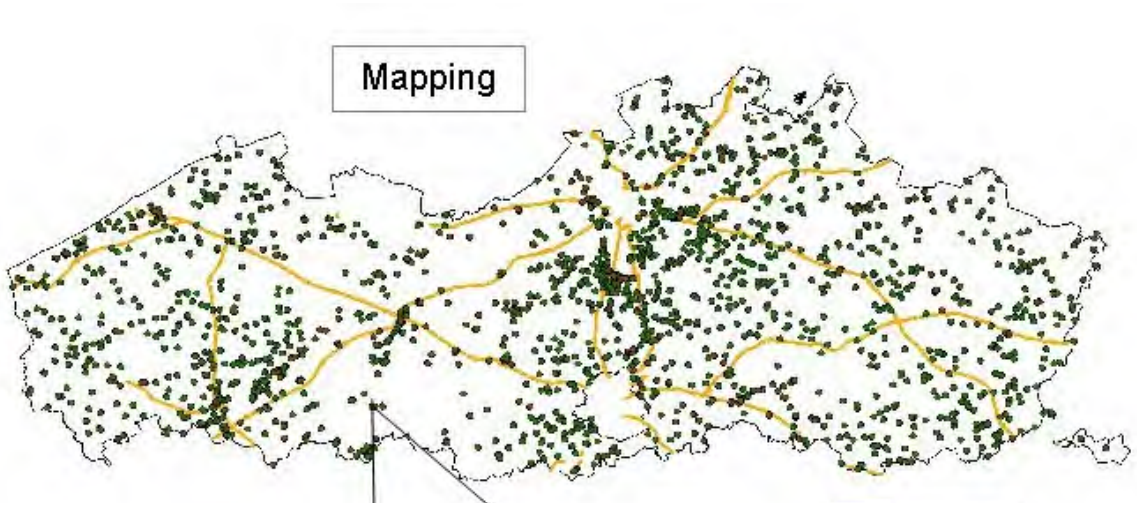
Compressive strength (MPa)		
7 days	28 days	90 days
35.1	81	112.6

	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	FeO
Comp.	5.1 ± 1.9	3.7 ± 0.6	11.5 ± 0.1	40.3 ± 2.1	0.7 ± 0.2	18.9 ± 2.5	1.5 ± 0.2	15.8 ± 1.2

L. Kriskova, L. Machiels, P. T. Jones, B. Blanpain, Y. Pontikes. Synthesis of inorganic polymers using a CaO-Al_2O_3-FeO-SiO_2 slag. Proceedings of the CIMTEC Conference, June8-13, 2014.

The future..

European Enhanced landfill mining consortium



EURELCO

Launched on March 11, 2014

www.elfm.eu

PLASMAT project

ScanArc

Started 1st of May 2014

Pilot scale testing as the next step towards industrialisation..

Publications:

Jones, P., Geysen, D., Tielemans, Y., Van Passel, S., Pontikes, Y., Blanpain, B., Quaghebeur, M., Hoekstra, N. (2013). Enhanced landfill mining in view of multiple resource recovery: a critical review. *Journal of Cleaner Production, 55*, 45-55.

Machiels, L., Arnout, L., Jones, P., Blanpain, B., Pontikes, Y. (2014). Inorganic polymer cement from Fe-Silicate glasses: Varying the activating solution to glass ratio. *Waste and Biomass Valorization, 5* (1), 12-29.

Pontikes, Y., Machiels, L., Onisei, S., Pandelaers, L., Geysen, D., Jones, P., Blanpain, B. (2013). Slags with a high Al and Fe content as precursors for inorganic polymers. *Applied Clay Science, 73*, 93-102.

L. Kriskova, L. Machiels, P. T. Jones, B. Blanpain, Y. Pontikes. Synthesis of inorganic polymers using a CaO-Al2O3-FeO-SiO2 slag. Proceedings of the CIMTEC Conference, June8-13, 2014.

Thank you!

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