



Building a sustainable future

Miguel Otero



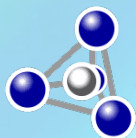
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Innovative geopolymer mortars from CDWs for 3D printing



GeoS²•3D

3D printing of landfill waste-based geopolymers
for Smart and Sustainable Construction



GEOPOLYMER
INSTITUTE

22/05/2025
Saint-Quentin, France

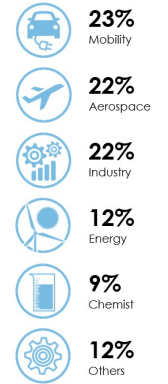
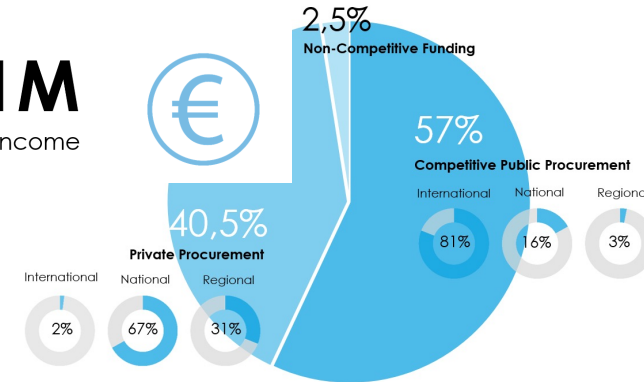
AIMEN Technology Center

Staff: >300 (50% in R&D)

- AIMEN is a 100% private, non-profit, multi-sectoral Technology Center, established in 1967, located in Spain, Galicia.
- We develop R&D&I PROJECTS and Technological Services of high added value..
- Our main capabilities are focused on:
 - Advanced Manufacturing
 - Sustainability
 - Process Digitalization
 - Materials Development



>21M
Annual Income



2 facilities

In O Porriño

9.500 m²

of scientific-technological
infrastructures





2015

2025

Sustainable Construction laboratories



BUILDING SECTOR



Constructive module: 4m x 3m x 3m



Geopolymer Bricks



GeoCel

Facade elements



STEEL MAKING SECTOR

Foundry molds



CIRCOM

Refractory Geopolymers



ENVIRONMENTAL SECTOR

Adsorbent geopolymers



Radioactive waste management



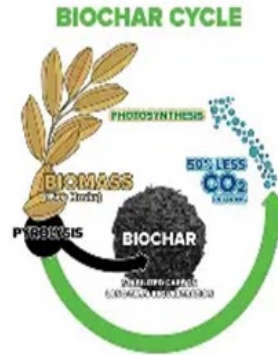
Geopolymers at AIMEN

FUNCTIONALITY

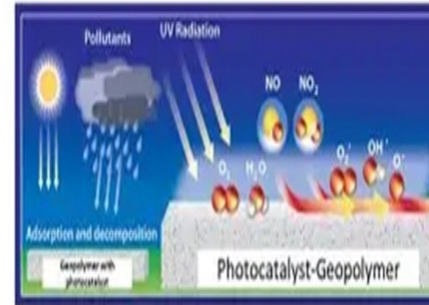
Electrical conductive



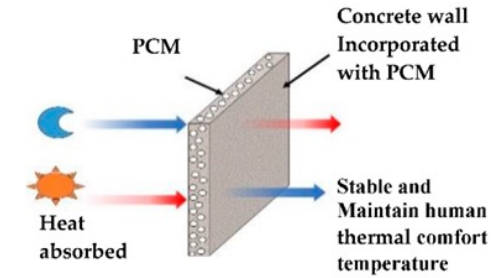
CO2 adsorption



Photocatalysis GP



Thermal confort



3D PRITING



GeoS²-3D project



- Budget: 1.5 M € (next generation)
- Objectives:
 - **Sustainability** (Geopolymers)
 - **Modernity** (Additive manufacturing)
- Partners:
 - RECINOR (waste manager)
 - AIMEN (material developer)
 - BeMore 3D (3D demonstrators)
 - CyE (technical validation)



Waste selection

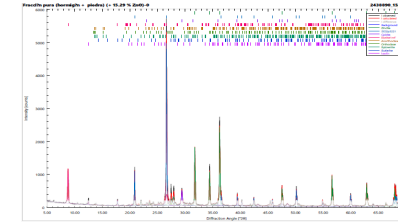
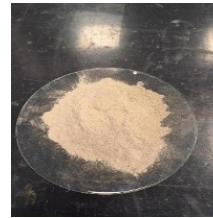
Milling

Sieving

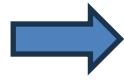
XRD, XRF, BET, PSD



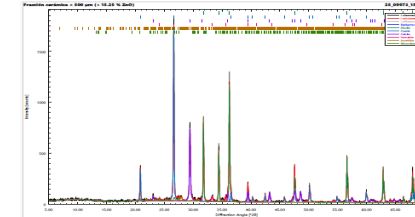
Concrete
fraction



Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe
1,7	0,5	20,0	28,0	0,2	0,3	0,1	2,2	6,5	0,2	1,2



Ceramic
fraction

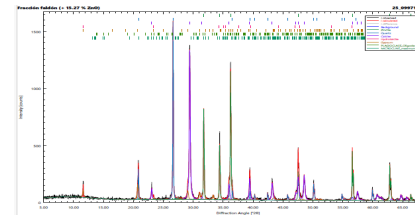


Al ₂ O ₃	CaO	Cl	CoO	CuO	Fe ₂ O ₃	K ₂ O	MgO	MnO
30,1	0,07	0,41	0,15	0,07	1,69	0,42	0,33	0,06

MnO	Mo	Na ₂ O	NiO	P ₂ O ₅	PbO	SO ₃	SiO ₂	TiO ₂
0,02	0,10	4,96	0,02	0,04	0,21	0,22	75,04	0,18



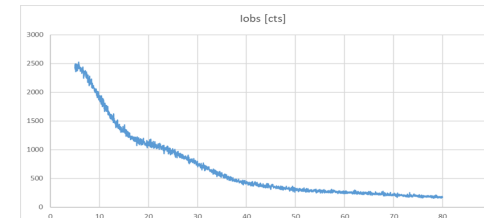
Mix
fraction



Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe
1,6	0,6	19,9	31,7	0,1	0,5	0,1	2,0	8,5	0,2	1,9



Glass
fraction



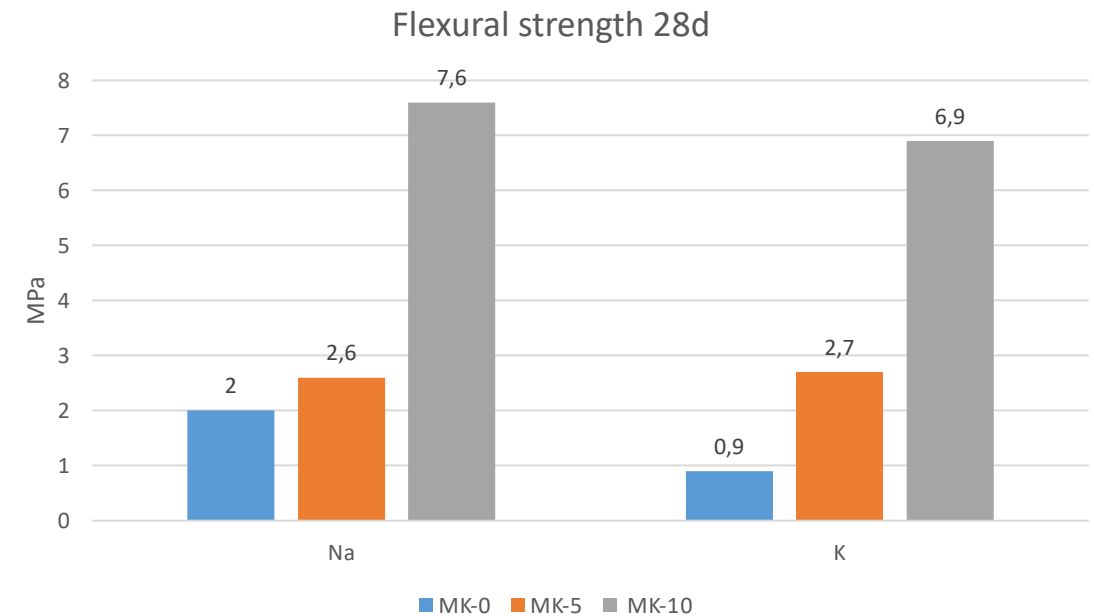
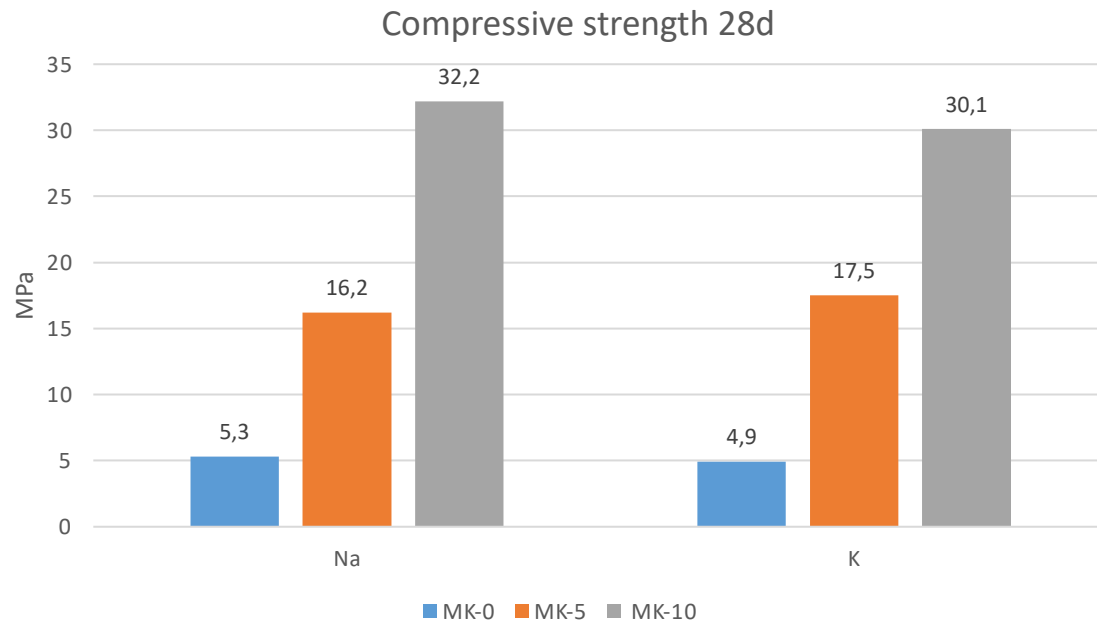
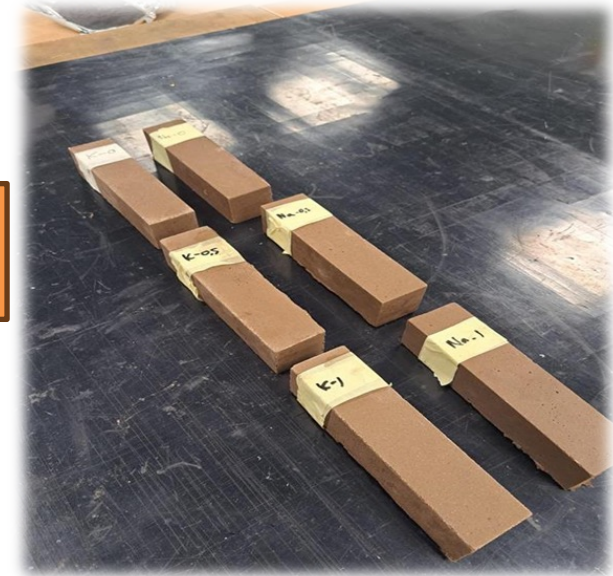
Al ₂ O ₃	CaO	Cl	Cr ₂ O ₃	CoO	CuO	Fe ₂ O ₃	K ₂ O	MgO
2,43	11,23	0,13	0,01	0,04	0,02	0,54	0,14	2,04

Mo	Na ₂ O	NiO	P ₂ O ₅	PbO	SO ₃	SiO ₂	TiO ₂	MnO	ZnO
0,11	7,33	0,02	0,04	0,08	0,71	74,89	0,18	0,02	0,04

Binder optimization:

	Metakaolin substitution		
	0	5	10
Na-Sil (Geosil 34417)	S/L=2,5		
K-Sil (Geosil 14517)	S/L=2,6		

Curing conditions: 20°C, 95% RH
(No heating curing!)

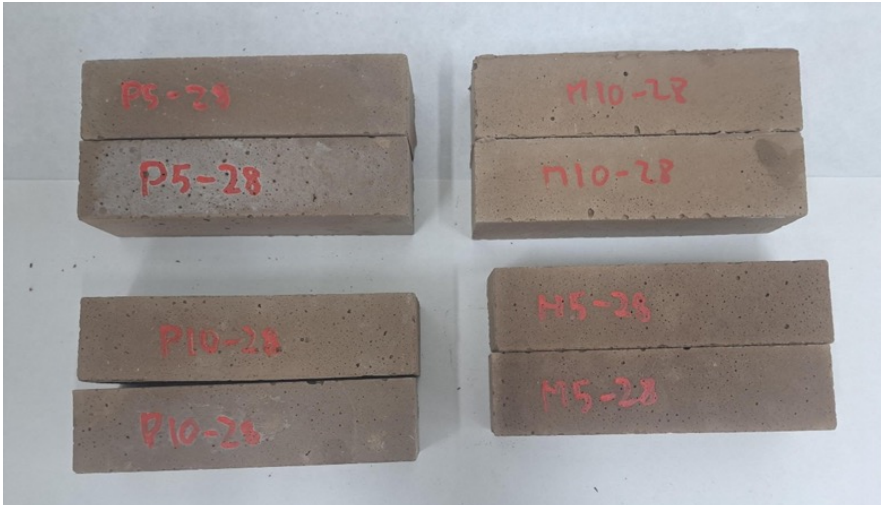


Printable mortar

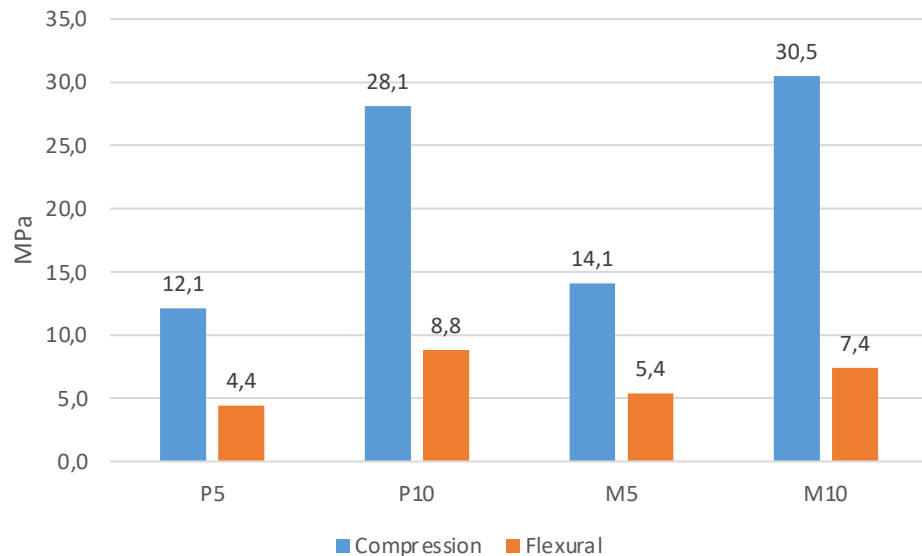
Aggregates, admixtures, fibers...

Component		Type	Effect
Aggregate		Concrete waste (0-1mm)	Reduce cost and carbon footprint
Fibers		Glass fiber	↑ Flexural strength
Admixtures	Thixotropic	Microcelulose Xanthan gum Actigel Optigel 2290	Improve thixotropic behaviour
	Superplastiziers	W-30 Polycarboxylate Melamine	Reduce water demand and improve flowability
	Setting modifiers	Ca(OH) ₂ Sikatard	Adapt setting to 3D printing
	Defoamer	BYK-1690 SD	Decrease porosity

Melamine & Policarboxylate



Mechanical Strength 28d-age



Rheological assessment

Materials

- HOLCIM



- SIKA



Mortero 3D

- BeMore 3D

El Mortero 3D es un Micro-Hormigón monocomponente, fibroreforzado y bombeable diseñado para uso en impresoras 3D de morteros. Tiene la consistencia idónea para realizar la superposición de las capas sin asentamiento de las capas inferiores.

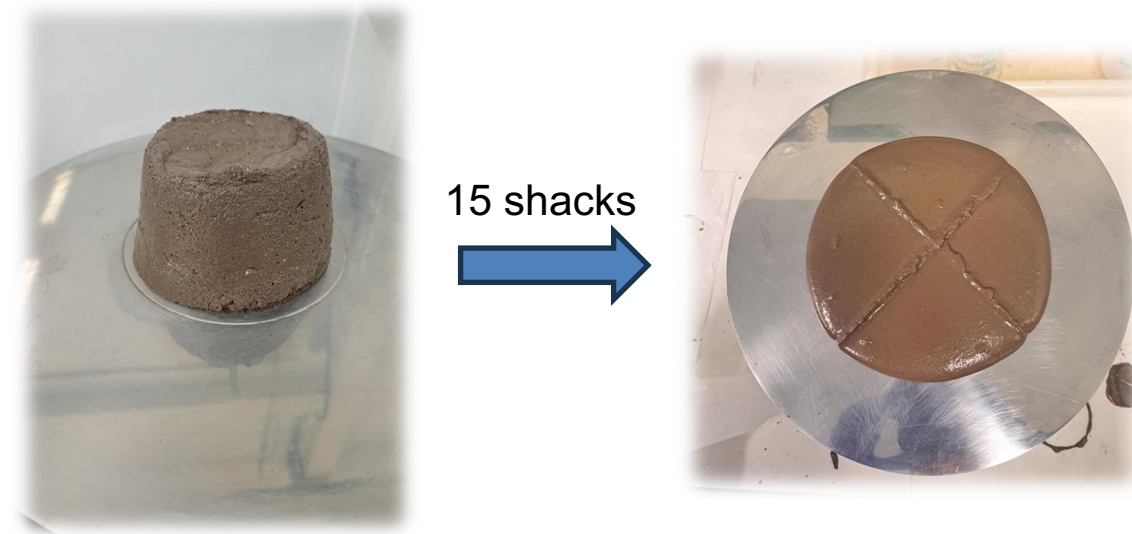
- GP-P (Policarboxylate)

- GP-M (Melamine)

Tests

- Flow table
- Buildability test
- Rheometer
 - 3ITT
 - Amplitude Sweep
 - Open Time

Flow table



3D Cement	Before/cm	After/cm
SIKA	12	17,5
HOLCIM	10,5	19
Bemore3D	11	15,2
GP-P	10,5	16
GP-M	10	16,5

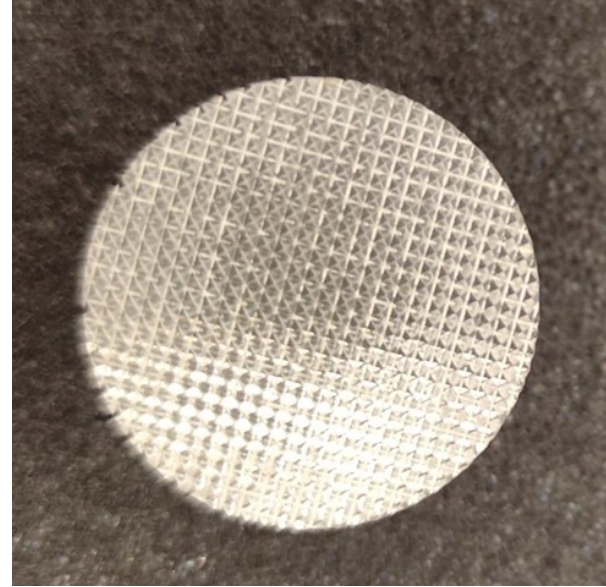
Buildability test



3D Cement	Settlement/cm
SIKA	1,5
HOLCIM	1,5
Bemore3D	2
GP-P	1,5
GP-M	1

Rheological assessment

Rotational rheometer (Anton Paar MCR 102e)



Rheological Properties

- Yield stress
- Viscosity
- Thixotropy
- Storage and loss modulus

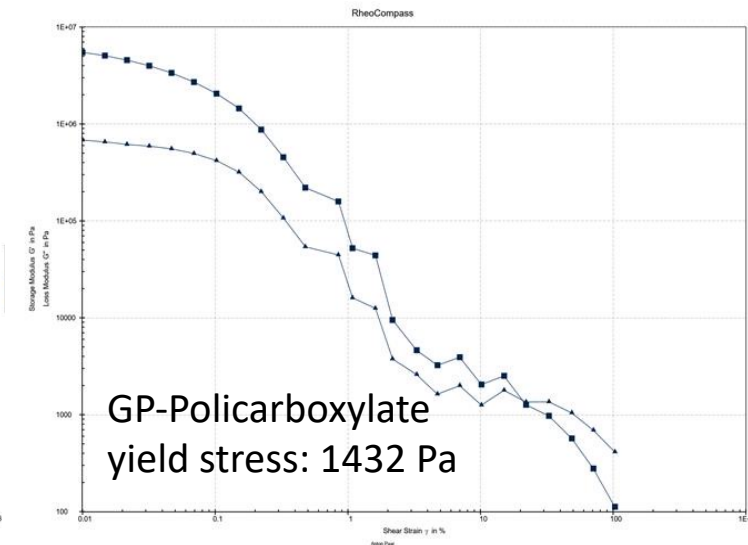
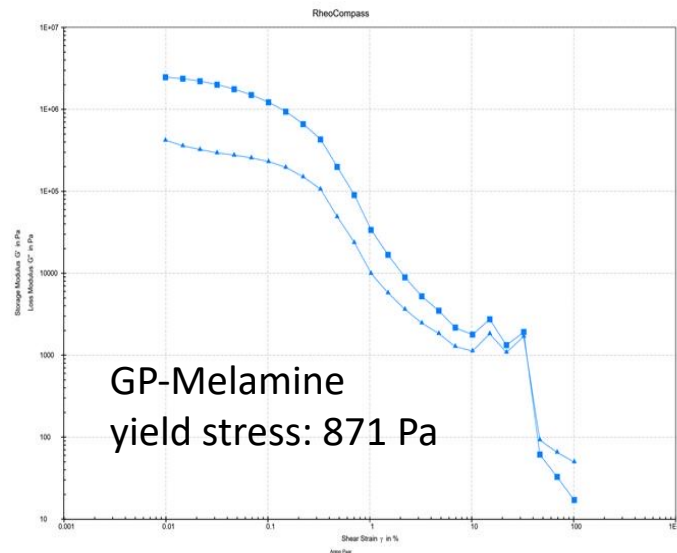
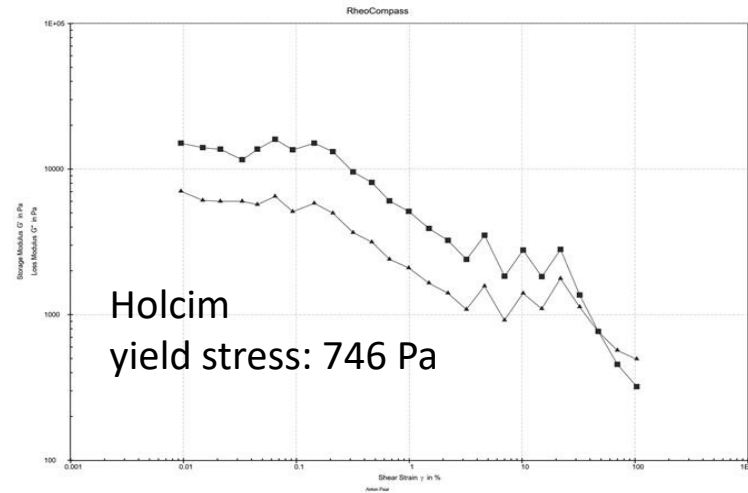
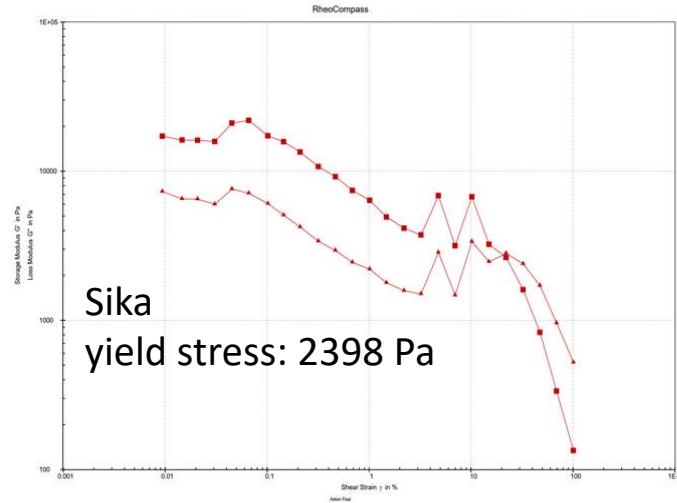


Rheological tests

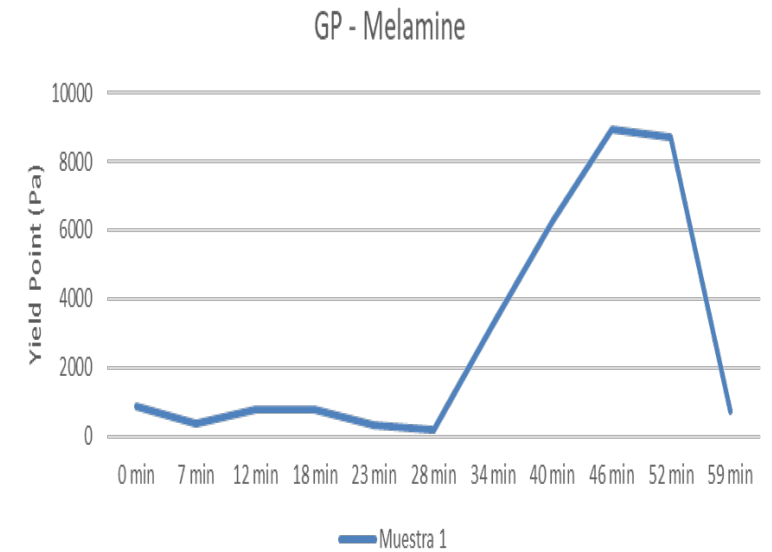
- Amplitude sweep
- Open time
- 3ITT



Amplitude sweep



Open time

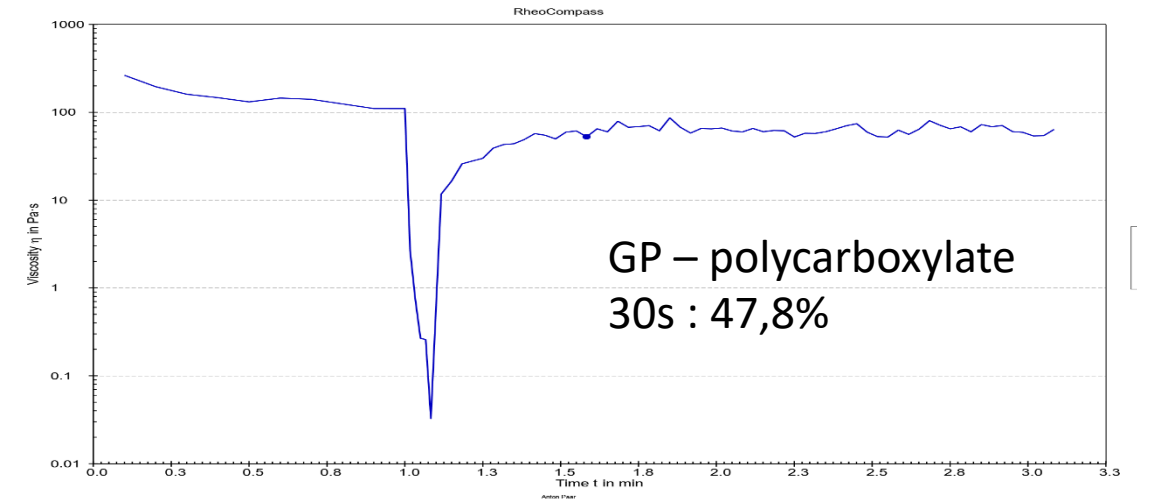
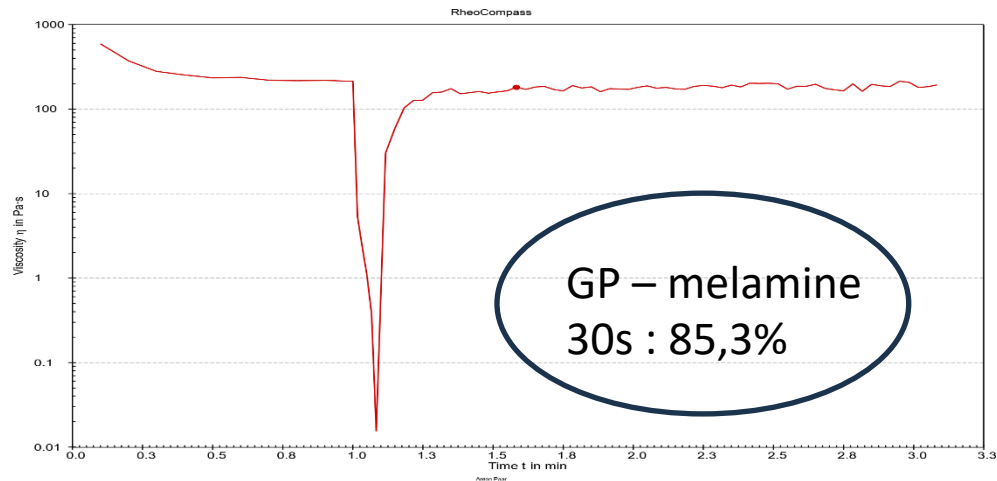
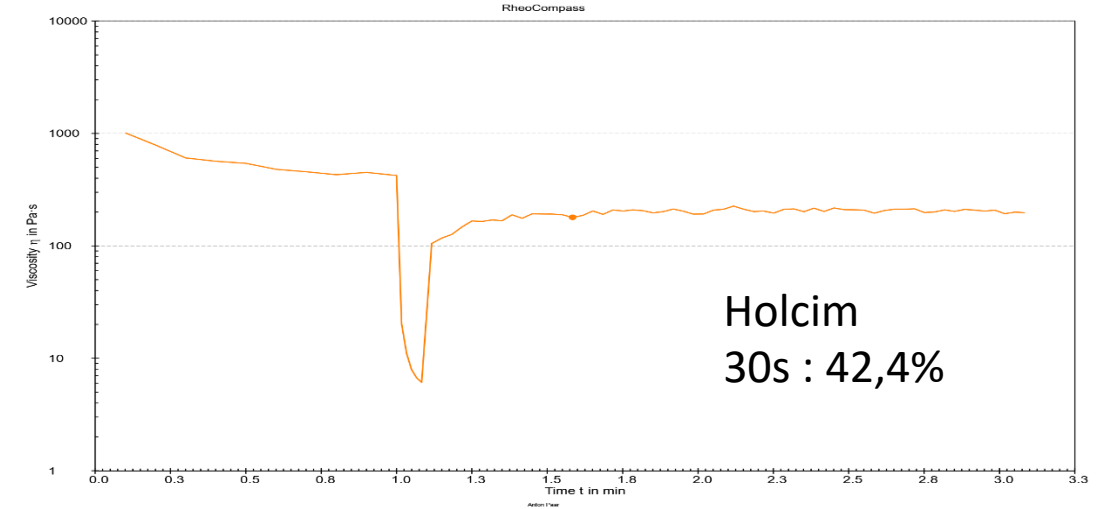
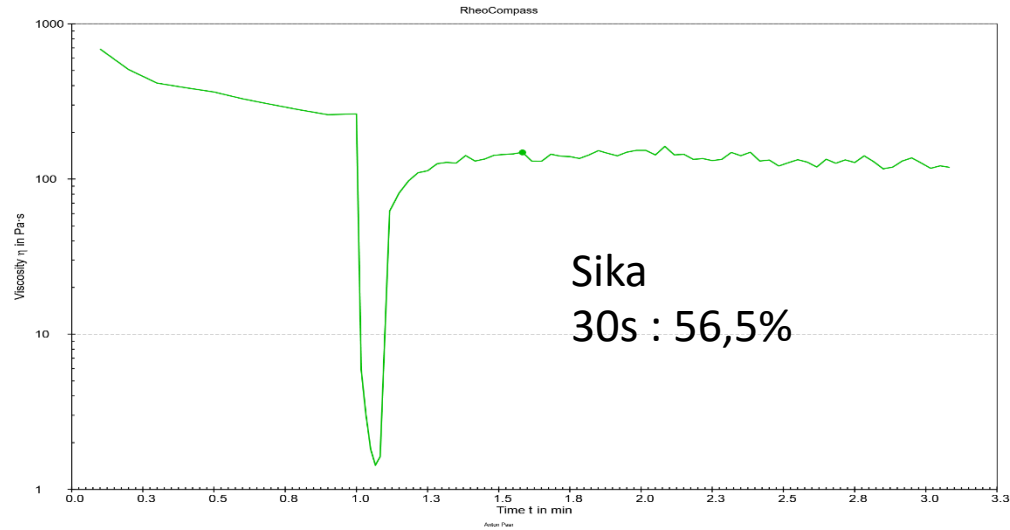


3D Cement	Open time
SIKA	20min
HOLCIM	27min
BeMore3D	30min
GP-P	30min
GP-M	28min

Rheological assessment

3ITT

1 Hopper **2** Extrusion **3** Building



Printing validation

DELTA WASP 40100 LDM

Melamine
based 3D
geopolymer



Collapse test



Shape stability test



Demonstrator (vase)



Collapse test



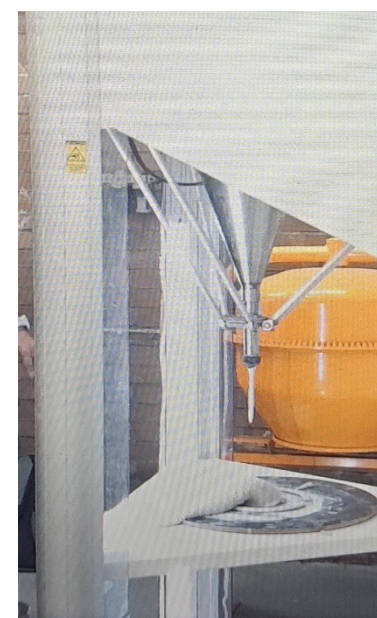
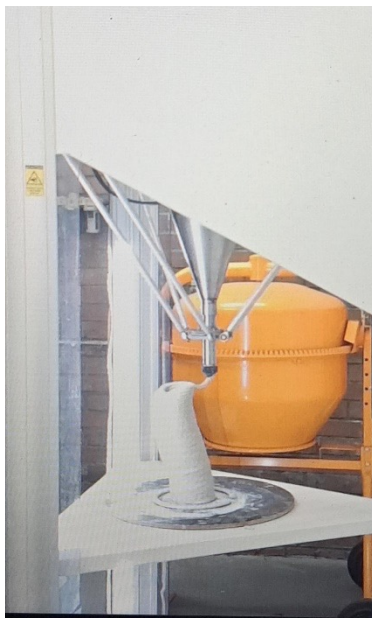
Part: Hollow cylinder, diameter 8cm.

Layer height: 4mm

Speed: 40 mm/s

Flow: Varies to obtain filament widths of 14 mm.

Geopolymer: Collapse at 6min, 60 layers, 24 cm

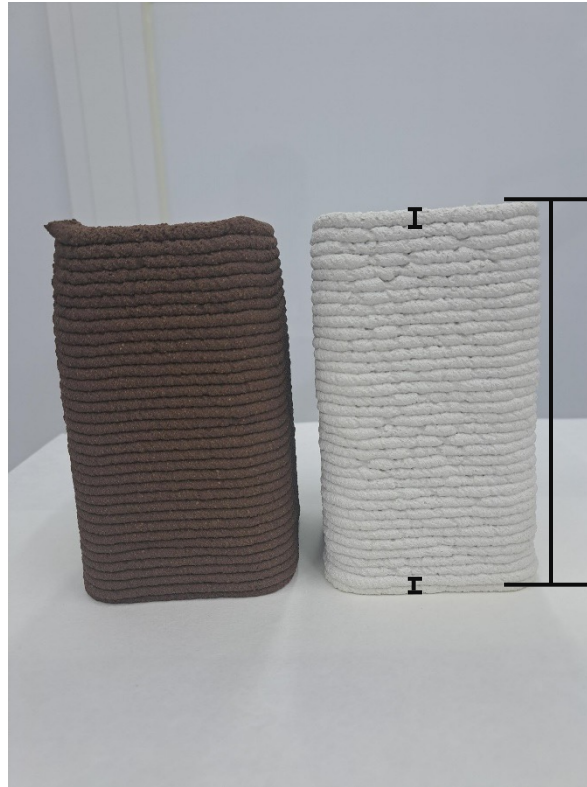


Holcim: Collapse at 6min 6seg, 61 layer, 24 cm

Shape Stability test



Part: Hollow prism, width 8cm, height 14cm
Layer height: 4mm
Speed: 20 mm/s
Flow: Varies to obtain filament widths of 14 mm.

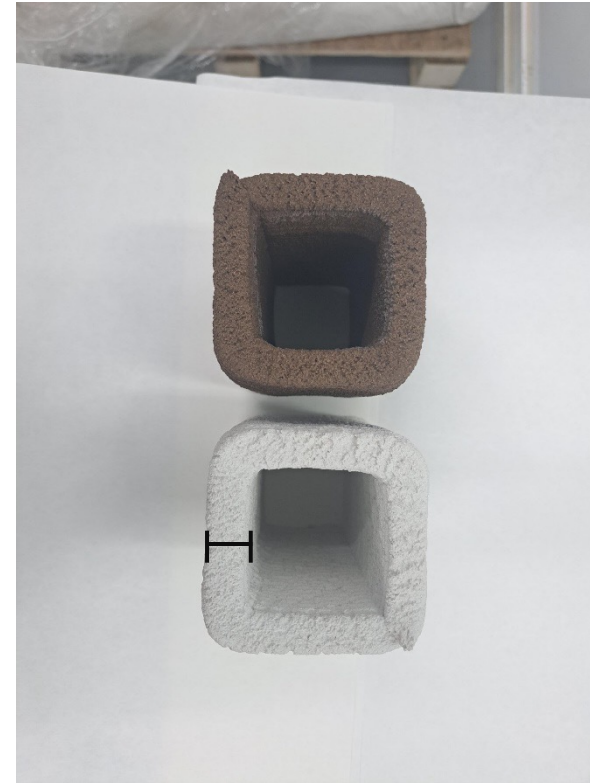


Theoretical/real height ratio:

- **GP:0,97**
- **Holcim:0,99**

Last/1st layer height ratio

- **GP: 0,67**
- **Holcim: 0,75**



Last/1st layer width ratio

- **GP: 0,7**
- **Holcim: 0,78**



standard deviation 5 layers

- **GP: 0,02**
- **Holcim: 0,32**

Printing validation

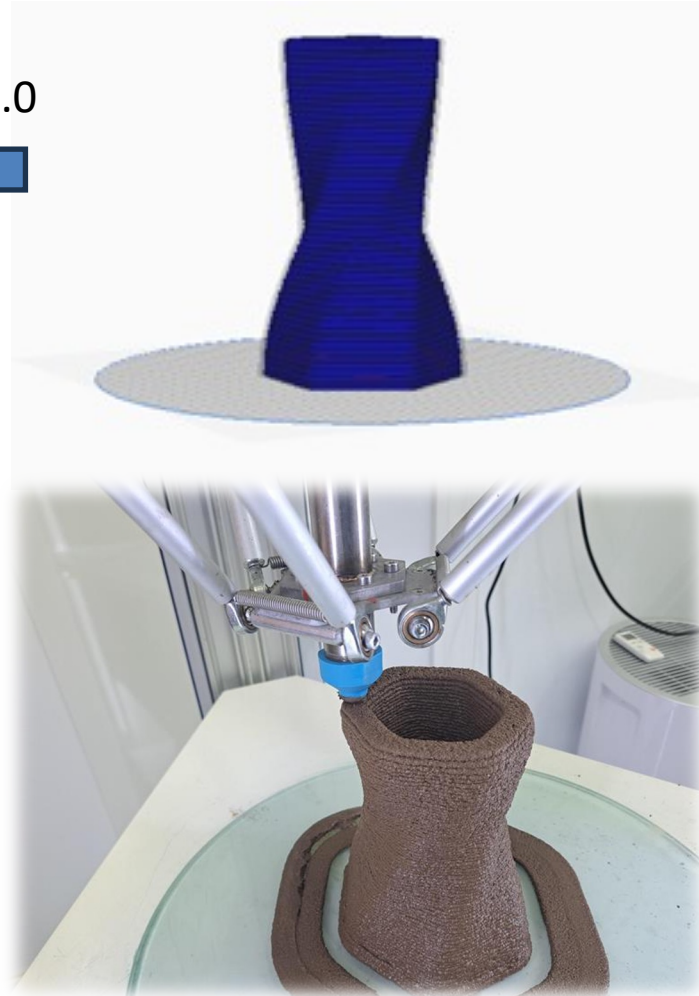
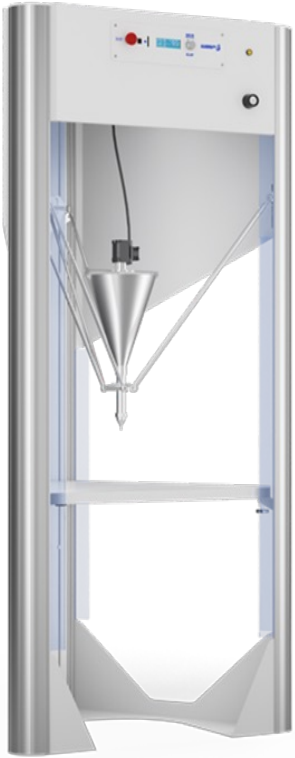
DELTA WASP 40100 LDM

Slicer:
Ultimaker Cura 5.9.0



Printing parameters

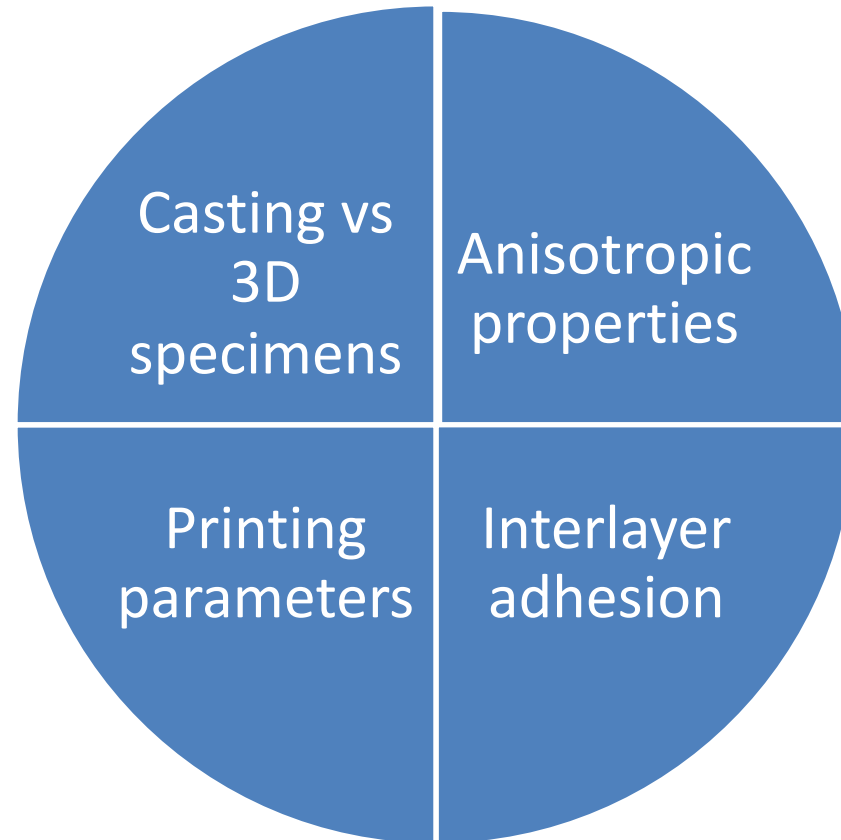
- **Filament width:** 12mm
- **Layer height:** 2mm
- **Flow:** 20%
- **Print speed:** 10mm/s
- **Nozzle size:** 8mm



Main features

<i>Melamine based geopolymer</i>	
Density	2,2 g/cm ³
Flexural strength	7,4 Mpa (28d)
Compressive strength	30,5 Mpa (28d)
Curing conditions	20°C, 50% RH
Waste content	>70%
Setting time	2h 20min
Open time	30min
Yield stress	871 Pa
Viscosity recovery	85% (30seg)

Lab-scale test



Scale-up

- BeMore3D
- Demonstrators: 3m height panels
- Thermal and acoustic insulation
- Tested in a real-building Spain





Thanks for your attention

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