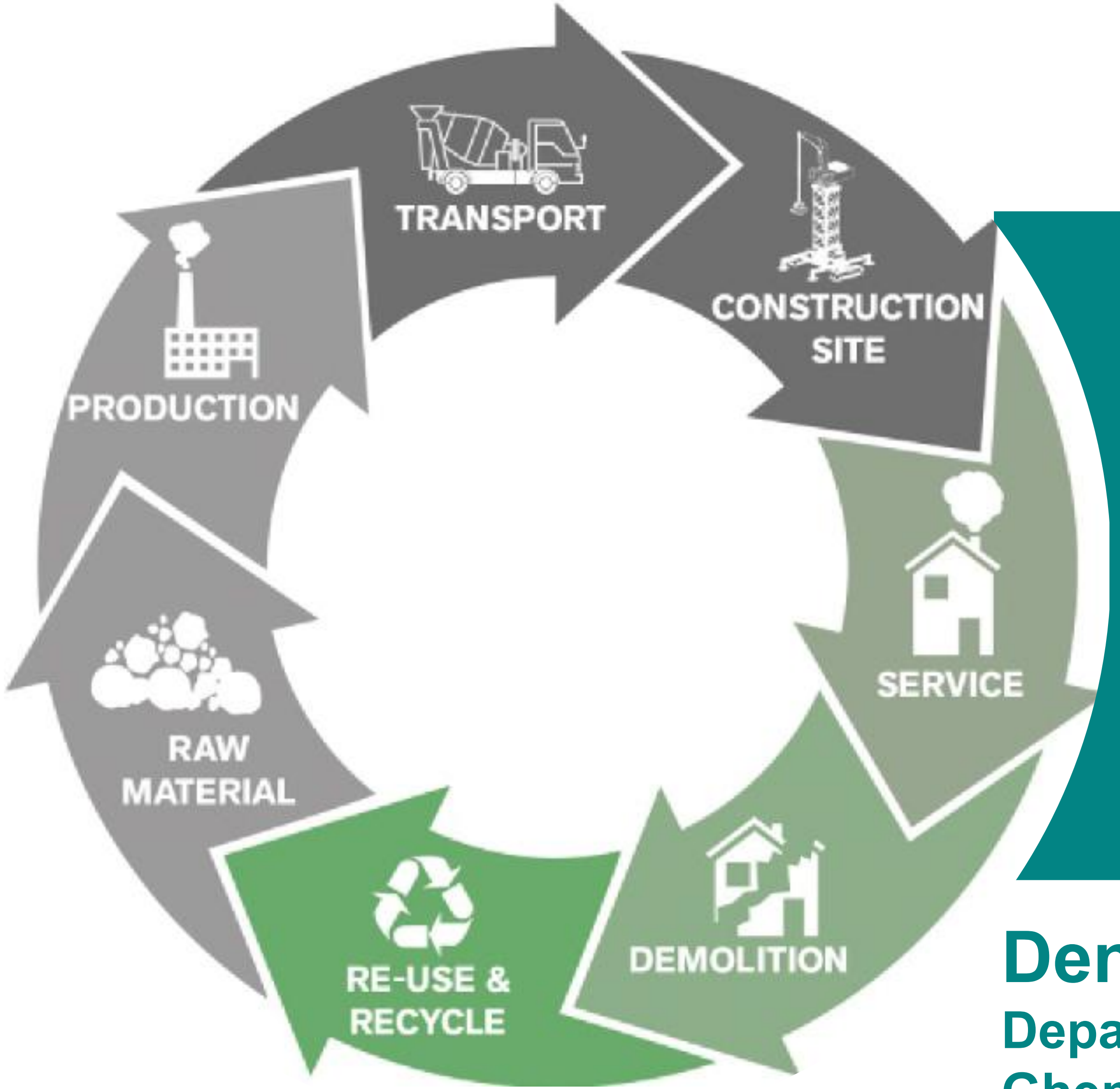
4th *fib Italy YMG* Symposium on Concrete and Concrete Structures
15th & 16th September 2025, Napoli, Italy



An innovative compression-dominant structural system for carbon-negative buildings: An overview of EIC Pathfinder project 'CARBCOMN'

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CARBCOMN
European Innovation Council
Funded by the European Union

OUTLINE

- PROJECT INFORMATION
- MAIN FRAMEWORK
- MATERIALS AND METHODS
- KEY RESULTS
- CONCLUSIONS

PROJECT INFORMATION

CARBCOMN

CARBon-negative COMpression-dominant structures for decarbonized and deconstructable CONcrete buildings

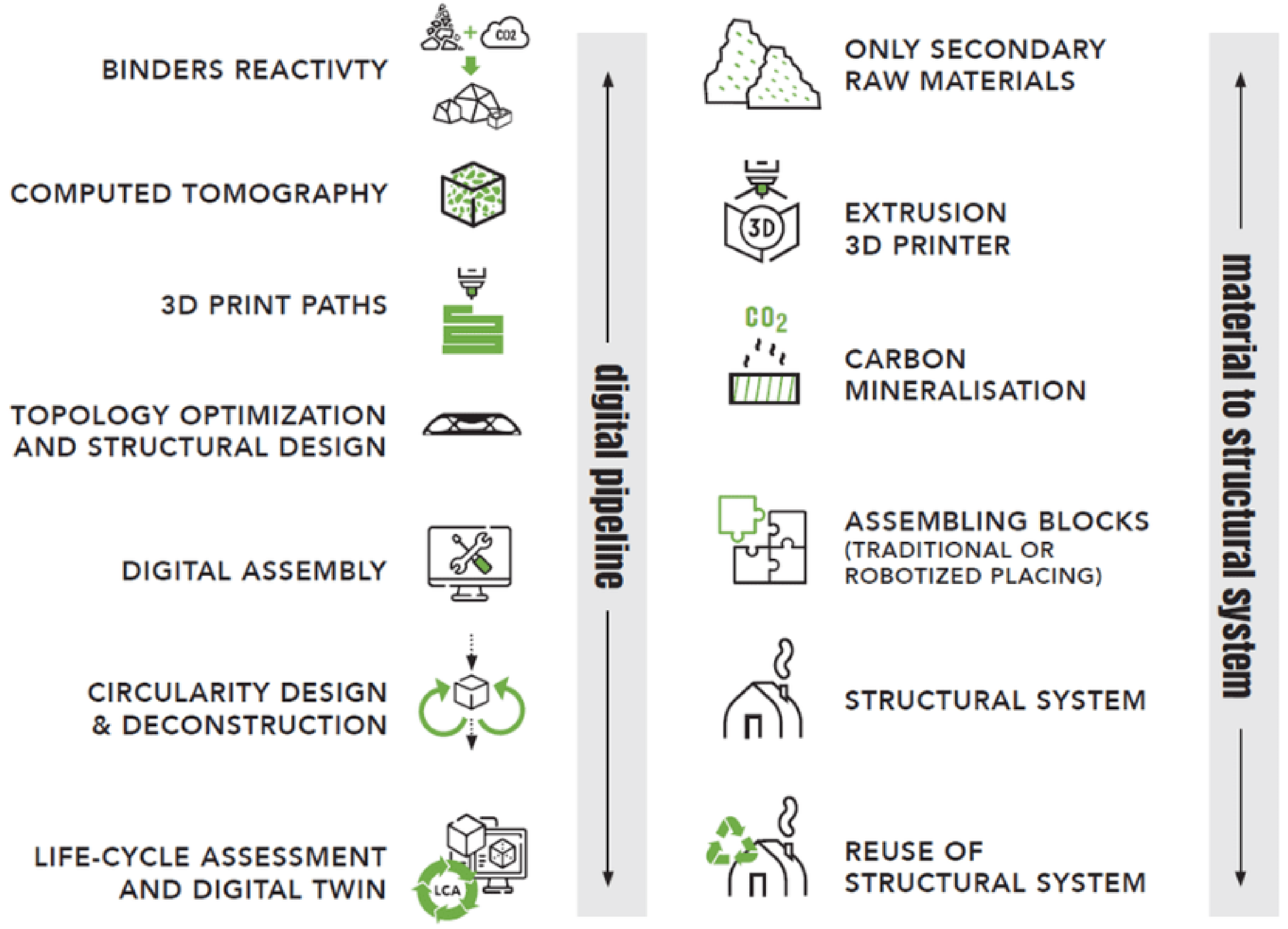
European Innovation Council — Funded by the European Union

Horizon Europe EIC Pathfinder programme (October 2024 – September 2028)

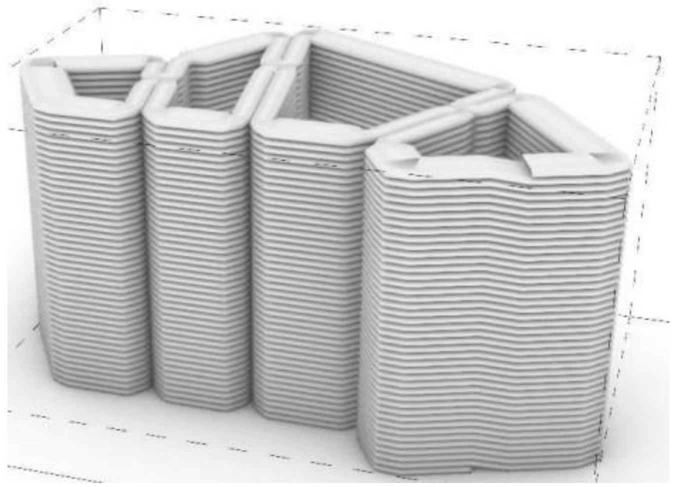
Consortium

5 research institutions & 6 industry partners

Universiteit Gent · Tesis s.r.l. · orbix · Technische Universität Darmstadt · University of Patras · incremental3d · mca · ETH Zürich · Empa · re-fer.eu · Zaha Hadid Architects



MAIN FRAMEWORK

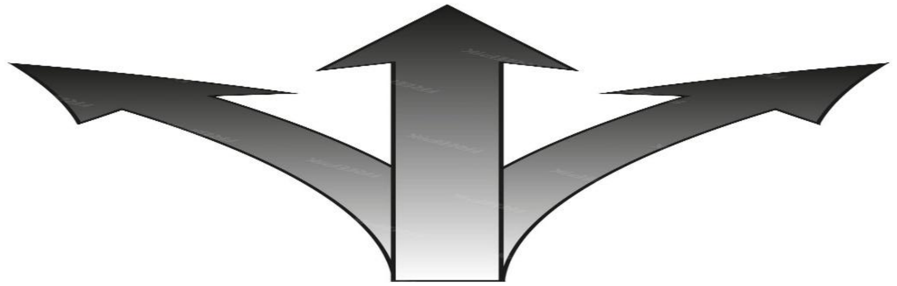


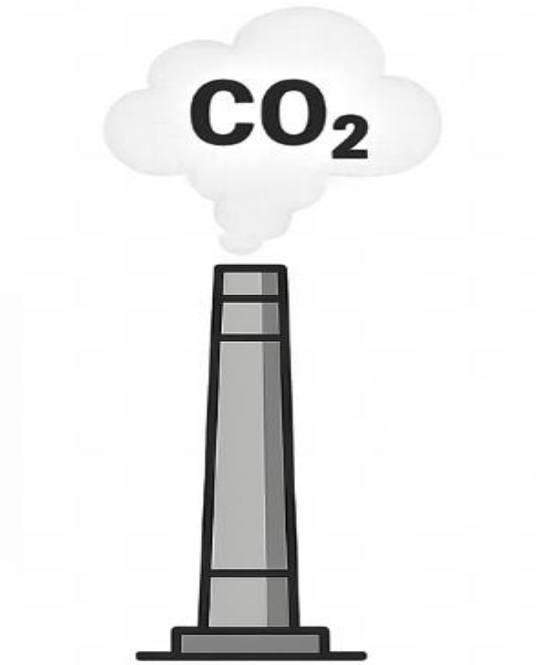
3D-printed concrete blocks

Long construction duration, labor shortage, material wastage, need for formwork

Metal Oxide-rich byproduct (binder & aggregates)

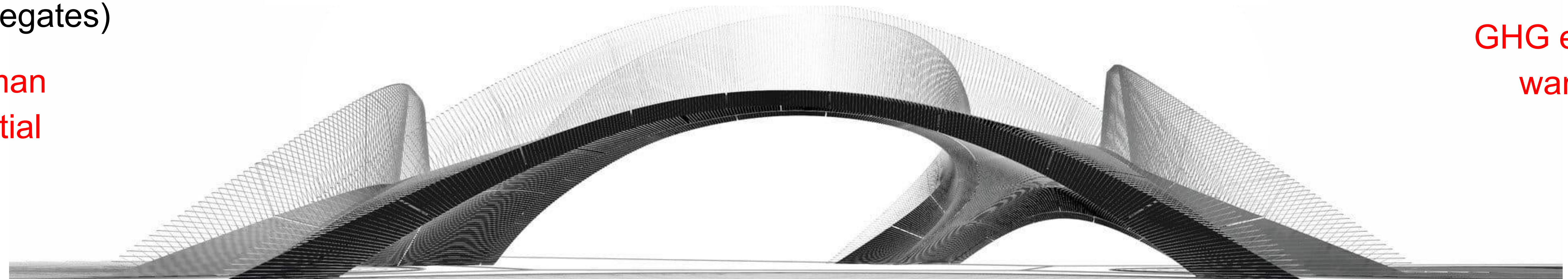
Dumping-human toxicity potential





Captured CO_2

GHG emission - Global warming potential

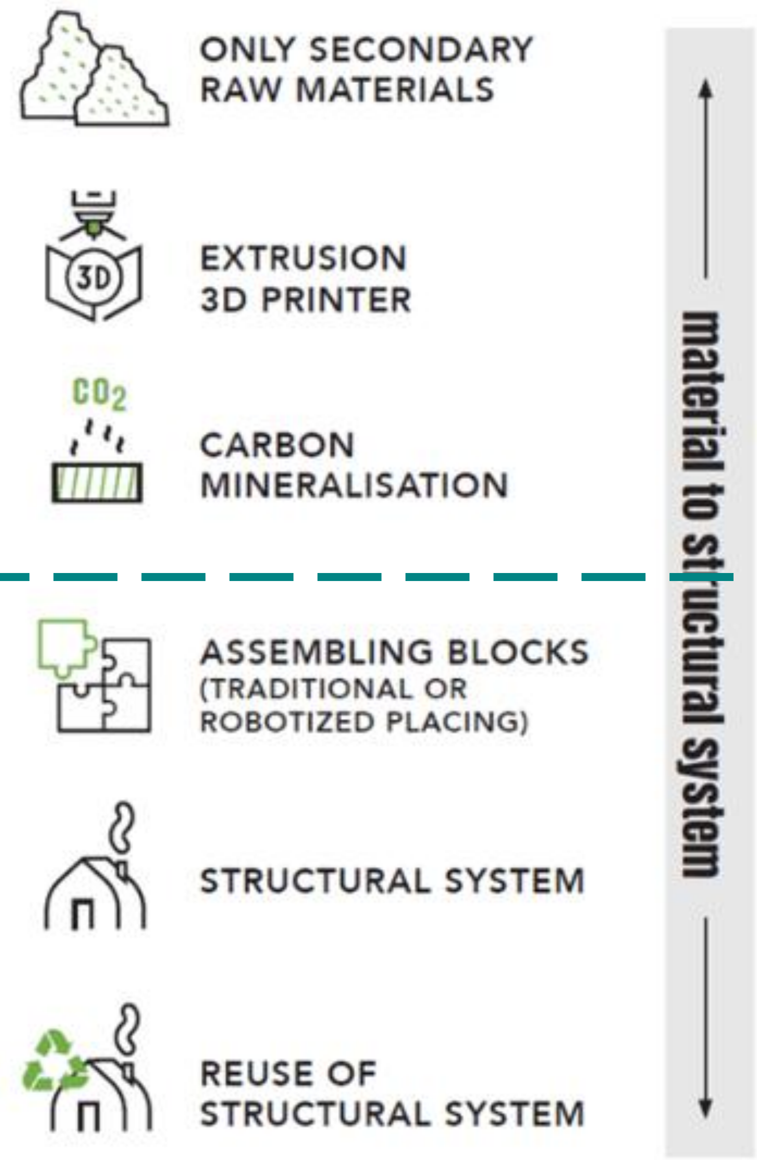


Compression-dominant structural logic

(A. Dell'Endice et. Al, 2023)

MAIN FRAMEWORK

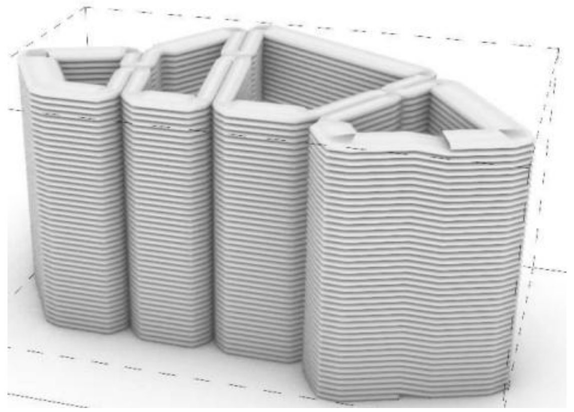
Material system



Process

- Optimization of formulations
- Flow assessment
- Yield stress evolution
- Extrudability assessment and small-scale specimen fabrication
- Carbon-curing of specimens
- Mechanical performance assessment
- 3D-print trial
- Carbon-curing of blocks
- Mechanical performance assessment of carbon-cured block

Short-term goal



First 3D-printed carbon-cured block

Towards the first 3D-printed carbon-cured block

MATERIALS & METHODS

Materials


Binder - Carbinox

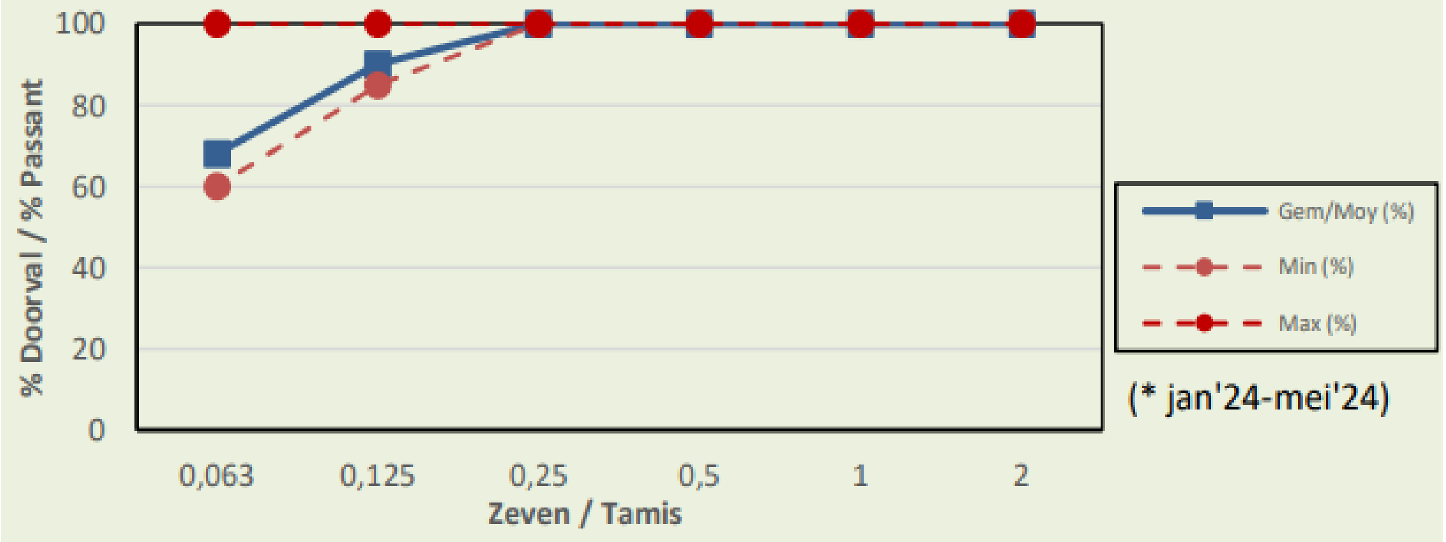
Fine stainless-steel slag fraction
Particle size: 0.25 mm max.
Bulk density: 1,000 kg/m^3
Apparent particle density: 2,527 kg/m^3


Aggregates - Stinox

Coarser blended slag fraction
Particle size: 2 mm max.
Bulk density: 1,586 kg/m^3
Apparent particle density: 1,775 kg/m^3
Water absorption capacity: 3.1 %

- Water - Potable
- VMA: HMC, Tylose (ShinEtsu)
- Superplasticizer: PCE MasterGlanium 51 (BASF)

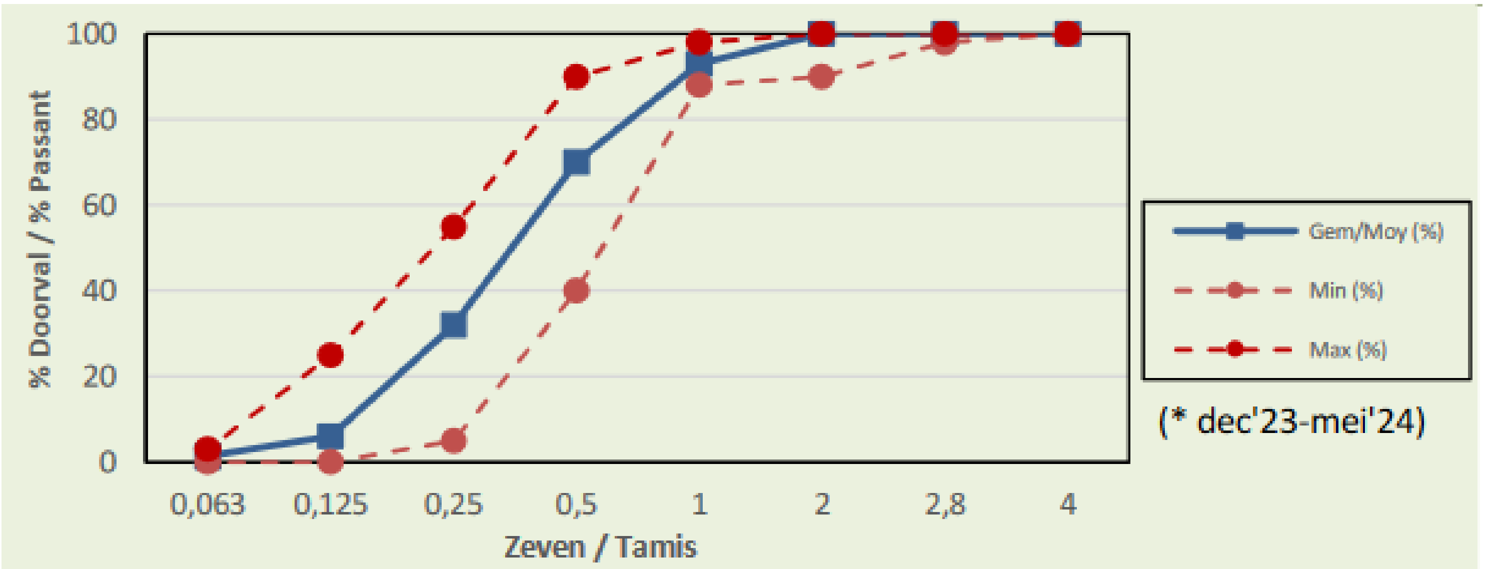
Printability optimization



Binder Gradation Curve - Orbix

Mineral Oxide	CaO	SiO_2	MgO	Al_2O_3	Mn_2O_3	Cr_2O_3	Fe_2O_3	TiO_2
% by mass	51.0	25.3	10.5	5.9	1.2	2.9	1.1	1.0

Chemical composition of binder- Orbix



Aggregates Gradation Curve - Orbix

Materials supplied by Orbix, Belgium

MATERIALS & METHODS

Methods

Optimized formulations

mix	A/B ratio	W/B ratio	SP/B ratio (%)	VMA/B ratio (%)	D1 (mm)	D2 (mm)	Davg. (mm)
M-0.5_0.25	**0.5**	**0.25**	**0.80**	**0.056**	**165**	**165**	**165**
M-0.5_0.30	0.5	0.30	0.25	0.056	155	160	158
M-0.5_0.35	0.5	0.35	0.00	0.075	170	165	168
M-0.7_0.25	0.7	0.25	1.00	0.080	155	150	153
M-0.7_0.30	0.7	0.30	0.50	0.080	165	160	163
M-0.7_0.35	0.7	0.35	0.00	0.045	155	155	155
M-1.0_0.25	1.0	0.25	1.75	0.090	150	150	150
M-1.0_0.30	1.0	0.30	1.00	0.090	150	155	153
M-1.0_0.35	1.0	0.35	0.50	0.090	160	160	160

Flow dia. 150 – 170mm

A/B - Aggregate-to-binder ratio
W/B - Water-to-binder ratio
SP/B - Superplasticizer-to-binder ratio
VMA/B - VMA-to-binder ratio
D1, D2 - Spread diameter in perpendicular directions
Davg. - Average of D1 & D2 (ASTM 1437-20)

Mixing time, 2.5 min rotary mixer

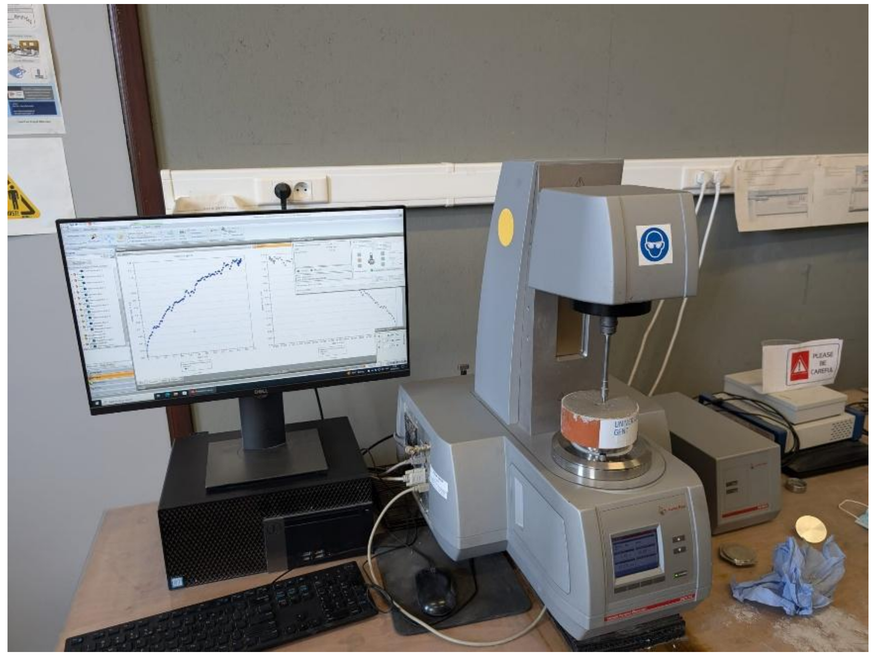
Mix M-0.5_0.25 considered reference mix for the first 3D-print test, its performance reported here as key result.

Flow optimization (ASTM 1437-20)

Before 25 drops

After 25 drops

Slow penetration tests



Anton-Paar MCR 102 Rheometer

Speed: 5 μm/s
Time: 600 s

MATERIALS & METHODS

Methods

Specimen extrusion

Extruded layered specimen

- Printing speed 40 mm/s
- Layer dimensions approx. 45 mm width & 15 mm height
- 2D Mortar gun
- Transferred to chamber 30 – 45 min after printing

Carbonatation

3% CO_2 20˚C Temp, 60% RH

Mechanical properties

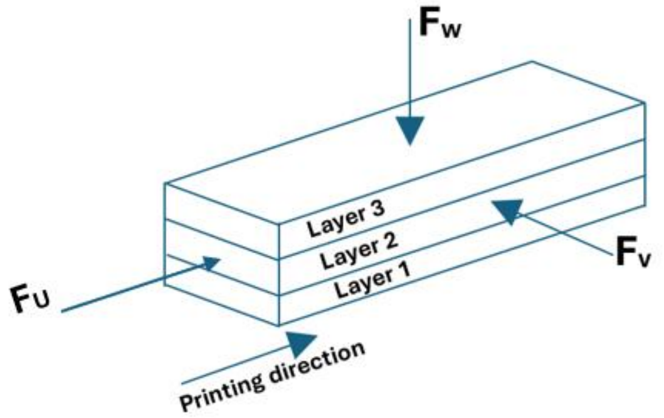
Flexural test (3-point bending)
EN 12390-5

Compression test
EN 12390-3

Carbonation depth

Uncarbonated

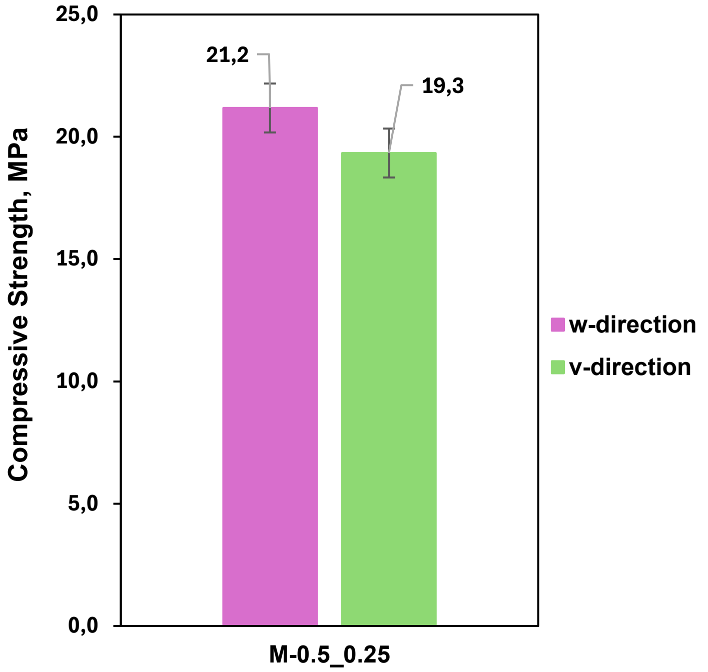
Fully carbonated (7 days)

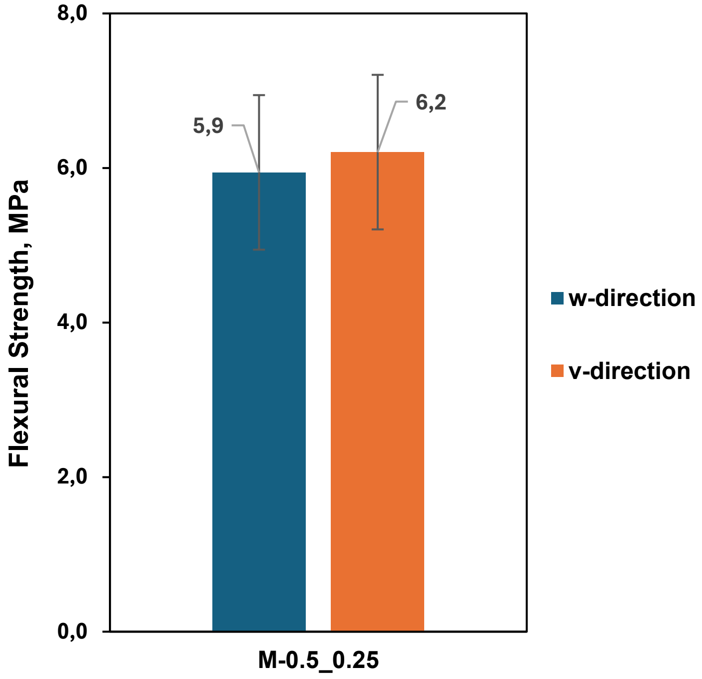


Loading sign convention

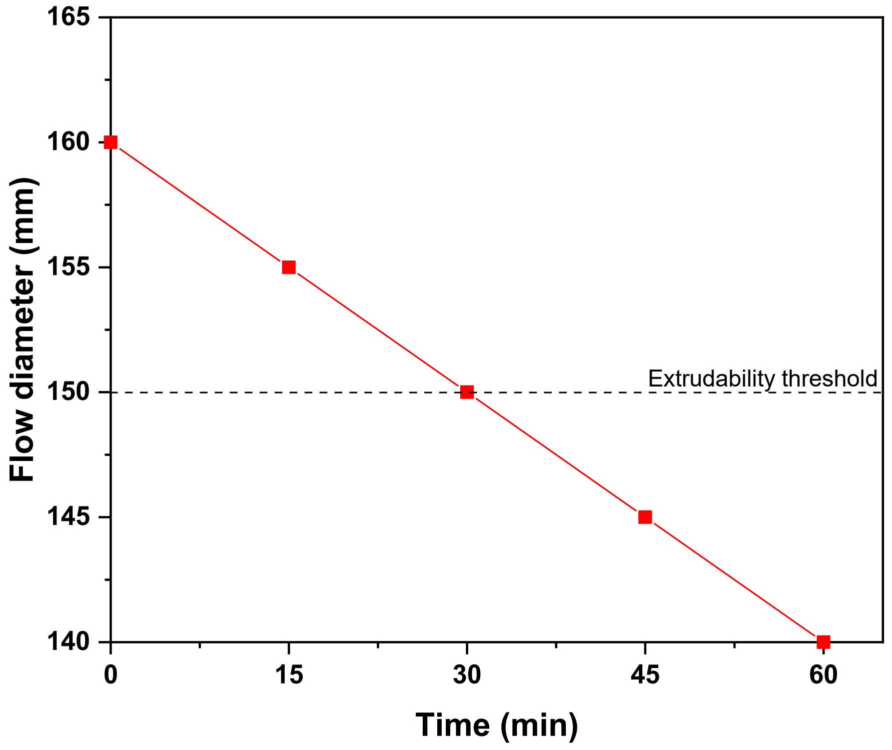
KEY RESULTS

Mechanical Performance – reference mix

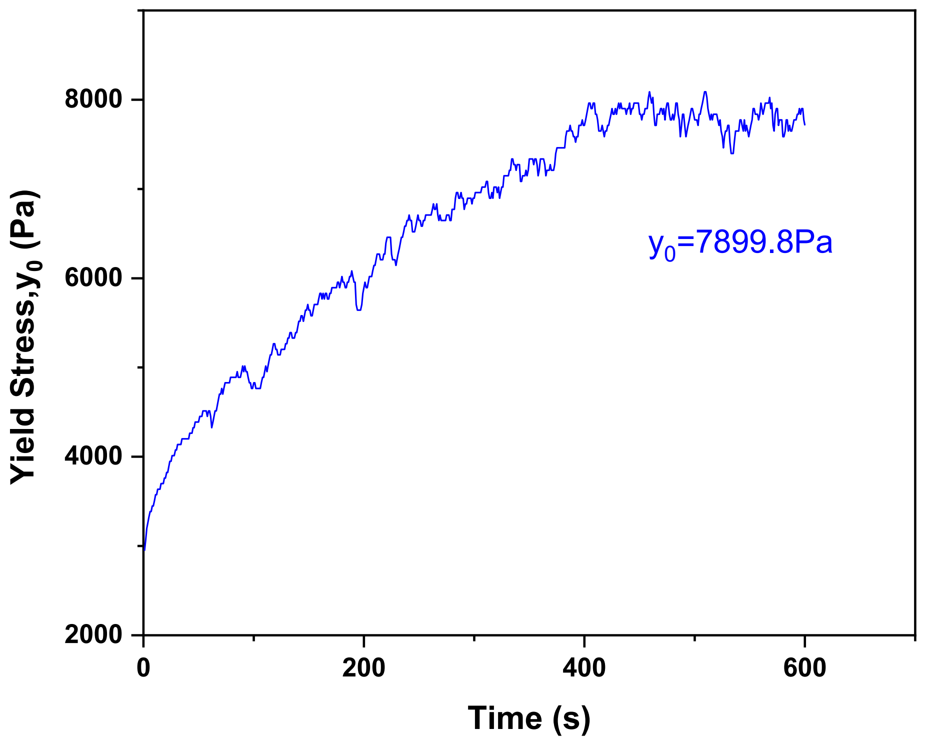




Flow retention



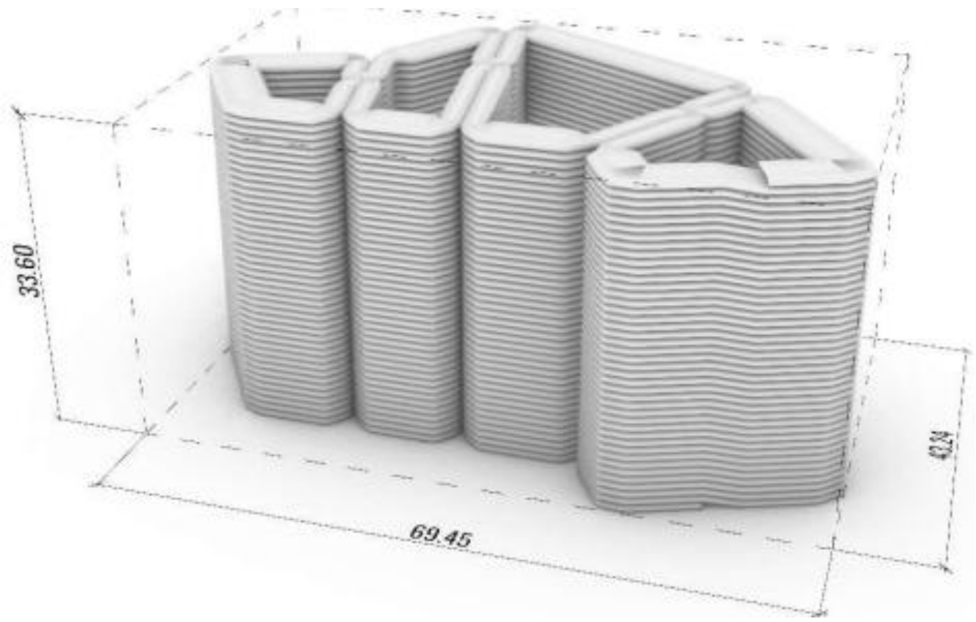
slow penetration test - buildability



$$Printing\ height, H_{cr} = \frac{\sqrt{3} \times y_0}{\rho_m \times g},$$

y_0 = 7,899.8Pa, ρ_m = 1882kg/ m^3, g = 9.81m/s^2

H_{cr} = 740 mm (Higher than proposed block geometry)



Proposed 3D-print trial geometry

3D-printing with 6-axis Robotic arm at UGent

Printed & Carbon-cured geometry

CONCLUSIONS

- **Flow optimization** enabled achievement of a printable rheology using **non-activated industrial slags** with additives

- Achieved up to **22 MPa compressive** and **6 MPa flexural strength** after **7 days of carbonation curing** (3% CO_2, 20˚C Temp, 60% RH)

- successful **first 3D-print trial** with **one-component (1k) system**

✅ **Demonstration of potential for ultra-low-carbon waste-based materials in 3D concrete printing (3DCP)**

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CARBCOMN

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