CDW-based geopolymer mortar with different binder-to-sand ratios

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RecyCon research group

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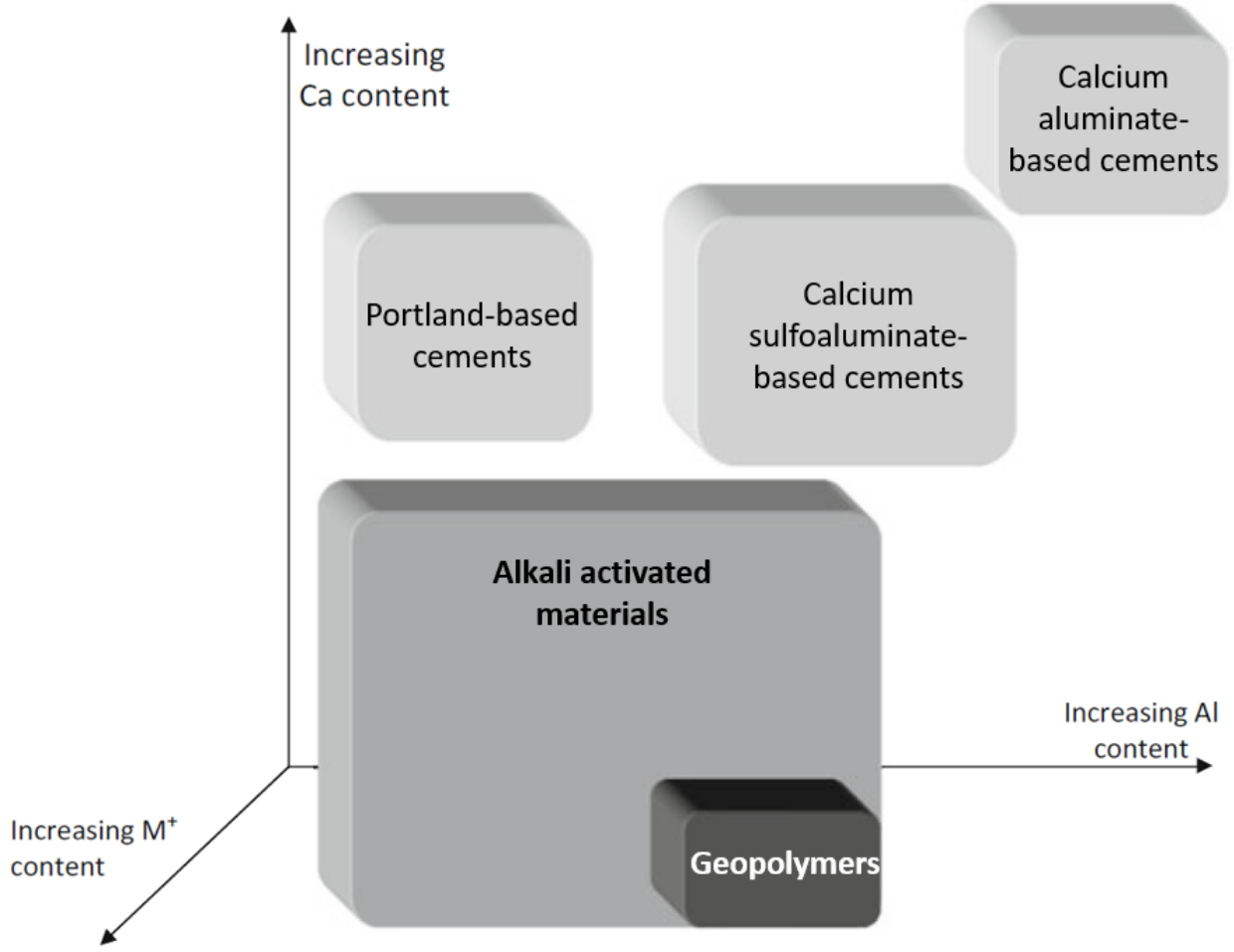
- Prof. Dr.-Ing. Jiabin Li

Geopolymer (GP) vs. alkali activated material (AAM)

- **AAM** = broadest classification
  - Alkali metal source
  - Solid silicate powder
- **GP** = subset of AAMs
  - Low calcium content
  - Polymerization of silicates and alumino-silicates in alkaline or acidic medium



[1] Provis, J.L.: Activating solution chemistry for geopolymers. In: Provis, J.L., van Deventer, J.S.J. (eds.) Geopolymers: Structure, Processing, Properties and Industrial Applications, pp. 50–71. Woodhead, Cambridge (2009)

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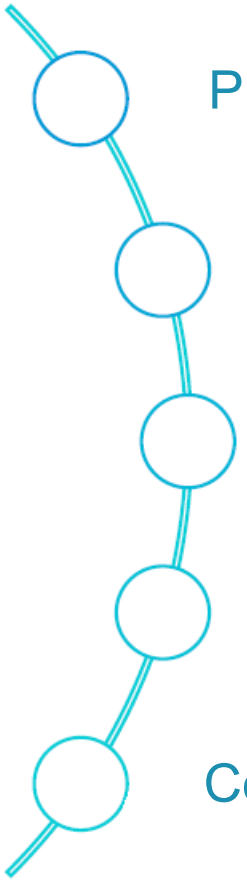
Presentation overview



Problem statement

Construction and Demolition Waste (CDW) fines

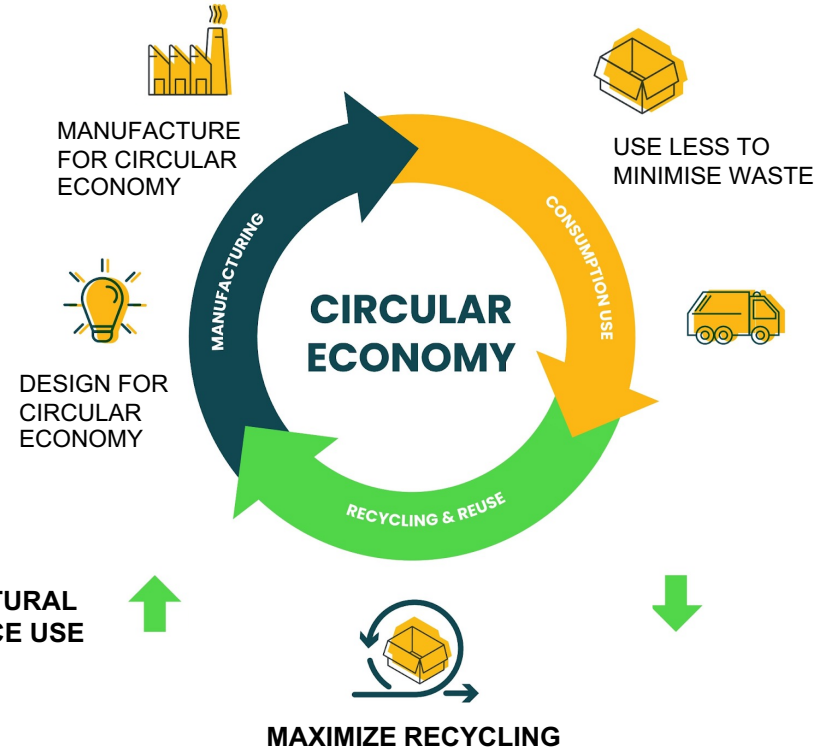
Materials and methodology

Research results

Conclusions and future research

Problem statement

- Environmental impact of construction industry
- Construction and demolition waste (CDW)
- Circular economy model



[3] Chen, C. et al. (2010). Environmental impact of cement production: detail of the different processes and cement plant variability evaluation. Journal of cleaner production.

[4] Mohamad, N. et al. (2022). Environmental impact of cement production and Solutions: A review. Materials Today: Proceedings.

Construction and demolition waste (CDW)

Recycled coarse and fine aggregate (RA)

90%

Recycled powder (RP)

10%

Low reactivity

Recycled concrete powder (RCP)

Recycled brick powder (RBP)

Recycling of CDW fines (< 125 µm)

Material properties – precursors

RBP & RCP:

Oven drying
+
Sieving < 125 µm

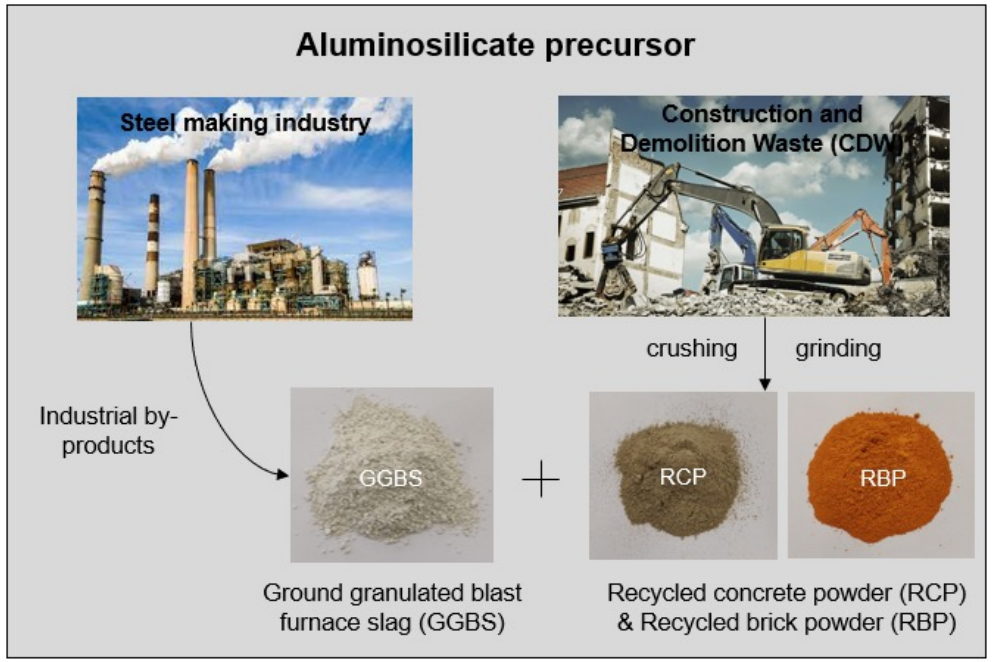
Precursors	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Others
GGBS	33.3	12.6	0.41	40.4	8.28	0.74	0.63	3.6
RBP	63.2	13.0	4.58	10.8	1.83	2.72	1.89	2.0
RCP	38.3	7.02	5.41	42.4	1.59	1.21	0.42	3.7

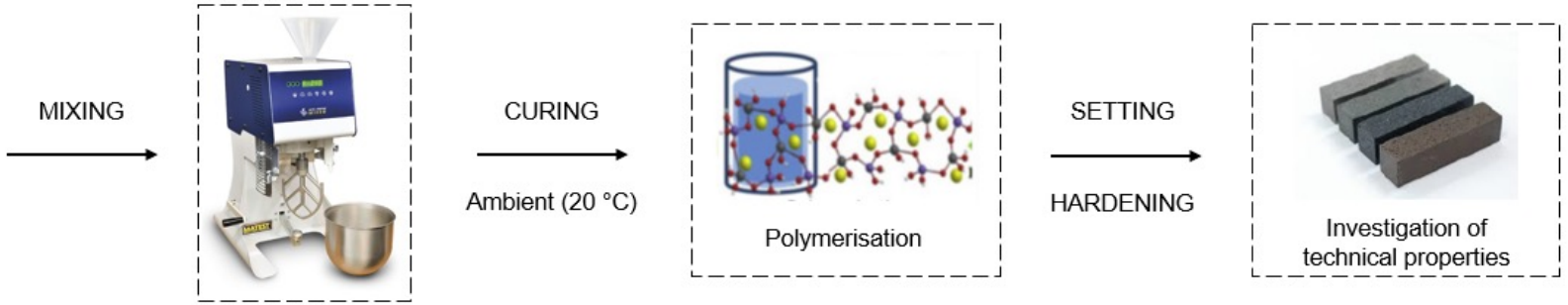
GGBS = Ground Granulated Blast Furnace Slag
RBP = Recycled Brick Powder
RCP = Recycled Concrete Powder

Precursors	Specific surface area [m^2/g]	D10 [µm]	D50 [µm]	D90 [µm]
GGBS	1.48	1.60	11.0	31.3
RBP	0.96	2.93	23.4	70.9
RCP	1.07	2.04	28.5	92.9

GGBS = Ground Granulated Blast Furnace Slag
RBP = Recycled Brick Powder
RCP = Recycled Concrete Powder

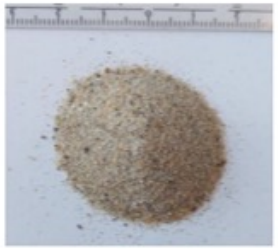
Research methodology – overview

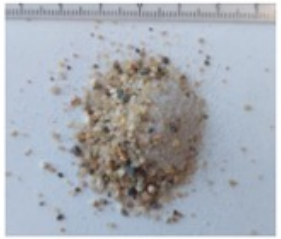




Sand type and content

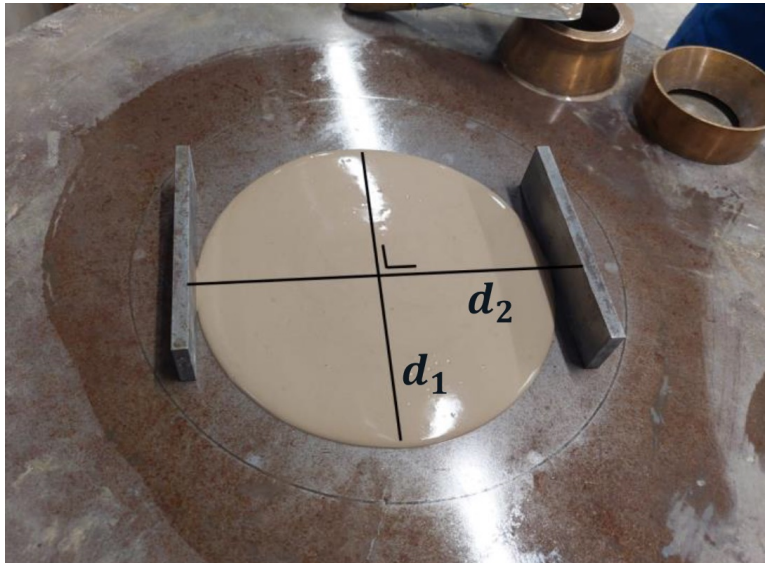

Sand 0/1 mm

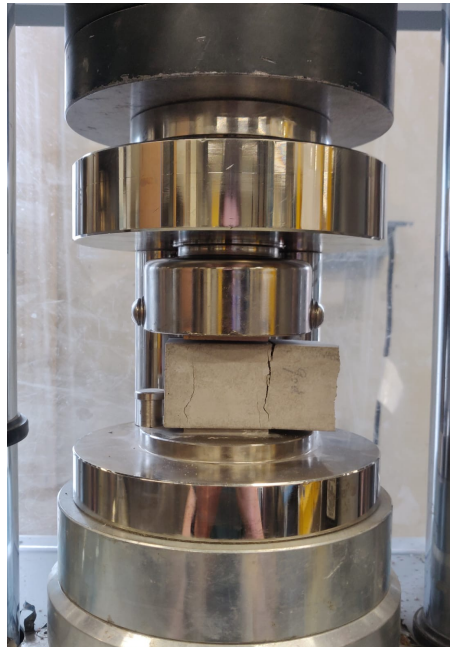

Sand 0/2 mm

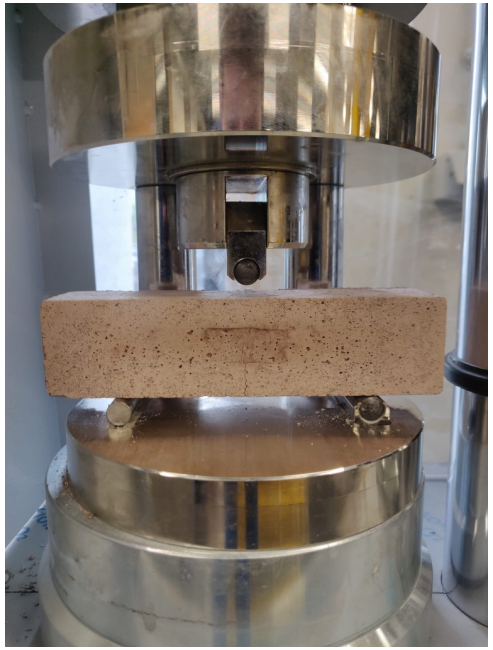

CEN standard sand

Methodology and testing

- Alkaline activator preparation
  - ➢ Preparation of NaOH solution
  - ➢ Mixing NaOH with Na_2SiO_3
- Alkali activated paste & mortar
  - ➢ 60% GGBS, 15% RCP, 25% RBP
  - ➢ Addition of sand (**0 wt.% → 60 wt.%**)
- Testing
  - Dry bulk density (NBN EN 12390-7)
  - Consistency of fresh mortar (NBN EN 1015-3)
  - Compressive/flexural strength (NBN EN 196-1)

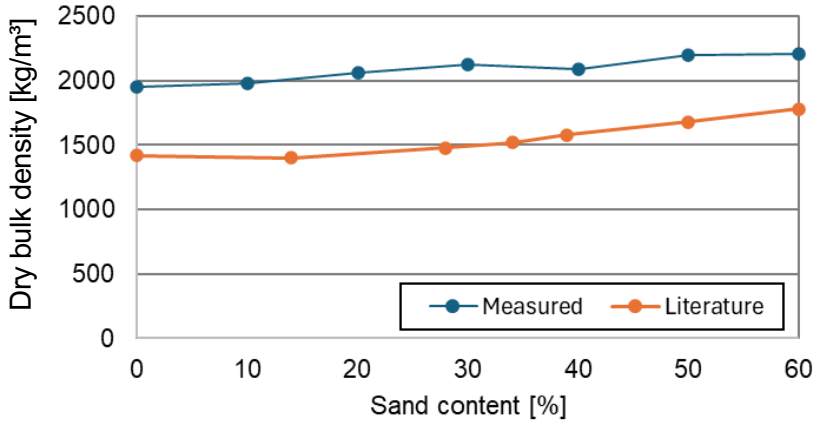




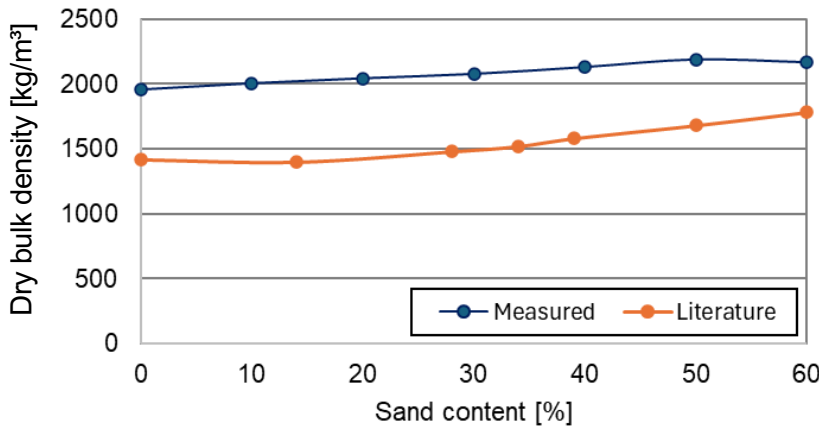


Dry bulk density (NBN EN 12390-7)

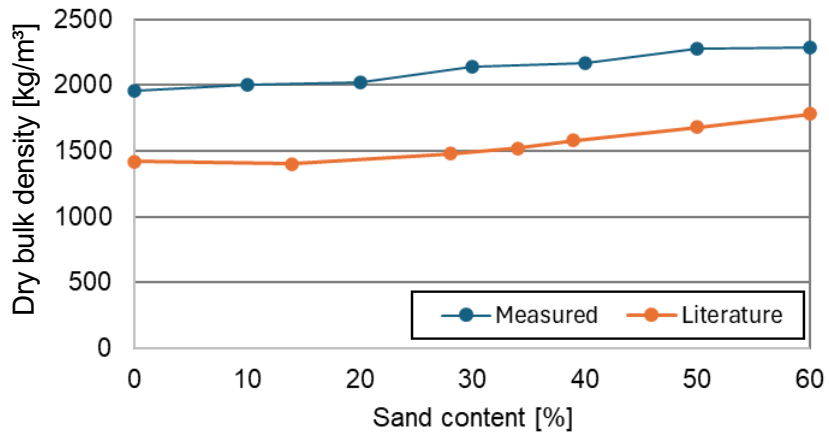
Sea sand 0/2 mm



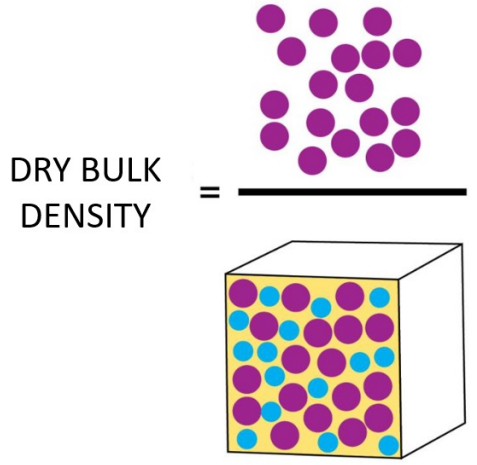
Sea sand 0/1 mm



CEN Standard sand

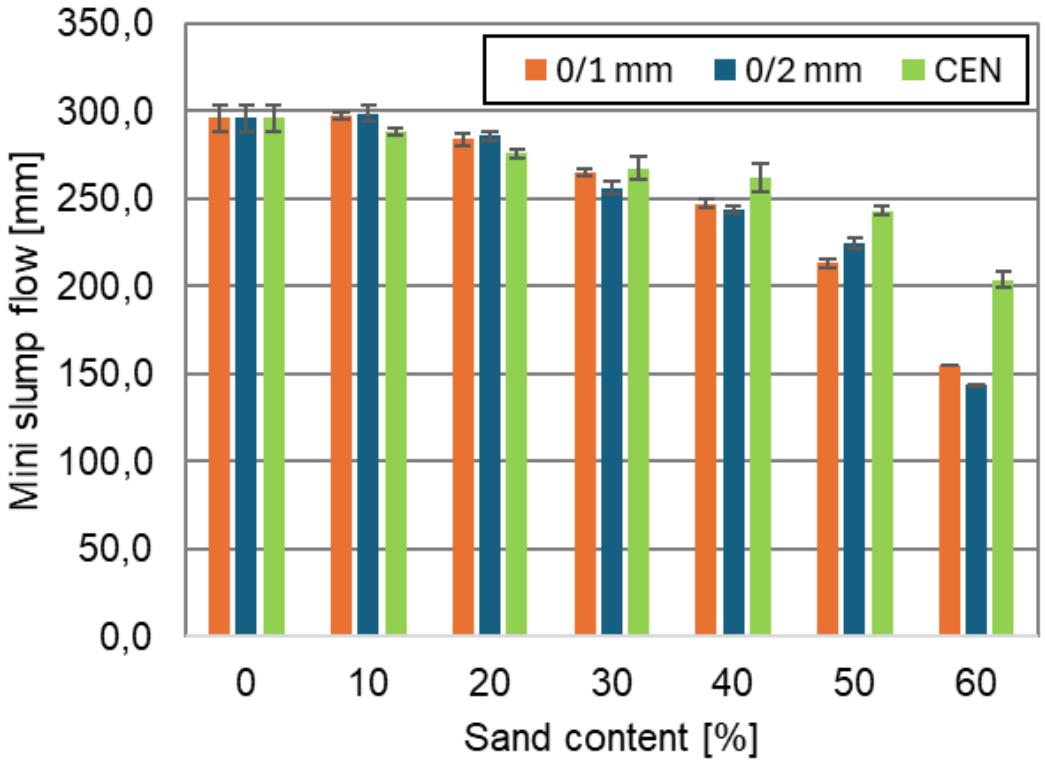


- Increasing sand content up to 50 wt.% → increase in bulk density
- At 50 wt.% = maximum bulk density is reached
- Sand contents exceeding 50 wt.% → decrease in bulk density



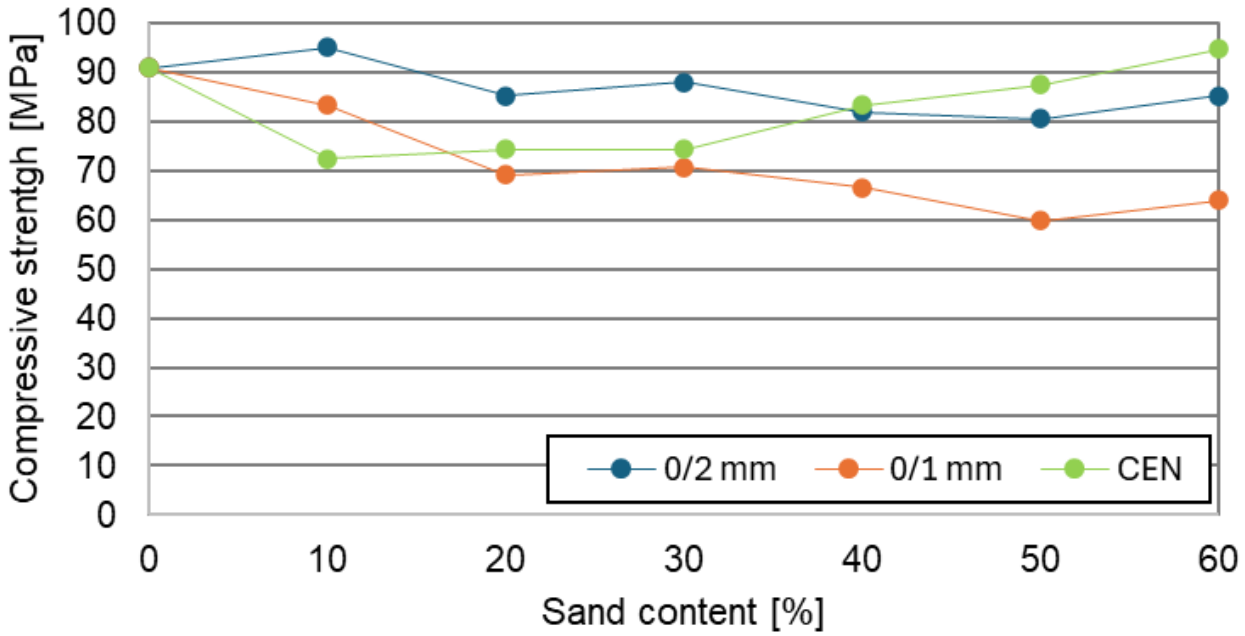
[5] SteinerOva, M. (2011). Mechanical properties of geopolymer mortars in relation to their porous structure. Ceramics-Silikáty, 55(4), 362-372.

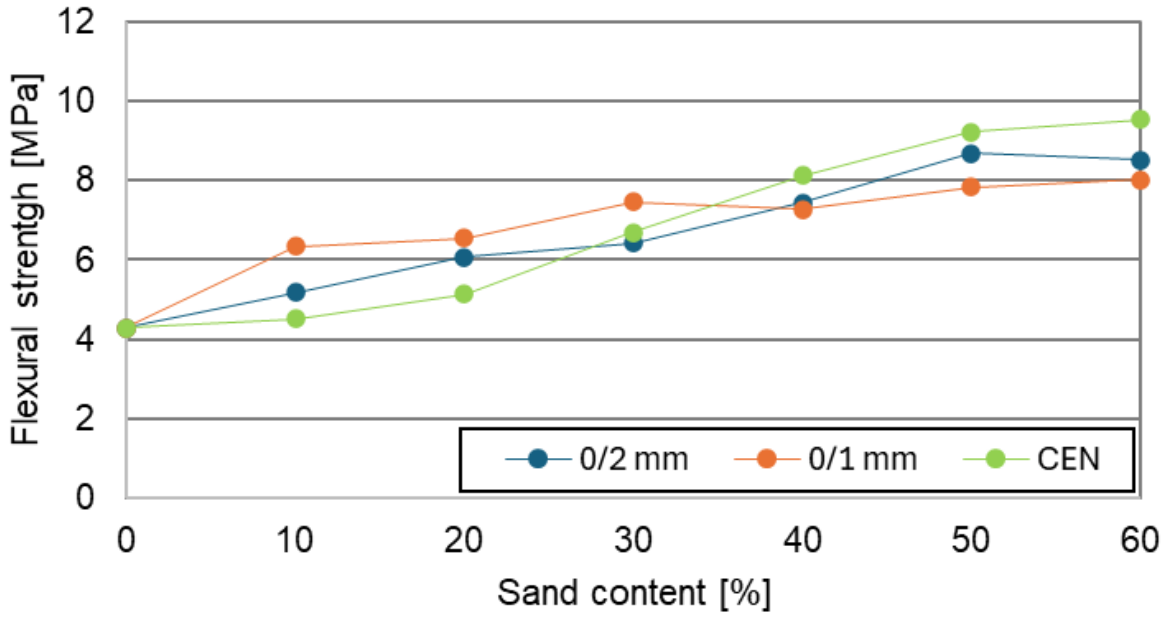
Consistency / workability (NBN EN 1015-3)



- Sand content ↑ → flowability ↓
- Finer sand particles = steeper decrease
- Optimal flow = 50 wt.% of CEN sand

Compressive versus flexural strength (NBN EN 196-1)





Compressive strength
- No significant influence of sand content
- Influence of sand type

Flexural strength
- Influence of sand content
- Influence of sand type

Research conclusions & applications

	Dry bulk density	Workability	Flexural strength	Compressive strength
Sand ↗ (up to 50 wt.%)	↗	↘	↗	→
Sand ↗ (> 50 wt.%)	→/↘	↘	→/↘	→
Fineness ↘	↗	↗	↗	↗

- **50% CEN standard sand addition** (in scope of this research)
- **Rheological properties** needs to be investigated
- **Porosity** (high-pressure mercury porosimetry or SEM microscopy images)
- **Long-term durability aspects** (freeze-thaw, carbonation, chemical and under water stability)

Future research needs

- MK addition for Tempozz (Ralf Tönnies) => real GP formulation

Product	temPozz	C90	C90f	M86	M88	M92
Calcination technique		flash	flash	flash	flash	flash
Colour	L	89,3	91,1	86,6	88,1	91,6
	a	0,4	-0,2	0,7	0,4	0,7
	b	2,1	1,4	2,8	2,7	3,4
Chapelle value	mg Ca(OH)2/g	1 200	1 300	1 200	1 300	1 400
Particle distribution	d10	1 µm	1 µm	1 µm	1 µm	1 µm
	d50	5 µm	2 µm	5 µm	3 µm	3 µm
	d90	15 µm	10 µm	15 µm	10 µm	10 µm
Chemical composition	SiO2	~52	~52	~54	~54	~54
	Al2O3	~45	~45	~43	~43	~43
	Fe2O3	<0,5	<0,5	<1,0	<1,0	<1,0
	TiO2	<0,8	<0,8	<1,2	<1,2	<1,2
	CaO	<0,5	<0,5	<0,5	<0,5	<0,5
	MgO	<0,2	<0,2	<0,2	<0,2	<0,2
	K2O	<0,1	<0,1	<0,1	<0,1	<0,1
	Na2O	<0,2	<0,2	<0,2	<0,2	<0,2

Thank you for your attention!

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