Workability and mechanical properties of CDW-GGBS based geopolymer composites

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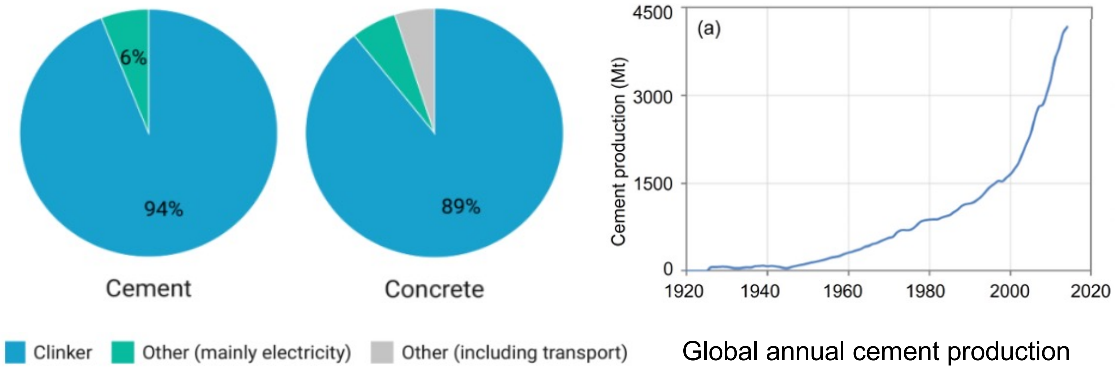
Presentation overview

- Problem statement
- Research methodology
- Materials and experimental methods
- Results
- Conclusions

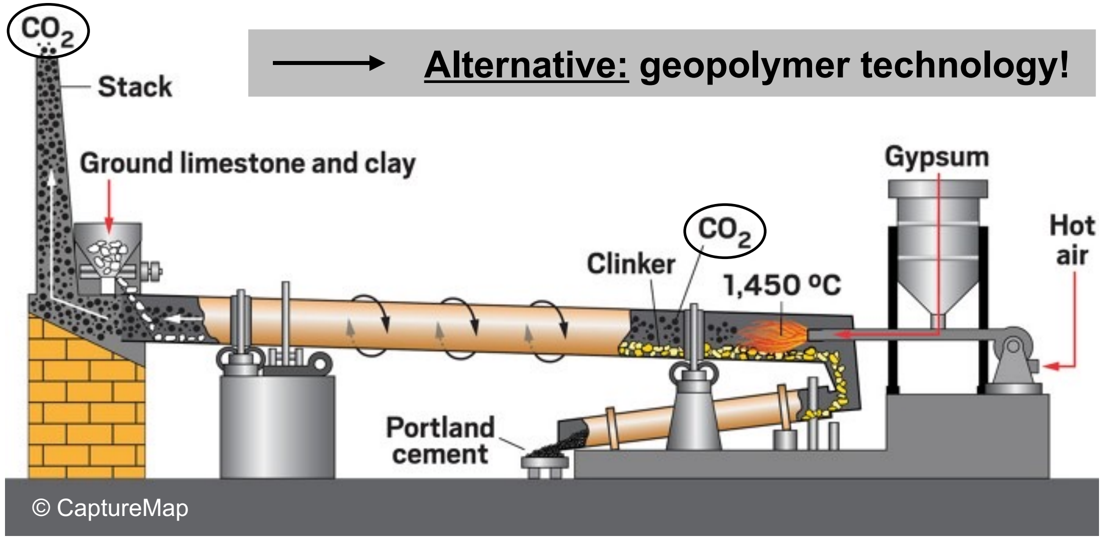
Problem statement (1)

Cement production and high CO_2−emissions[1,2]

Concrete: about 8% of global emissions and rising. What can we do to help for achieving the goal of net zero by 2050?



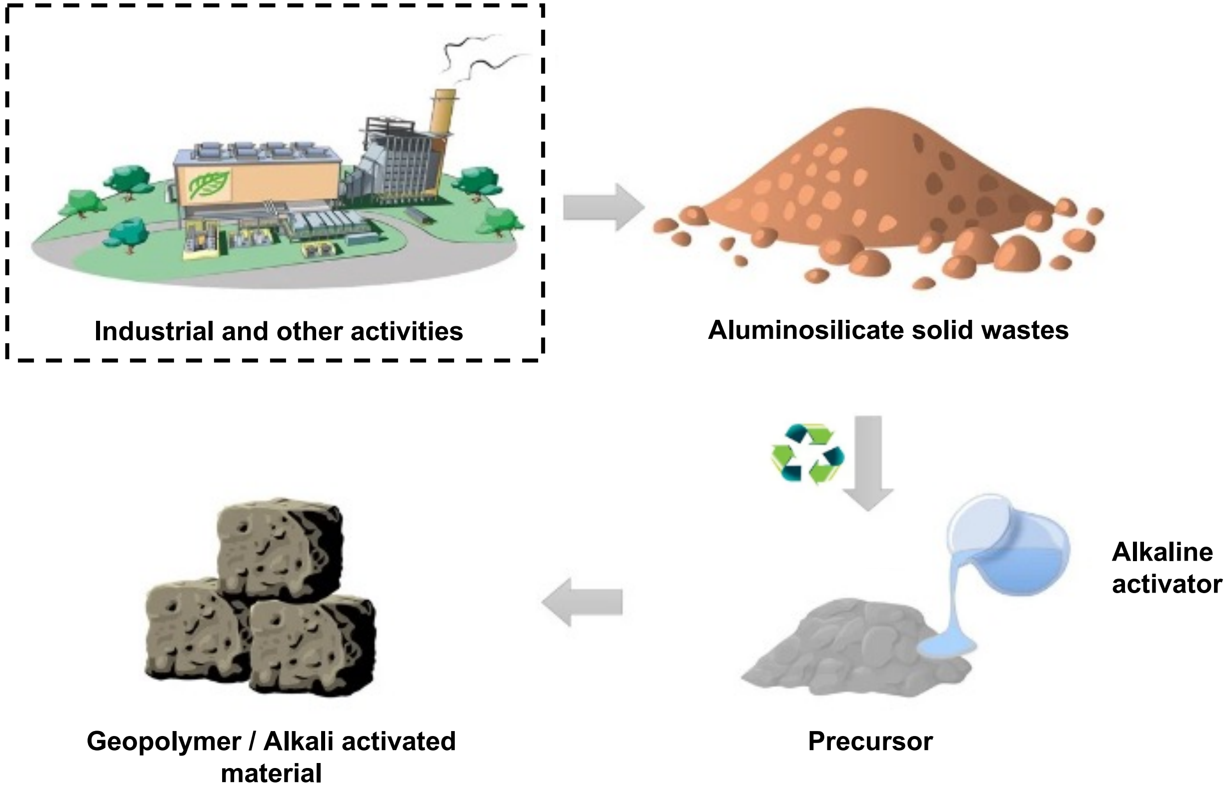
→ <u>Alternative:</u> geopolymer technology!



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

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

Problem statement (2)



Solution: Use of ground CDW as precursor

Resource shortage of traditional geopolymer precursors[3]

Landfilling of Construction and Demolition Waste (CDW)[4]

[3] Kamseu, E. et al. (2021). Dependence of the geopolymerization process and end-products to the nature of solid precursors. Journal of cleaner production.

[4] Marzouk, M., & Azab, S. (2014). Environmental and economic impact assessment of construction and demolition waste disposal. Resources, conservation and recycling.

Geopolymer precursors

Reduction in landfilling!

Industrial and other activities

Recycling of CDW

High reactivity for geopolymerisation
=> strength ↑

GGBS/MRAP
50/50 – 60/40
70/30 – 80/20

Avoid high-temperature curing

=> Blended use of GGBS and MRAP

Limited amount of amorphous aluminosilicate phases

Low reactivity for geopolymerisation!
=> strength ↓

Research methodology

GEOPOLYMER PREPARATION AND MIX DESIGN PARAMETERS

Aluminosilicate precursor

crushing | milling

Industrial by-products

Ground granulated blast furnace slag (GGBS)

+

Mixed Recycled Aggregate Powder (MRAP)

GGBS/MRAP
50/50 – 60/40
70/30 – 80/20

+

Alkaline Activating Solution

Sodium hydroxide (NaOH)

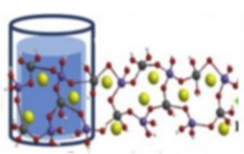
Sodium silicate ($NaSiO_3$)

+

Na_2O/b = 8 - 10 %
SiO_2/Na_2O = 1.0 - 1.33
w/b = 0.35 - 0.4

MIXING →

CURING →
Ambient (20 °C)



Polymerisation

SETTING →
HARDENING

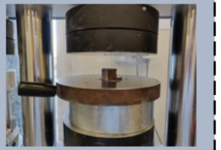
Physical and mechanical characterisation

WORKABILITY AND STRENGTH

PHYSICAL CHARACTERISATION - WORKABILITY

Flowability index | Initial and final setting time

MECHANICAL CHARACTERISATION - STRENGTH

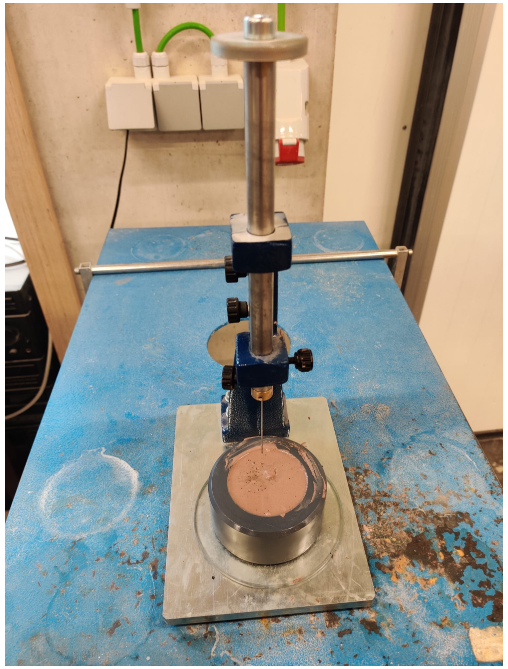


Workability and strength testing

MINI SLUMP TEST
EN 1015-3

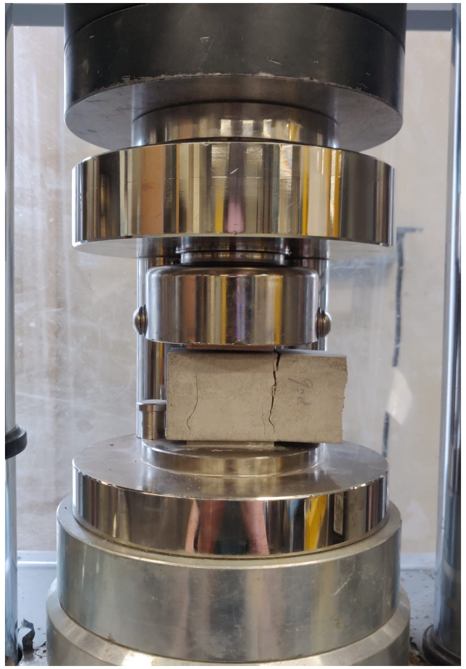
Flowability index D

VICAT TEST
EN 196-3



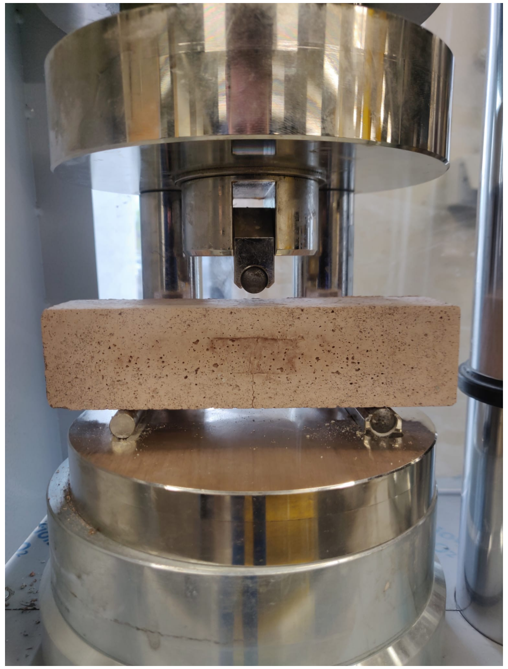
Initial/final setting time

COMPRESSIVE STRENGTH TEST
EN 196-1



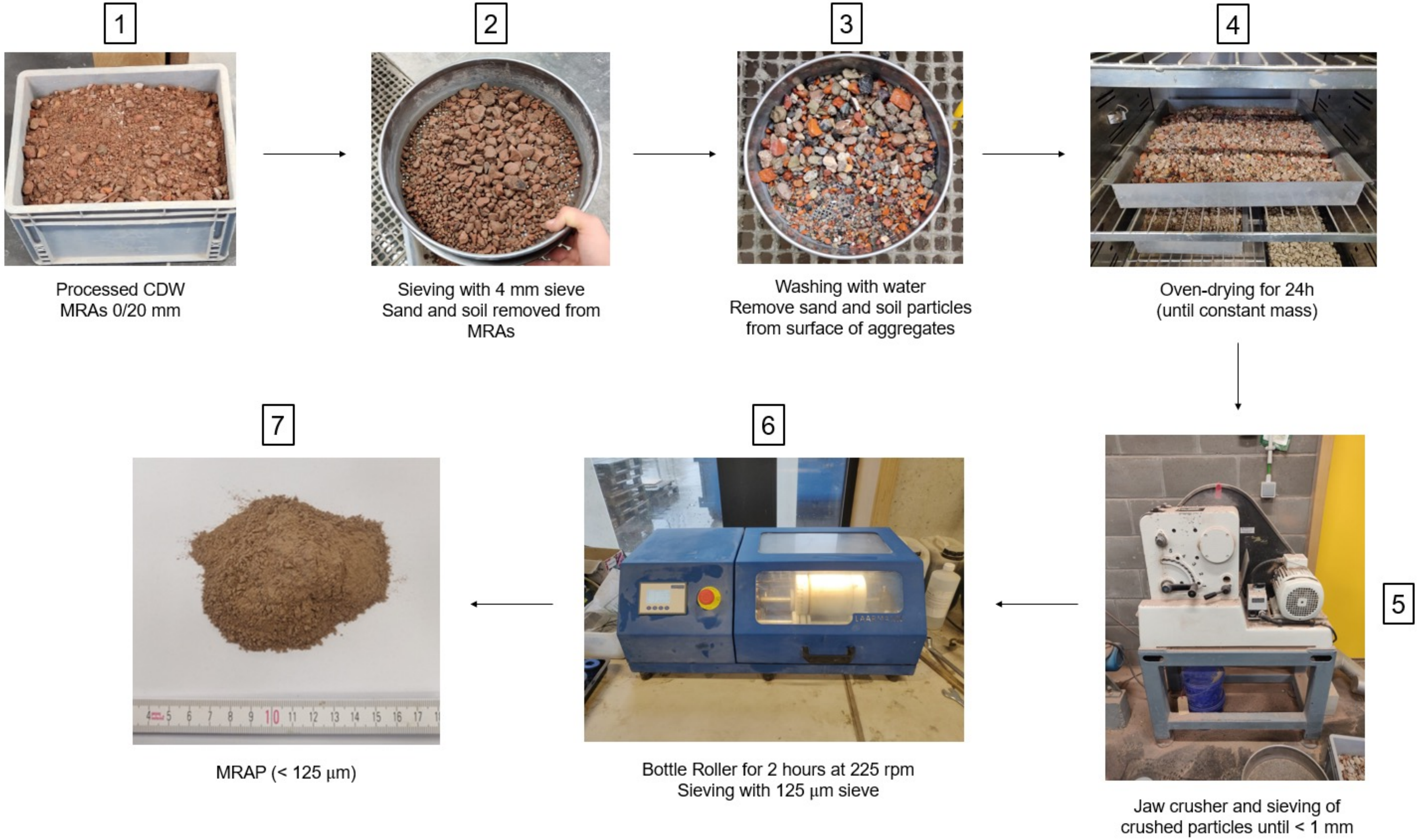
1d, 7d, 28d

FLEXURAL STRENGTH TEST
EN 196-1

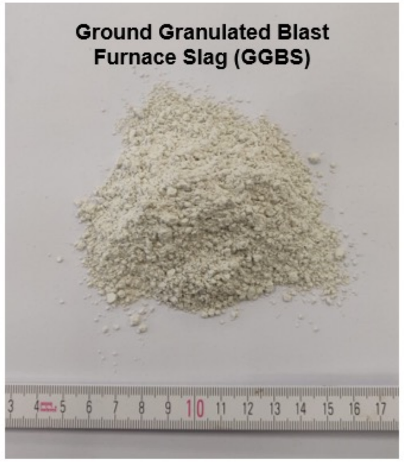


7d, 28d

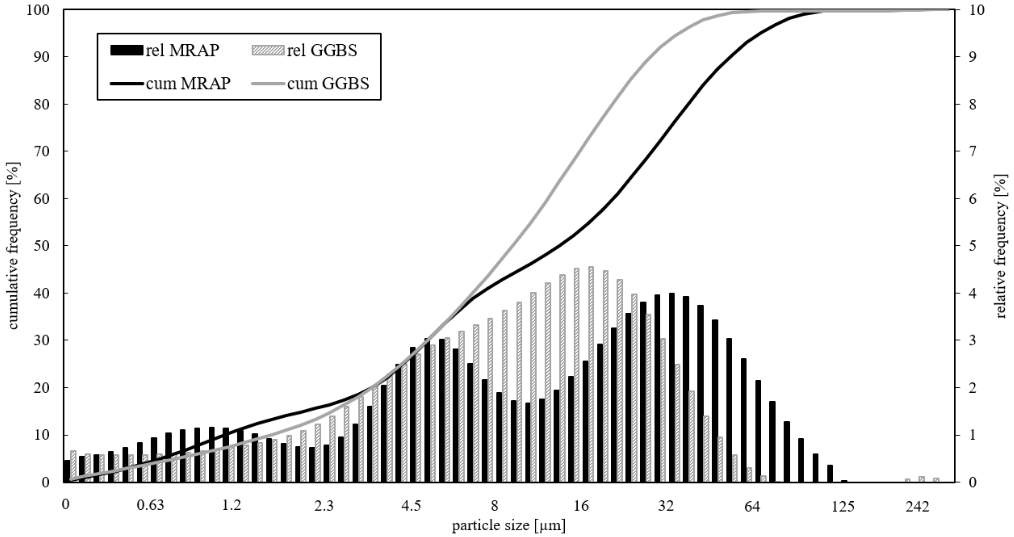
Materials and experimental methods



Materials and experimental methods



Chemical composition	MRAP (wt%)	GGBS (wt%)
SiO_2	54.2	33.5
Al_2O_3	8.3	13.4
Fe_2O_3	4.1	1.1
CaO	26.6	37.7
MgO	1.8	9.3
K_2O	1.7	0.6
SO_3	1.8	2.5
Na_2O	0.6	0.3



G-X%-Y-Z-a/b

X = Na_2O/b

Y = SiO_2/Na_2O

Z = w/b

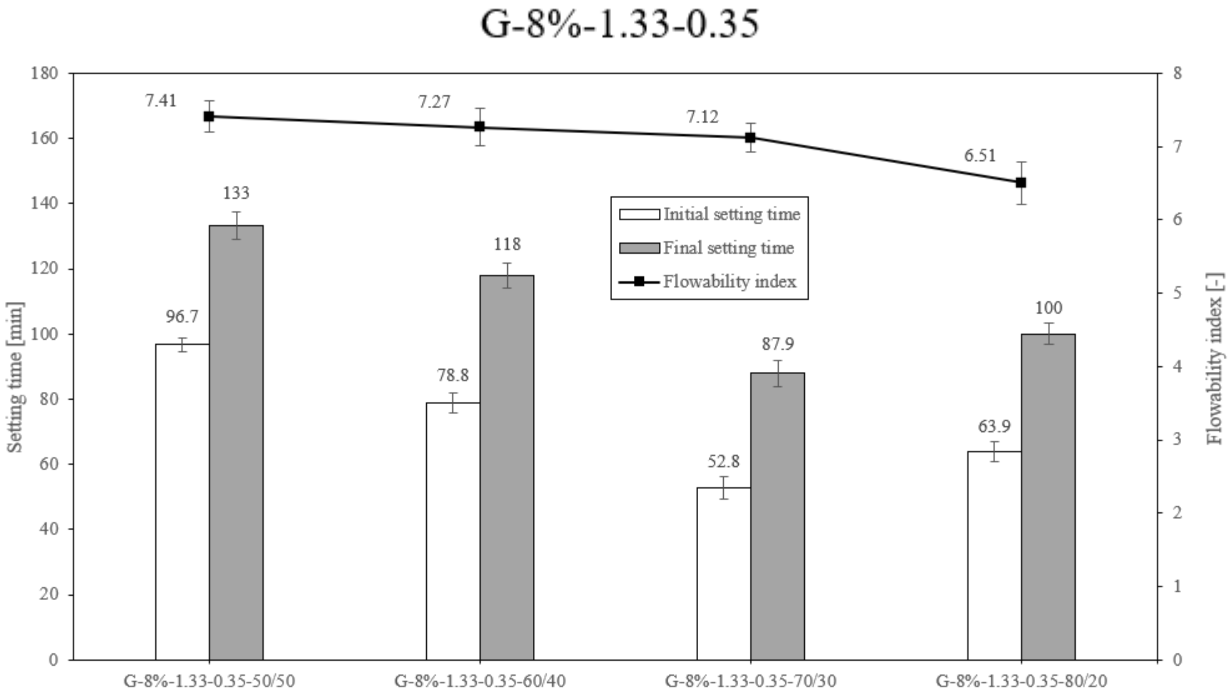
a/b = GGBS/MRAP

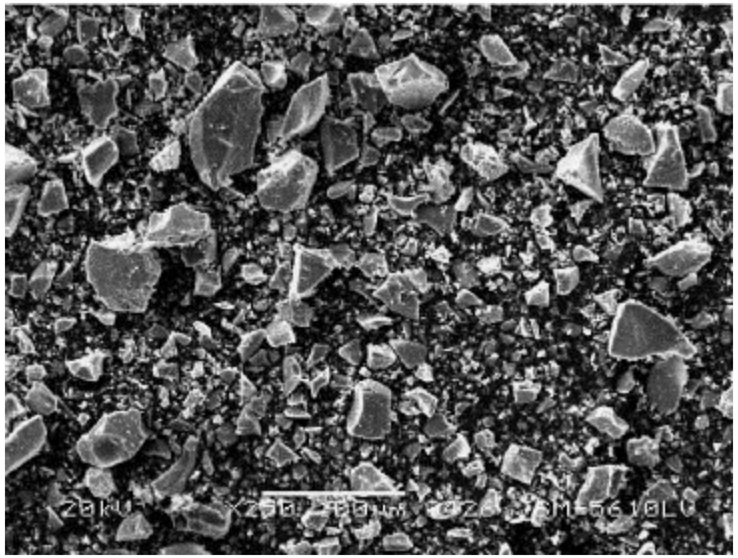
GGBS/MRAP

50/50 – 60/40
70/30 – 80/20

No.	Mixture ID	GGBS [g]	MRAP [g]	NaOH [g]	Na_2SiO_3 [g]	H_2O [g]
1	G-8%-1.33-0.35-50/50	200	200	155	24	41
2	G-8%-1.33-0.35-60/40	240	160	155	24	41
3	G-8%-1.33-0.35-70/30	280	120	155	24	41
4	G-8%-1.33-0.35-80/20	320	80	155	24	41
5	G-8%-1.33-0.4-50/50	200	200	155	24	61
6	G-8%-1.33-0.4-60/40	240	160	155	24	61
7	G-8%-1.33-0.4-70/30	280	120	155	24	61
8	G-8%-1.33-0.4-80/20	320	80	155	24	61
9	G-10%-1.33-0.4-50/50	200	200	193	30	37
10	G-10%-1.33-0.4-60/40	240	160	193	30	37
11	G-10%-1.33-0.4-70/30	280	120	193	30	37
12	G-10%-1.33-0.4-80/20	320	80	193	30	37
13	G-8%-1-0.4-50/50	200	200	116	29	86
14	G-8%-1-0.4-60/40	240	160	116	29	86
15	G-8%-1-0.4-70/30	280	120	116	29	86
16	G-8%-1-0.4-80/20	320	80	116	29	86

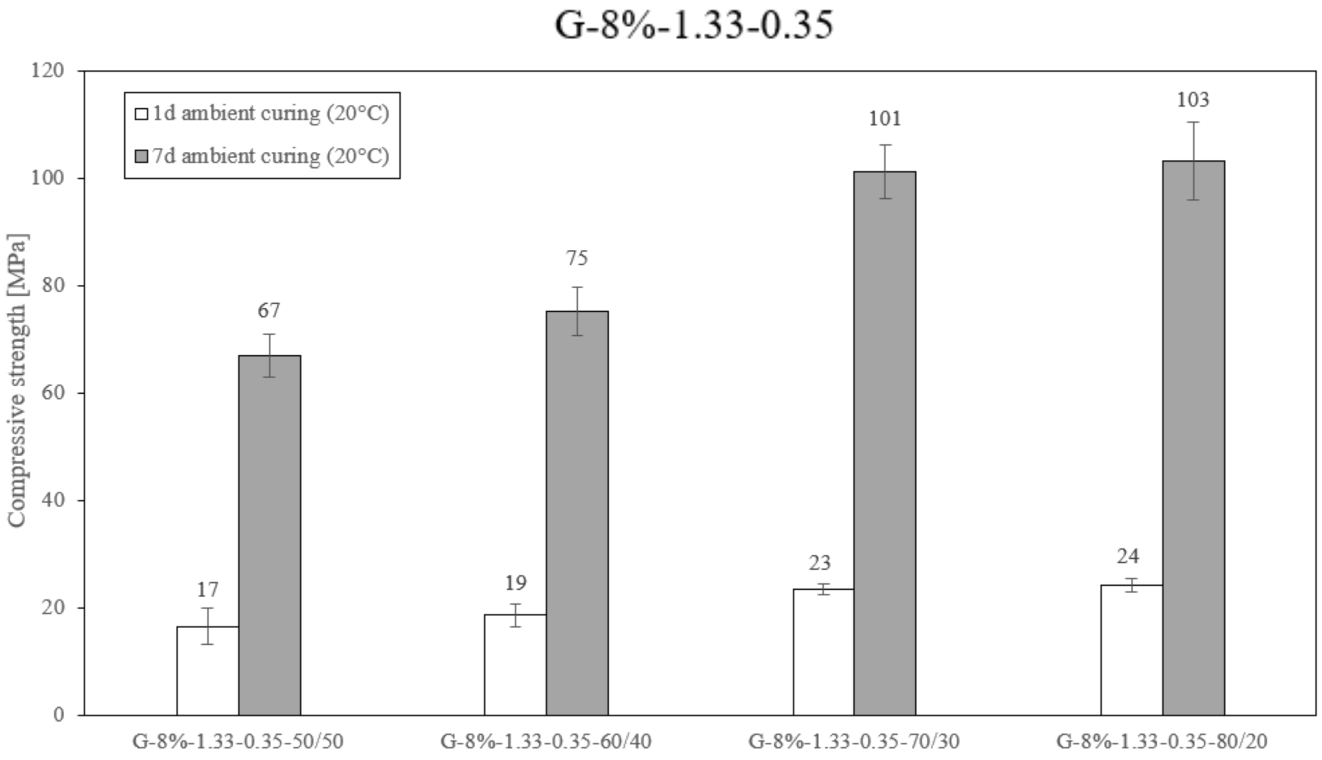
Setting time and slump flow – geopolymer paste

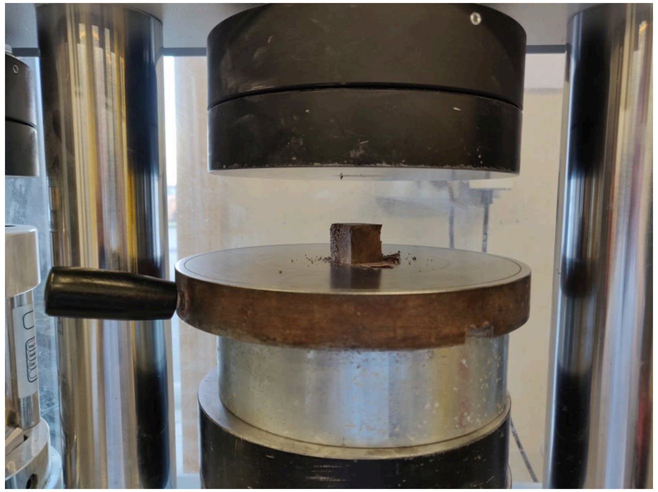


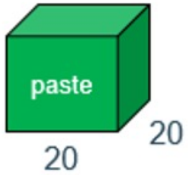


- As the **slag** content **increases** from 50/50 to 70/30, a reduction in **setting time** can be observed from 95 until 55 minutes (initial setting time), and from 135 to 90 minutes (final setting time).
- **Flowability** gradually **decreases** with **increasing GGBS** content.

Compressive strength results – geopolymer paste







$f_{c,1d}$ $f_{c,7d}$

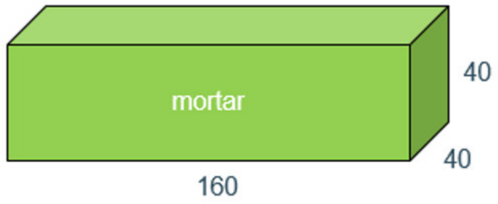
- Increasing slag content has a beneficial effect for **compressive strength gain** of geopolymer composites.
- Only a **significant strength increase** is observed when GGBS/MRAP ratio increases from **50/50 to 70/30**.

Strength results – geopolymer mortar

Compressive strength

G-8%-1.33-0.55

53.9 ± 4.9 MPa

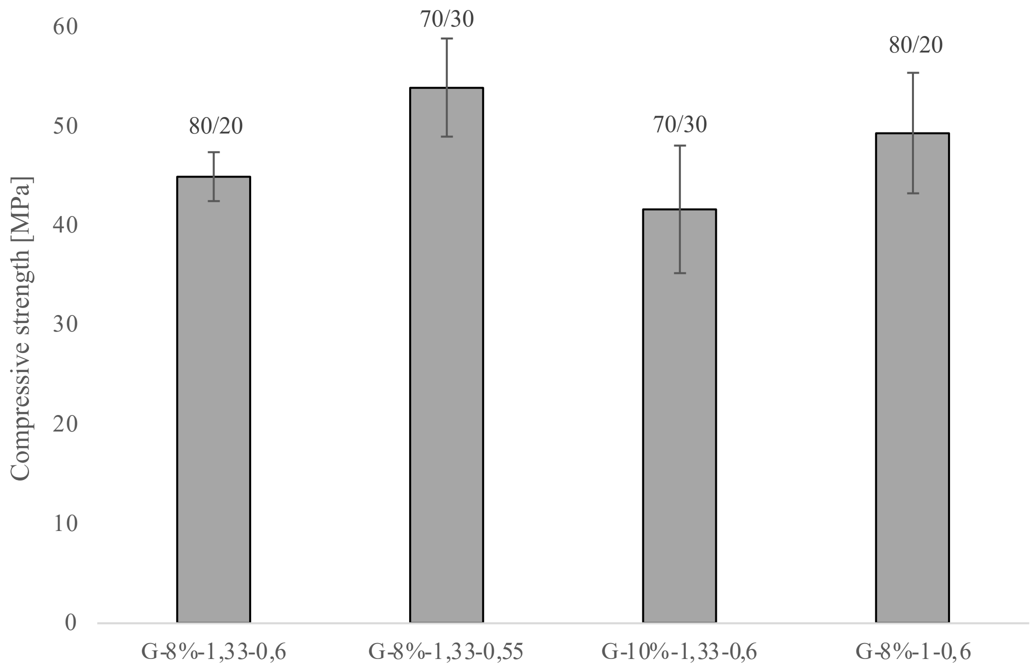


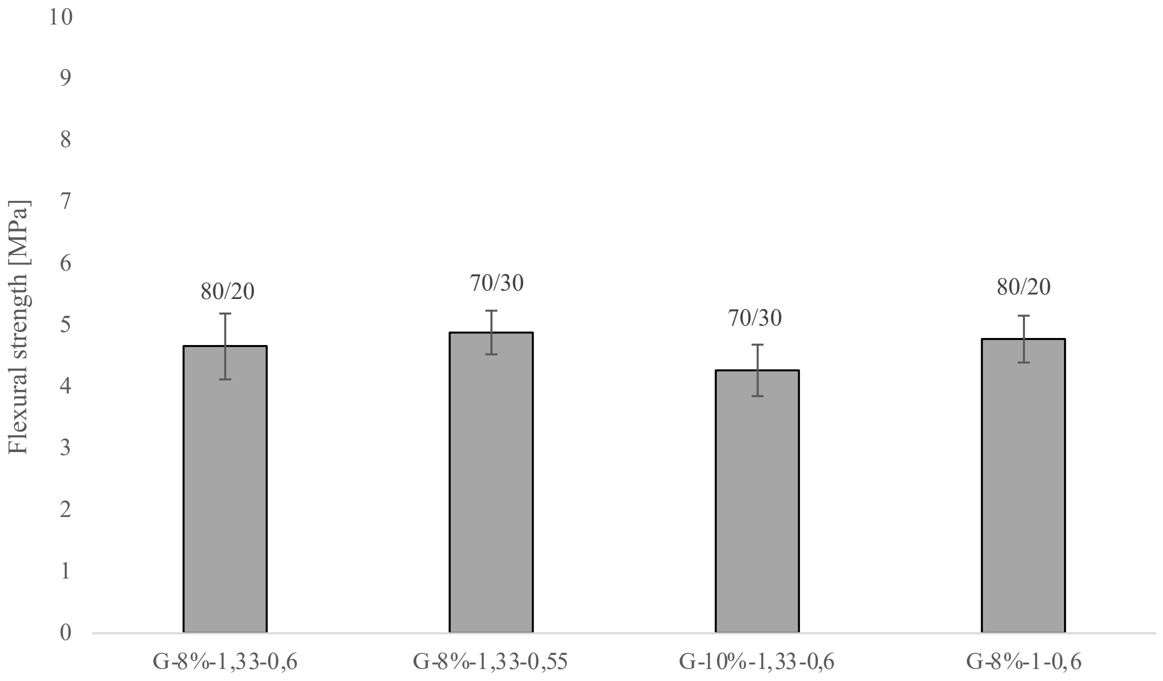
$f_{c,28d}$ $f_{fl,28d}$

Flexural strength

G-8%-1.33-0.55

4.88 ± 0.35 MPa





Conclusions

- Geopolymer mixture **G-8%-1.33-0.35** (Na_2O/b = 8% - SiO_2/Na_2O = 1.33 - w/b = 0.35) shows the **best compressive strength** results (up to 24 MPa after 1d ambient curing, up to 100 MPa after 7d ambient curing), for 20x20x20 mm³ specimens. A **28d-compressive** and **28d-flexural strength** of 53.9 $\pm$ 4.9 MPa and 4.88 $\pm$ 0.35 MPa is obtained, for 40x40x160 mm³ specimens.
- **GGBS/MRAP** ratio of **70/30** is most optimal in terms of **flowability** and **strength properties**.
- When **slag** is added in geopolymer, the **setting process accelerates**. High-temperature curing is no more needed.
- Increasing **slag** content leads to a general **increase** in **compressive strength**, and **reduction** in **setting time**.

Thank you for your attention!

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