

Insight into the geopolymerization of earth-based materials: Effect of clay/silt precursor and $\text{Na}_2\text{SiO}_3/\text{NaOH}$ activator on geopolymerization

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Presentation Outline

1 Context

2 Objectives

3 Materials & methods

4 Results

5 Conclusion & perspectives

Context

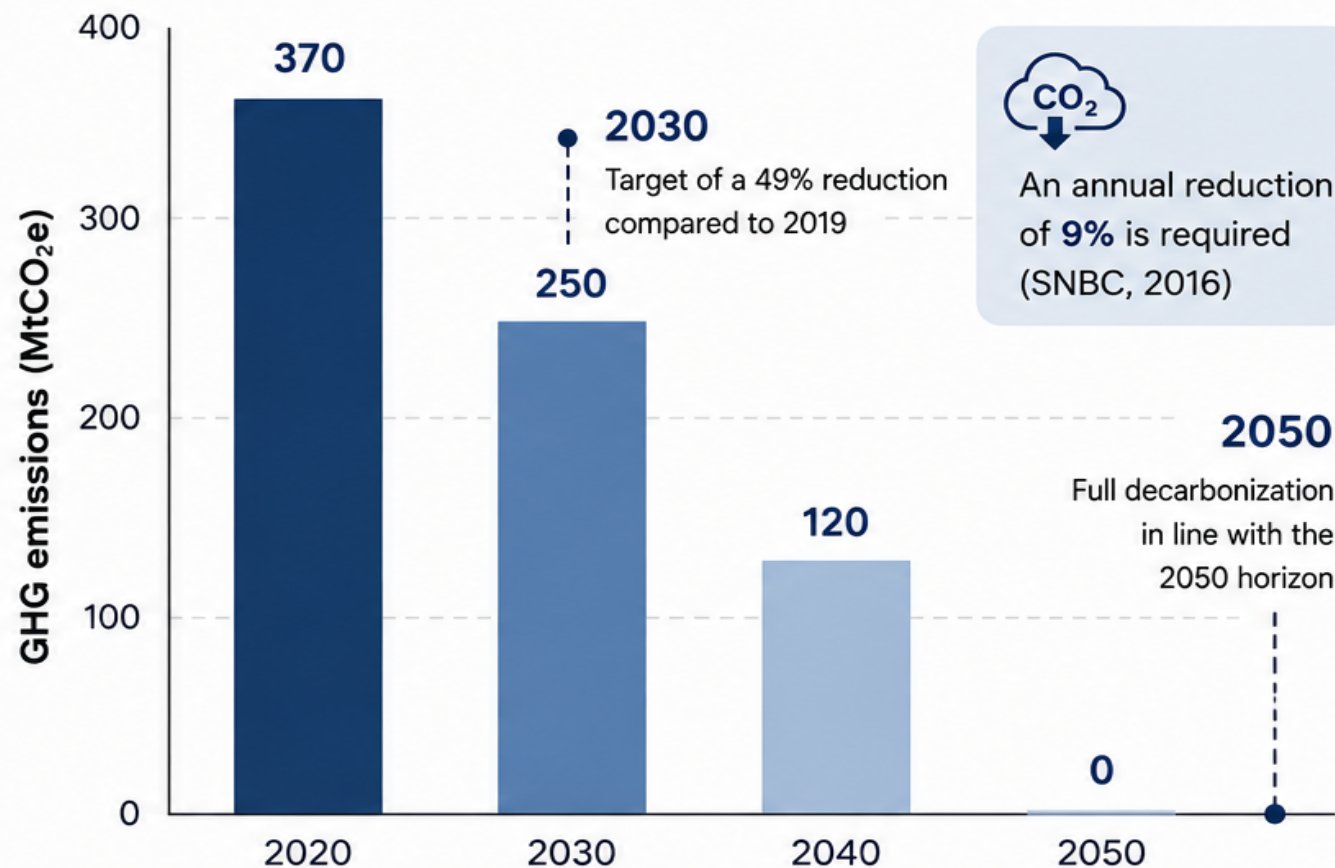


The building sector accounts for nearly **43%** of the energy consumed in France and is responsible for **23%** of the country's total greenhouse gas (GHG) emissions. Cement production alone contributes to **7 to 8%** of global emissions.

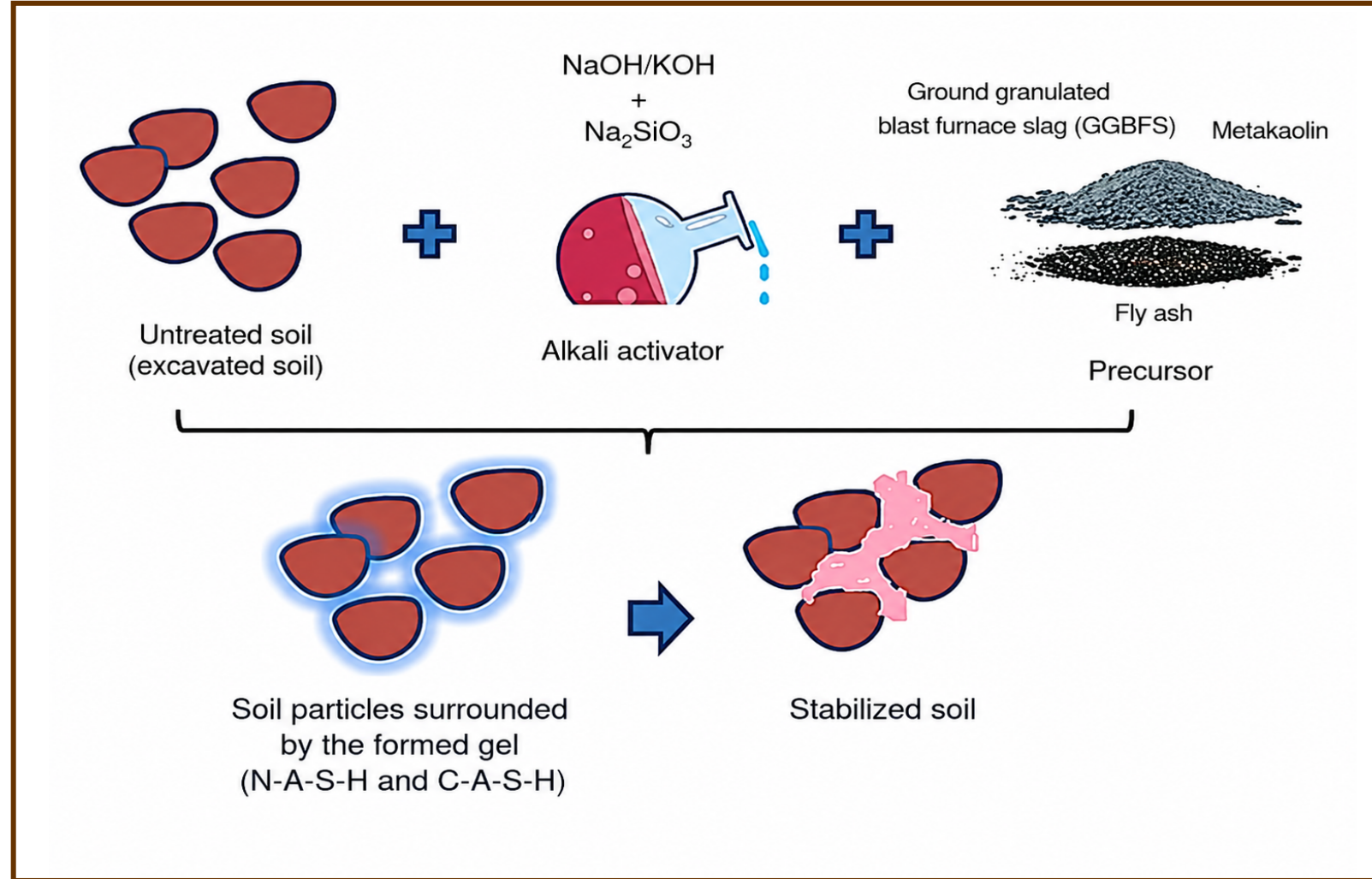


**2050 TARGET:
COMPLETE
DECARBONIZATION**

Trajectory for reducing greenhouse gas emissions from the building sector according to the SNBC



Context



Principle of soil stabilization by geopolymerization.

Valorize local excavated clay and silt soils into building materials through geopolymerization.

Optimize material properties for sustainable construction applications.

- Raw materials

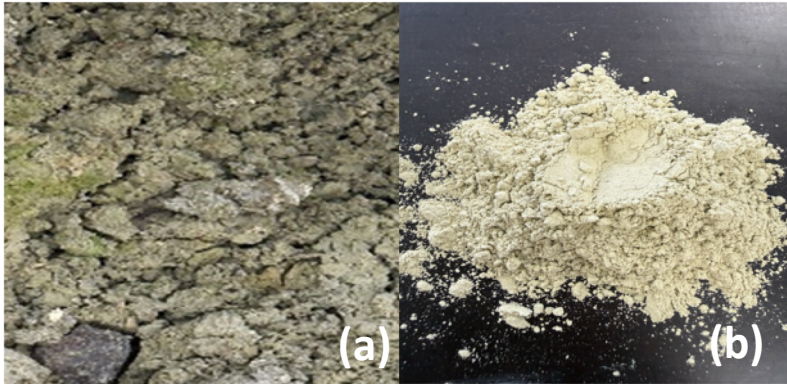


Fig.1. (a) Natural excavated clay; (b) ground clay powder.

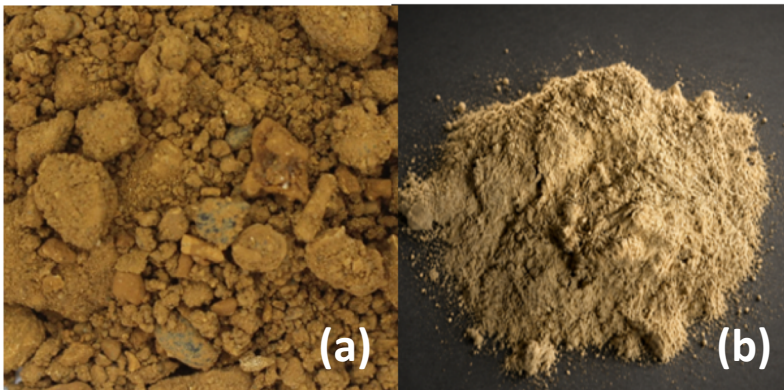


Fig.2. (a) Natural excavated Silt; (b) ground silt powder.

Ratio	Silt	Clay
Ca/Si	0,4	0,5
Al/Si	0,3	0,2

According to the literature, the optimum are:

- Ca/Si ratio: ~0.8-1.2
- Al/Si ratio: ~0.3-0.5

Table 1. Chemical composition of clay and silt

Element (%)	Clay	Silt
Na ₂ O	4,5	-
MgO	1,5	3,5
Al ₂ O ₃	11,2	15,4
SiO ₂	54,0	52,0
P ₂ O ₅	0,4	0,7
SO ₃	0,4	0,5
Cl	0,2	0,2
K ₂ O	2,4	5,1
CaO	18,0	13,0
TiO ₂	1,1	1,2
MnO	0,2	0,1
Fe ₂ O ₃	6,0	8,4
ZrO ₂	0,1	0,1

- Raw materials preparation



Drying at 105°C/24H



TM300 Ball Mill

Grinding protocol with TM300 :

- 1/3 raw material
- 1/3 grinding balls with sizes (20 mm, 10 mm, and 5 mm)
- 1/3 empty volume
- Rotational speed of 80 rpm for 60 minutes.
- Sieving until a particle size of less than 100 μm .

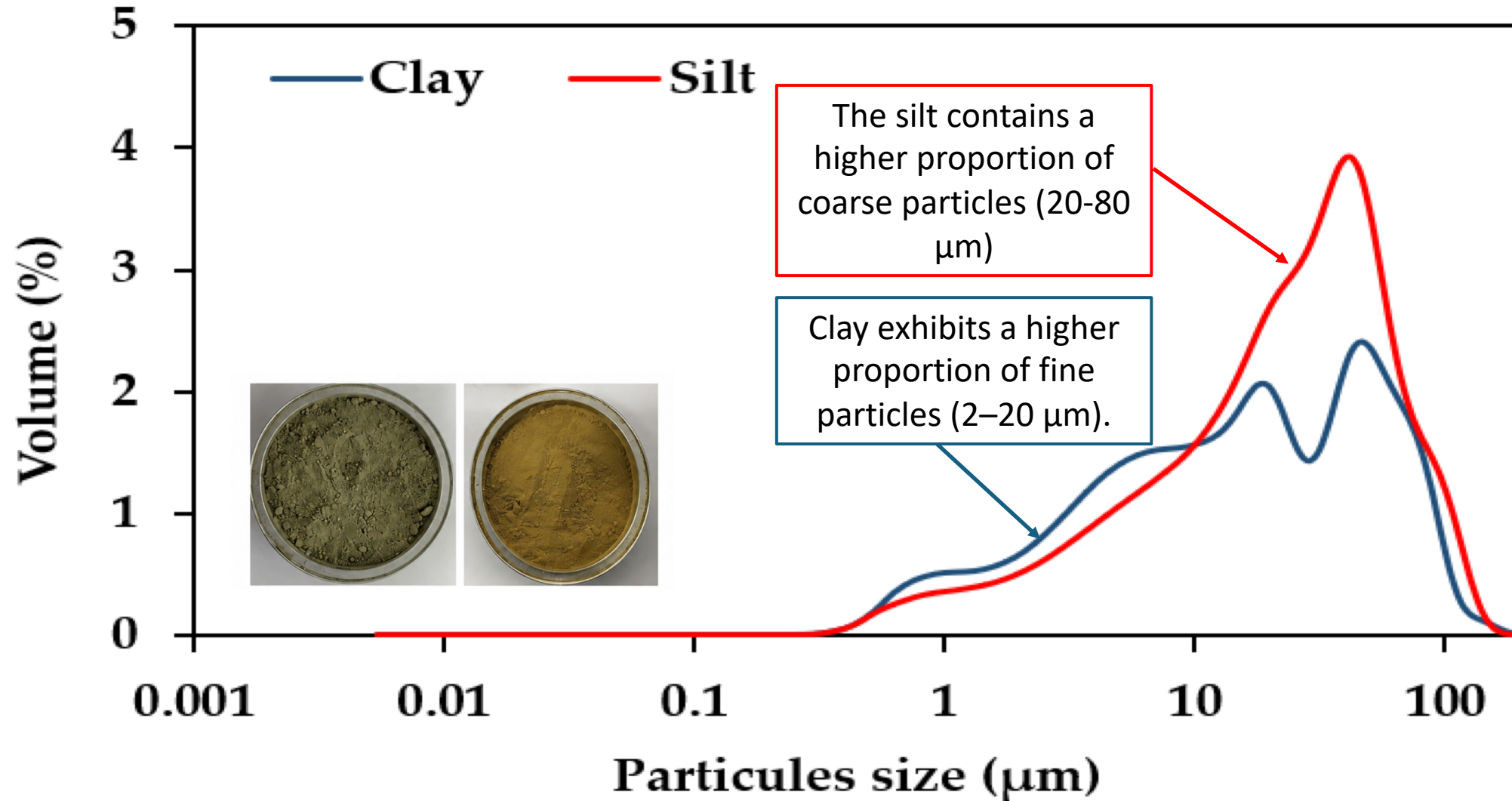


Clay



Silt

- Particle Size Distribution



Context

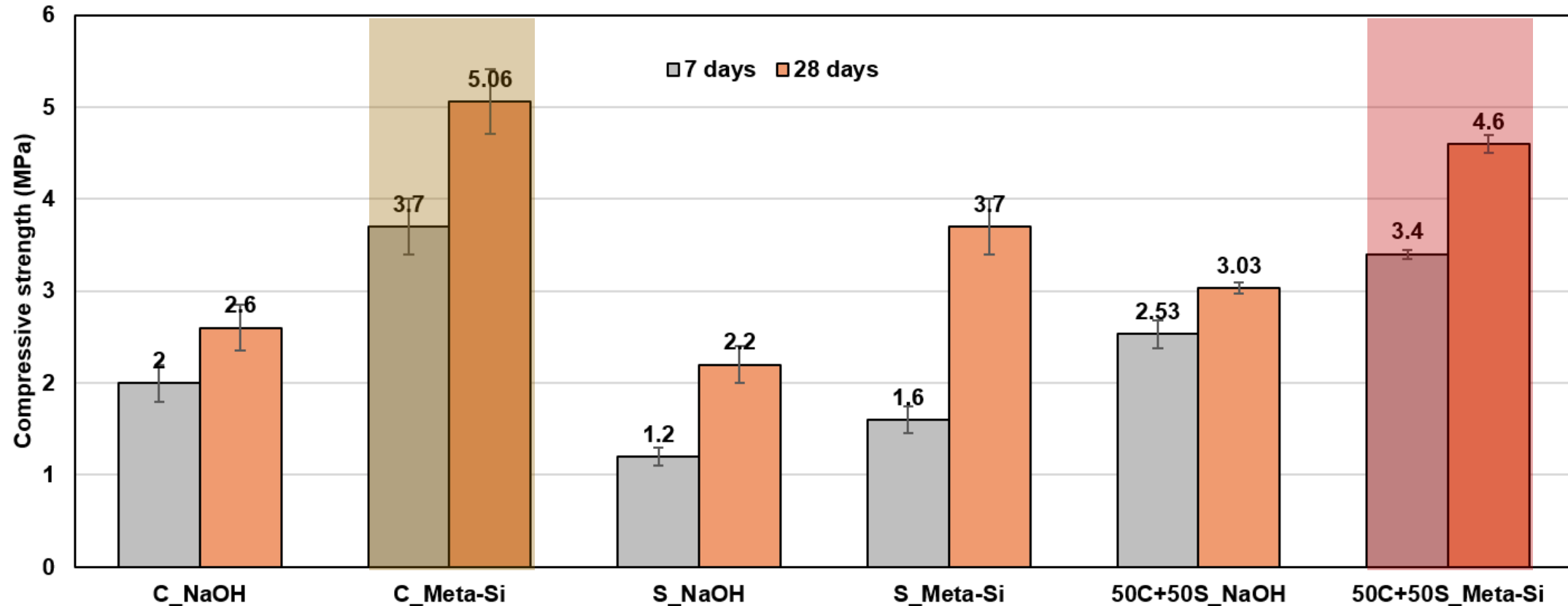
Objectives

Materials & Methods



Properties	ω_P (%)	ω_L (%)	$\omega_{optimal}$ (%)	Density (g/cm ³)
Clay	50	70	39.4	2.9
Silt	25	60	22.5	2.7
A/P	NaOH	Meta-Si	Curing	
0.4	10 mol/L	$\text{Na}_2\text{SiO}_3/\text{NaOH} = 2$	65 °C / 24 H	

- Compressive strength



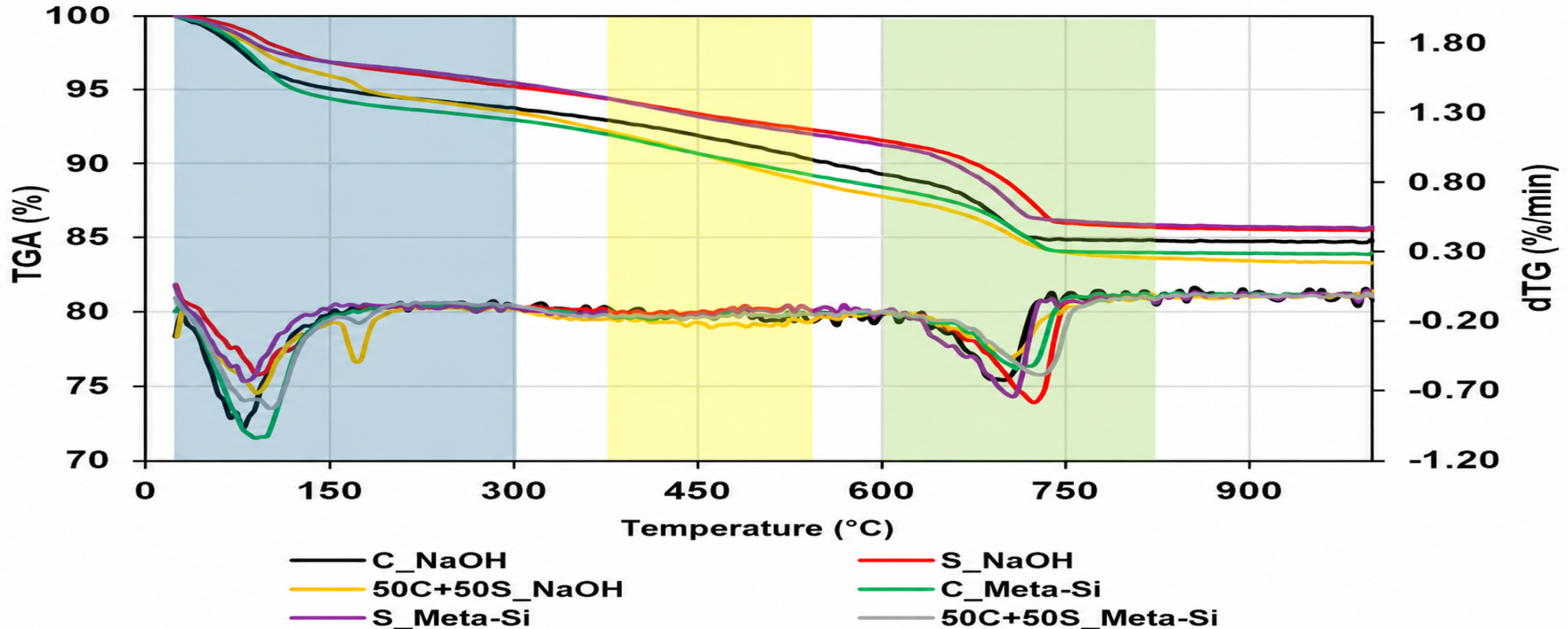
- Clay exhibits the highest compressive strength.
- Sodium silicate (Meta-Si) is the most effective activator.

Meta-Si: $\text{Na}_2\text{SiO}_3/\text{NaOH}=2$

C: Clay

S: Silt

- TGA



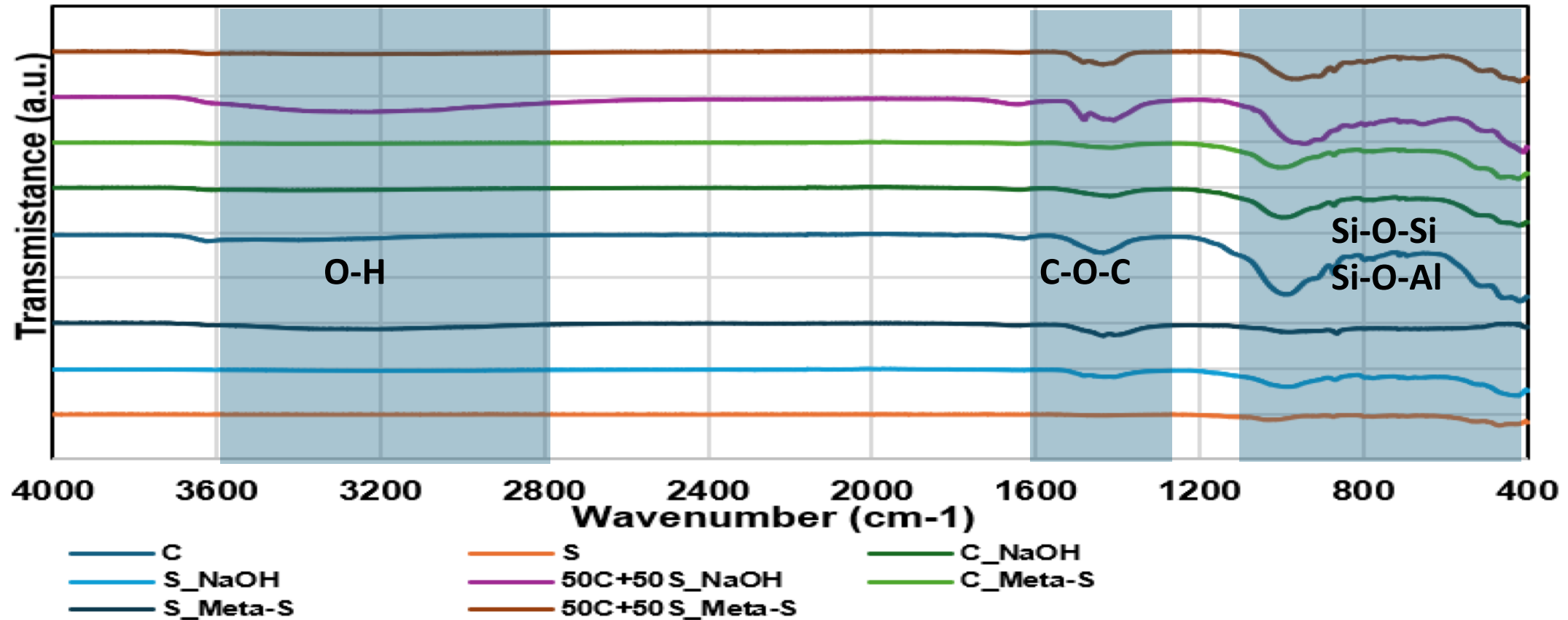
- < 300 °C: Loss of physically adsorbed water and dehydration of geopolymer gels (N-A-S-H and C-A-S-H).
- 400-550 °C: Decomposition of illite and montmorillonite.
- 600-800 °C: Decomposition of carbonate minerals.

¹ Shuang Tian, Peike Sun, Ting Li, Shanzhen Li, Liang Tang, Xianzhang Ling, Shi Liu, Experimental investigation of a mixture of coal gangue and rubber crumbs stabilized with a geopolymer cementitious material with freeze – Thaw cycle effects, Construction and Building Materials, Volume 493, 2025, 143337, ISSN 0950-0618.

² Sen Wang, Lloyd Gainey, Daniel Baxter, Xiaodong Wang, Ian D.R. Mackinnon, Yunfei Xi, Thermal behaviours of clay mixtures during brick firing: A combined study of in-situ XRD, TGA and thermal dilatometry, Construction and Building Materials, Volume 299, 2021, 124319, ISSN 0950-0618, <https://doi.org/10.1016/j.conbuildmat.2021.124319>.

³ Yadong Li, Jianfeng Li, Jie Cui, Yi Shan, Yanfei Niu, Experimental study on calcium carbide residue as a combined activator for coal gangue geopolymer and feasibility for soil stabilization, Construction and Building Materials, Volume 312, 2021, 125465, ISSN 0950-0618, <https://doi.org/10.1016/j.conbuildmat.2021.125465>.

- FTIR



- 2800–3600 cm⁻¹: O-H stretching of adsorbed water and N-A-S-H/C-A-S-H gels.
- 1500 cm⁻¹: Carbonate (O-C-O) vibrations.
- 1100–1000 cm⁻¹: Si-O-Si and Si-O-Al stretching.
- 400 cm⁻¹: Si-O-Si and Si-O-Al bending.

- ❑ This study confirmed the potential of excavated clayey and silty soils as precursor materials for geopolymer production.
- ❑ Meta-Si activation proved to be an effective strategy for improving the overall performance of the developed materials.
- ❑ These findings provide a solid basis for the development of sustainable alternatives to conventional cementitious materials.

Perspectives

- ➔ Study the influence of mineral additions and the $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio on the performance of excavated soil-based geopolymers.

**THANK YOU FOR
YOUR ATTENTION.**