Enhancing the alternative and circular industrial ecosystem for aluminosilicate-based construction materials

18th Geopolymer Camp — July 8-10, 2026 | Saint-Quentin, France

Introduction

Interreg programme priority 2

Strengthening the **resilience** and adaptation of territories to risks related to climate change

Specific objective 2.4

Promoting **adaptation to climate change**, disaster risk prevention and resilience, taking into account ecosystem-based approaches.

Project proposed solution

Recovery and valorization of untapped local and/or circular resources in the Interreg FWVL area for the formulation of demonstrators aimed at fostering the industrial uptake of alternative binders such as geopolymers and alkali-activated binders in the construction sector.

Target sector

- Construction sector
- Quarrying sector
- Recycling sector
- Infrastructure providers
- Contracting authorities
- Policy makers

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WP2 : Clay minerals & the need for activation

Context & motivation

Natural, fine, layered minerals with remarkable properties — but most must be activated to become reactive.

Definition
- Fine particles, < 2 µm
- Hydrated phyllosilicates
- Stacked nanometric layers (~1 nm)

Key properties
- Plasticity
- High specific surface area (SSA)
- Ion-exchange capacity
- Swelling / shrinkage

Applications
- Construction: cement, bricks, concrete
- Industry: ceramics, paper, paint
- Environment: depollution, water retention

Limits → activation
- Many clays show low chemical reactivity
- Limited performance in the raw state
- Activation is required to use them

Activation modifies the structure to boost reactivity, performance and added value.

WP2 : What drives clay reactivity?

Chemistry · structure · surface · size

Clay reactivity is governed by four coupled factors *(Dan Meng et al., 2026):*
https://doi.org/10.1016/j.mattod.2025.11.024

Chemistry — Si/Al ratio

Lower Si/Al (≈2) → greater reactive potential

Crystalline structure

Layer type (1:1 vs 2:1) sets the framework

Specific surface area (SSA)

Higher SSA → more reactive sites

Particle size (PSD)

Finer particles → faster dissolution

Clay type	Si/Al	Structure	Reactivity
TO	Low	Simple	**Higher**
TOT	High	Complex	**Lower**

Different chemistries → different behaviours.

Mechanochemical activation (MCA)

High-energy grinding lowers bond energy and drives the structure toward an amorphous state. disaggregation & fragmentation

Efficiency factors

Mill type, grinding time & speed, media, ball-to-powder ratio, mineral hardness.

The more complex the structure, the higher the reactivity — larger SSA and finer particles accelerate dissolution and reaction.

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WP2 : Activation routes compared

Energy · cost · time · trade-offs

Route	Principle	Energy / Cost	Time	Advantages	Limitations
Thermal — classic	Heating 600–900 °C → dehydroxylation & amorphization	High / High	min–h	Mature, industrial; high reactivity	Energy-intensive; recrystallization risk
Thermal — flash	**Ultra-fast (~0.1–1 s) gas-suspension heating**	**Medium / opt.**	**~0.1–1 s**	**Very high reactivity (~80%)**	**More complex; precise control**
Mechanical — MCA	Intensive grinding → structural disorder	Low / Low	medium	Simple & eco-friendly; low cost	Lower reactivity alone
Chemical — acid/alkaline	Reagents modify the structure	Variable / High	medium	Boosts reactivity; combinable	Reagent cost; environmental impact
Combined	Several techniques combined	High / High	variable	Maximum, tunable reactivity	Industrial complexity; high cost

→ Flash calcination is the activation route adopted in Al2SiBuild: very high reactivity at a low energy footprint.

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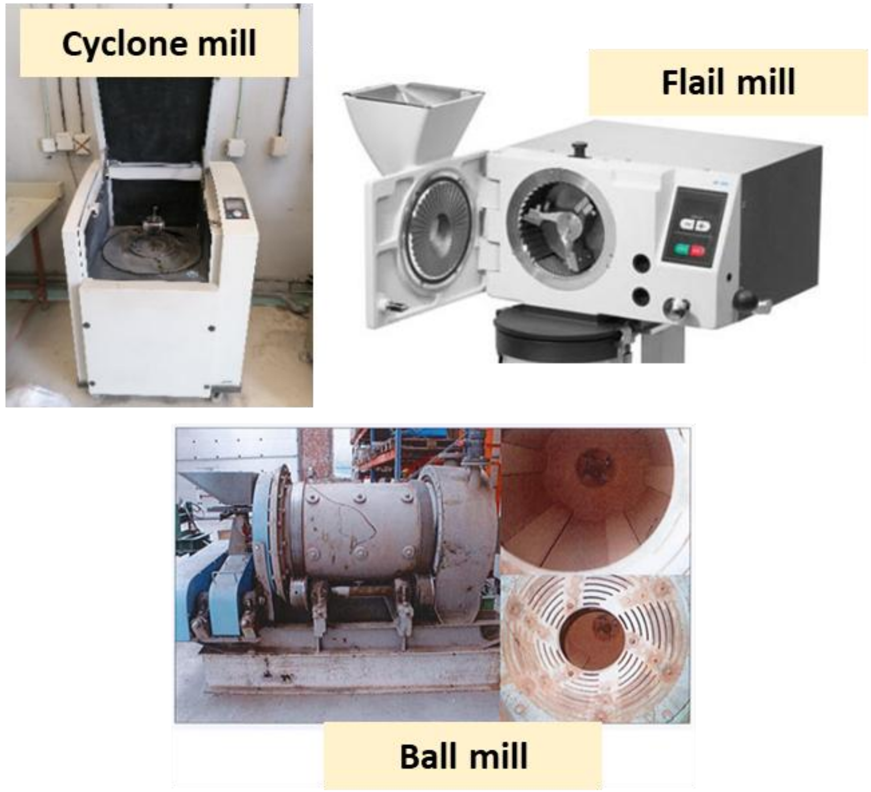
WP 2 - Adaptation of raw materials

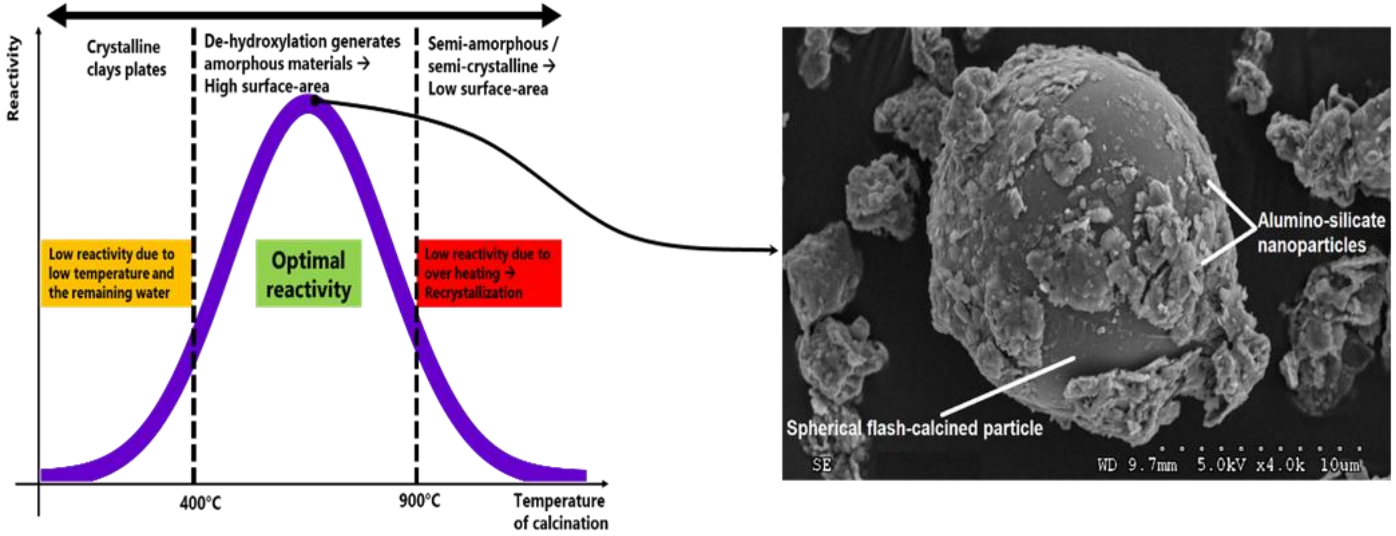
Materials preparation & activation

- Fine grinding after drying (before calcination)



Grinders

- Optimization of initial characteristics



WP 2 - Adaptation of raw materials

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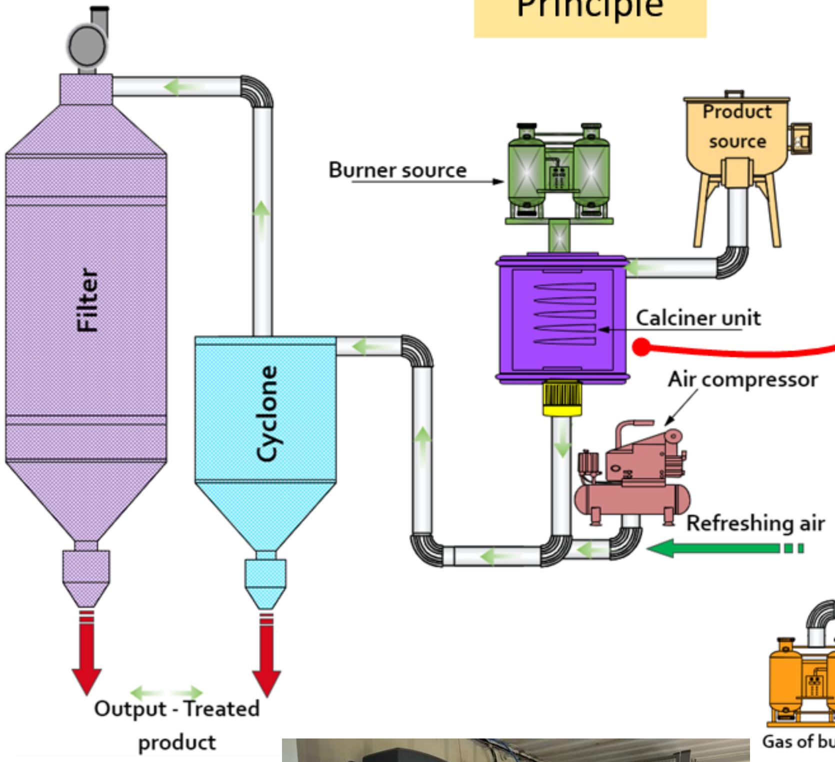
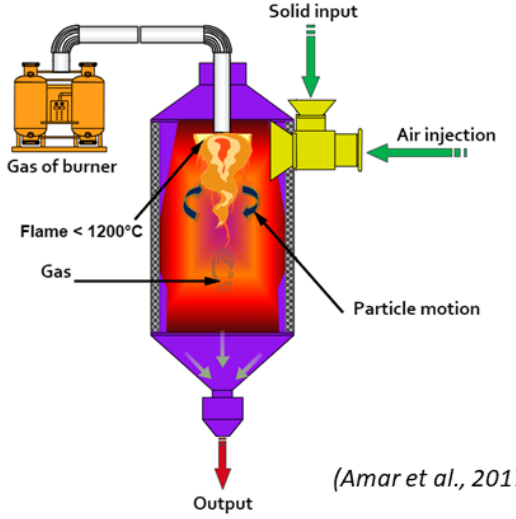
Materials preparation & activation

Flash calcination principle

Principle





(Amar et al., 2017)

Advantages

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Quickness

- The process takes about **1 s**
- Good flow rate (about a minimum **Q = 10 kg/h**)

Cost

- **Low-energy** consumption
- **No post-processing** needed

Activation

- **Pozzolanic activation** of materials
- Removal of **organic matter**
- Reduction of **pollutant** content

Adaptability

- **Adaptable** to different types of materials **(clay, sludge, soil, etc.)**
- Different energy sources **(gas, electricity, PV)**
- **Simple process**

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WP2 : Thermal activation (calcination):a three-step mechanism

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400–1100 °C

Step I — Dehydration

Endothermic · ~120–250 °C

- Release of free & interlayer water
- A positively charged diffusion layer forms

Step II — Dehydroxylation

~400–900 °C

- OH groups lost → water released
- Crystal lattice disorders → amorphous
- Reactivity strongly increases

Step III — Recrystallization

Exothermic

- Nucleation & crystal growth
- New, stable crystalline phases
- Reactivity drops (over-firing)

← Flash calcination windows →

Excessive temperature triggers recrystallization and a performance loss — flash calcination targets the optimal window.

Multiphase clays: each mineral phase has its own optimal temperature, so the process must be optimized batch by batch.

WP 2 - Adaptation of raw materials to AAM/GP technologies

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Kaolin from Heidelberg (Transinne)

- Calcination on traditionnal hoven 60 minutes
- Reactivity test (Davidovitz et al.)
- Grinding and thieving at 100 µm

Drying 120°C - 16h

Disagglomeration 2 min / 2kg

Grinding

Sieving at 100 µm

Quartering 4x5kg

1st grinding	Particle size (µm)		
	d_{10}	d_{50}	d_{90}
White kaolin	1,92	8,11	30,6
Yellow kaolin	1,93	7,92	43,2
Red kaolin	1,99	8,31	38,9
Black Clay Quenast	3,91	28,7	96,1
Grey Clay Antoing	11,7	55,1	106

- White kaolin (<100µm) : 4x5 kg
- Yellow kaolin (<100µm) : 4x5 kg
- Red kaolin (<100µm) : 4x5 kg

3 x 10 kg for flash calcination
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3 x 10 kg for calcination
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WP 2 - Adaptation of raw materials to AAM/GP technologies

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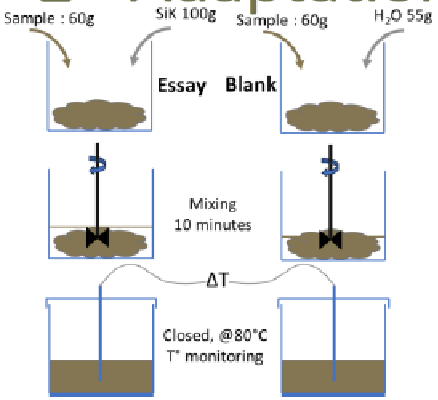
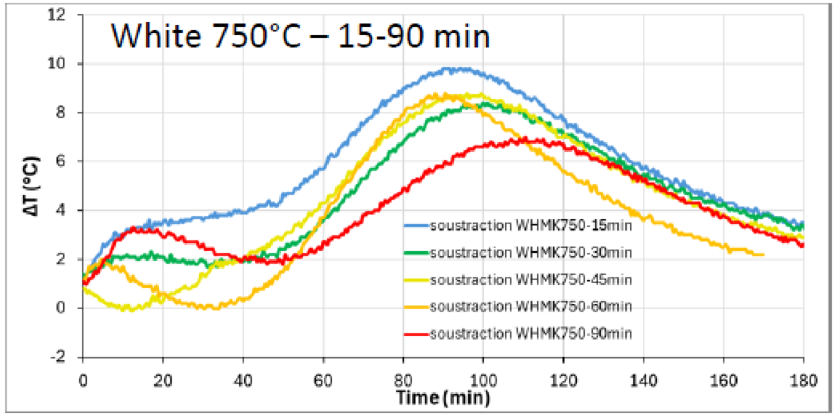
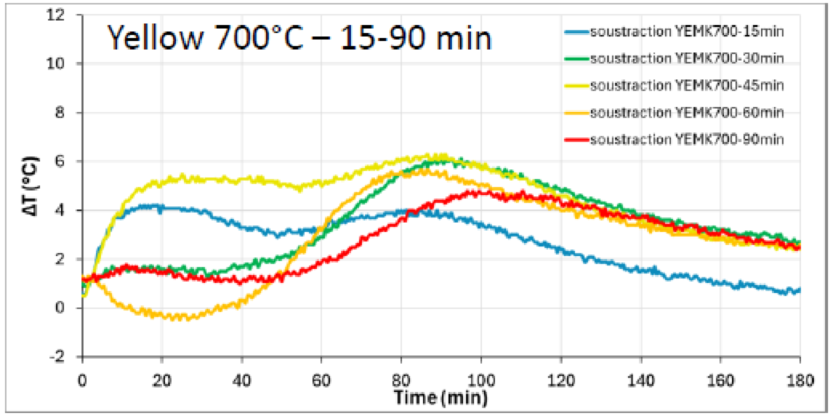


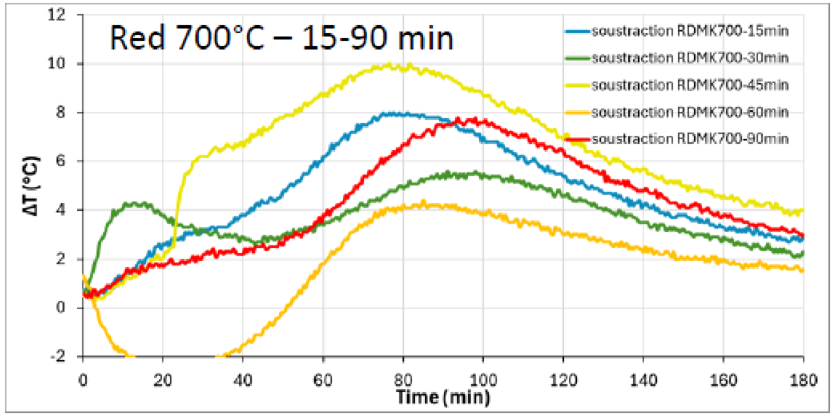
Calcined Kaolin from Heidelberg (Transinne)

- Calcination on traditionnal hoven 60 minutes
- Reactivity test (Davidovitz et al.)

- White kaolin (<100µm) : best activity for 750 °C – 15 min + 15
- Yellow kaolin (<100µm) : best activity for 700 °C – 15/30 min + 15
- Red kaolin (<100µm) : best activity at 700 °C – 45 min + 15







WP 3 - Formulation of alternative (complete/partial) binders

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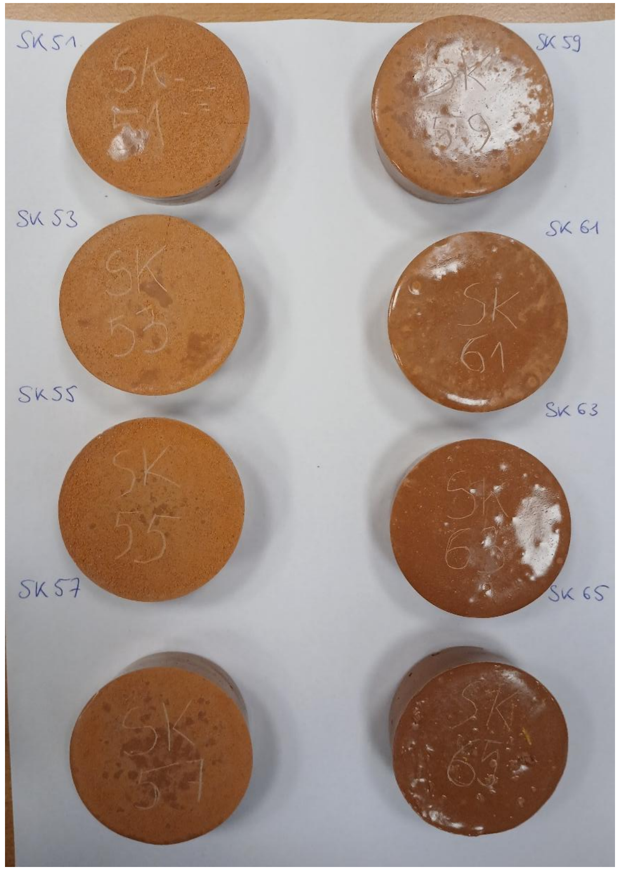
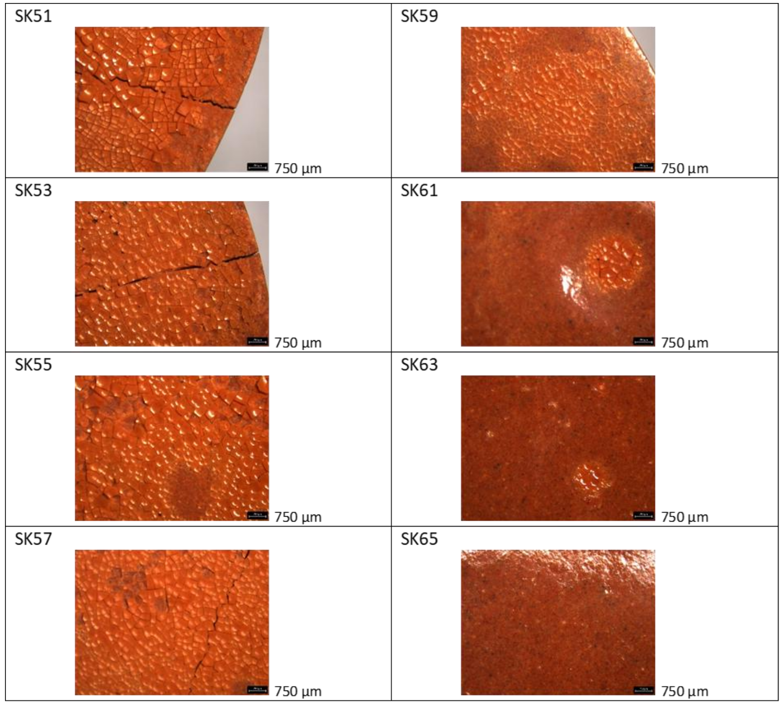
Benchmark tests UGent - IMT Nord Europe

- tests on 2 commercially available metakaolin (MK) i.c.m. with sodium silicate solution (SSS) or potassium silicate solution (PSS)
  - characterisation MK
  - theoretical calculations pastes
  - tests on paste:
    - water stability
    - heat development
    - MIP
    - FTIR
    - NMR
  - tests on mortars:
    - workability Hagerman cone (minimum of 14 cm: draft Buildwise)
    - strength/density on 7/28 days
    - setting time Vicat
  - scaling up to concrete





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WP 3 - Formulation of alternative (complete/partial) binders

Benchmark tests UGent - IMT Nord Europe

- tests on commercially available metakaolin (MK) i.c.m. with sodium silicate solution (SSS) or potassium silicate solution (PSS)
  - tests on mortars:
    - workability Hagerman cone
    (minimum of 14 cm based on draft Buildwise)
    - strength/density on 7/28 days
    - setting time Vicat

26C2			
	Flexural strength [MPa]	Compressive strength [MPa]	Ratio [%]
SK62	7,6	67,6	11,3
SK63	9,5	57,5	16,5
SK64	10,2	55,3	18,4
SK62W/S0,3	8,6	52,5	16,3
SK63W/S0,3	9,4	53,4	17,6
SK64W/S0,3	8,7	61,8	14,1

  - scaling up to concrete

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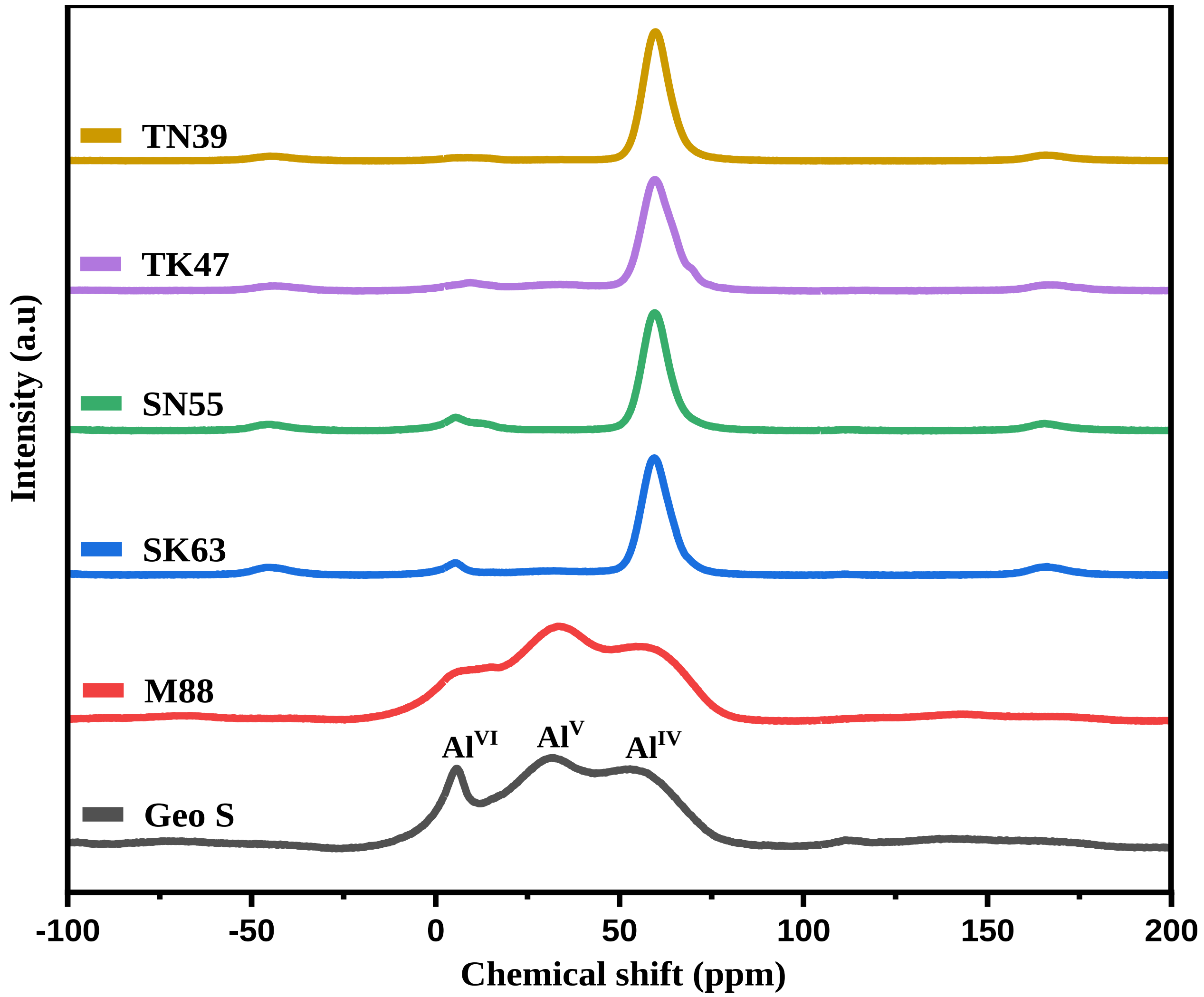

- **Precursor (Geo S):** Three Al coordination environments detected by 27Al MAS NMR: **VI (~0 ppm), V (~30 ppm), and IV (~55–60 ppm)**.

- **After geopolymerization:** Spectra are dominated by a **single IV resonance (~60 ppm)**, indicating precursor dissolution and Al incorporation into the aluminosilicate network.

- **Key finding:** The **sharp AlIV peak** indicates a **highly polymerized, chemically homogeneous geopolymer gel**, confirming successful geopolymerization for all formulations.

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Roadmap & Next Steps (2026–2028)

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- Period 1 (Jan–Jun 2026): Raw material prospecting & characterization (WP1) | Flash calcination optimization (WP2) | Benchmark GP binders MK+SSS/PSS (WP3)
- Period 2 (Jul 2026–Dec 2027): Activation of local clays (flash & conventional) | Full binder formulations with local precursors | Scaling to mortar & concrete (WP3-4)
- Period 3 (Jan–Dec 2028): Demonstrators (bricks, precast, urban furniture) | Normative testing & LCA (WP5-6) | Ecosystem map & dissemination (WP7-8)
- **IMT Nord Europe next steps: calcination trials on Heidelberg kaolinites (600–750°C) and other materials | reactivity index (SiK test) | geopolymer concrete mix design**

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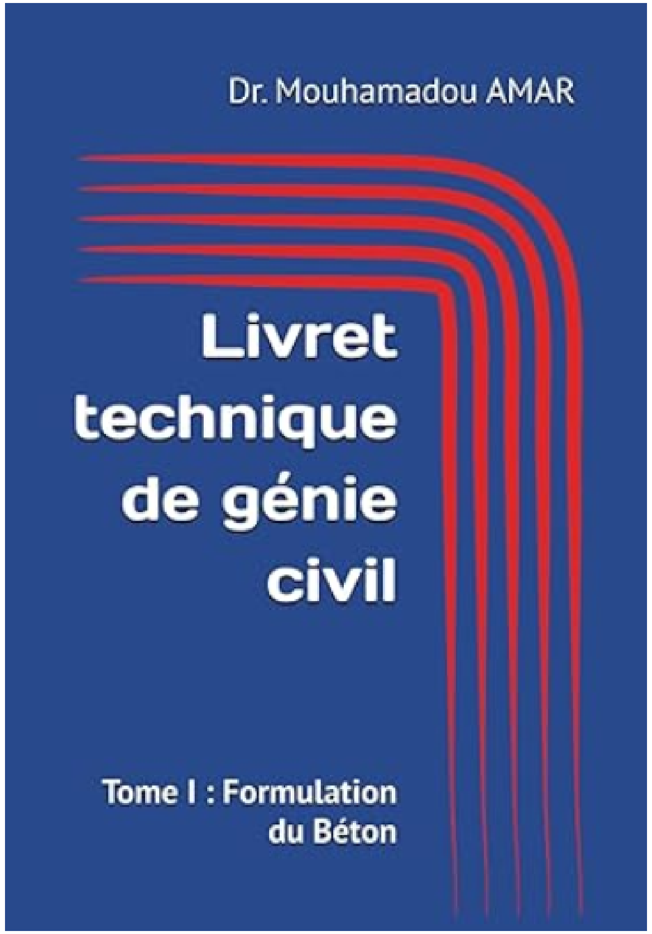

Livret technique de génie civil: Tome I : Formulation du Béton

Paperback – 26 Dec. 2025

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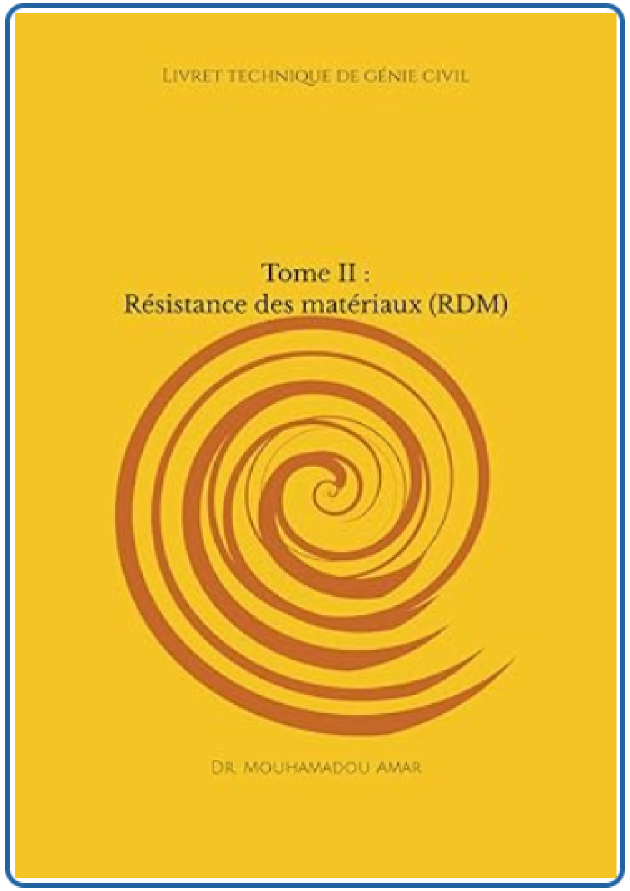
Tome II



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