

# The influence of activating solutions on the kinetics and compressive strength of an iron-rich slag paste

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## Introduction

The activating solution used in inorganic polymer synthesis has a profound impact on the properties of the final product. While this impact has been thoroughly investigated for geopolymers<sup>1</sup>, i.e. aluminosilicate inorganic polymers<sup>2</sup>, the same cannot be said for inorganic polymers derived from iron-rich precursors. Even though the trends for these types of inorganic polymers are similar to those seen for geopolymers, detailed quantification of these trends is still lacking. Therefore in this work activating solutions with different alkali atoms (M=Na/K), moduli (SiO<sub>2</sub>/M<sub>2</sub>O molar ratio) and H<sub>2</sub>O/M<sub>2</sub>O molar ratio will be mixed with an iron-rich slag in order to obtain inorganic polymers. The reaction kinetics, structure and compressive strength of these inorganic polymers will be reported and briefly discussed on this poster.

### Precursor slag composition

(XRF results, estimated relative error of 10%)

	FeO	SiO <sub>2</sub>	CaO	Al <sub>2</sub> O <sub>3</sub>	MgO
Wt %	45	33	11	4	2

### Activating solutions

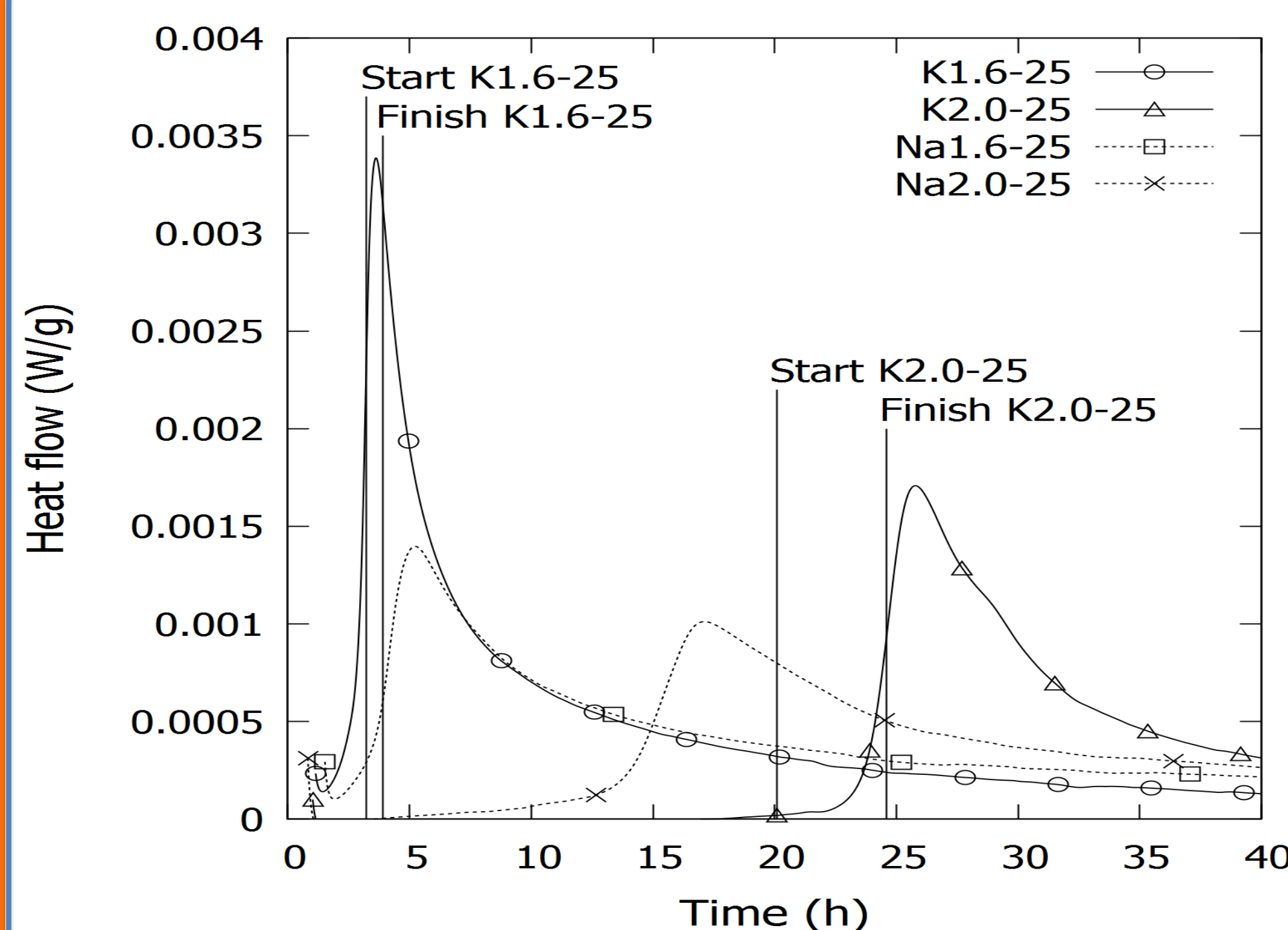
(table content shows the naming convention used here)

	M = Na ; K	H <sub>2</sub> O/M <sub>2</sub> O:	
		25	30
SiO <sub>2</sub> /M <sub>2</sub> O:	1.6	M1.6-25	M1.6-30
	2.0	M2.0-25	M2.0-30

H<sub>2</sub>O/Slag  
= 0.28

Inorganic polymer

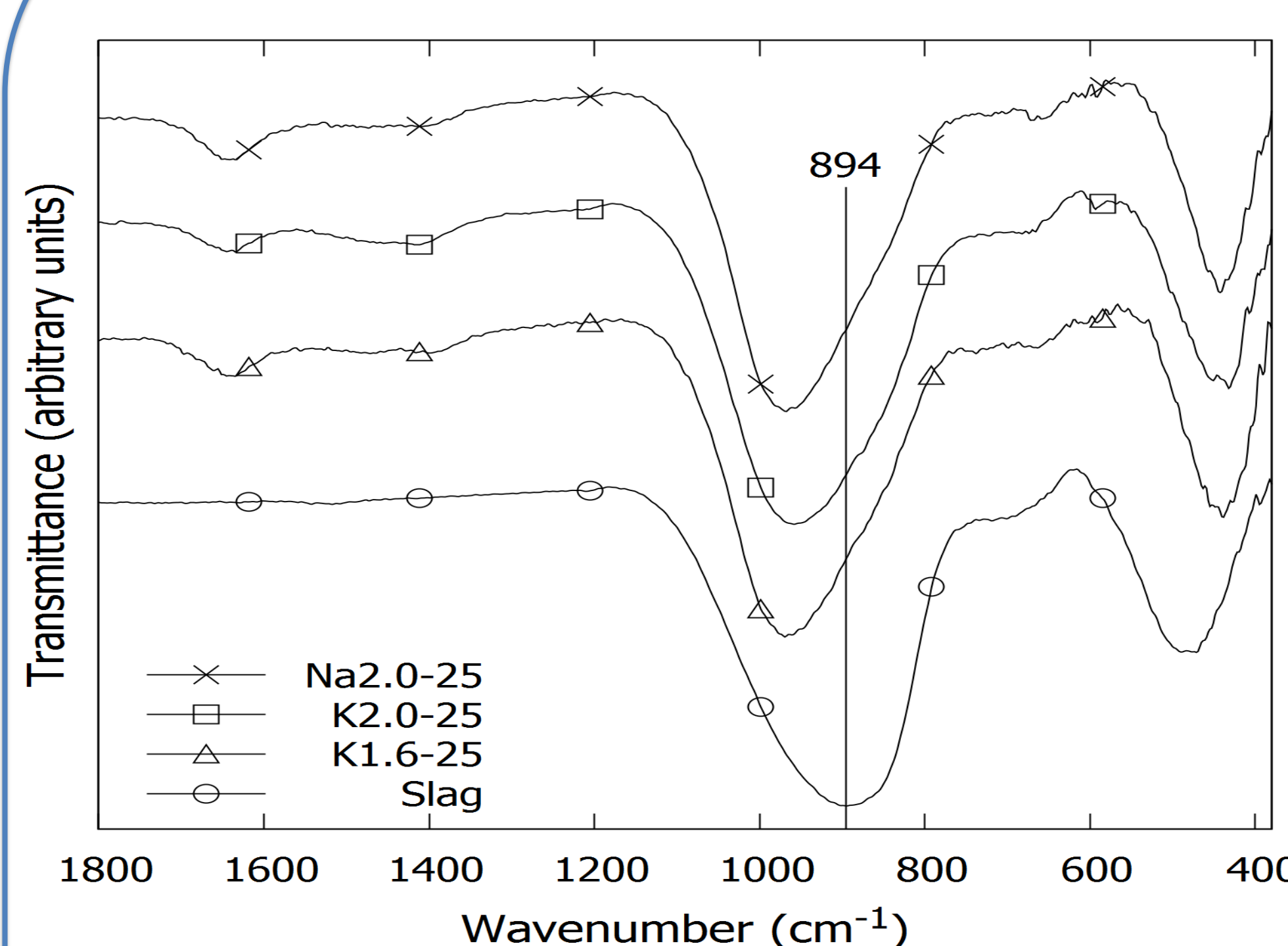
## Reaction kinetics



A comparison of the setting data (vertical lines) and calorimetry data shows good agreement, indicating that the peaks are the result from the setting reaction. The heat flow after the peaks is still non-zero, showing that the further polymerization and hardening is still ongoing.

Increasing the modulus increases the setting time, with a higher influence for K-based samples in comparison to Na-based samples.

## Structure

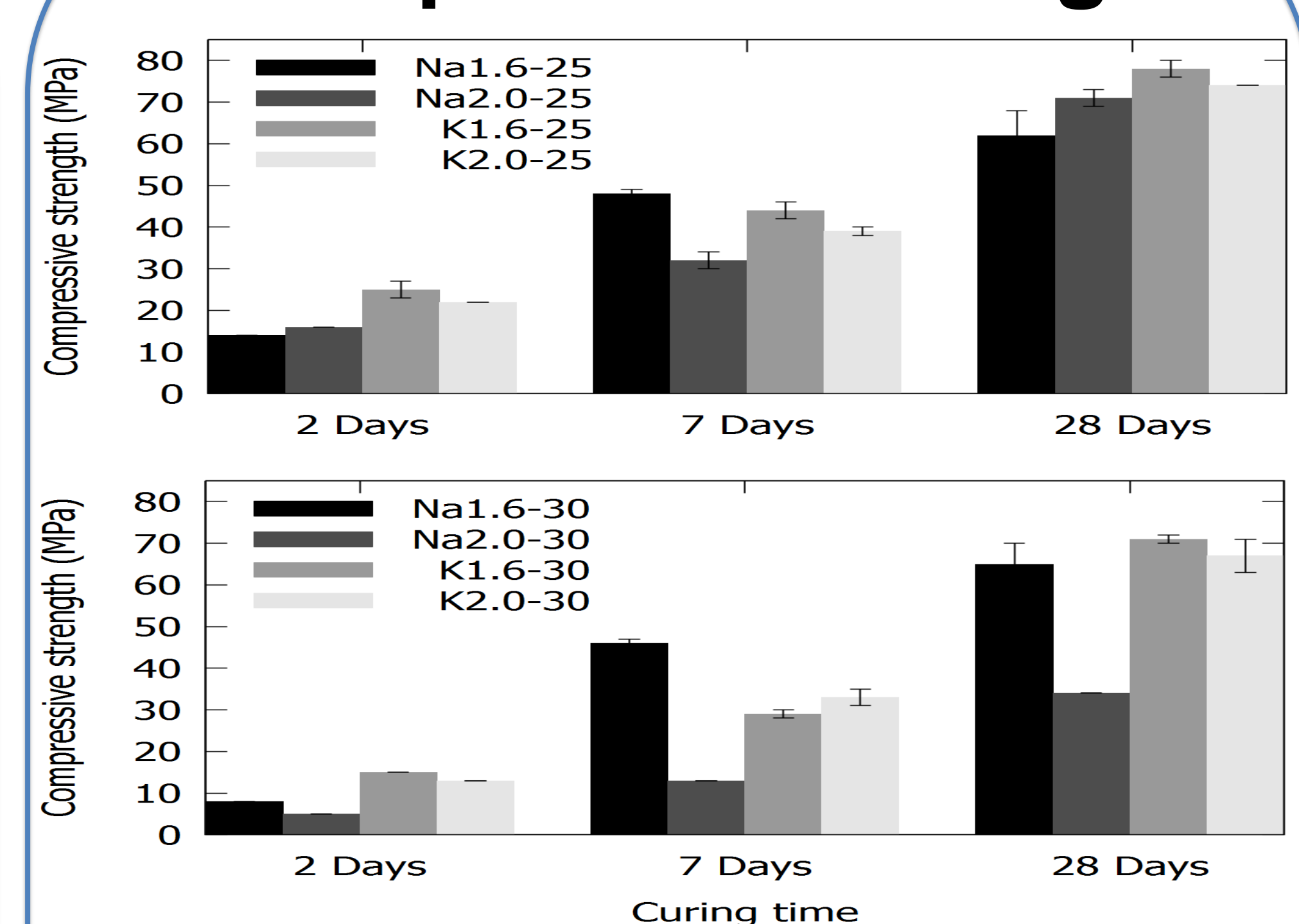


The main bands in the FT-IR spectra are a Si-O rocking band (400-500 cm<sup>-1</sup>) and a Si-O-T stretching band (900-1000 cm<sup>-1</sup>).<sup>3</sup> Due to the formation of the inorganic polymers, both these bands experience a shift.

In the area of the Si-O-T stretching band another, smaller, band is also present, most likely due to residual unreacted slag.

The smaller bands at 1650 cm<sup>-1</sup> and 1400 cm<sup>-1</sup> most likely correspond to respectively O-H vibrations and C-O stretching.

## Compressive Strength



Hardening can be seen to continue even after 28 days for all samples. For low moduli the Na-based samples obtain higher early-age strength after 7 days, however after 28 days K-based samples always have the highest compressive strength.

Increasing the H<sub>2</sub>O/M<sub>2</sub>O ratio can lead to lower reactivity<sup>4</sup> and higher porosity.<sup>5</sup> Consequently almost all samples see a decrease in compressive strength. This effect is most notable for the Na-based sample with a high modulus.

## Conclusions

The composition of the activating solution is seen to have a major effect on the properties of the final inorganic polymer. High amount of silicates lead to major delay in setting time, with a higher influence on K-based than on Na-based samples. Compressive strength generally decreases with increasing water and silicate content of the activating solution, except for Na-based samples at low H<sub>2</sub>O/M<sub>2</sub>O ratio. The highest strength (78 MPa) is obtained with a K-based activating solution with low modulus and H<sub>2</sub>O/M<sub>2</sub>O ratio.

<sup>1</sup> P.W. Ken, M. Ramli and C.C. Ban, "An overview on the influence of various factors on the properties of geopolymer concrete derived from industrial by-products", *Constr. Build. Mater.*, **77** 370-395 (2015).

<sup>2</sup> J. Davidovits, *Geopolymer Chemistry and Applications*, Geopolymer Institute, Saint-Quentin, France, 2008.

<sup>3</sup> F. Gervais, A. Blin, D. Massiot, J.P. Coutures, M.H. Chopinet and F. Naudin, "Infrared reflectivity spectroscopy of silicate glasses", *J. non-cryst. solids*, **89** 384-401 (1987).

<sup>4</sup> H. Rahier, J. Wastiels, M. Biesemans, R. Willem, G. Van Assche and B. Van Mele, "Reaction mechanism, kinetics and high temperature transformations of geopolymers", *J. Mater. Sci.*, **42** (9) 2982-2996 (2007).

<sup>5</sup> S. Chuah and W.H. Duan and Z. Pan and E. Hunter and A.H. Korayem and X.L. Zhao and F. Collins and J.G. Sanjayan, "The properties of fly ash based geopolymer mortars made with dune sand", *Mater. Design*, **92** 571 - 578 (2016).