Determining factors for geopolymeric reactivity using NaOH of Korean Class F fly ashes

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FACTORS AFFECTING GEOPOLYMER STRENGTH

- **External Factors (Much stronger factors)**
  - Activator type (e.g., NaOH, waterglass or Na_2SO_4)
  - Activator concentration (e.g., 5M or 10M)
  - Solution/binder ratio (e.g., s/b = 0.4 or 0.6)
  - Curing conditions (e.g., 25˚C or 60˚C)
  - Etc.

- **Intrinsic Factors of Materials**
  - **Oxide chemical composition (e.g., XRF result)**
  - **Glass content (e.g., XRD result)**
  - Local structure of Si or Al (e.g., solid NMR result)
  - Bonding characteristics (e.g., IR result)
  - Particle size distribution (e.g., particle size analysis)
  - Etc.

GLASS STRUCTURE OF FLY ASH

Crystalline state **Amorphous state**

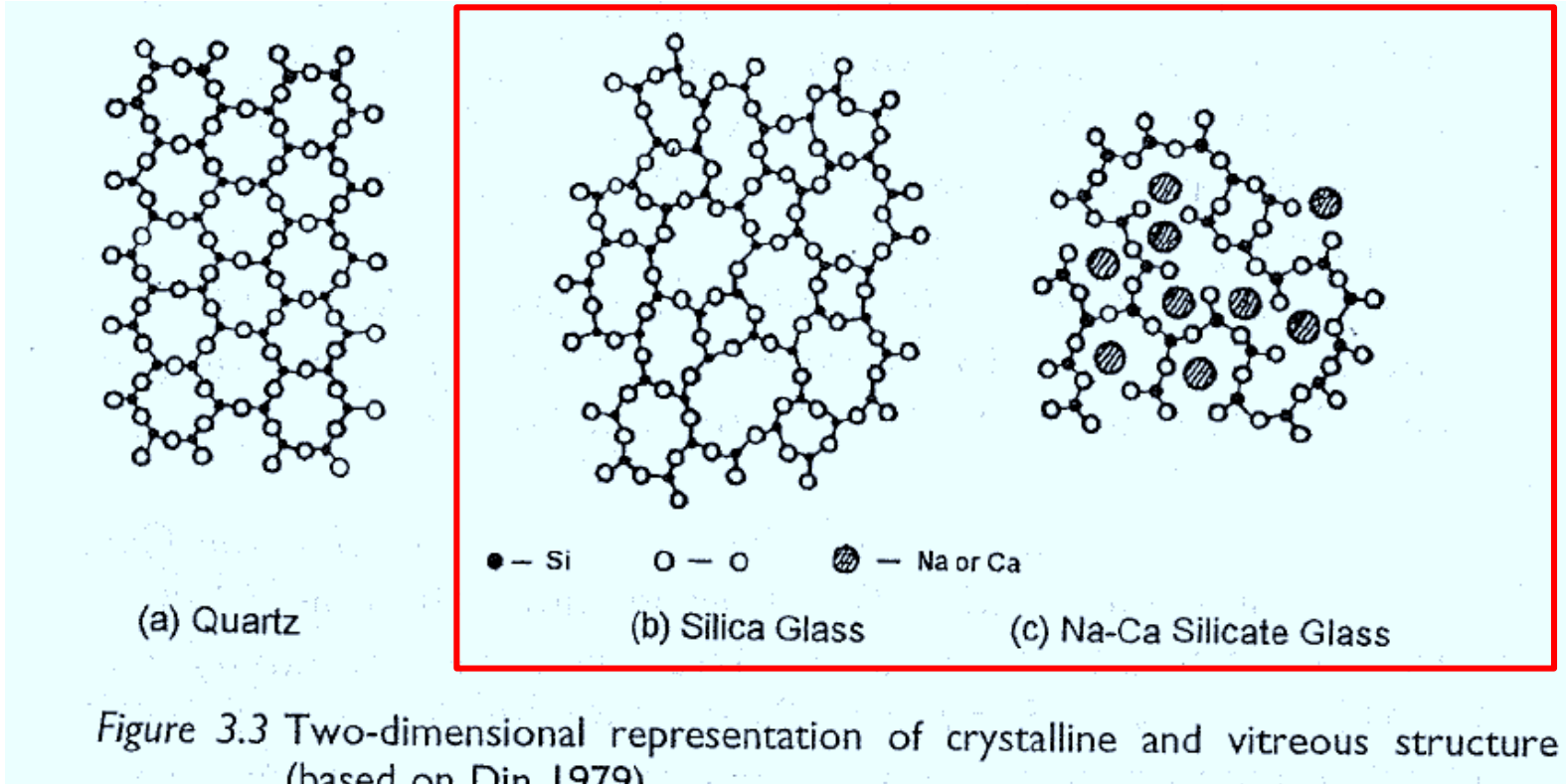
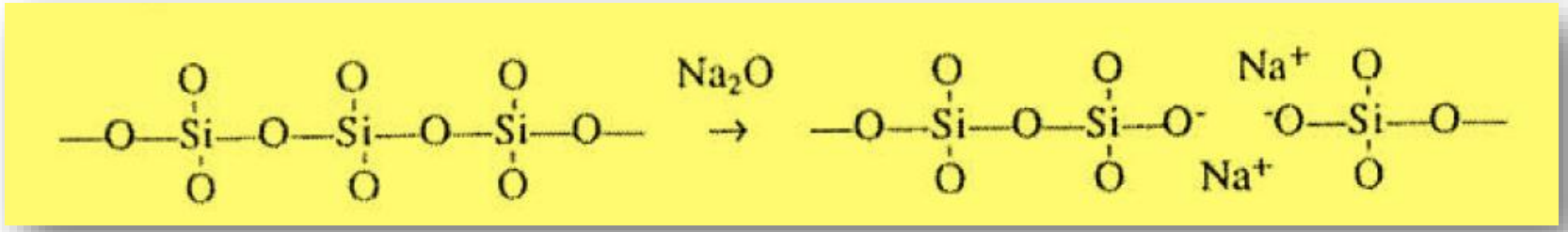


Figure 3.3 Two-dimensional representation of crystalline and vitreous structure (based on Din 1979).

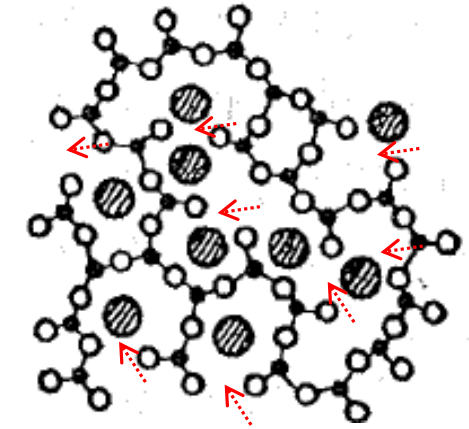


GLASS MODIFICATION

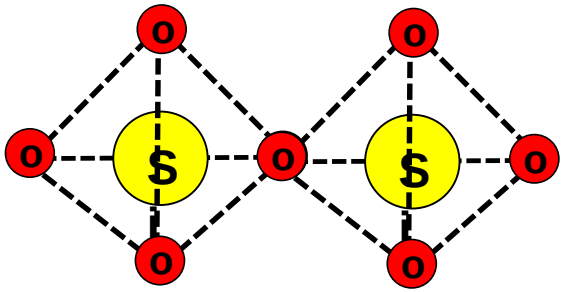
Depolymerization position

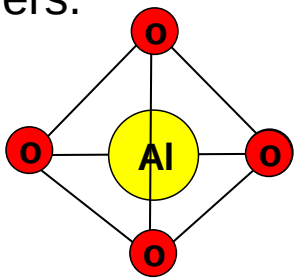
According to the network theory, Zachariasen (1932)

1) **Network formers: Si, Al**
   - Coordination number = 3 or 4
   - Small ionic radii
2) **Network modifiers: Na, K, Ca, Mg**
   - *Coordination number* = 6 *or* 8
   - Large ionic radii.
   - *These depolymerize the network*.
3) **Intermediates: Al, Mg**
   - *Coordination number* = 4 as network formers
   - *Coordination number* = 6 as network modifiers.

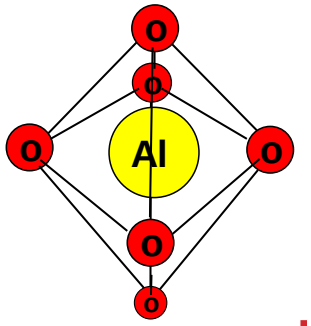


c) Na-Ca Silicate Glass





Al(IV)



Al(VI)

IN THIS STUDY….

WHICH IS MORE INFLUENTIAL

ON COMPRESSIVE STRENGTH OF FLY ASH GEOPOLYMER?:

GLASS CONTENT

VS.

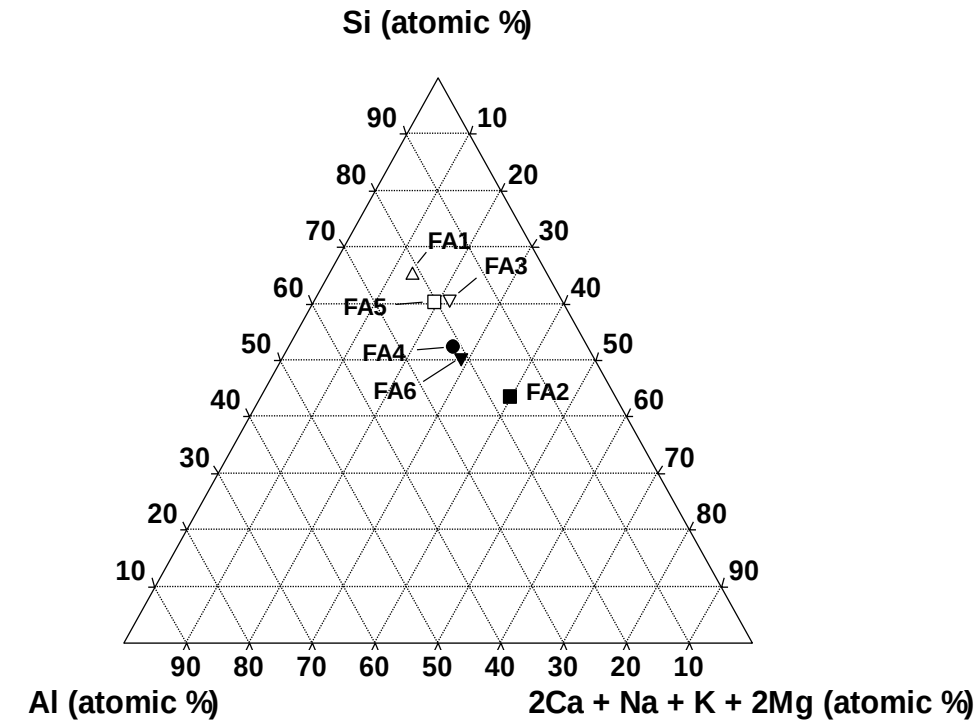
NETWORK MODIFIER CONTENT

EXPERIMENTAL

- **Materials**
  - Six different fly ashes from South Korea
- **Activator**
  - NaOH 5M or NaOH 10M solution
- **Solution/Binder ratio = 0.6 for all samples**
- **Curing condition**
  - For the first day = 30°C or 60°C
  - Until tested = room temperature
  - 99% relative humidity
- **Compressive strength test**
  - At 7 days and at 28 days
- **Characterization Methods**
  - X-ray fluorescence (XRF)
  - High power powder X-ray diffraction (XRD)
- **Analysis tool**
  - PANanalytical X'pert Highscore plus (ver, 2012)
  - ICDD PDF-2 database

XRF

Element	Atomic %					
	FA1	FA2	FA3	FA4	FA5	FA6
Si	58.6	40.9	53.5	46.9	54.3	44.2
Al	19.4	15.7	15.5	19.1	18.4	18.4
Ca	3.9	15.7	7.0	8.5	5.8	7.7
Fe	9.0	18.7	16.4	15.1	12.4	18.1
Mg	0.5	1.7	1.0	1.1	0.9	1.3
Na+K	3.2	2.3	2.8	4.3	3.9	6.8
2Ca+Na+K+2Mg	12.1	37.3	18.8	23.6	17.2	24.8

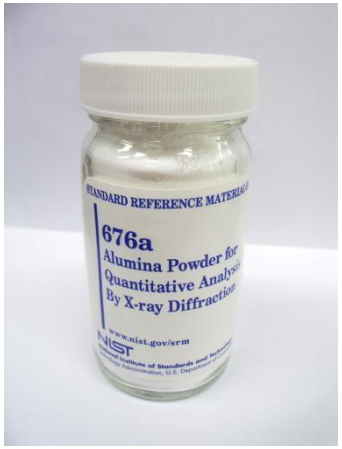


GLASS CONTENT IN WEIGHT

Quantitative XRD Analysis

(RIR METHOD + Internal Standard Method)

Internal Standard



3g

Al_2O_3 from NIST (Reference Material)

+

Raw Fly Ash

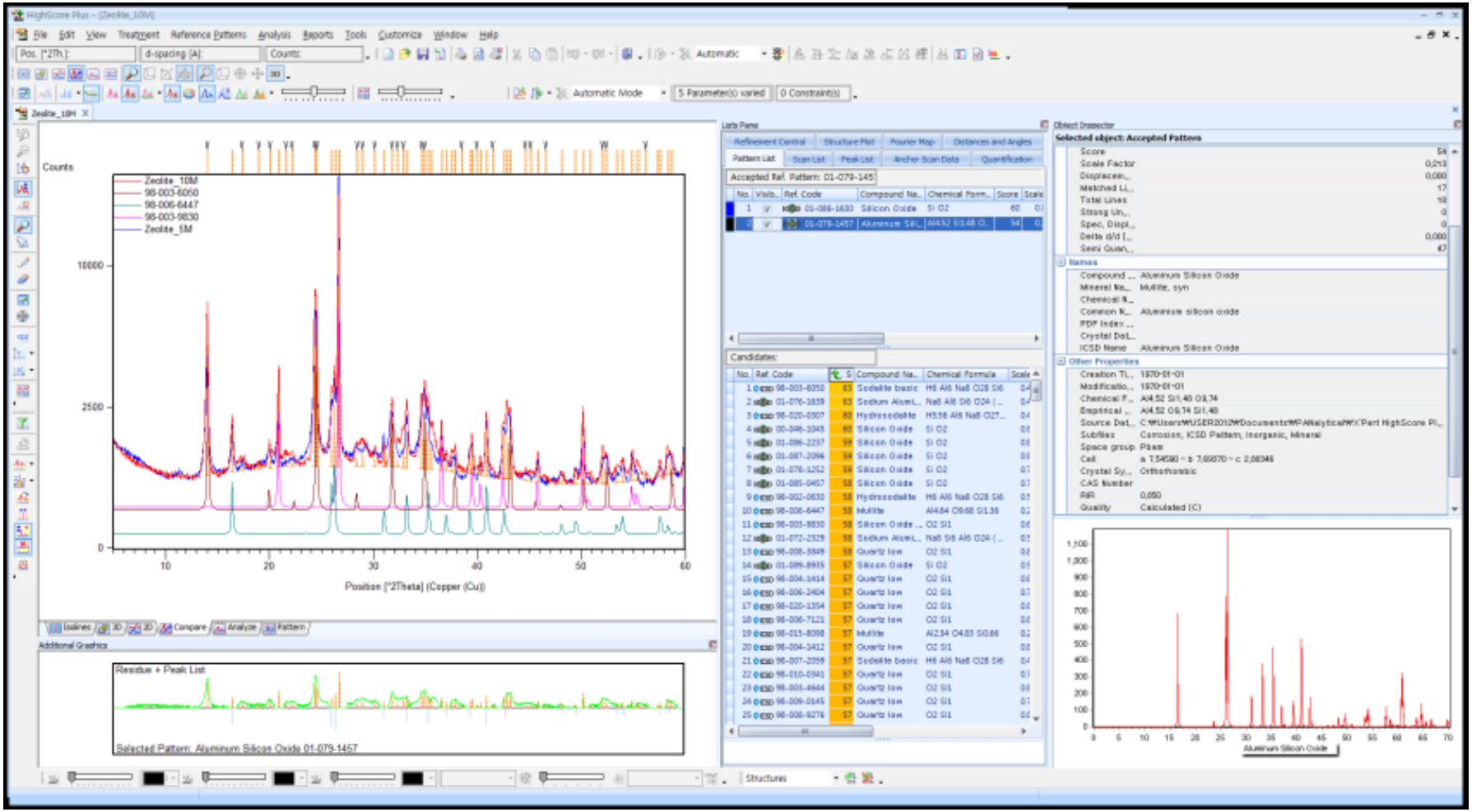
27g

High Powder X-ray Diffractometer,
XRD: D/MAX 2000V/PC

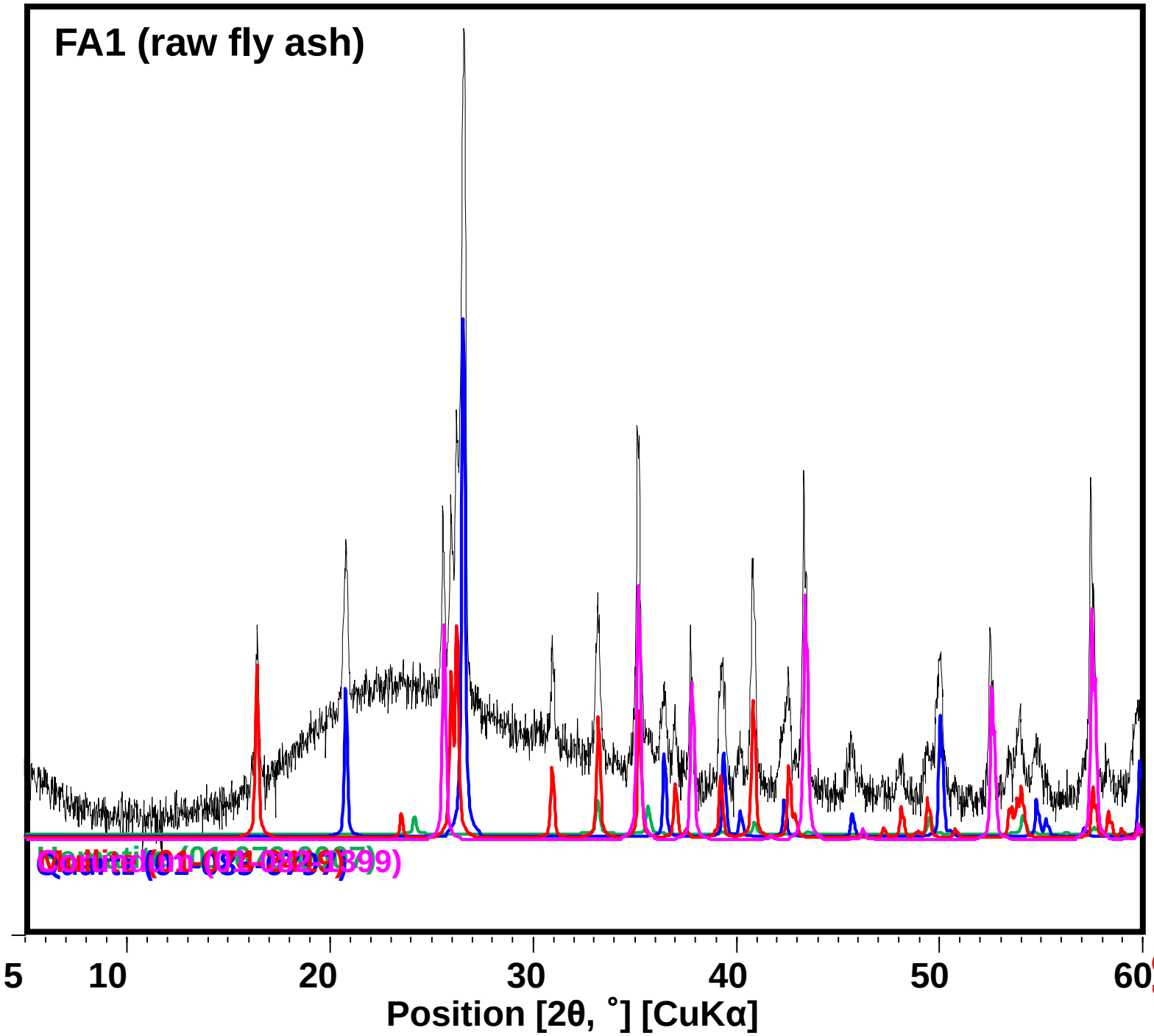
GLASS CONTENT IN WEIGHT

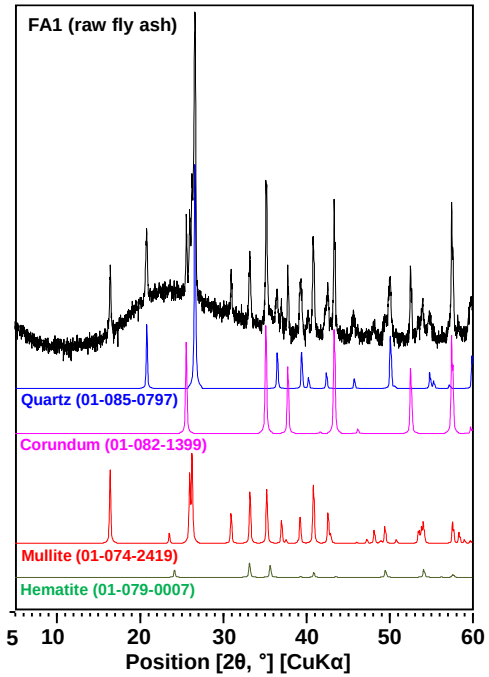
Quantitative XRD Analysis

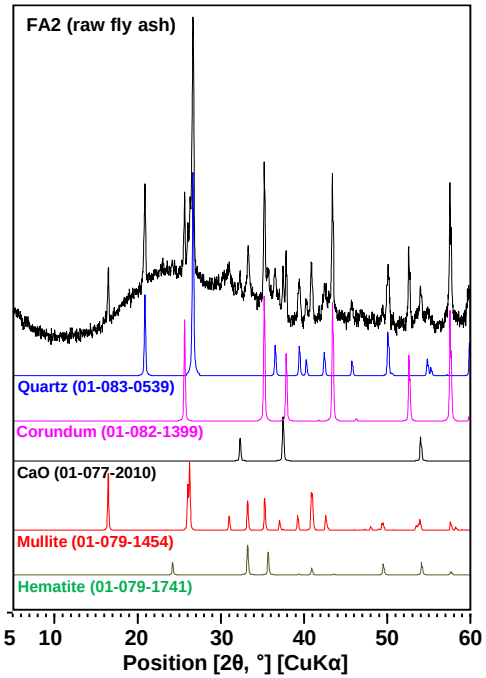
(RIR METHOD + Internal Standard Method)

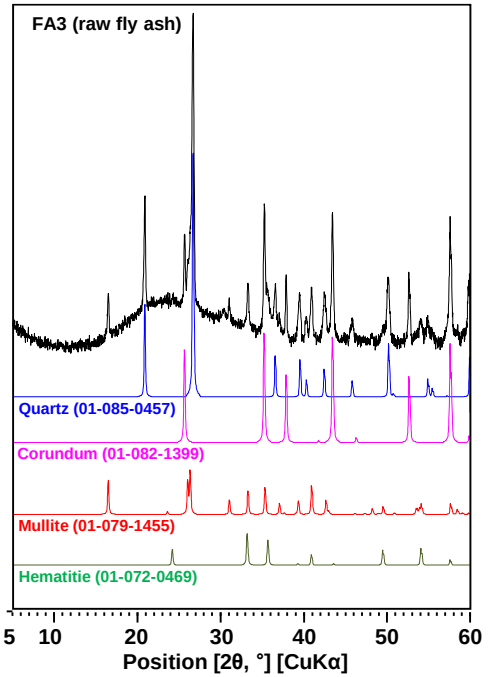


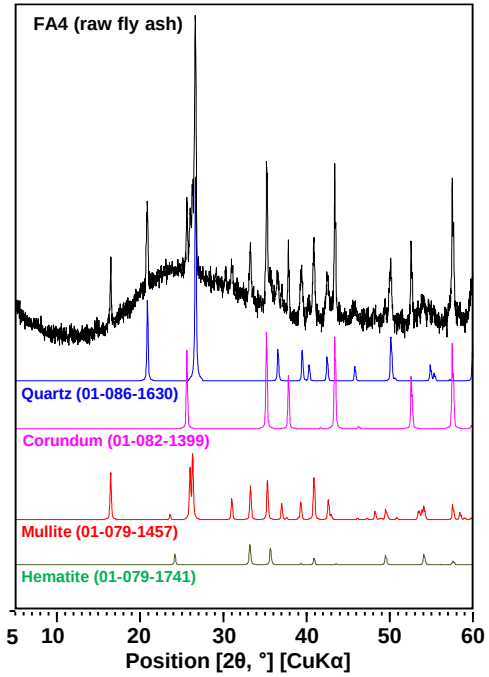
XRD

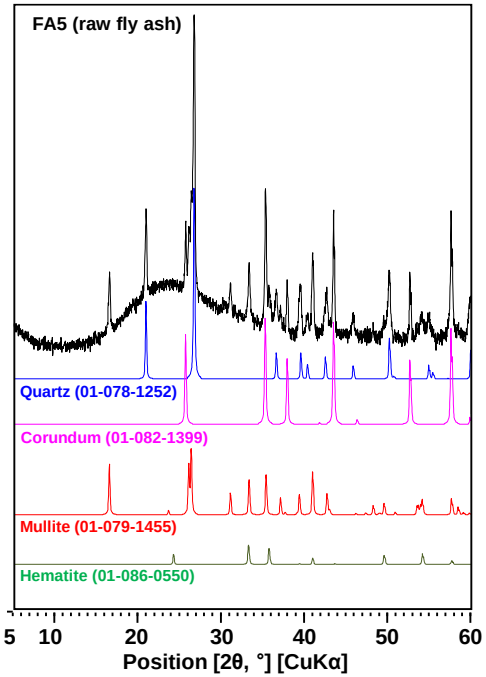

FA1 (raw fly ash)
Quartz (01-085-0794)
5
10
20
30
40
50
60
Position [2θ, °] [CuKα]

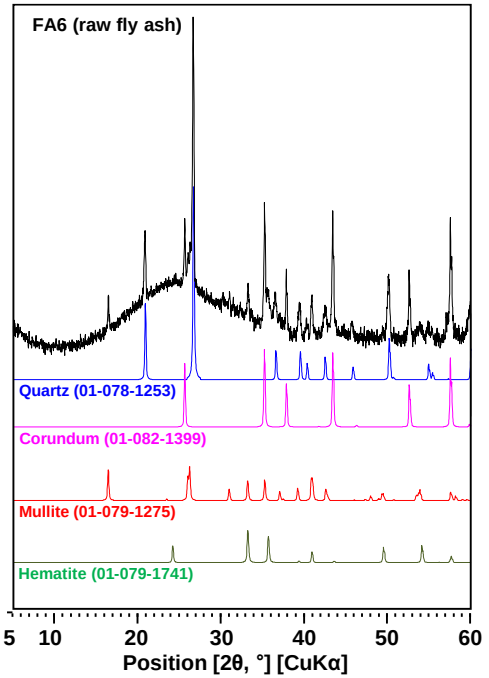

FA1 (raw fly ash)
Quartz (01-085-0797)
Corundum (01-082-1399)
Mullite (01-074-2419)
Hematite (01-079-0007)
5 10 20 30 40 50 60
Position [2θ, °] [CuKα]


FA2 (raw fly ash)
Quartz (01-083-0539)
Corundum (01-082-1399)
CaO (01-077-2010)
Mullite (01-079-1454)
Hematite (01-079-1741)
5 10 20 30 40 50 60
Position [2θ, °] [CuKα]


FA3 (raw fly ash)
Quartz (01-085-0457)
Corundum (01-082-1399)
Mullite (01-079-1455)
Hematitie (01-072-0469)
5 10 20 30 40 50 60
Position [2θ, °] [CuKα]


FA4 (raw fly ash)
Quartz (01-086-1630)
Corundum (01-082-1399)
Mullite (01-079-1457)
Hematite (01-079-1741)
5 10 20 30 40 50 60
Position [2θ, °] [CuKα]

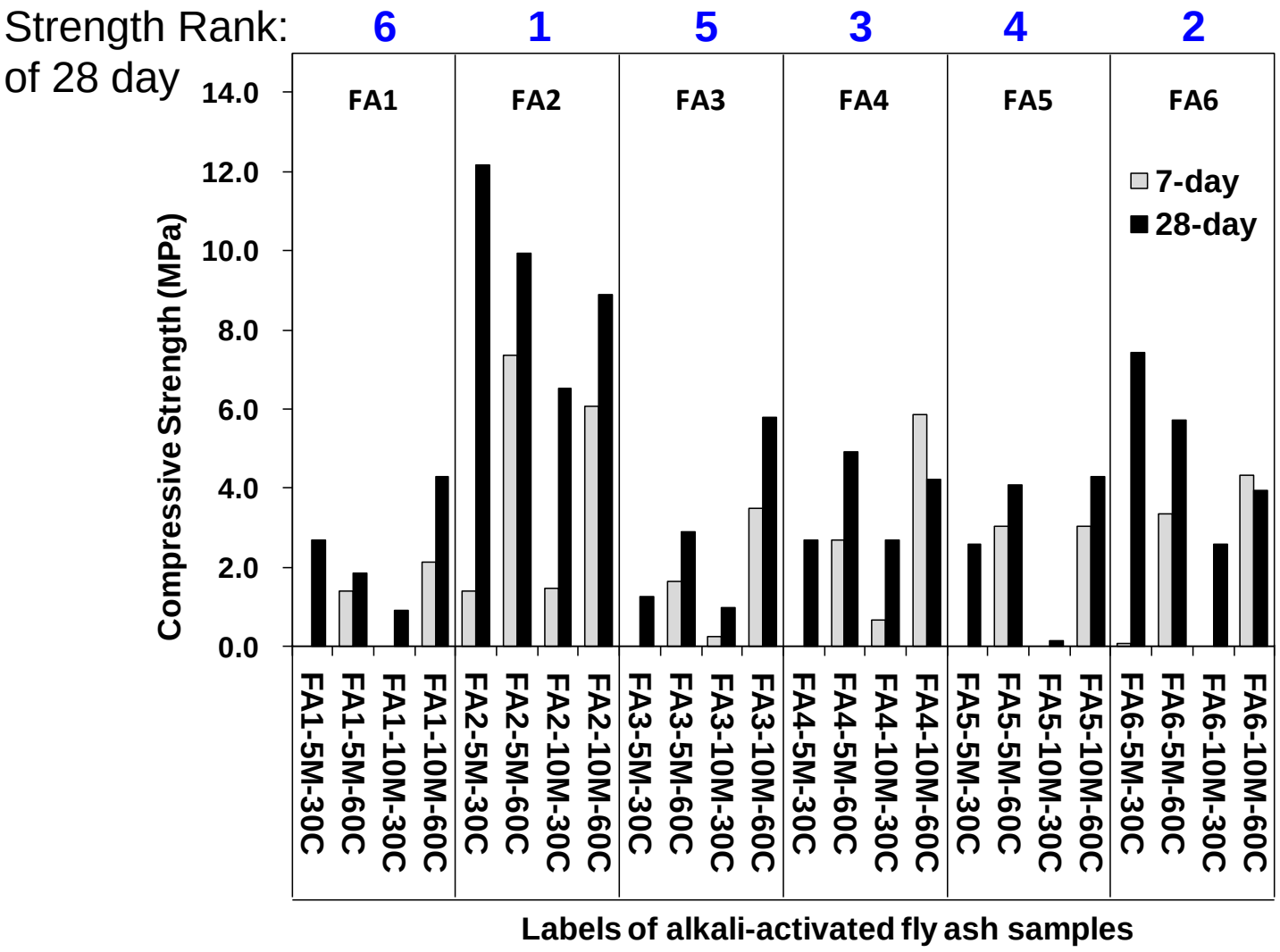

FA5 (raw fly ash)
Quartz (01-078-1252)
Corundum (01-082-1399)
Mullite (01-079-1455)
Hematite (01-086-0550)
5 10 20 30 40 50 60
Position [2θ, °] [CuKα]


FA6 (raw fly ash)
Quartz (01-078-1253)
Corundum (01-082-1399)
Mullite (01-079-1275)
Hematite (01-079-1741)
5 10 20 30 40 50 60
Position [2θ, °] [CuKα]

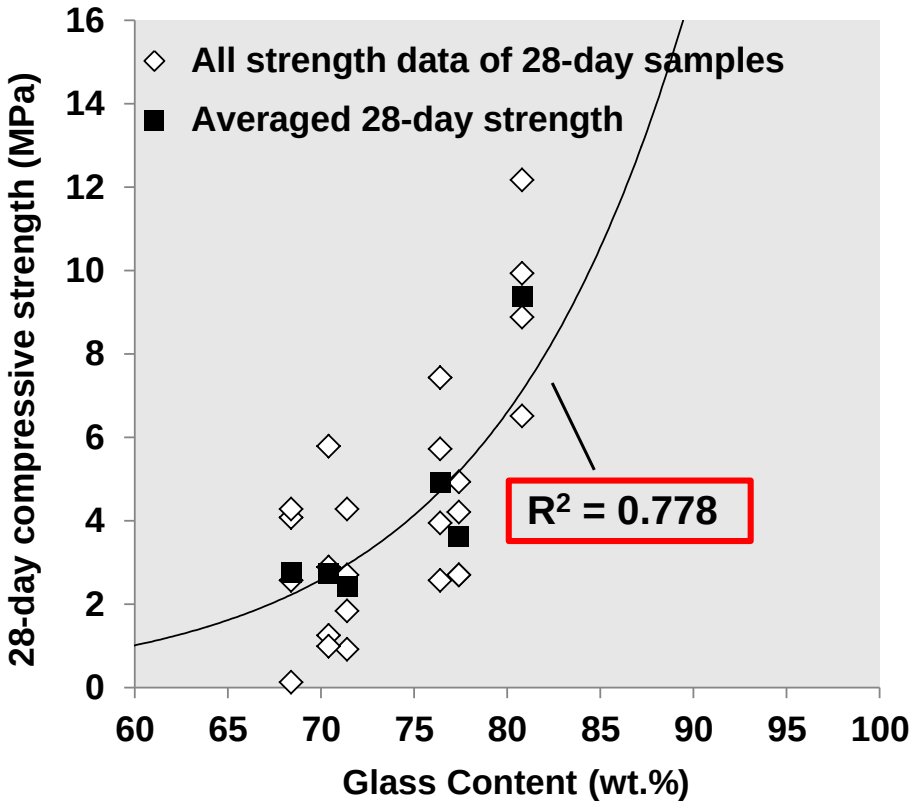
GLASS CONTENT RESULT

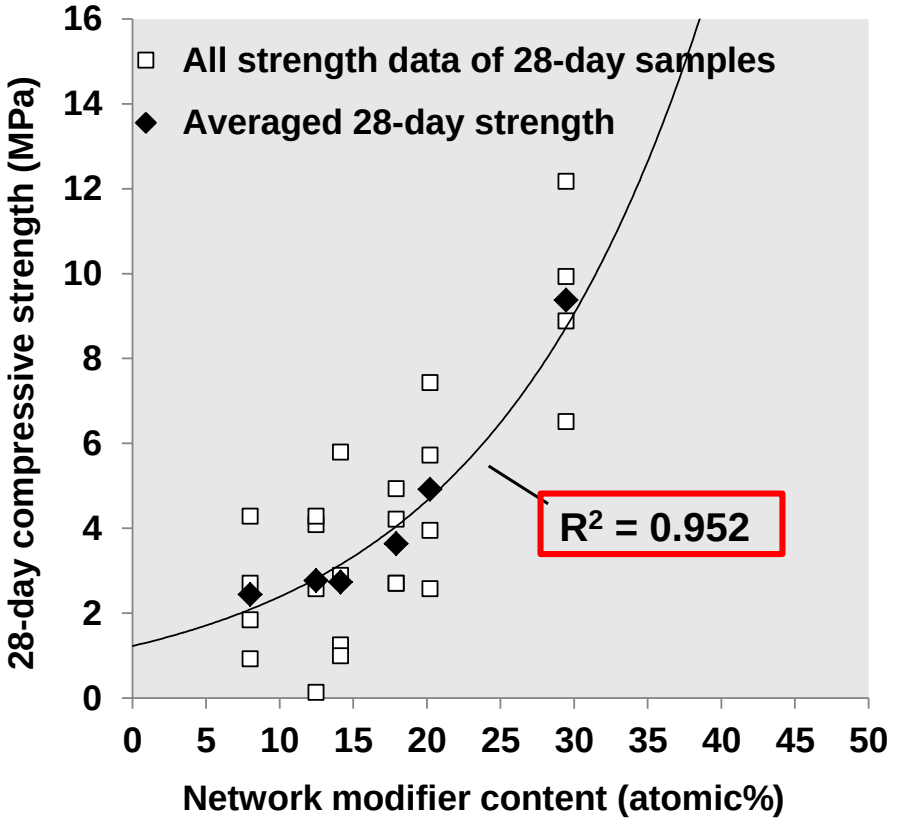
Phase	Phase weight (%)					
	FA1	FA2	FA3	FA4	FA5	FA6
Quartz	13.5	9.9	18.1	11.5	16.7	14.6
Mullite	13.9	7.8	10.7	10.1	13.6	8.0
Hematite	1.2	1.2	0.8	1.0	1.3	1.0
Crystalline CaO	0.0	0.3	0.0	0.0	0.0	0.0
Glass Content	71.4	80.8	70.4	77.4	68.4	76.4
Total sum	100.0	100.0	100.0	100.0	100.0	100.0

STRENGTH TEST RESULT

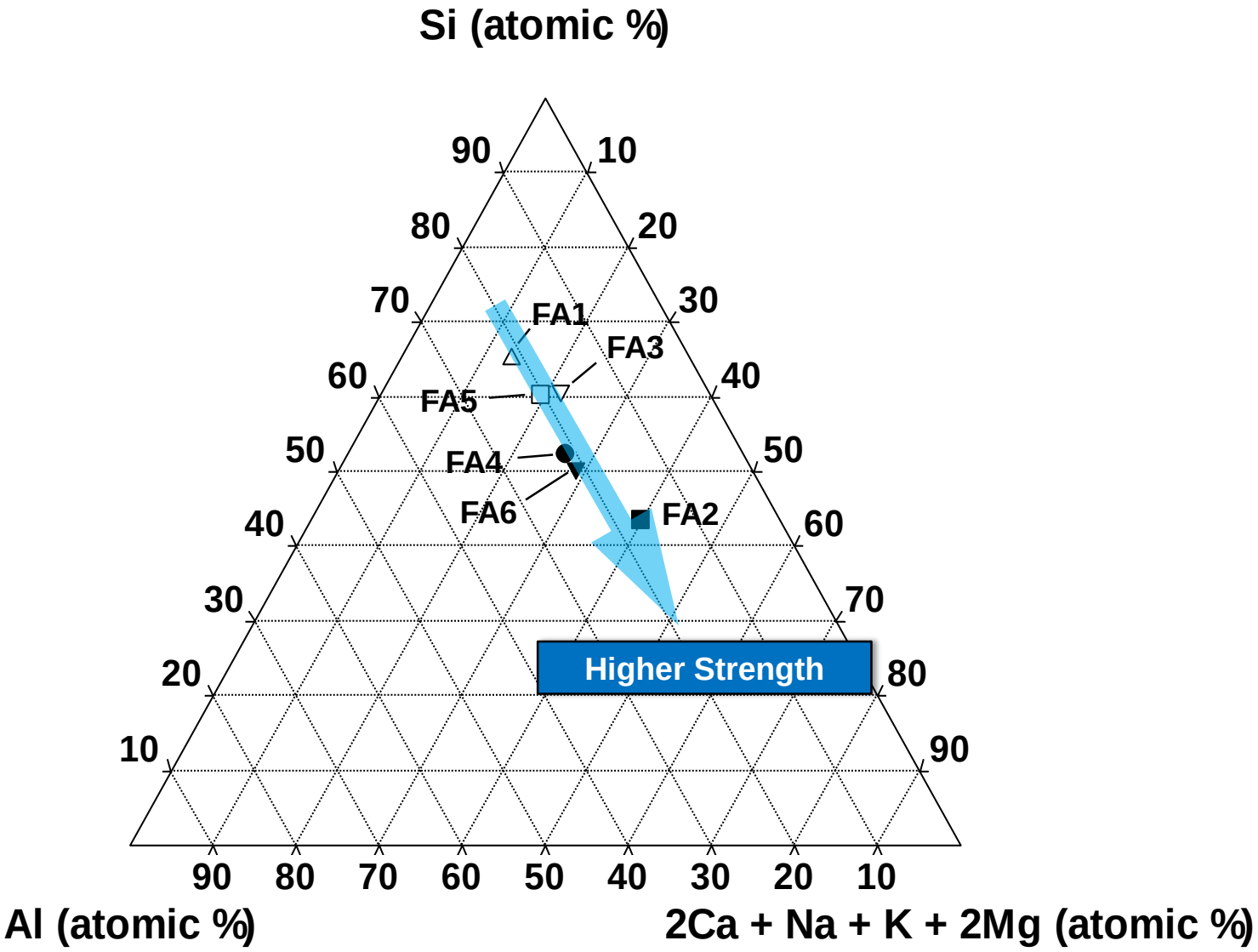


GLASS CONTENT VS. NETWORK MODIFIER CONTENT





STRENGTH VS. XRF



CONCLUTION

- The content of network modifying element (e.g., Na, K, Mg, Ca) is a better indicator for geopolymeric reaction of fly ash
- The content is obtained by an easy characterization, XRF
- This results are only available to low strength geopolymer samples because the strength is more affected by the external factors (e.g., curing temp, activator types)