

# Strength and Microstructural Characteristics of Cement Kiln Dust Activated Alternative Binding Materials

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# Outline of the Talk

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- Motivation for the study
- Materials
- Experimental program
- Compressive strength
  - CKD-FA (Paste and Concrete)
  - CKD-Slag (Paste and Concrete)
- Mineralogical and morphological investigation
- Summary

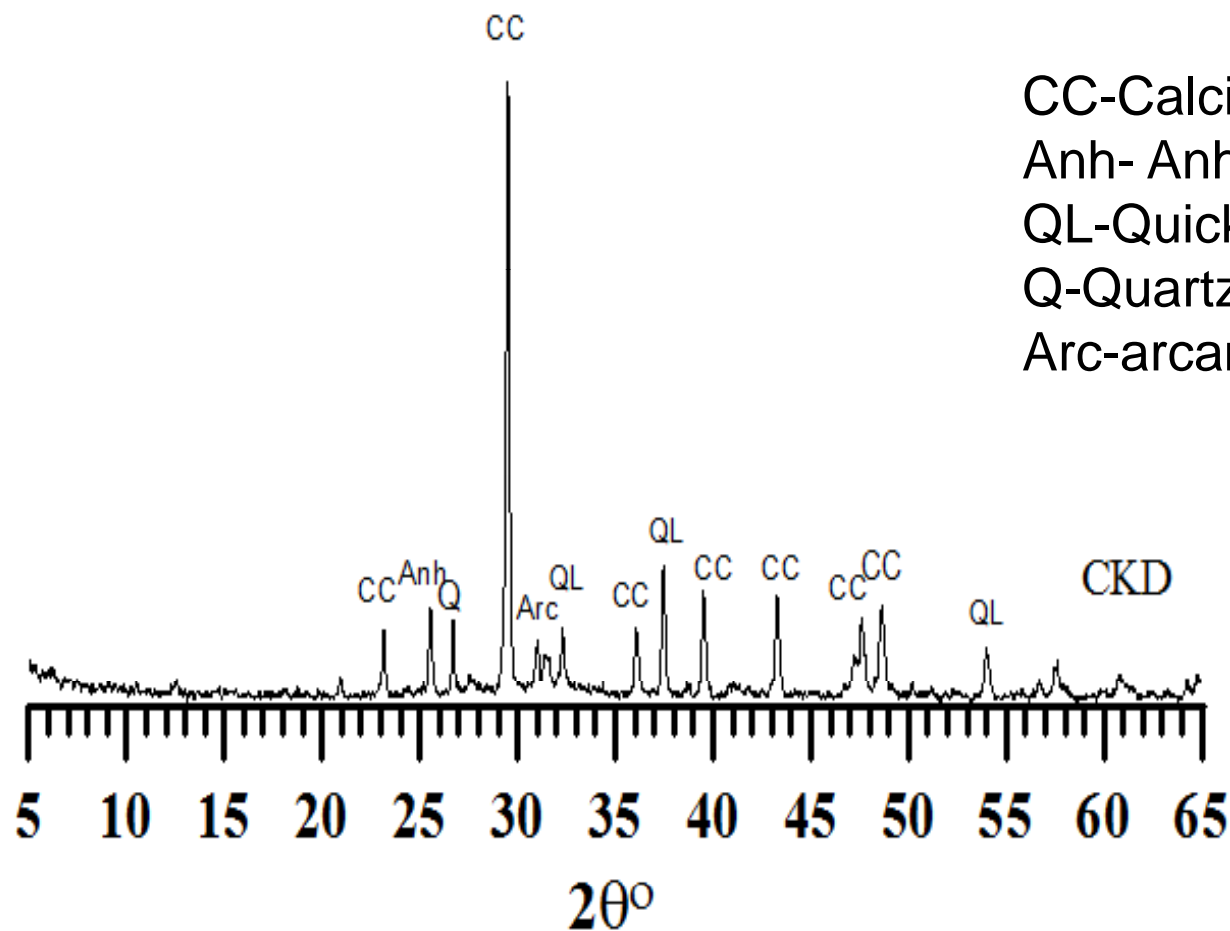
# Motivation and Objectives

- Alkali activated concrete
  - Mechanism and limitations
- Can we develop a binder with cement kiln dust as an activator and FA/Slag as the base material?
- How to proportion the materials?
- What are the processing techniques?
- What is mechanical/durability performance of such a concrete?
- What is the mechanism of strength development?

# Chemical Compositions of the Materials

| Chemical Composition           | CKD<br>(% by mass) | Fly Ash<br>(% by mass) | GGBFS<br>(% by mass) |
|--------------------------------|--------------------|------------------------|----------------------|
| SiO <sub>2</sub>               | 14.55              | 50.20                  | 36.00                |
| Al <sub>2</sub> O <sub>3</sub> | 4.46               | 28.70                  | 10.50                |
| Fe <sub>2</sub> O <sub>3</sub> | 2.11               | 5.72                   | 0.67                 |
| CaO                            | 61.15              | 5.86                   | 39.80                |
| MgO                            | 3.84               | 1.74                   | 7.93                 |
| Na <sub>2</sub> O              | 0.80               | 0.96                   | 0.27                 |
| K <sub>2</sub> O               | 3.45               | --                     | 0.08                 |
| SO <sub>3</sub>                | 10.62              | 0.51                   | 2.11                 |
| Loss on Ignition(LOI)          | 23.40              | 1.85                   | 3.00                 |

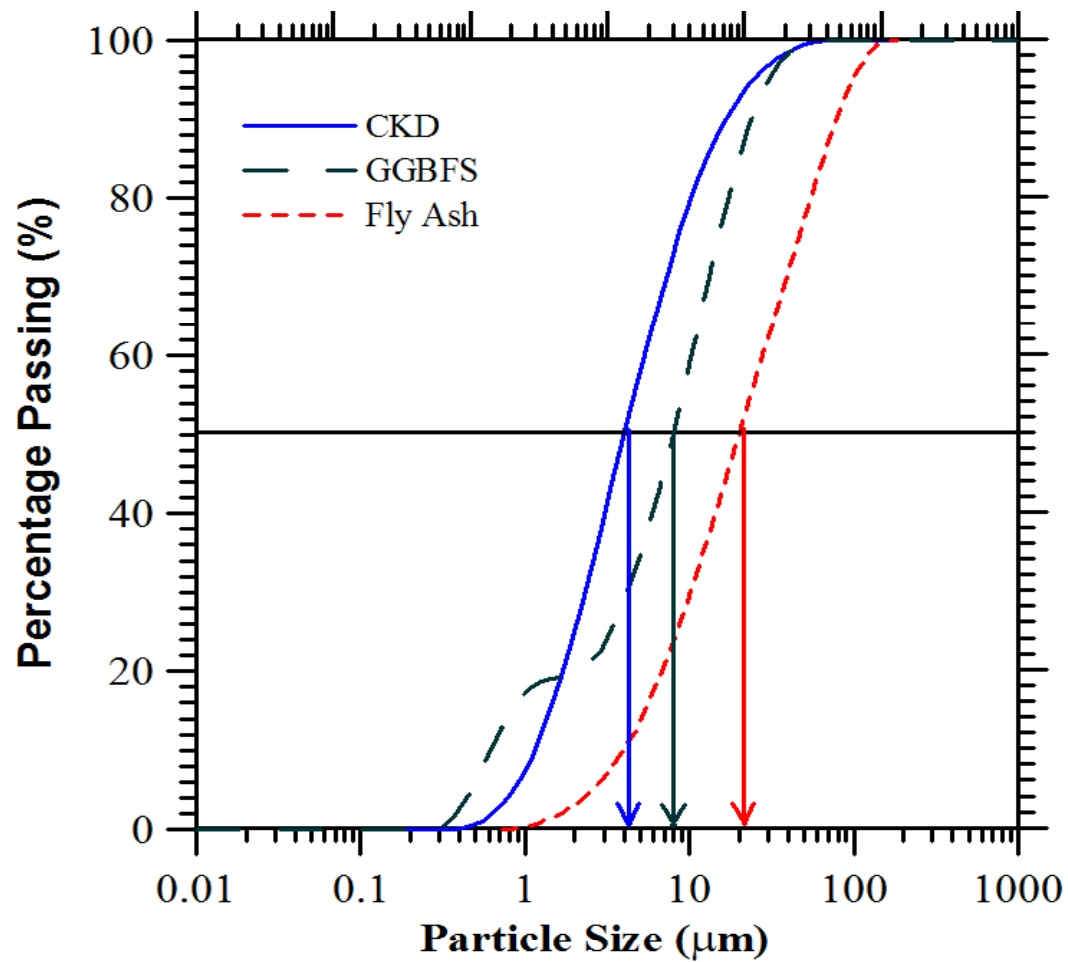
# Cement Kiln Dust (XRD)



CC-Calcite  
Anh- Anhydrite  
QL-Quick lime  
Q-Quartz  
Arc-arcanite

CKD Powder

# Particle size distributions (PSD)

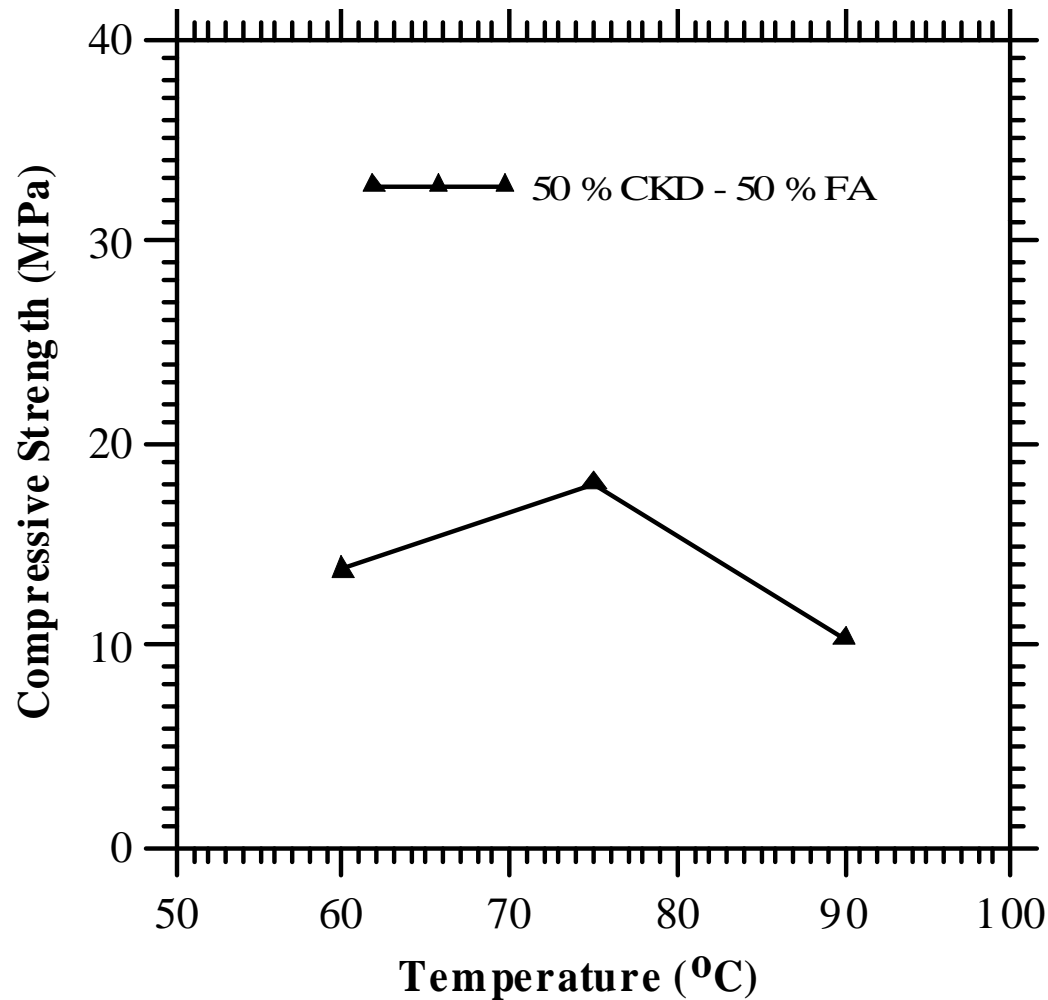


# Experimental Program

- Selection of optimum proportions and optimum temperature using paste mixtures
- Evaluation of the paste samples-strength
- Selection of optimum mixture proportion for making concrete
- Sulfate/ASR induced expansion
- Microstructural evaluation of the activated system

# Processing conditions

## ■ Curing Temperature

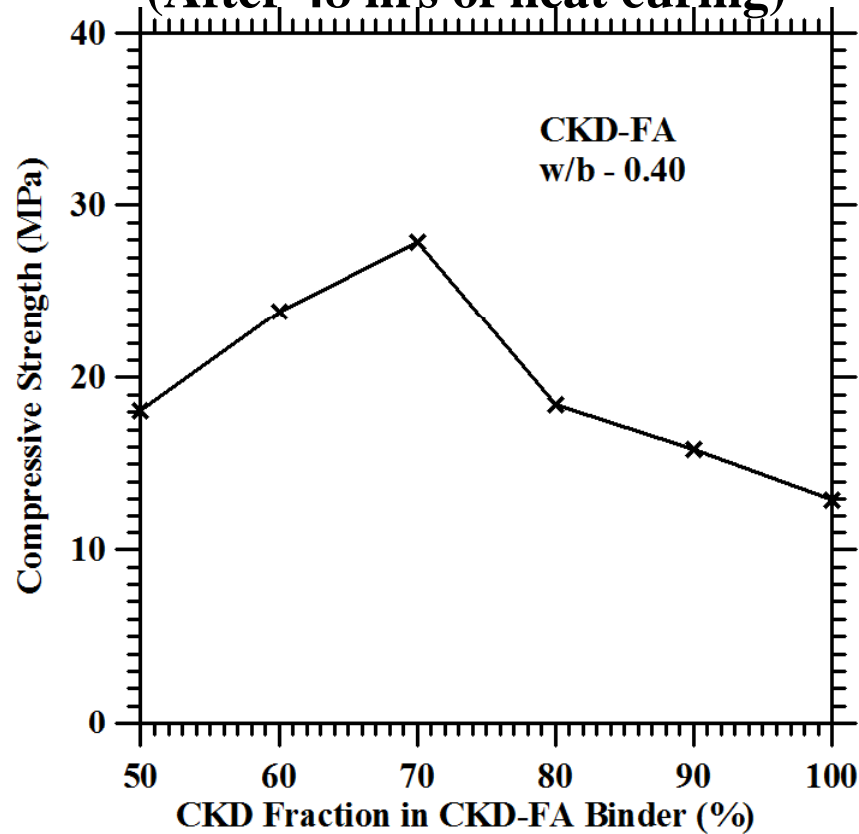




# Material Proportion

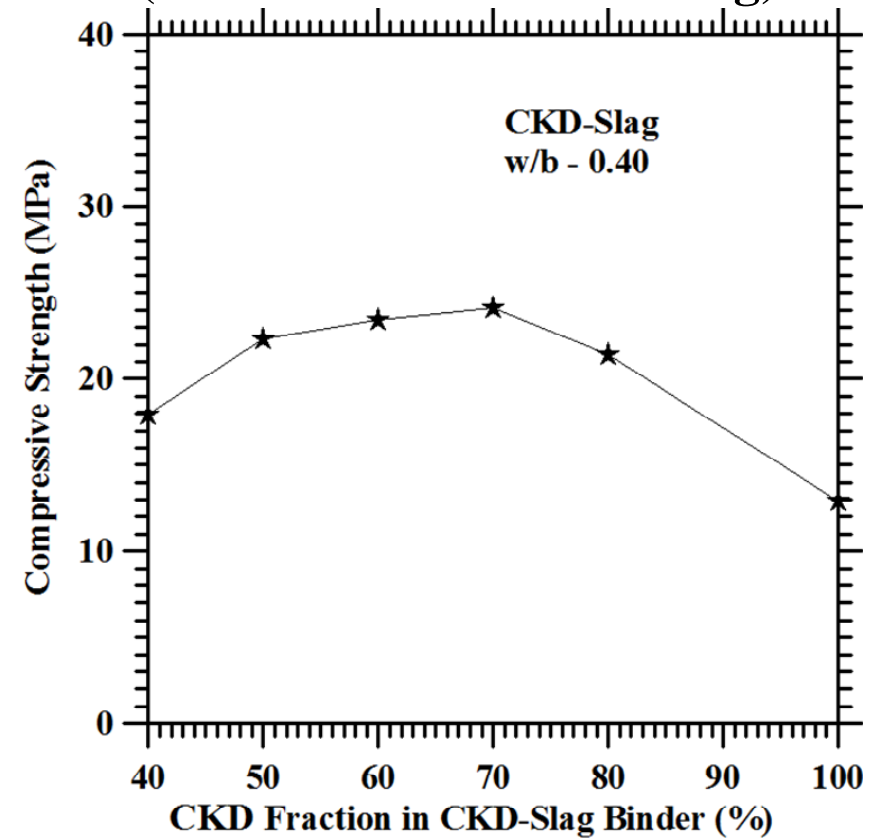
## CKD-FA Paste

(After 48 hrs of heat curing)



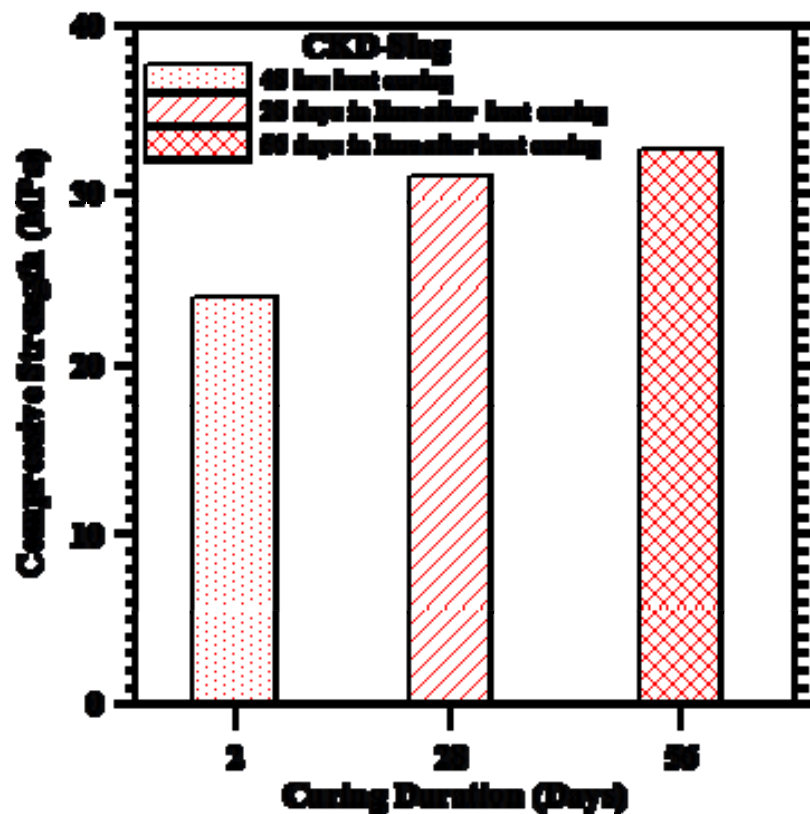
## CKD-Slag Paste

(After 48 hrs of heat curing)

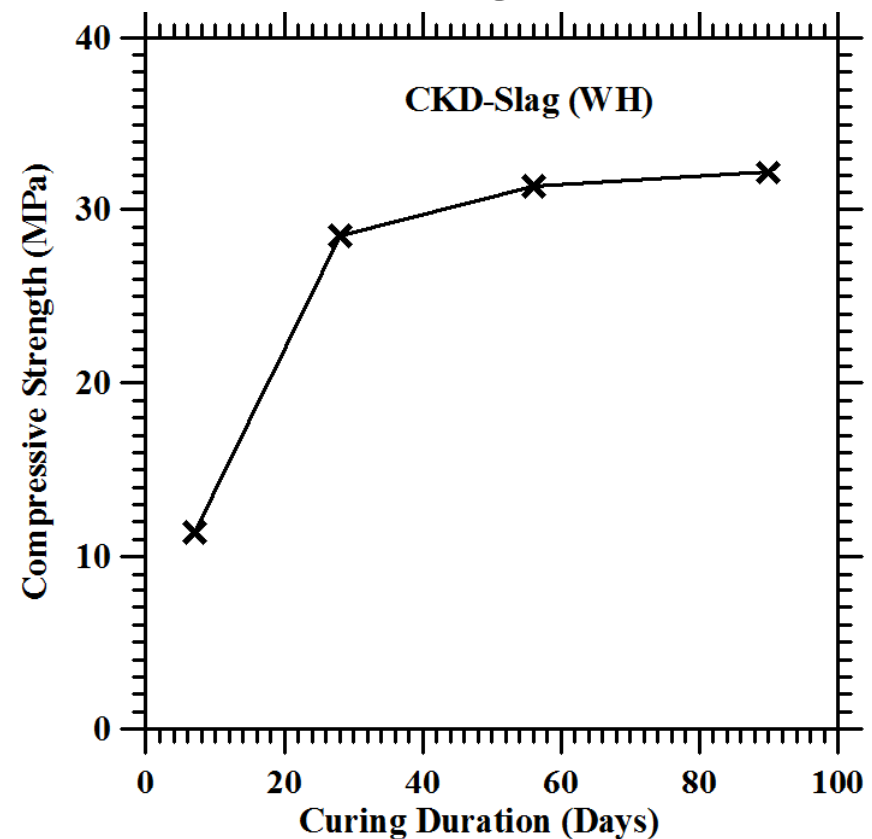


# Strength development in CKD-slag system

CKD-Slag Paste with heat curing

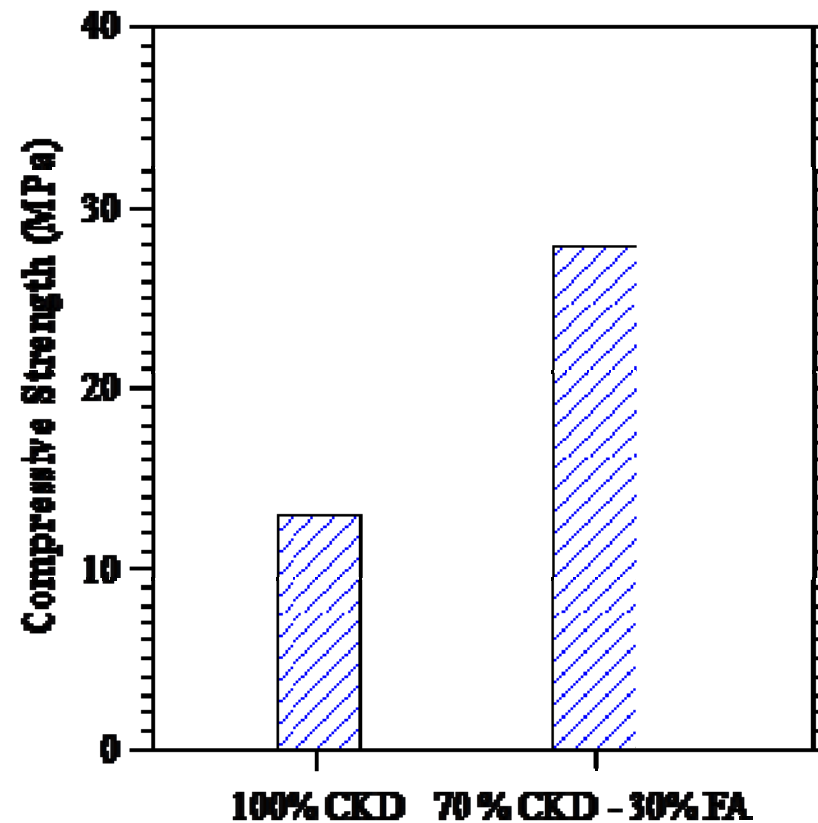


CKD-Slag Paste without heat curing



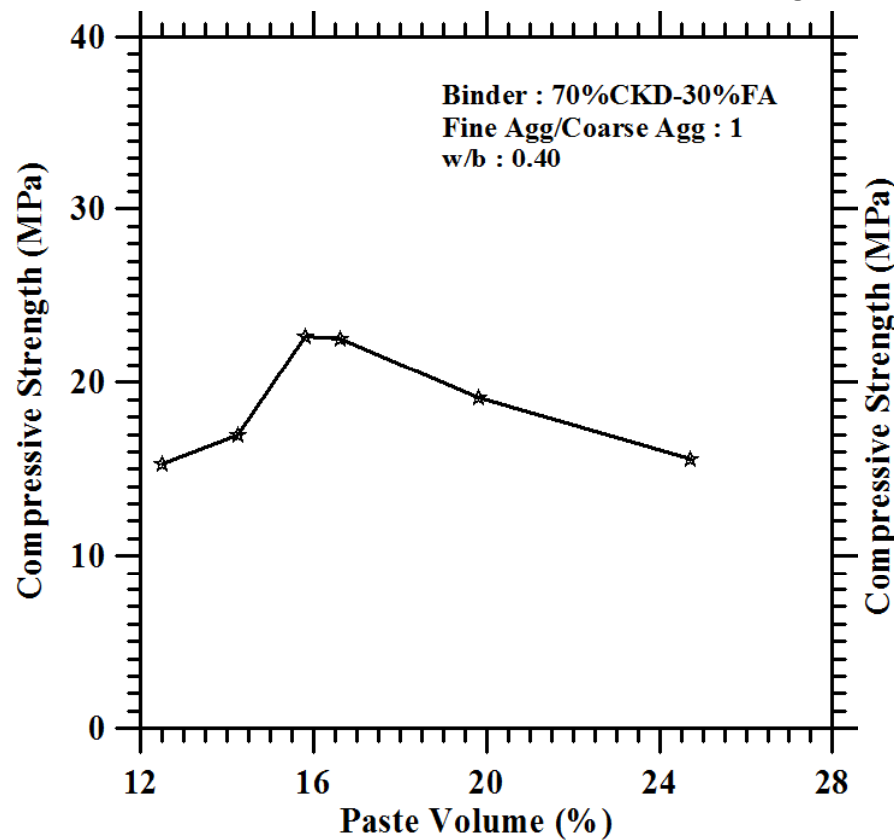
# Strength Comparison-CKD and CKD-FA

Strength of CKD alone and CKD-activated FA

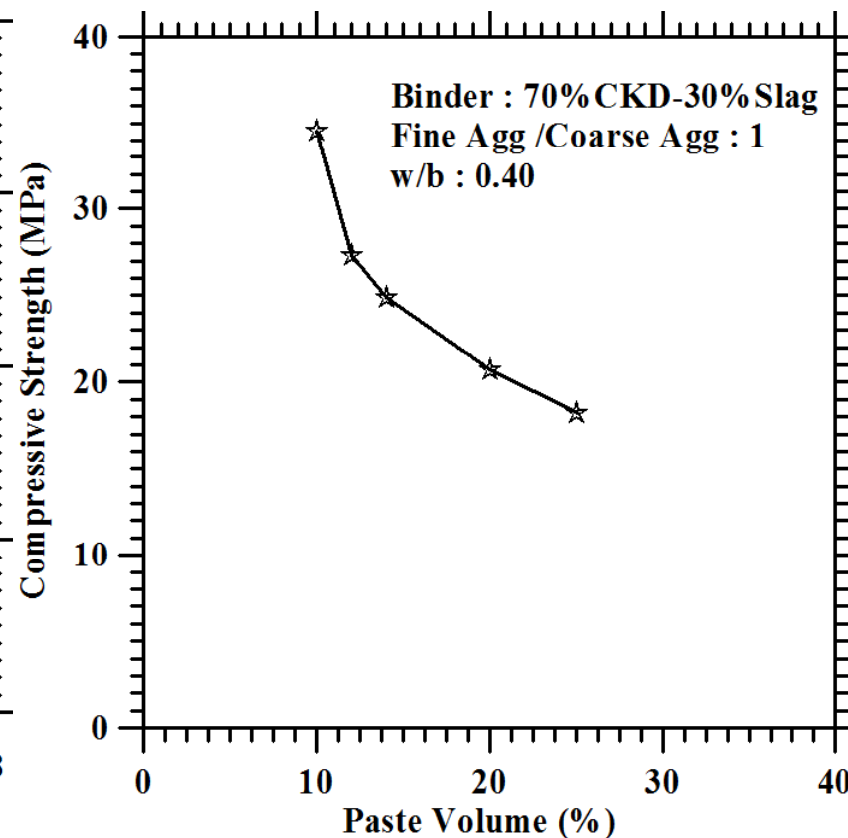


# Concrete Strength

CKD-FA Concrete  
(After 48 hrs of heat curing)



CKD-Slag Concrete  
(After 48 hrs of heat curing)



# Durability Performance

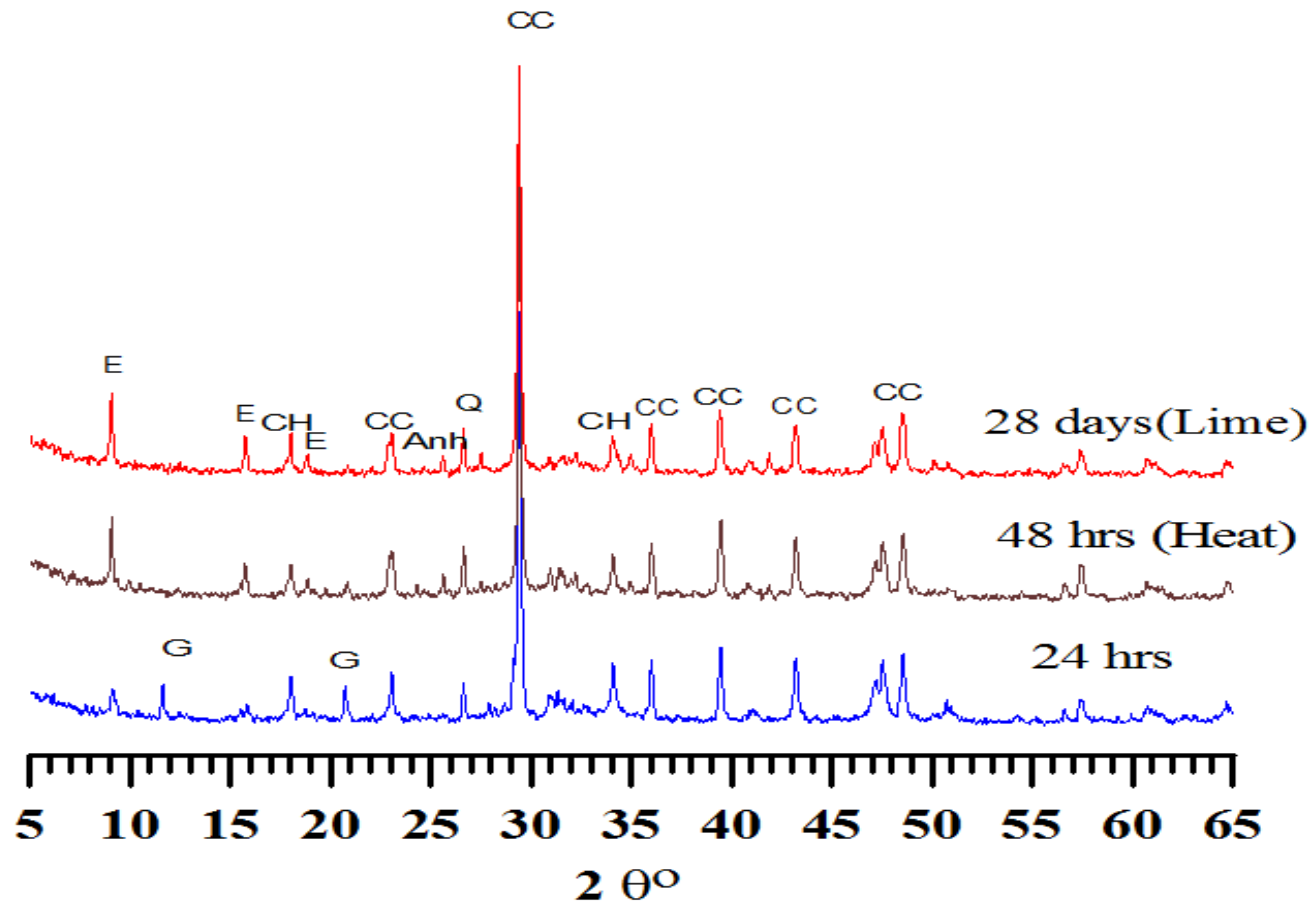
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Sulfate induced expansion

ASR induced expansion

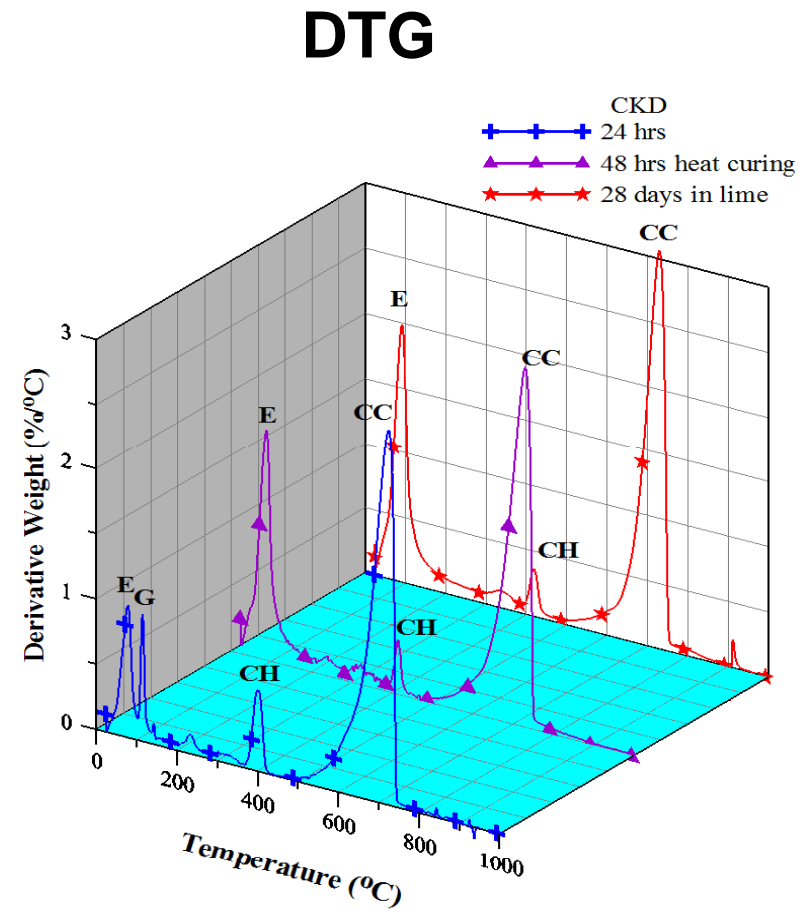
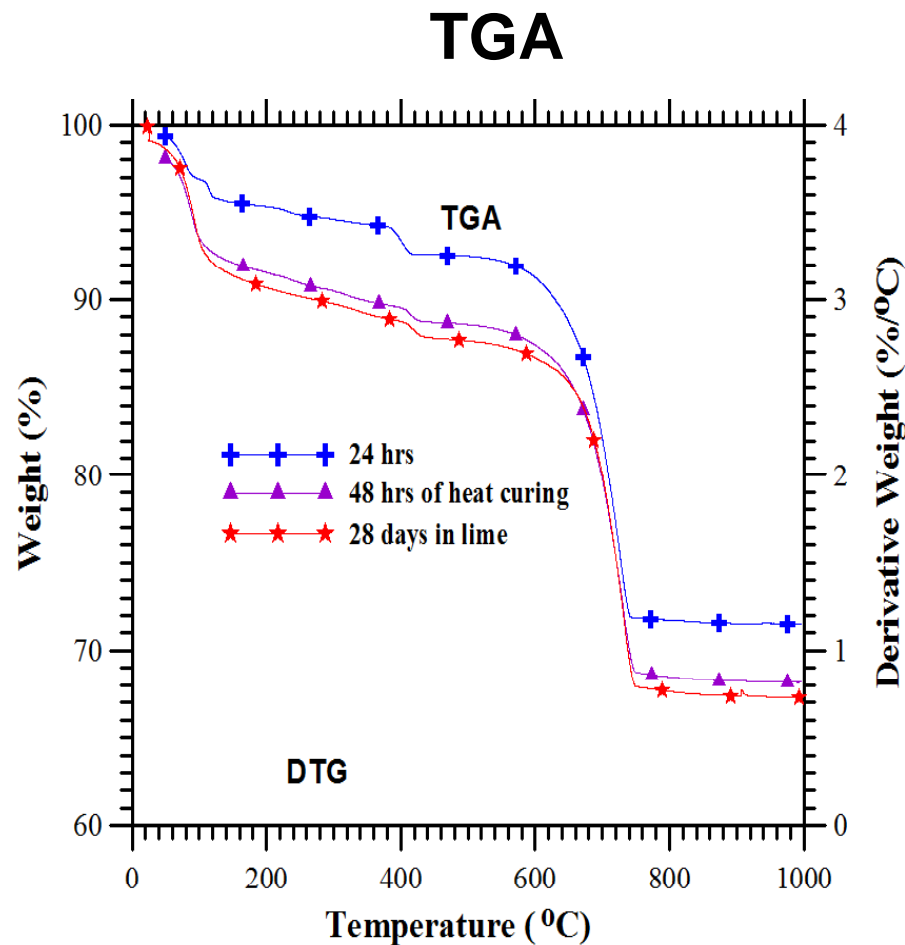
# CKD Activated FA and Slag Reaction Mechanism

# Mineralogical Investigation of CKD alone



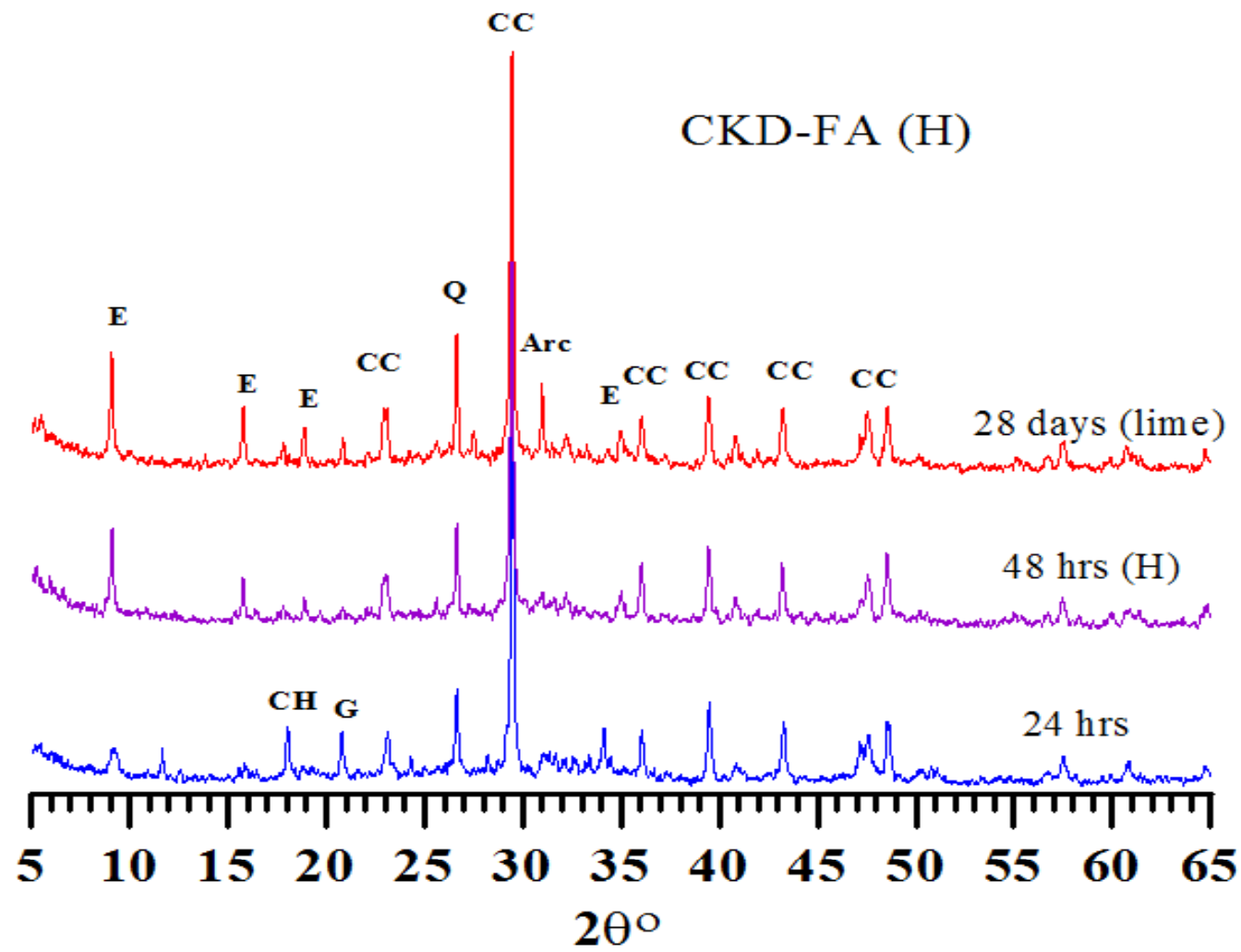
- CH present till 28 days
- Gypsum Consumed/converted to anhydrite during the heat curing
- No change in the Ettringite peak height between 48 hours heat curing and extended curing in lime water

# Mineralogical Investigation Cont'd (Heat Cured CKD)



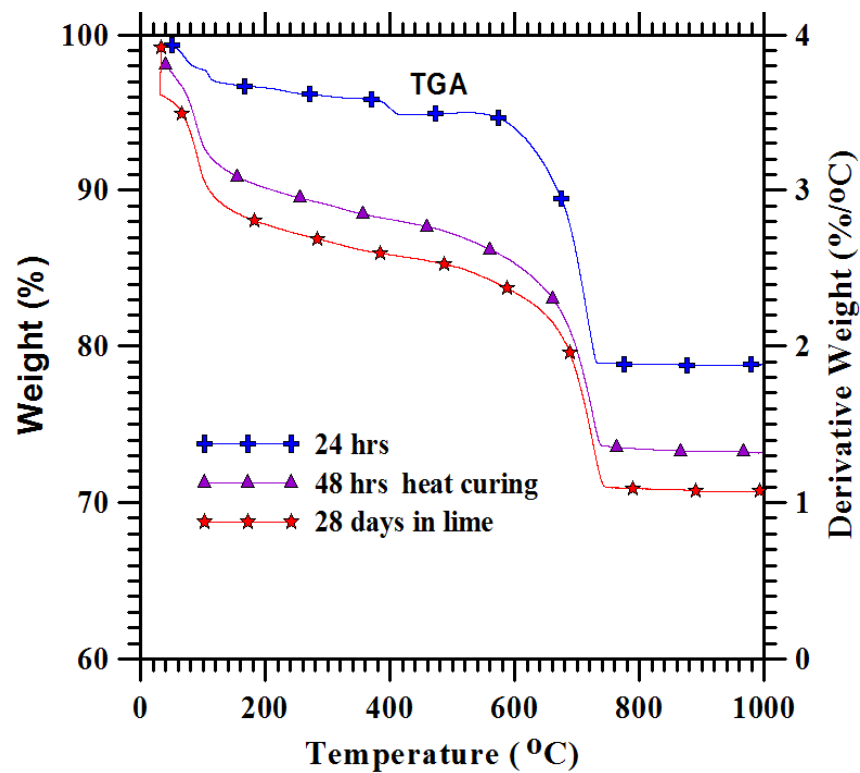


# CKD- FA system mineralogical changes

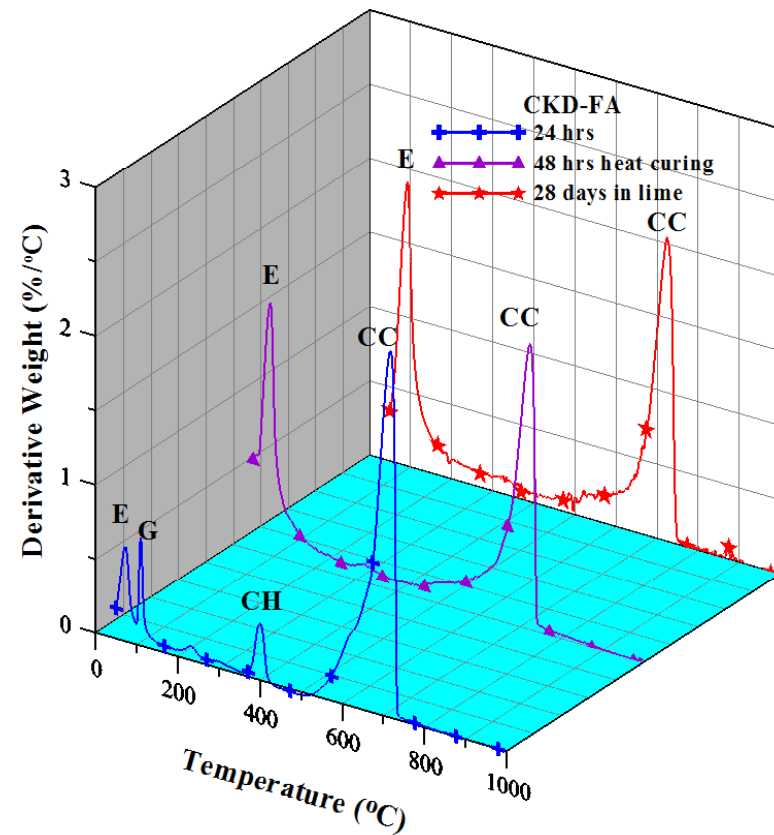


# CKD- FA system mineralogical changes

## TGA

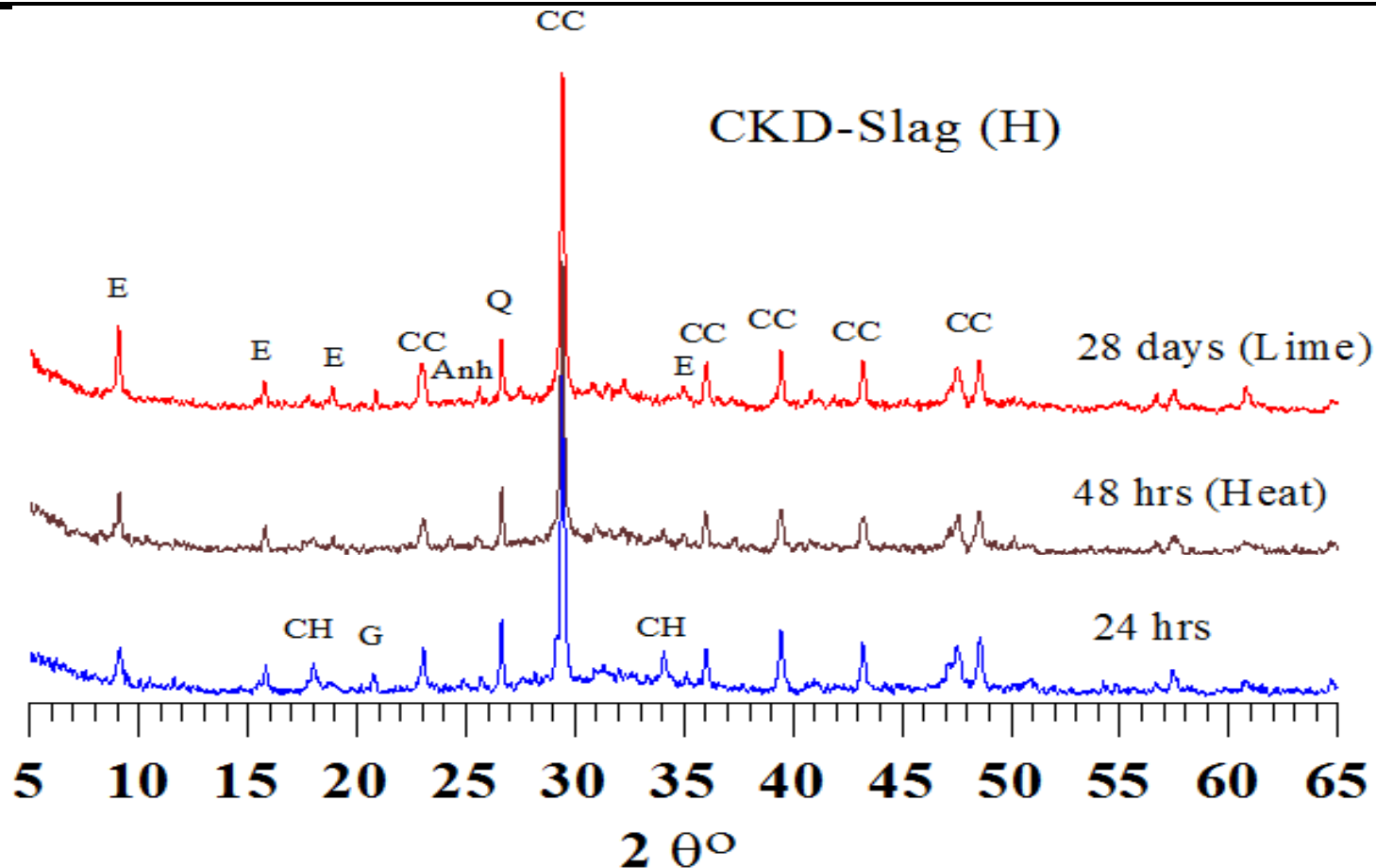


## DTG



# CKD-Slag systems

## Mineralogical Investigation Cont'd

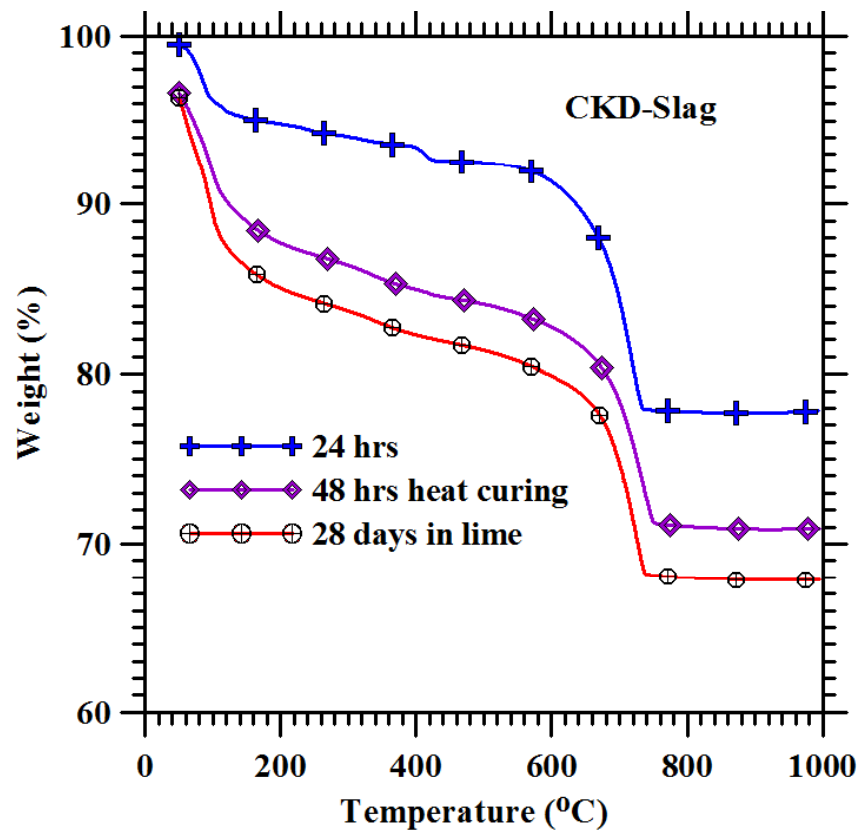


- CH consumed during the heat curing.
- Ettringite peak seems to be more intensified on lime curing after 48 hrs of heat curing.

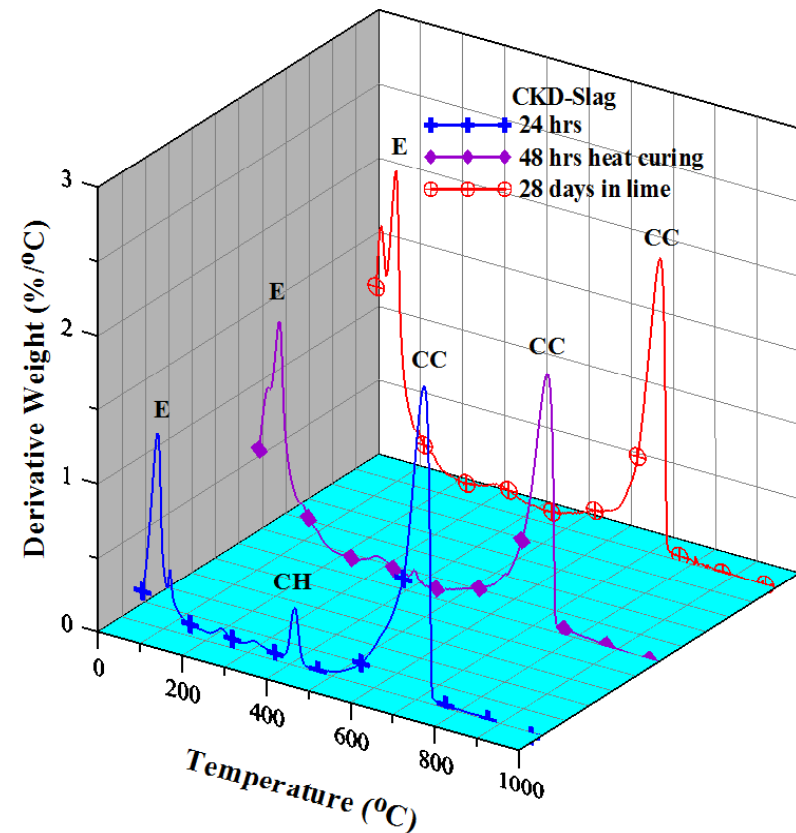
# CKD-Slag systems

## Mineralogical Investigation Cont'd

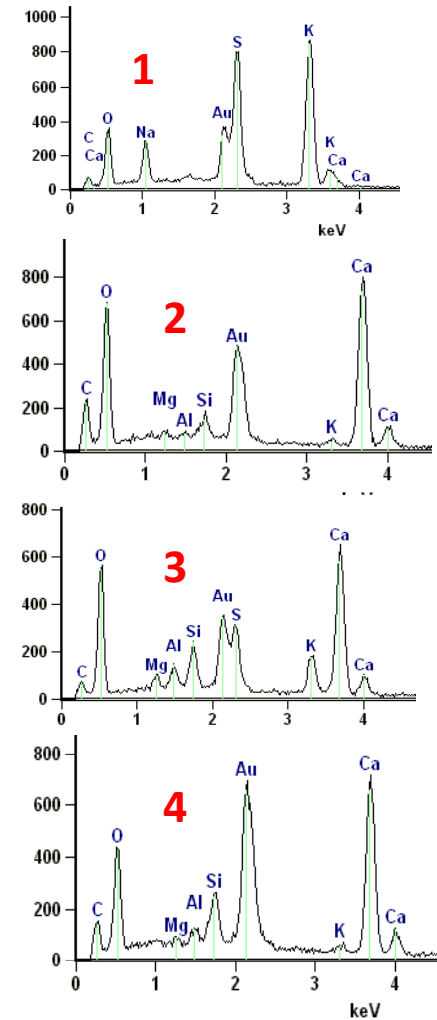
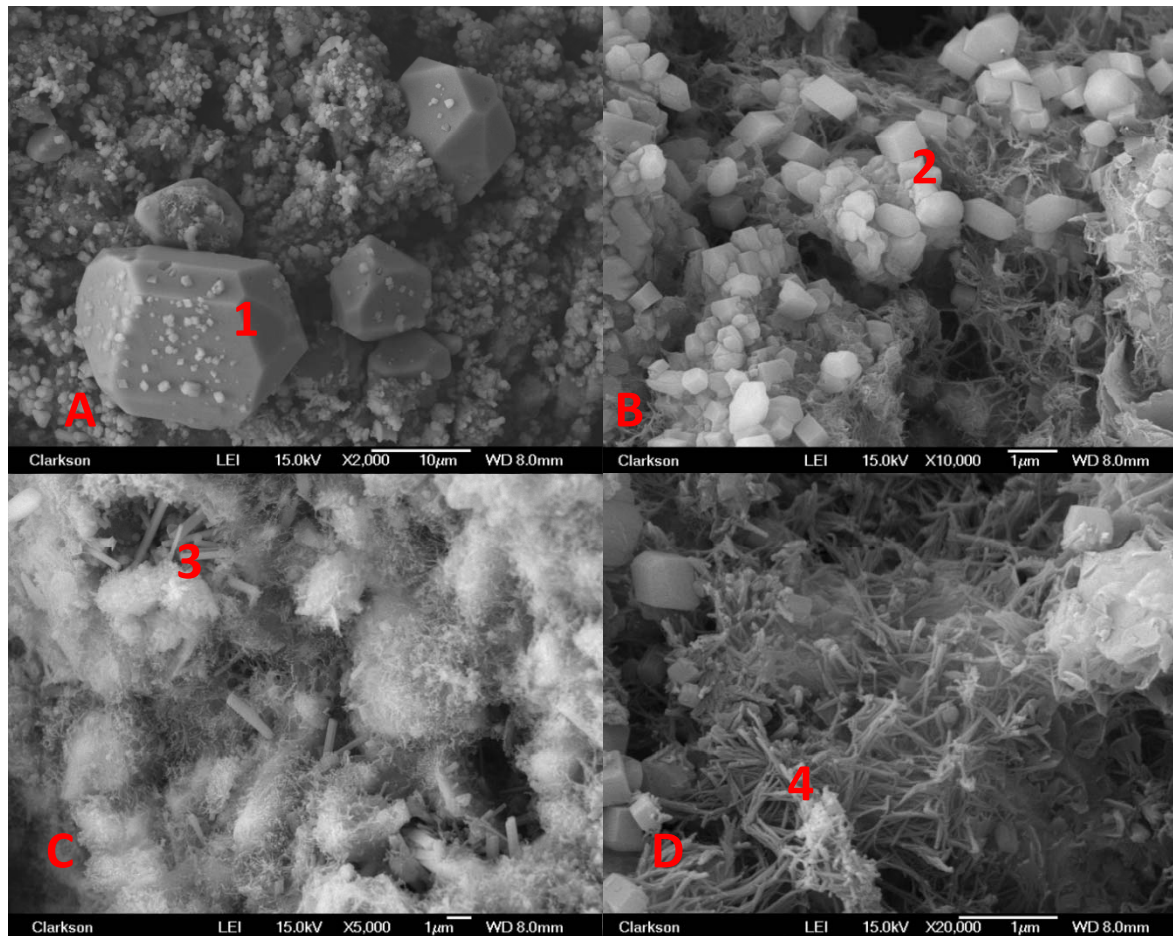
### TGA



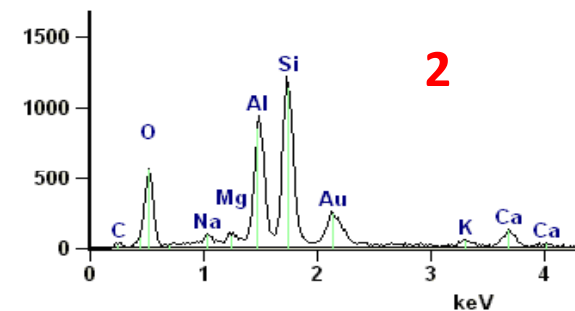
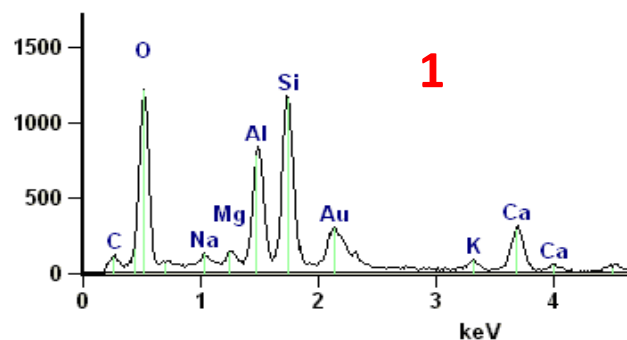
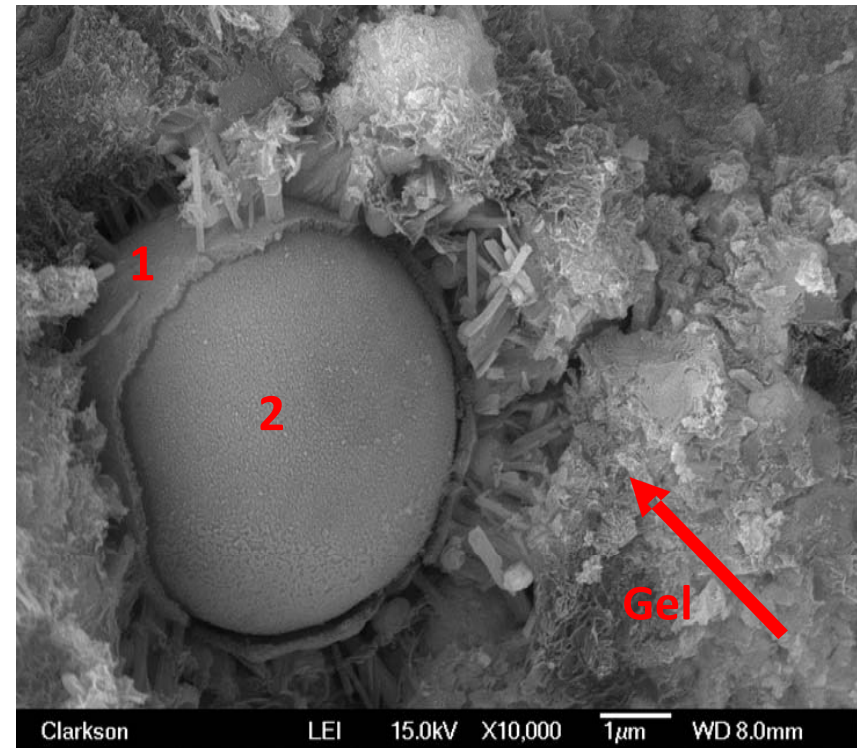
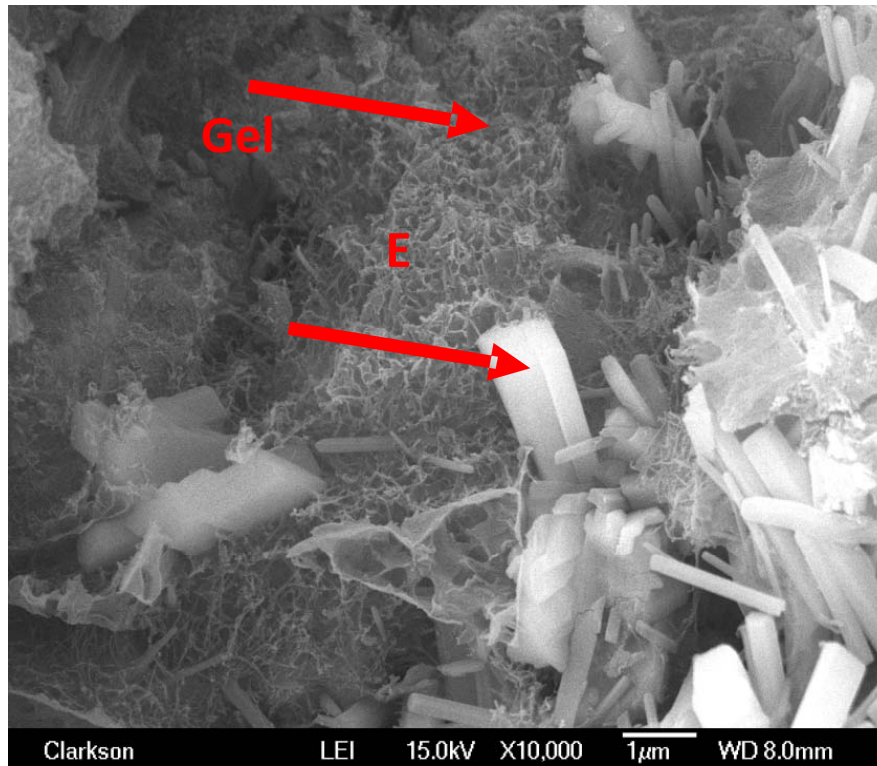
### DTG



# Morphological Investigation (CKD after 48 hrs of heat curing)

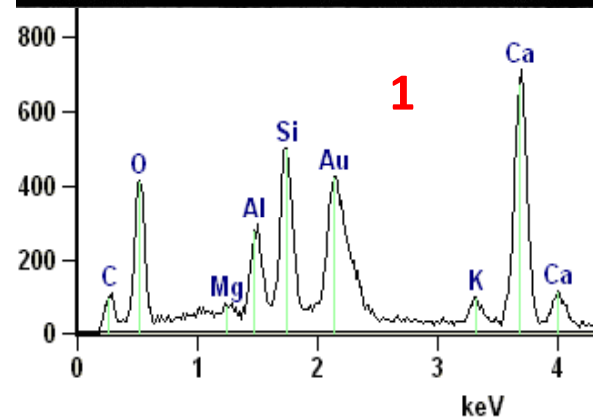
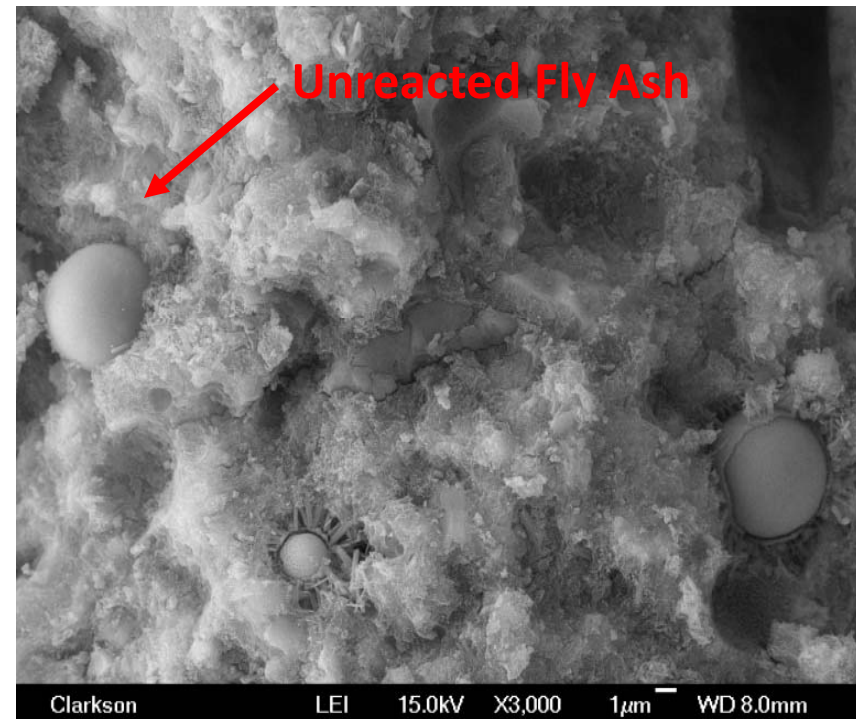
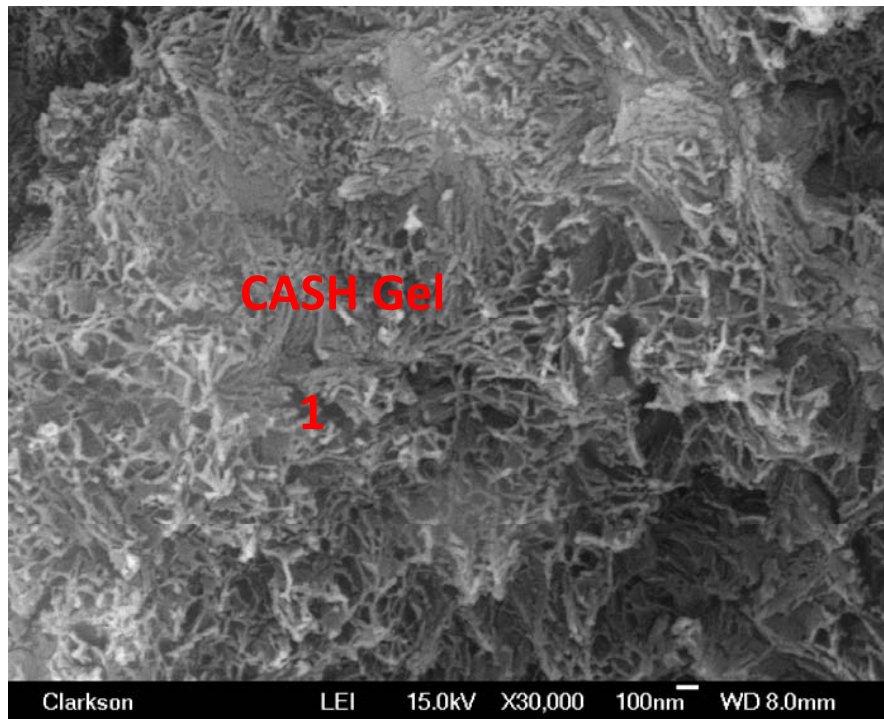


# Morphology (CKD-FA after 48 hrs of heat curing)

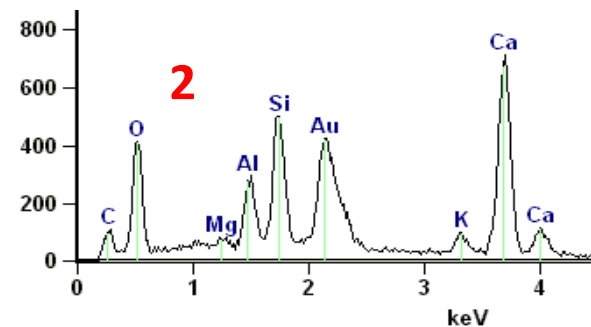
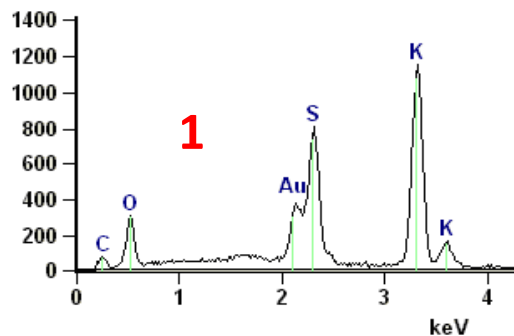
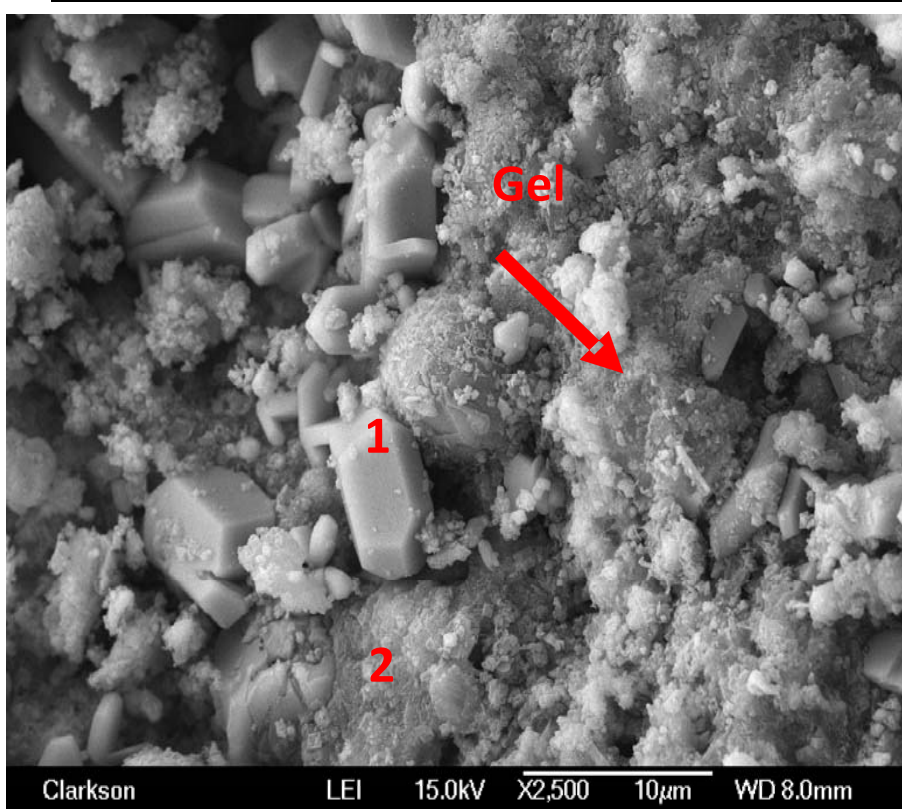




# CKD-FA after 48 hrs of heat curing

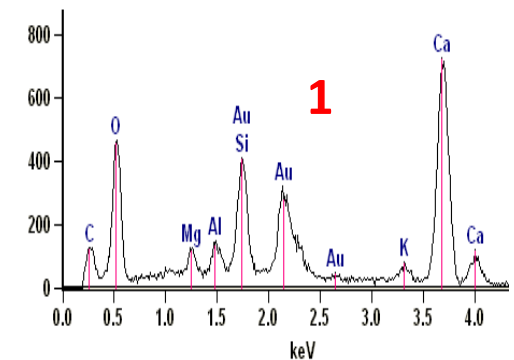
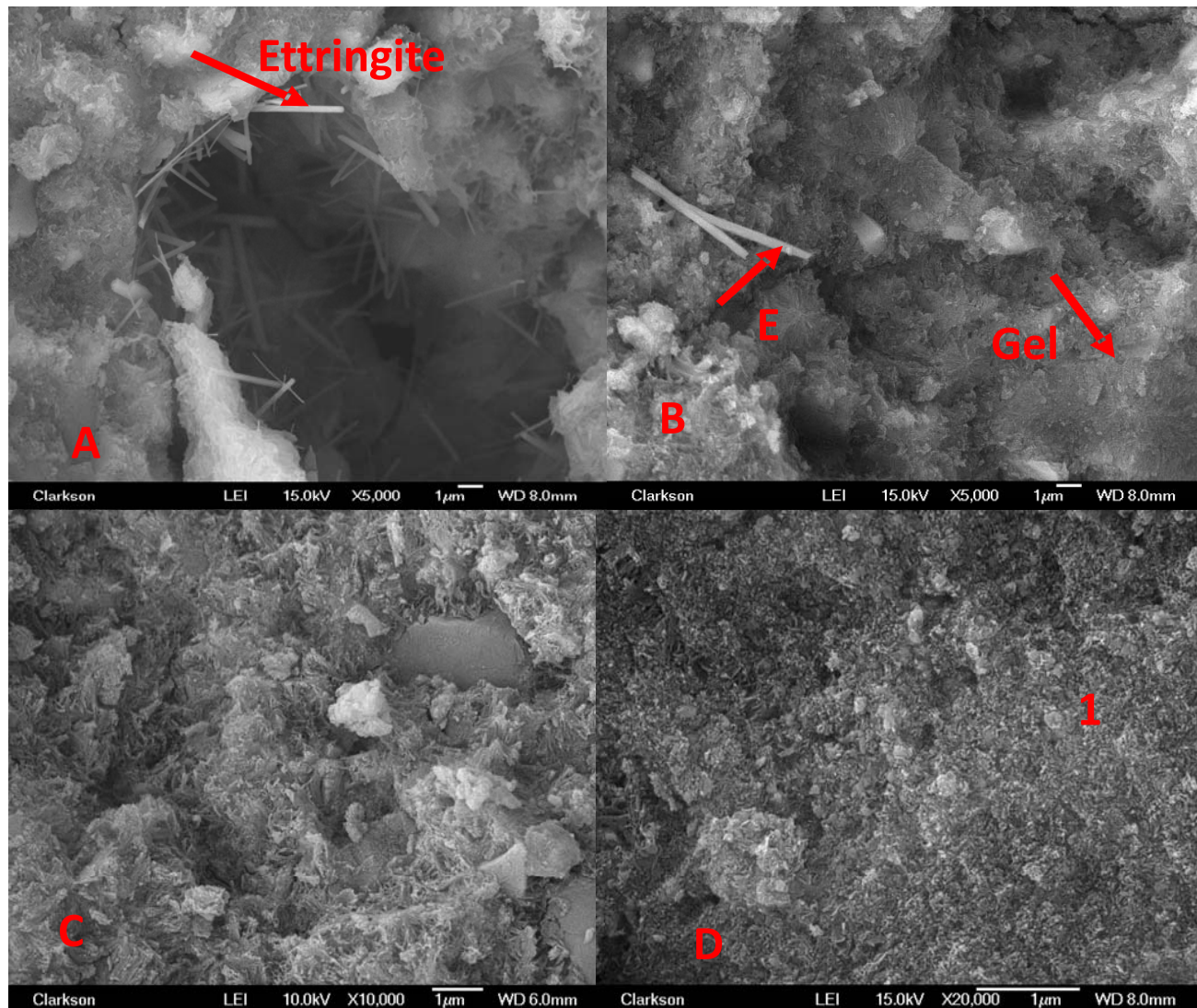


# Morphology : CKD-FA after 28 days in lime

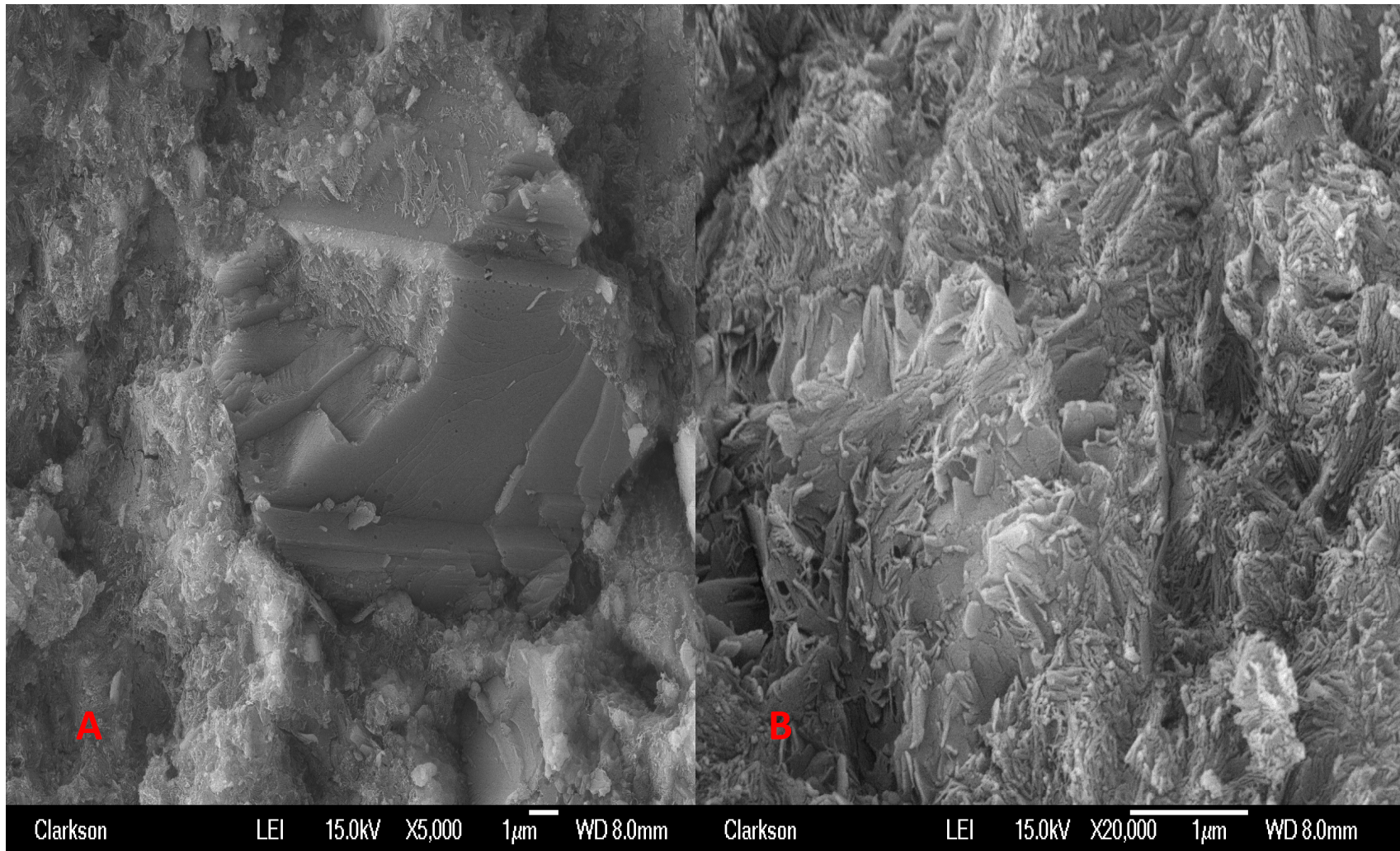




# Morphology : CKD-Slag systems after 48 hrs heat curing



# Morphology : Heat Cured CKD-Slag after 28 days in lime





# Summary

- CKD used in this study are very effective in activating FA/Slag
- Heat curing is required for CKD-FA systems
- In CKD-slag system–heat curing can be avoided
- Ettringite and C-S-A-H were found as main hydration products in CKD-FA while ettringite and C-S-H were seen in CKD-Slag binder.
- Long term durability evaluation is in progress–to date no expansion

# Summary

- Relatively low paste volume is required for obtaining 40 MPa concrete