

# Research on Green Concrete by utilizing FA and Slags



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# Outlines of FA-GGBS-HMNS based geopolymer

Part i  
OPC Statistics

Part ii  
Geopolymers  
By-Products Material-Why?  
Geopolymerization process  
Reaction mechanism

Part iii  
My Research Project  
Objectives  
Research Approach  
Results

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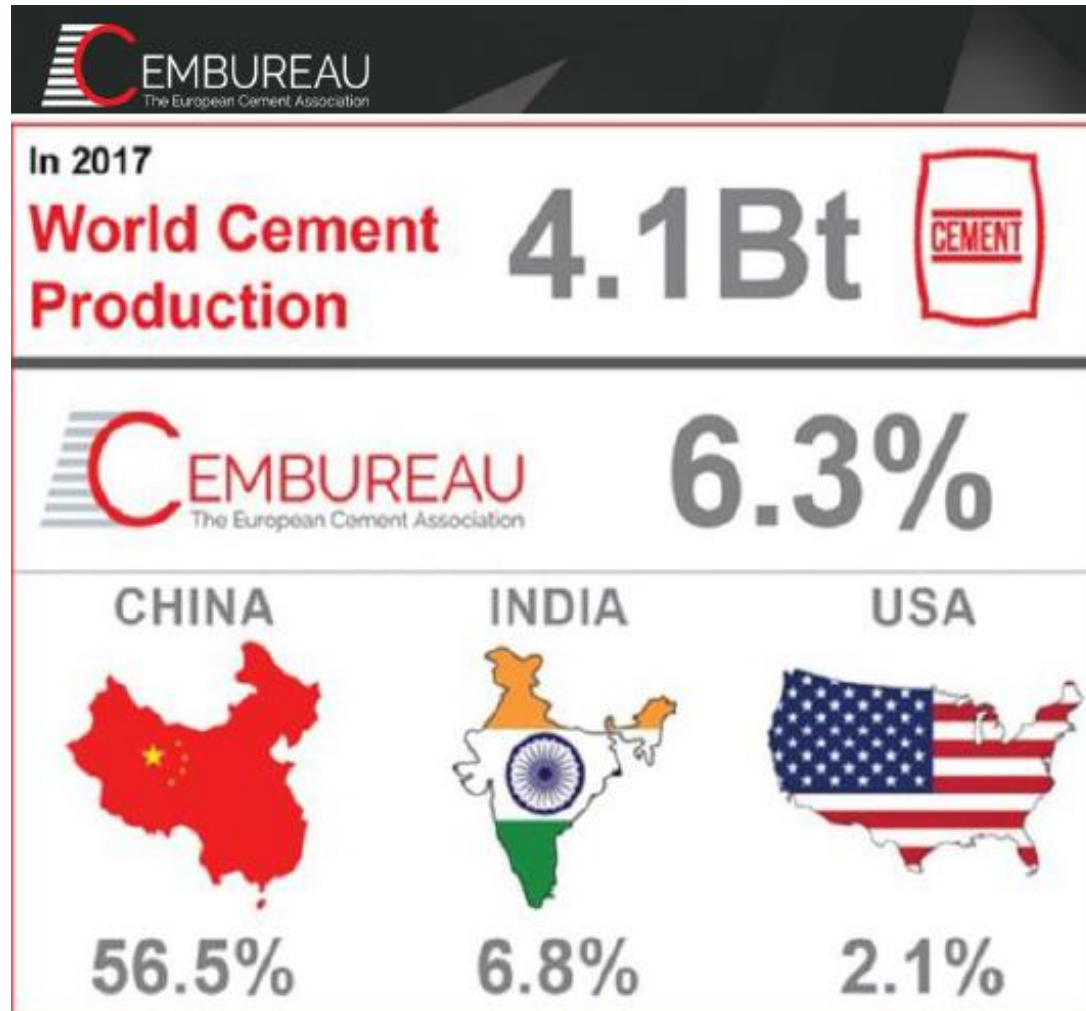
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# OPC Statistics!



# OPC issues!

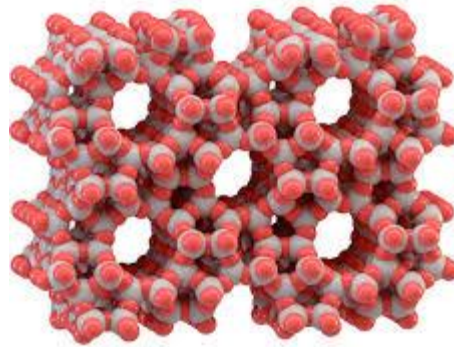
- Consumption of natural materials which need quarrying
- Very energy intensive (**125 L** of fuel, **118 kwh** for **1 tonne** of OPC)
- **8%** worlds CO2 from concrete production, **6 Billion** tonnes of CO2 in 2015 (**3x more** than global aviation)
- Poor immobilization of contaminants
- Low chemical resistance



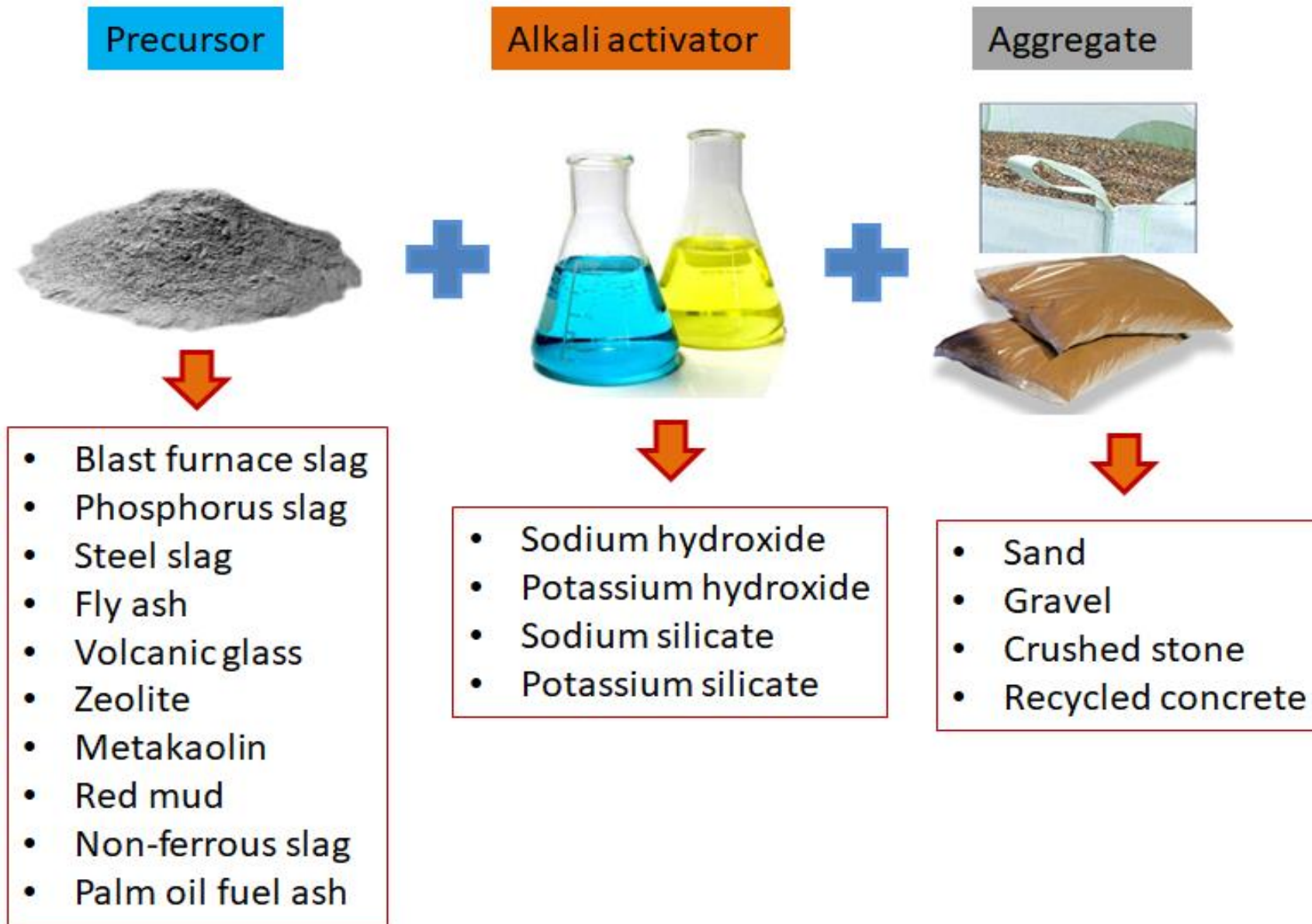
## Part ii. Geopolymers

- It is a family of **mineral binders** with chemical composition similar to **zeolites** but with an **amorphous microstructure**.

3D structure of Zeolite (\*)

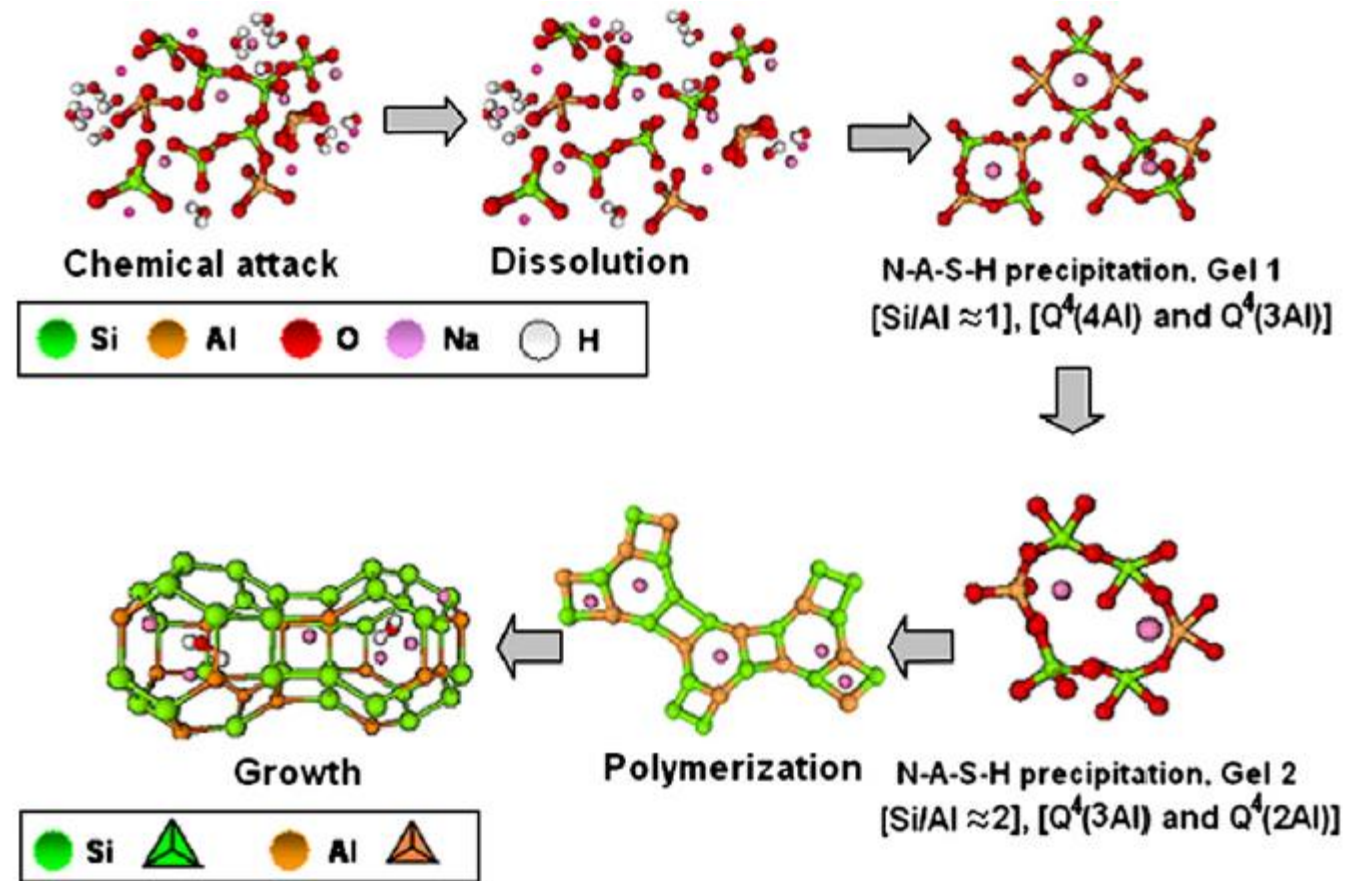


# Geopolymer concrete (GPC)





# Microstructural development of GP binder



# By-products material-why?

Fly ash



GGBS



HMNS

## ...By-products production

Fly ash	GGBFS	HMNS
<p>In the United States about 131 Mt of fly ash are produced annually</p> <p>125 Mt/year in the EU, 300 Mt/year China &amp; India (*)</p>	<p>1.6 bn tonnes of iron and steel production worldwide produces around 250Mt of slag.(*)</p>	<p>The production of 1 tonne of steel leads to generate between 0.2 and 0.4 tonne of furnace slag.</p> <p>In China, the annual generation of nickel slag is about 800,000 tonnes. (*)</p>

*(\*)Back to Reference page for more details*



# Disposal

- In the past fly ash produced from power plants was simply entrained in flue gasses and released into the atmosphere. Now in the U.S regulations requires more than 99% of total fly ash produced in a plant to be captured and either stored, recycled, or disposed.
- More than 65% of fly ash produced in the world is disposed of in landfills or ash ponds.



# Part iii. Details of research project

## Research approach

### Micro/nano-scale investigation

Particle size distribution analysis (**PSA**)

X-ray diffraction characterization (**XRD**)

Fourier transform infrared spectroscopy  
analysis (**FTIR**)

Scanning electron microscopy imaging  
(**SEM/EDX**)

Optical microscopy (**OM**)

### Macro-scale Study

Uniaxial compressive strength test

Split tensile strength test

Setting time

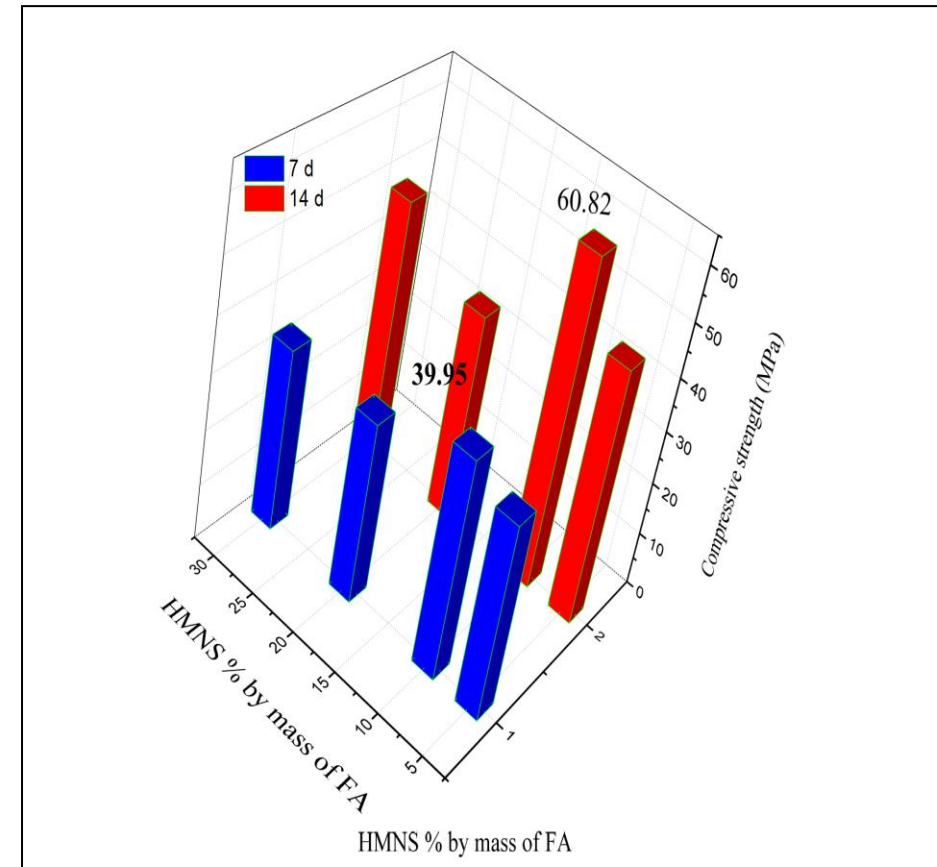
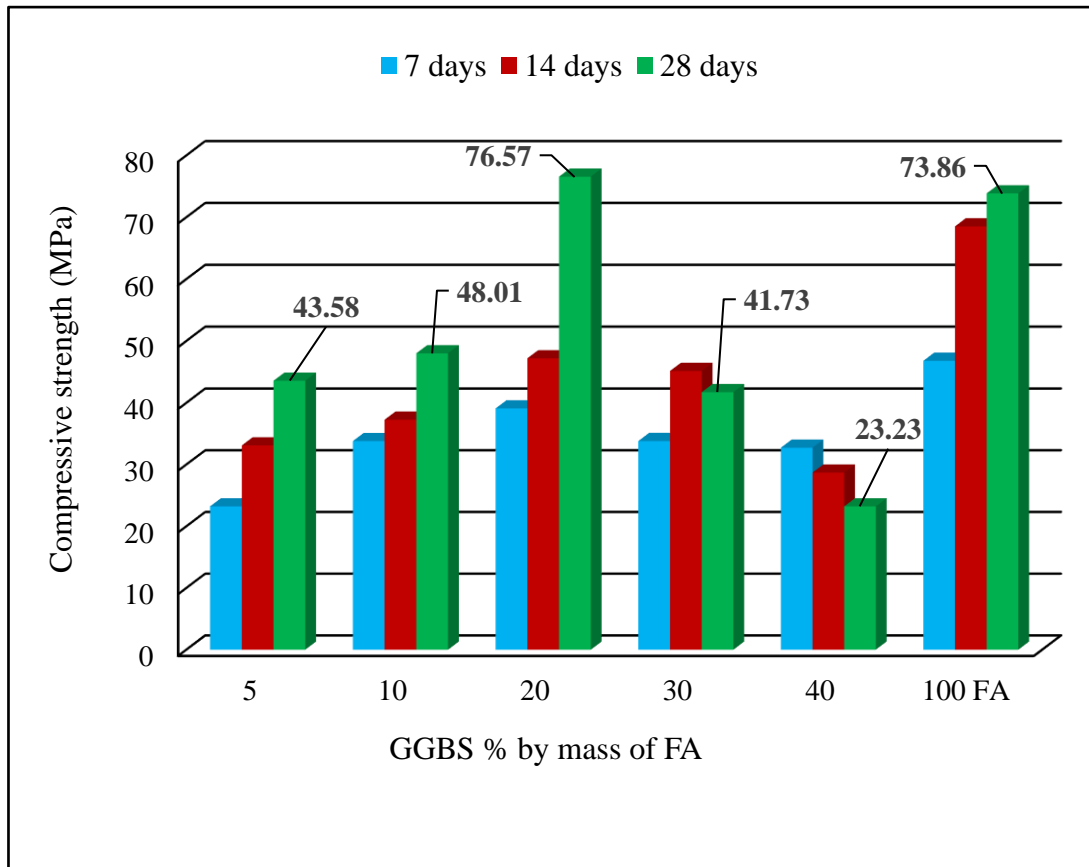
Workability

Durability test

Residual strength after high temperature

Dynamic behaviour

# Compressive strength of GP paste

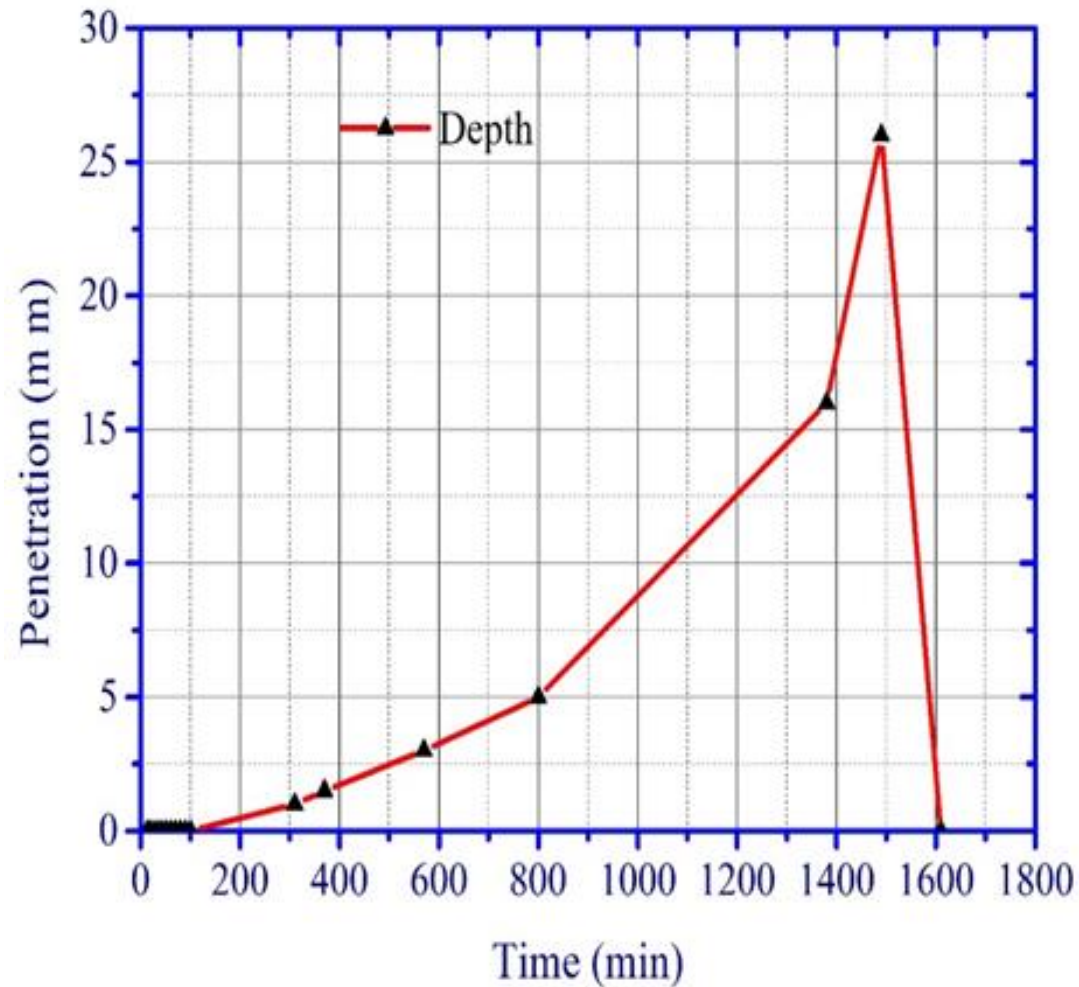




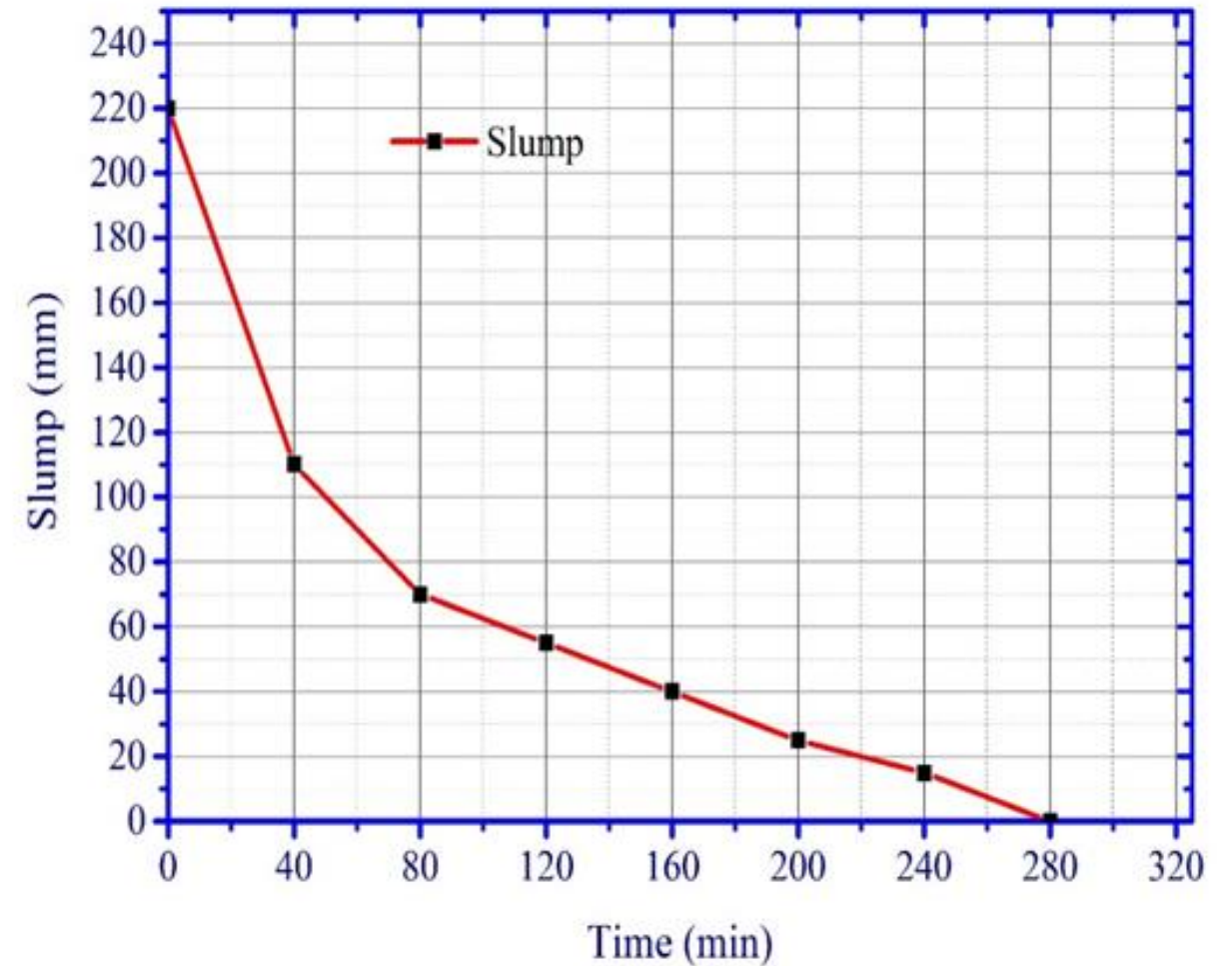
# Fresh GP concrete test



## ...Testing of fresh GP concrete



Setting time



Slump



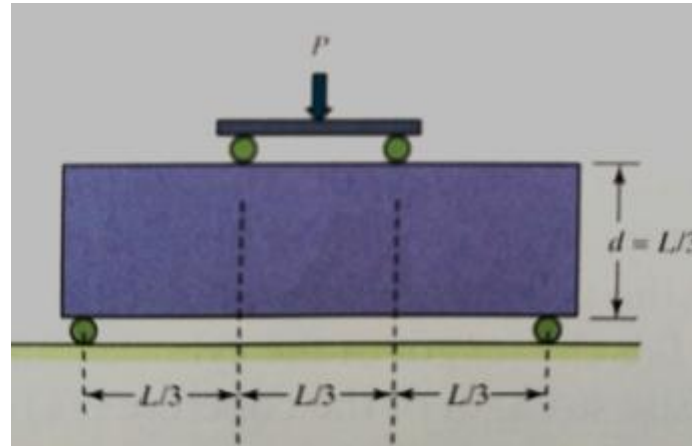
# Compressive strength test



10 cm cube  
15 cm cube

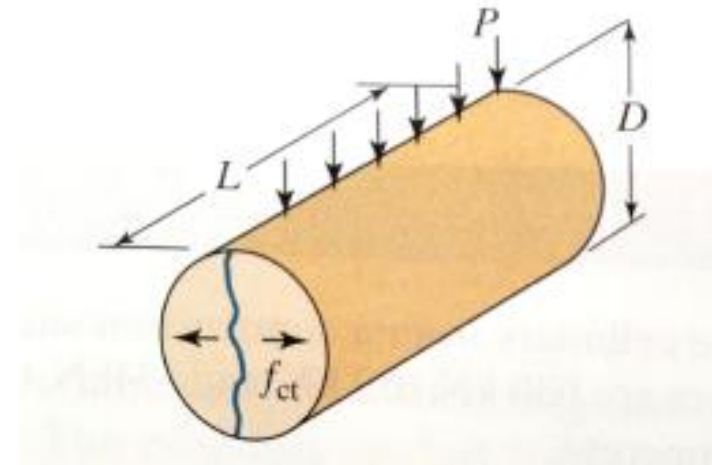


# Tensile strength test



Flexural strength test  
ASTM c78 (2010)  
(150x150x500 mm size)

$$f_r = \frac{PL}{bd^2}$$



Split strength test  
ASTM C496 (2011)  
(D=150 mm, L=300 mm)

$$f_{ct} = \frac{2P}{\pi LD}$$

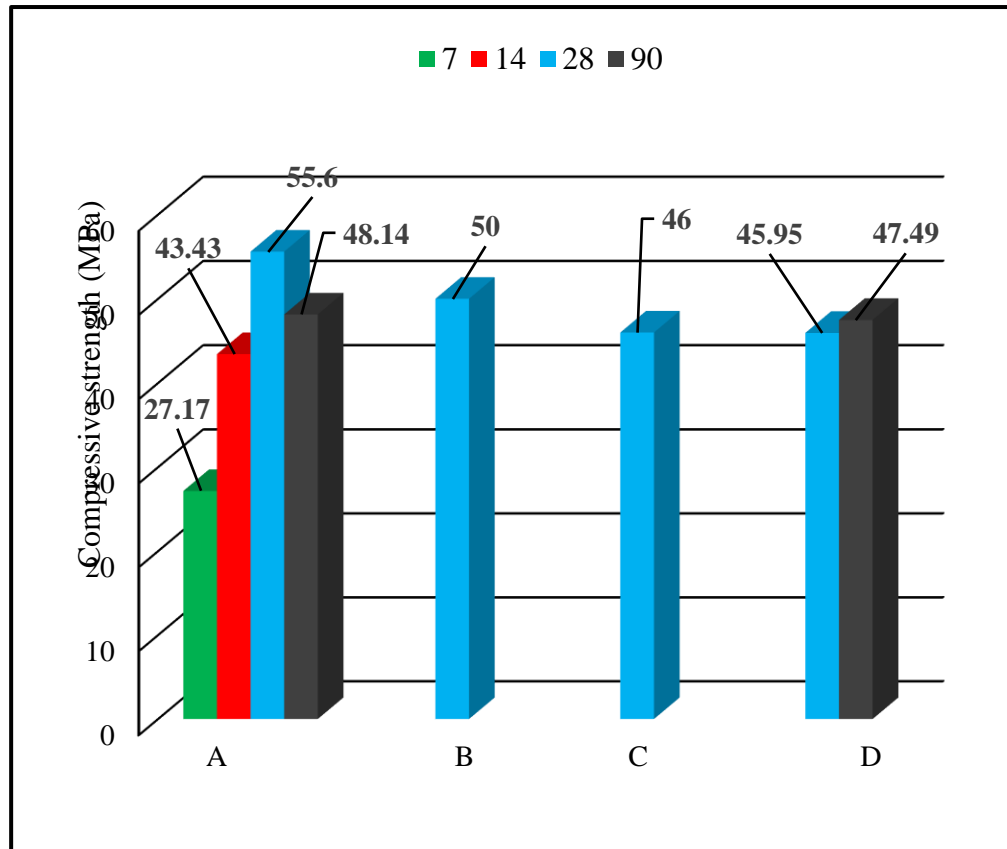
# Testing of hardened GP concrete





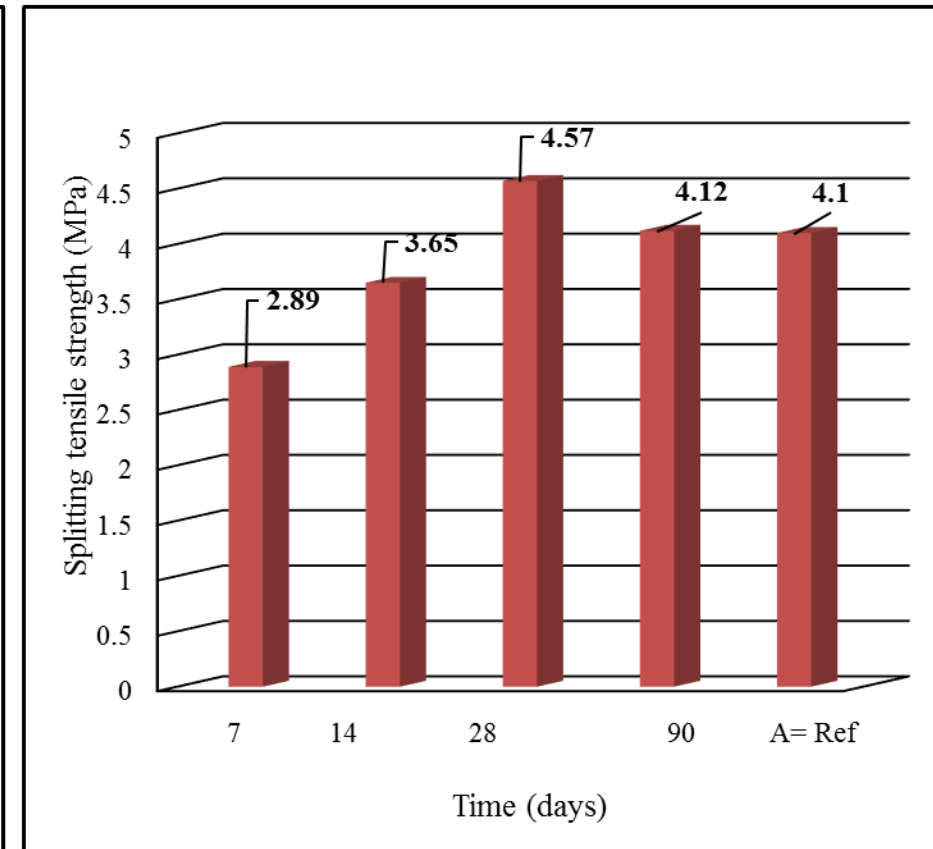
# ...Testing of hardened GP concrete

Compressive strength



*B, C and D = Ref*

Split-tensile strength

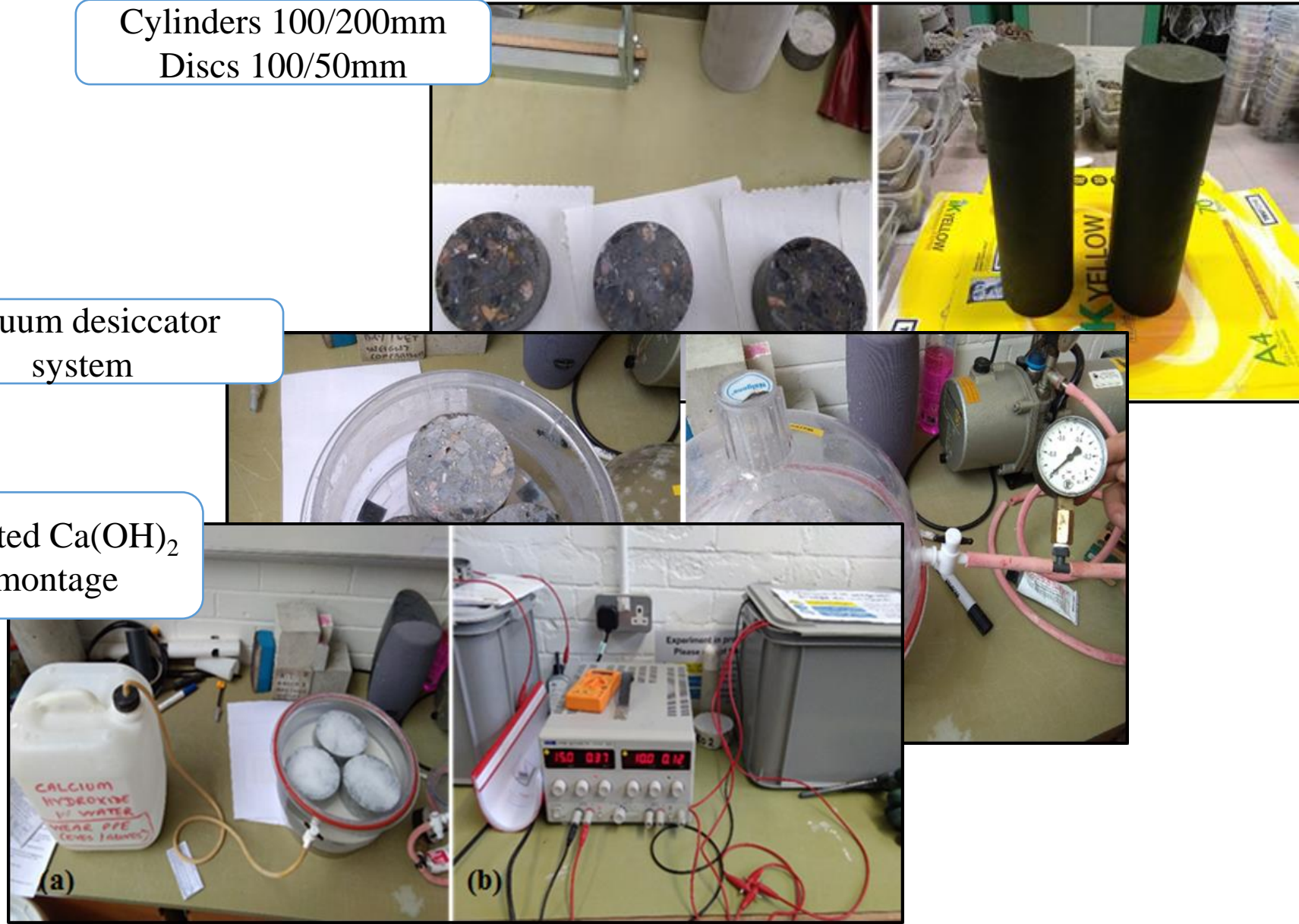


# Rapid chloride migration test (RCM)

Cylinders 100/200mm  
Discs 100/50mm

Vacuum desiccator  
system

(a) Saturated  $\text{Ca}(\text{OH})_2$   
(b) RCM montage



# Chloride migration test (RCM) (cont.)

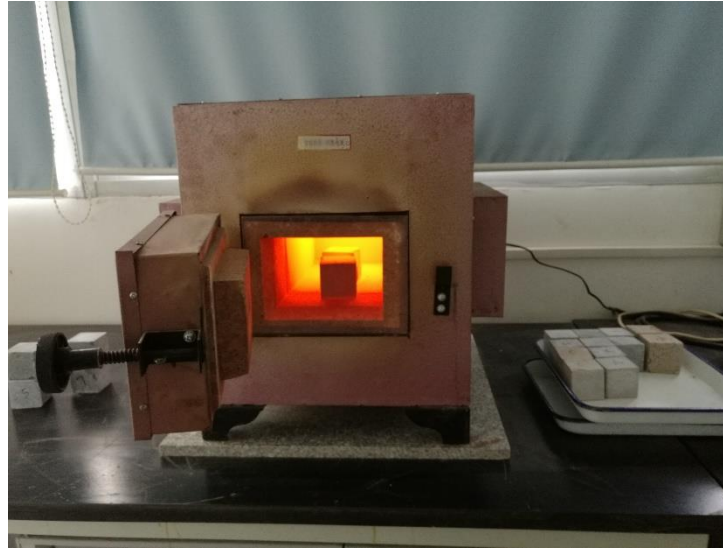




# Residual strength after elevated temperature exposure

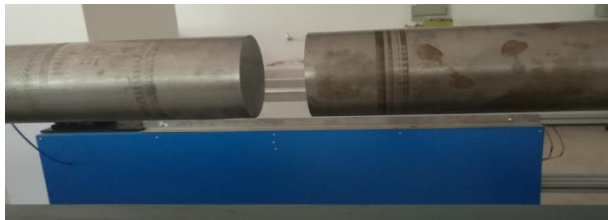


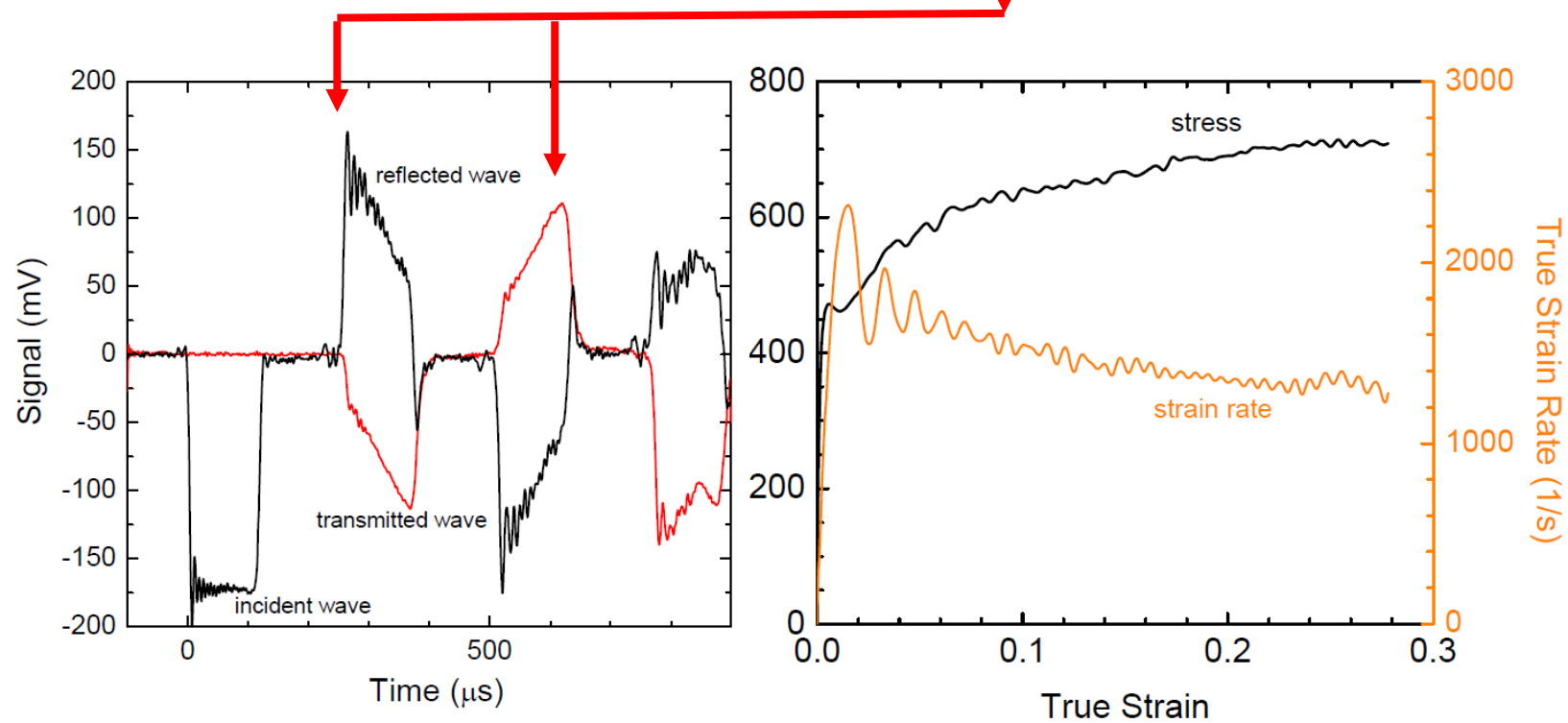
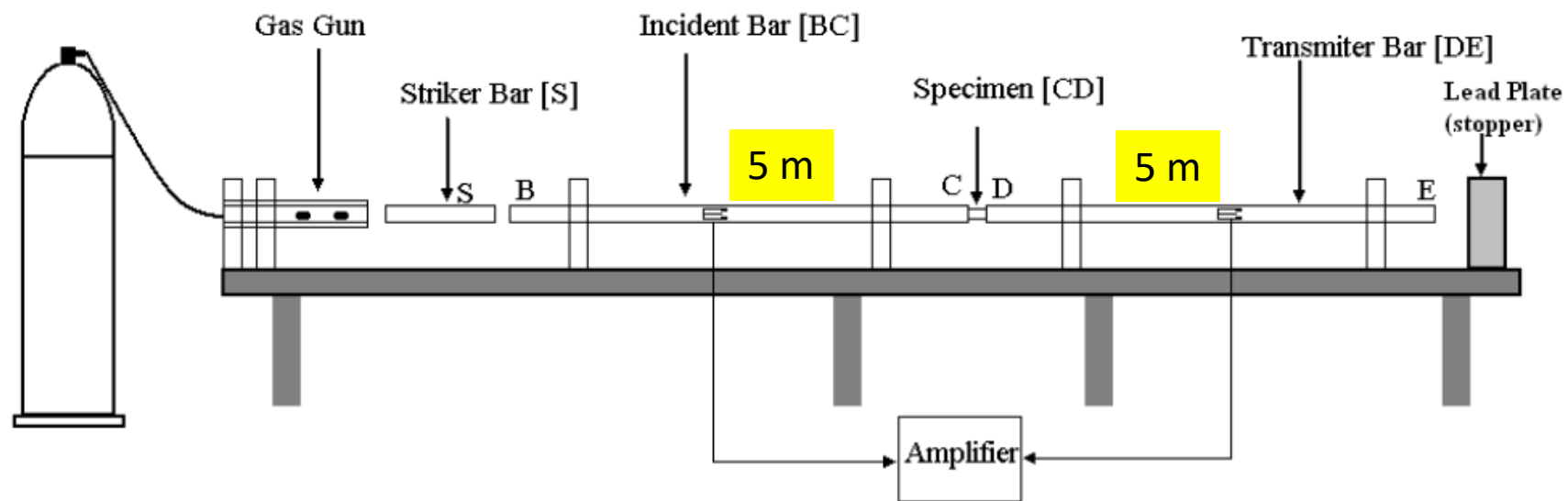
# Residual strength test

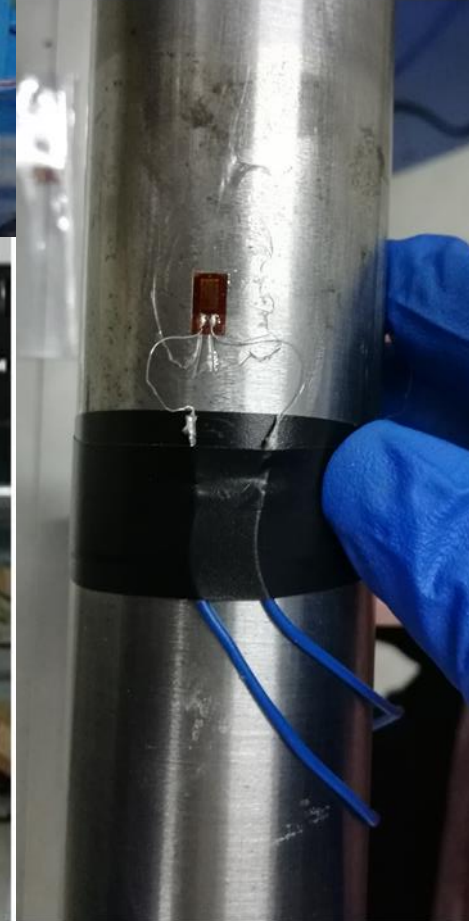
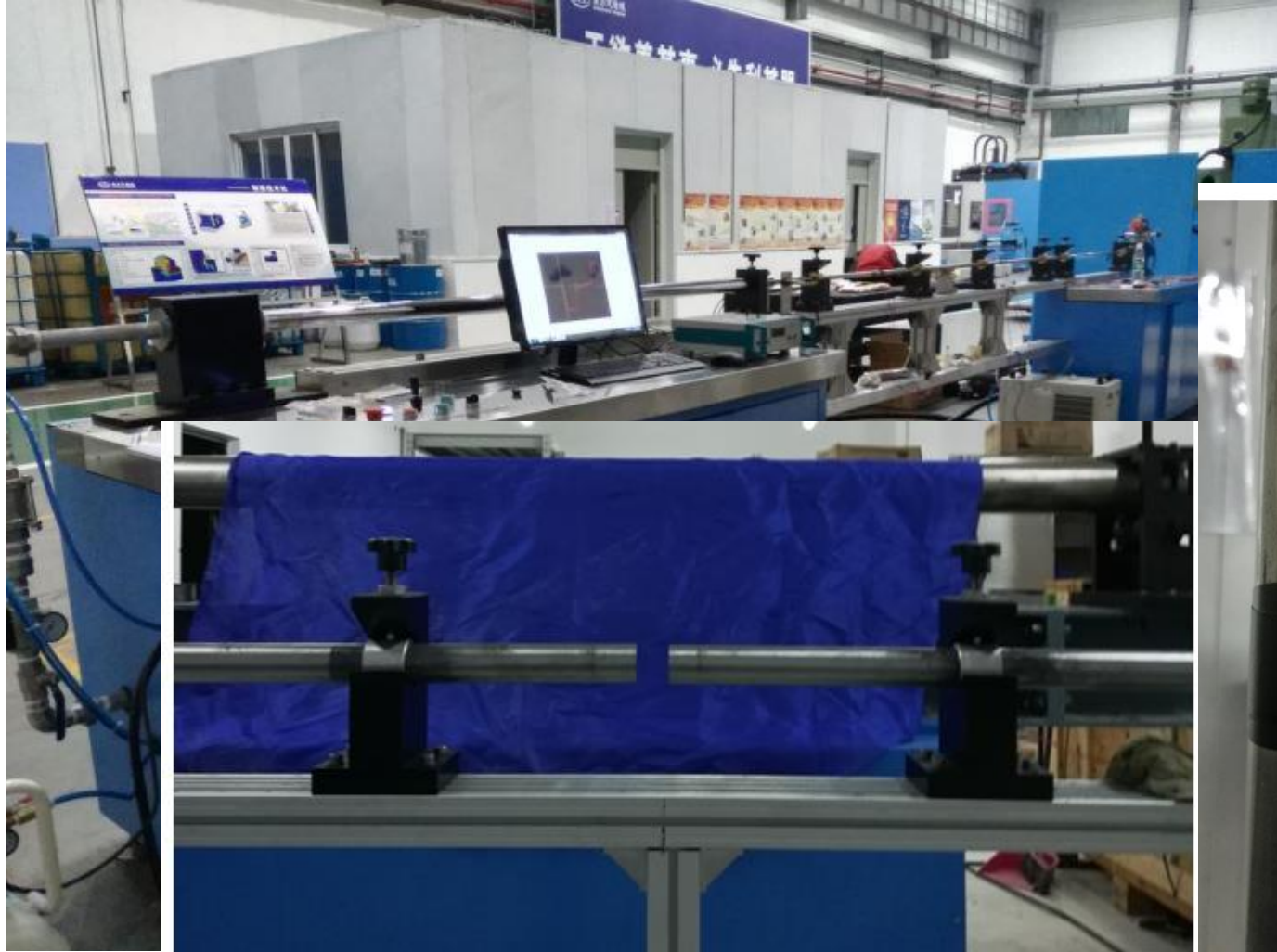




# Impact strength test machine







# Preparation of disk specimens ( $\sim\phi 35 \times 18$ )

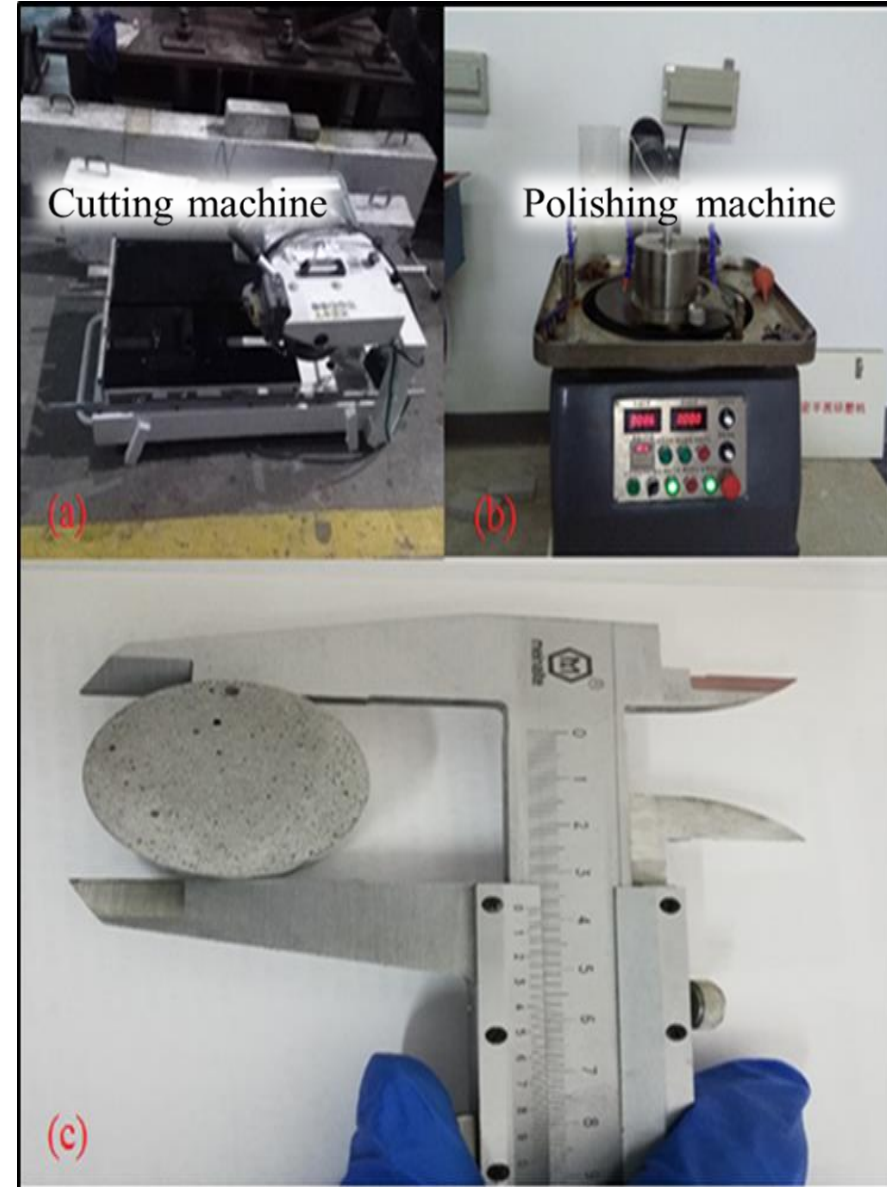


Preparation of specimens  
Specimen diameters (33, 36 and  
37 mm, with 18mm thickness

Group a = 2 m/s

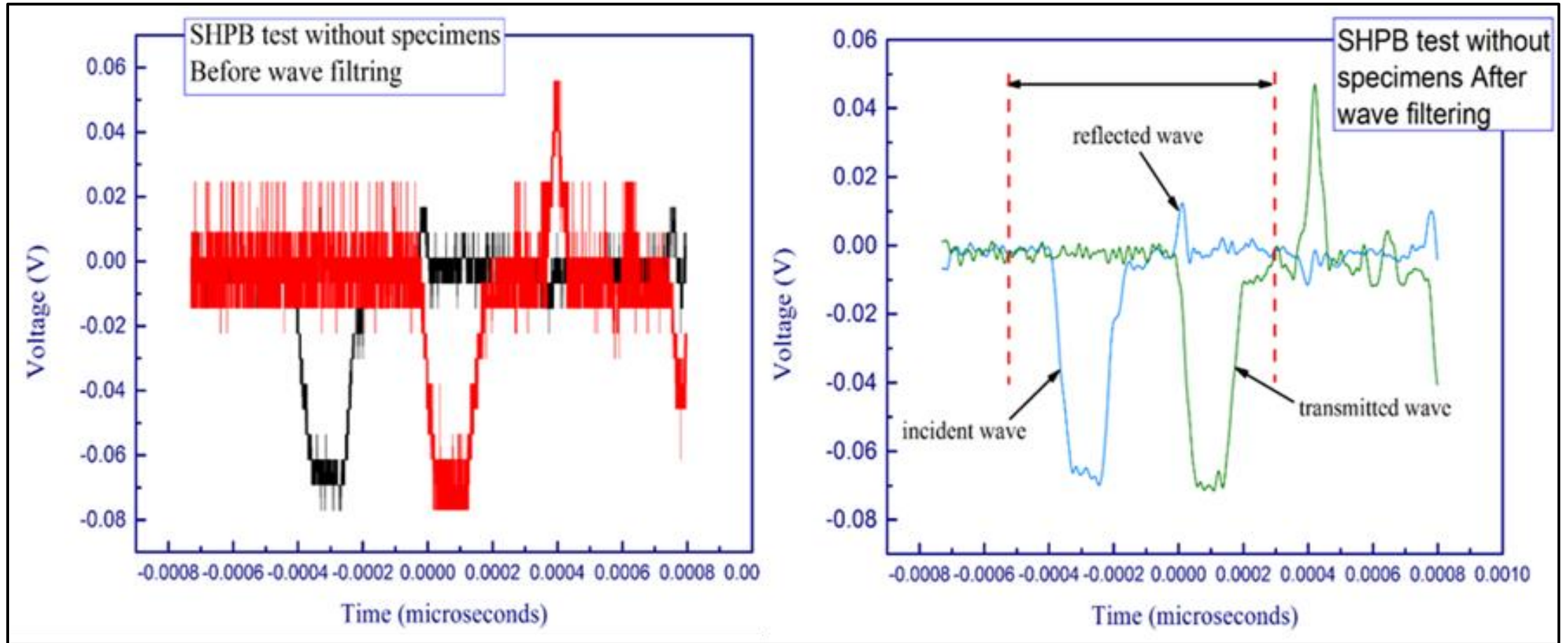
Group b = 4 m/s

Group c = 6 m/s

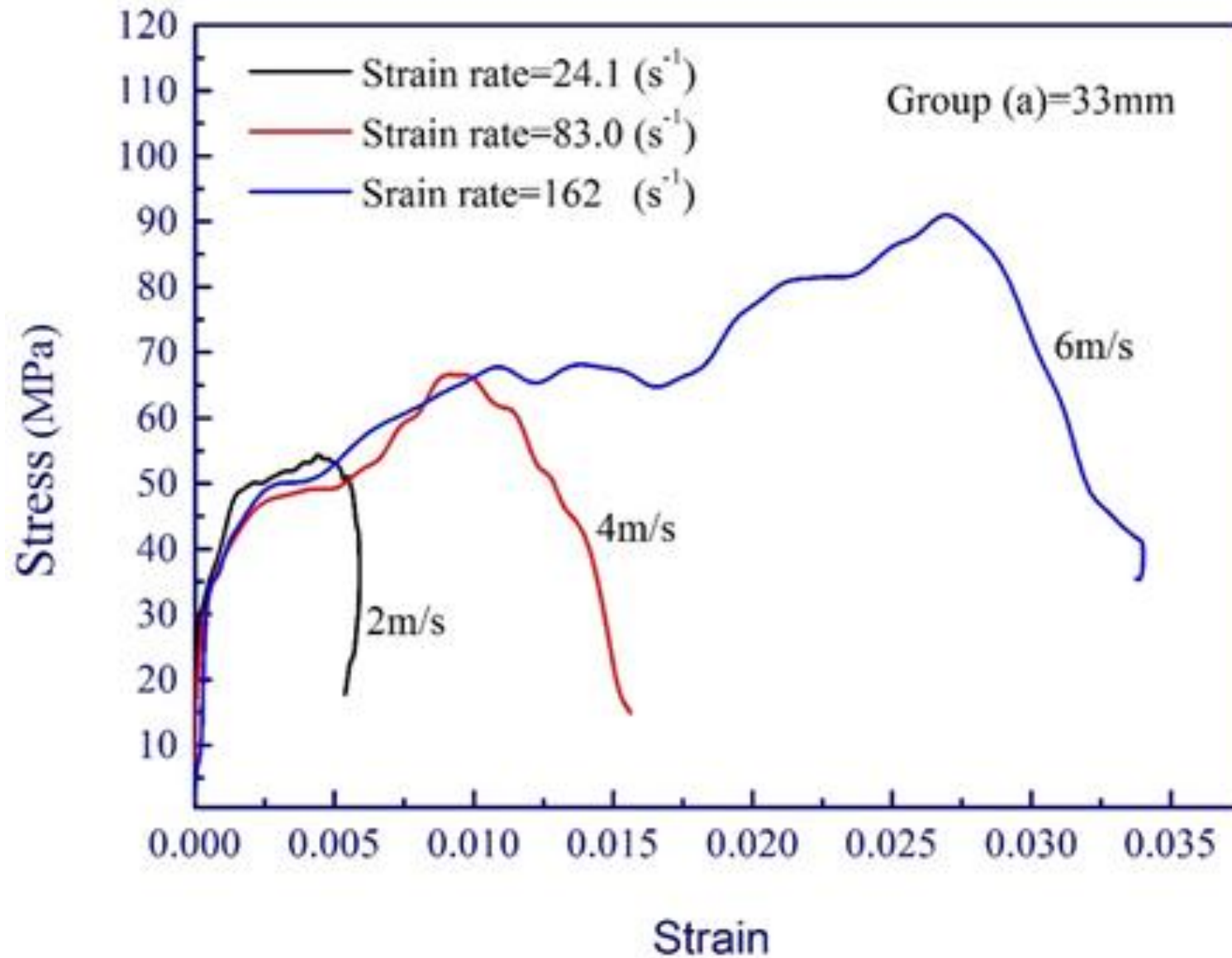




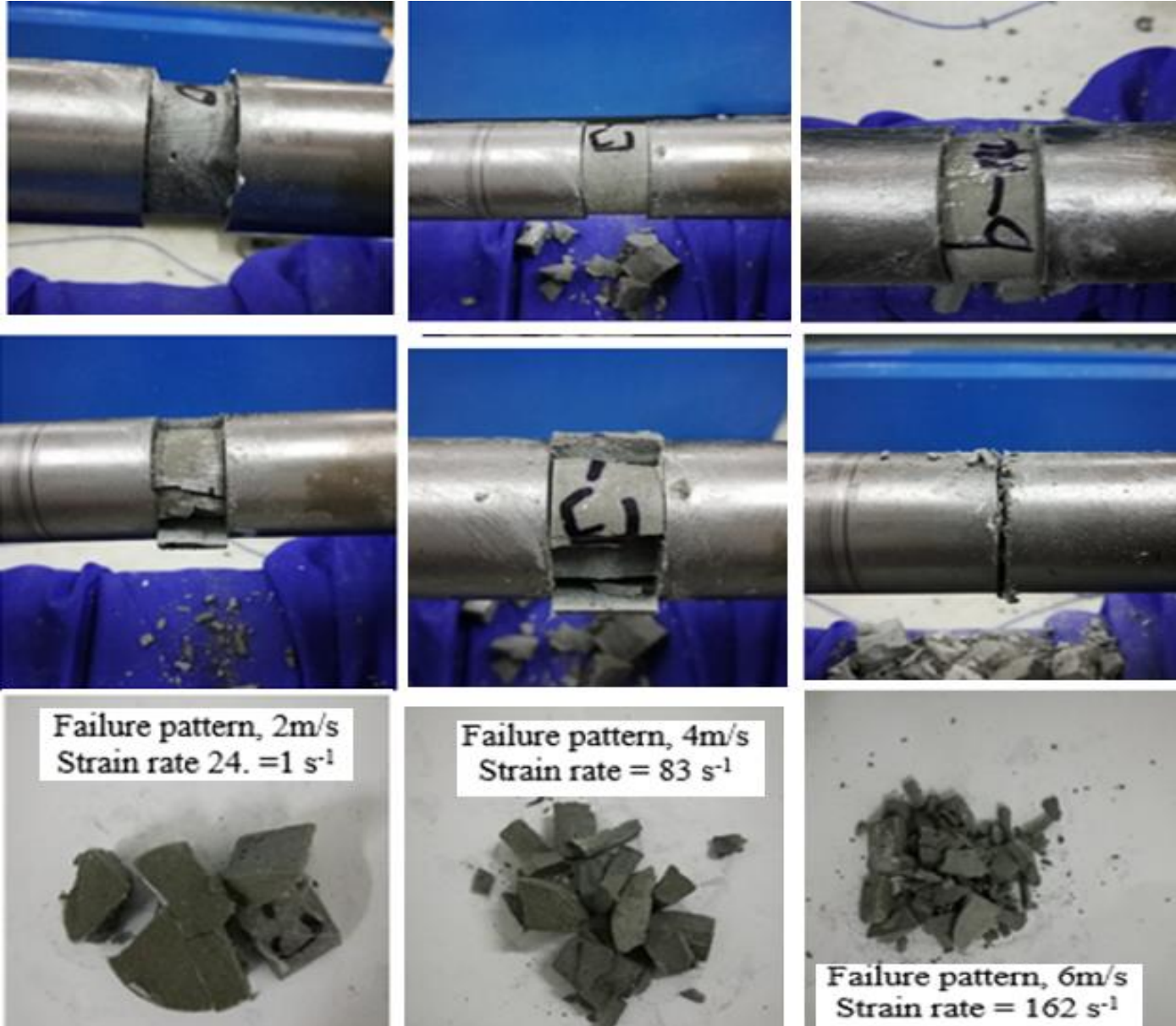
# Data capture before and after filtering



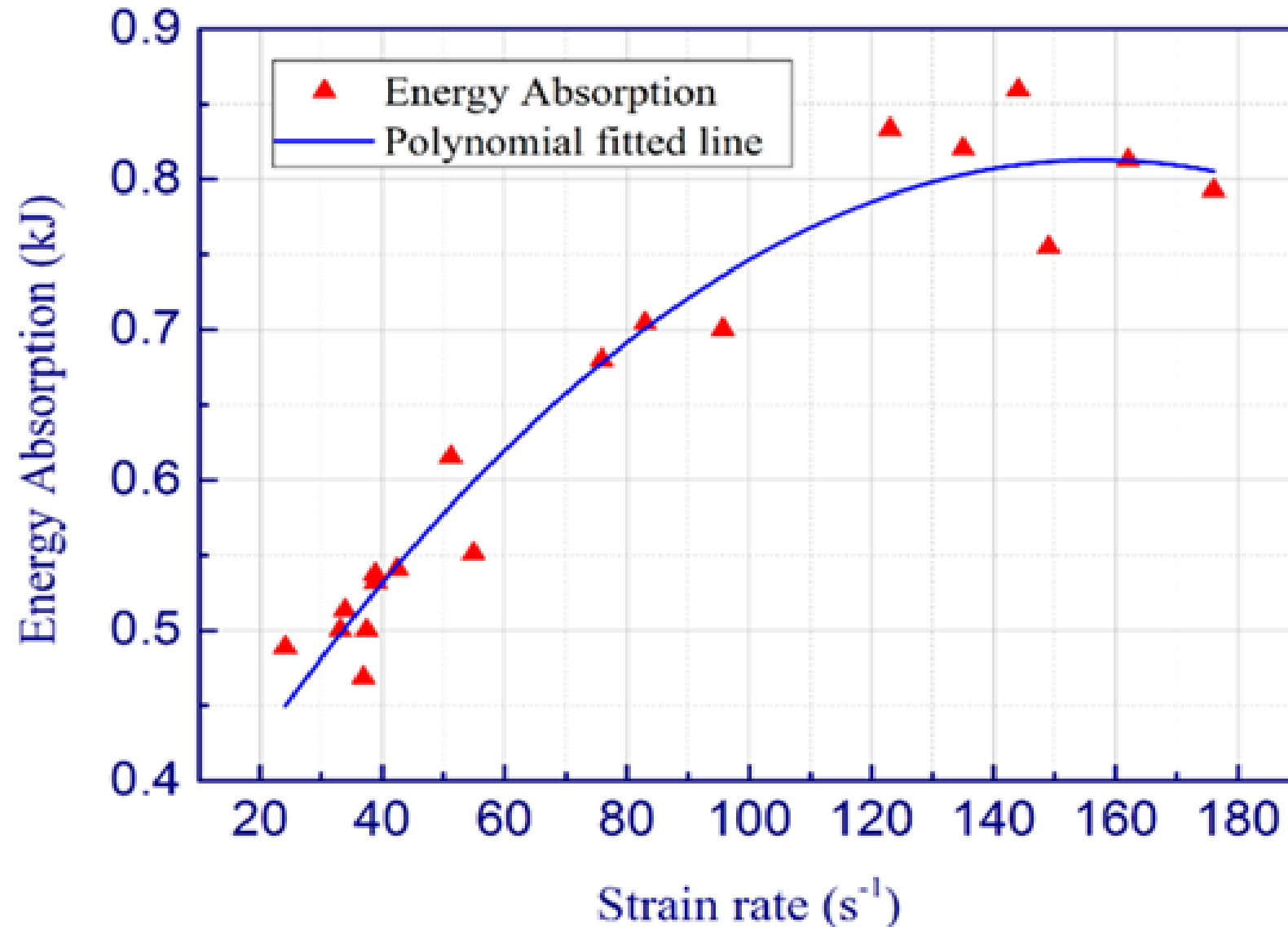
# Dynamic $\sigma$ - $\epsilon$ curves (FA-GGBS-HMNS based GP paste )



# Failure Patterns

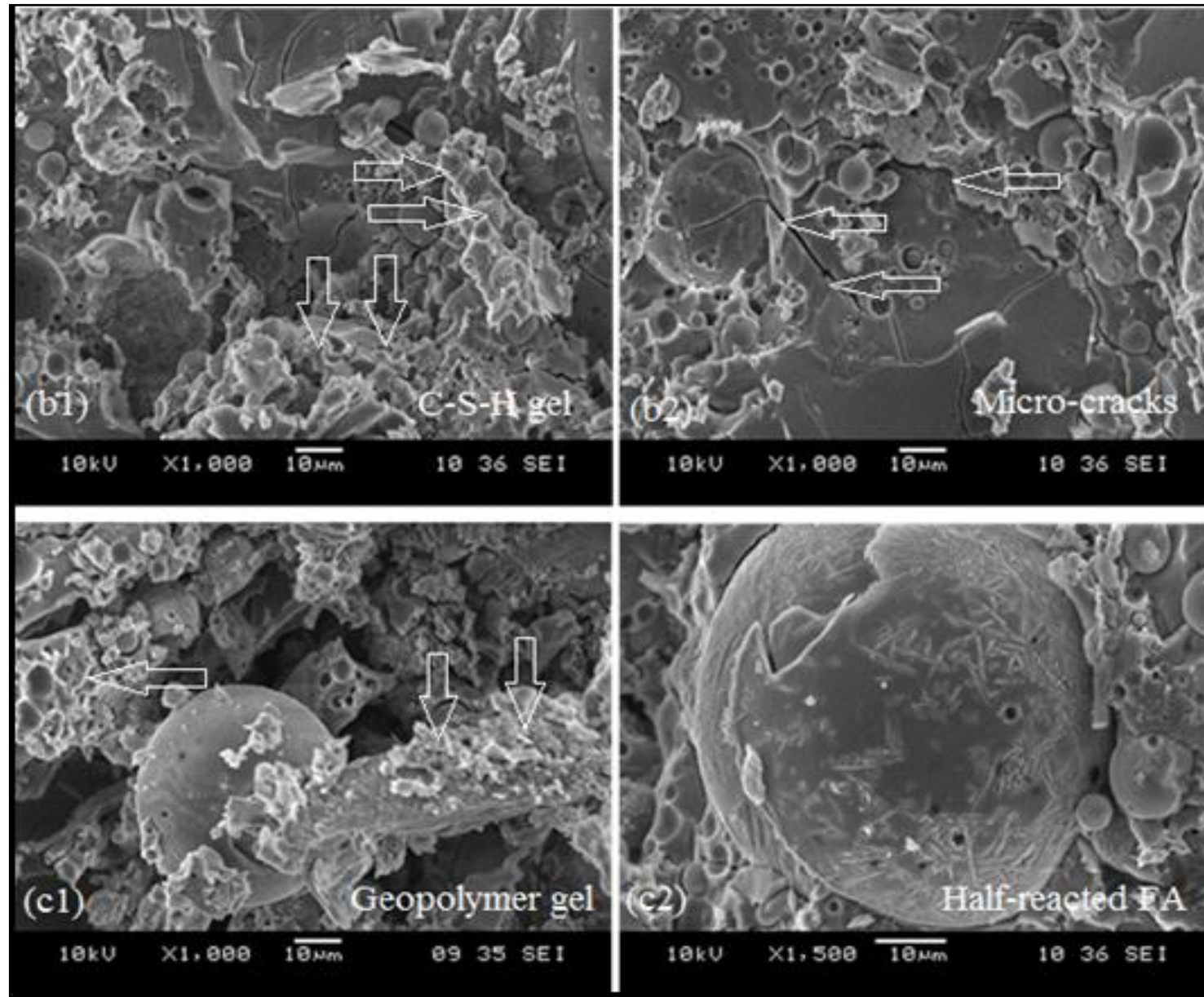


# Strain energy absorbed in impact

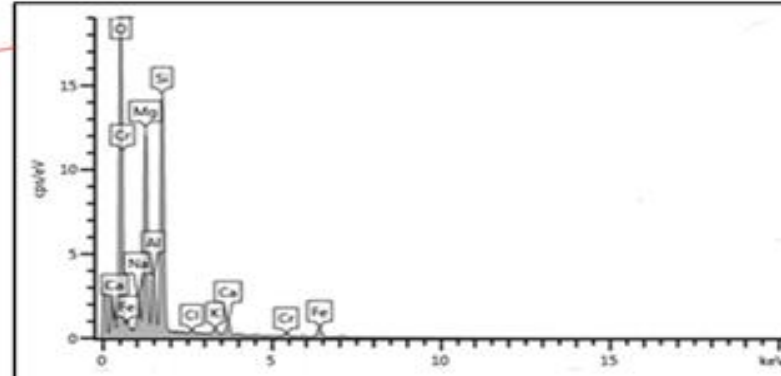
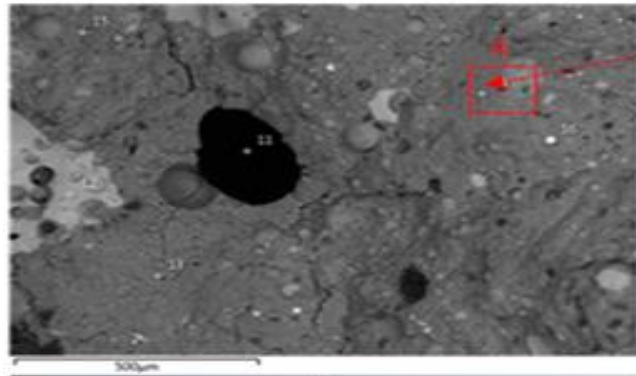
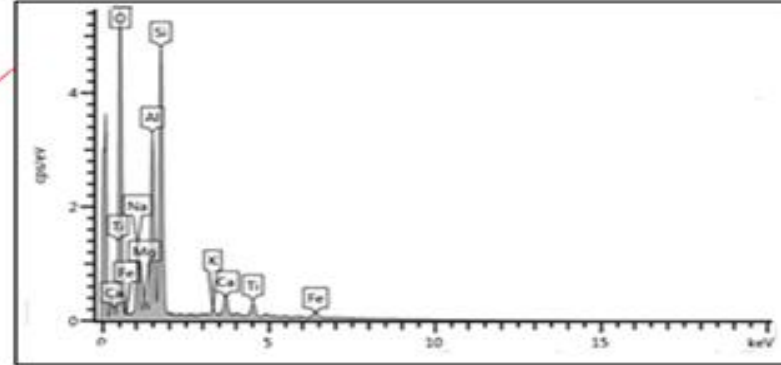
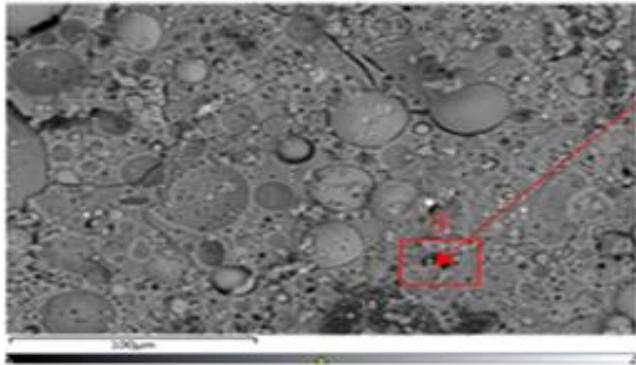
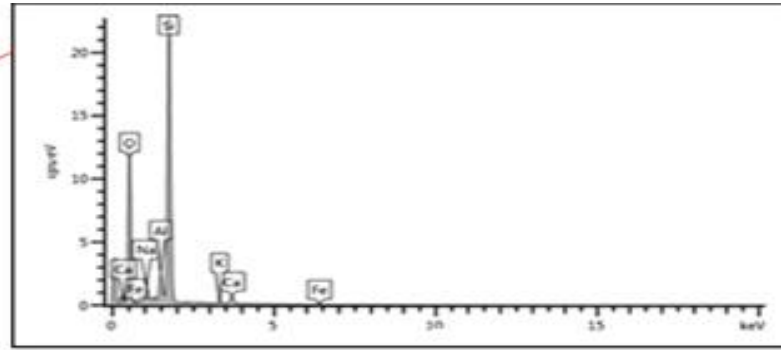
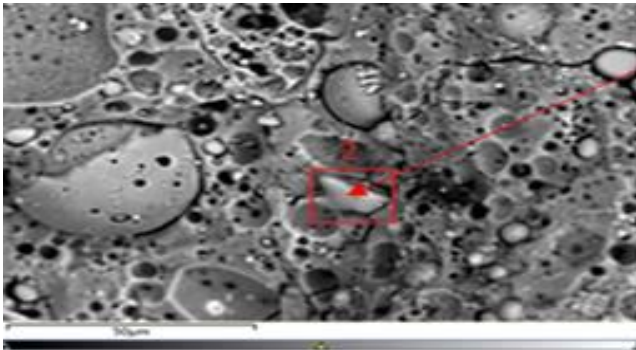




# Microstructural analysis (SEM)



# Material characteristic analysis (EDX)



# Conclusions

- The future trend of geopolymers research shall focus on the understanding of polymerization mechanisms and this will **standardize geopolymers for commercial production**.
- This might include the route of geopolymer synthesis with designable **strength** and **properties**, for example, the material with suitable activators and curing conditions, etc.

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