

# **Fire Resistance Properties of Waste Glass Incorporated Geopolymer Mortar**

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Dr. Binyu ZHANG

Prof. Chi-Sun POON

Department of Civil and Environmental Engineering

The Hong Kong Polytechnic University

# Outline

- Hong Kong's Waste Glass Problem
- Applications – From Waste to Construction
- Glass Incorporated Geopolymer Mortar
  - Mechanical properties
  - Fire resistance
- Conclusions and Issues

# Waste Glass in Hong Kong



- Daily output **354 tonnes** in Hong Kong (2016)
- Lack of local glass **manufacturing industry**
- Recycling ratio only **7%**
- Mostly **landfilled**



# Waste Glass Recycling

Mandatory **Producer Responsibility Scheme** is expected to be launched by Hong Kong Government to encourage waste glass recycling



Residential Generated



F&B Catering



# From Landfills to Raw Material



Waste Glass

1. Preliminary cleaning & labels elimination



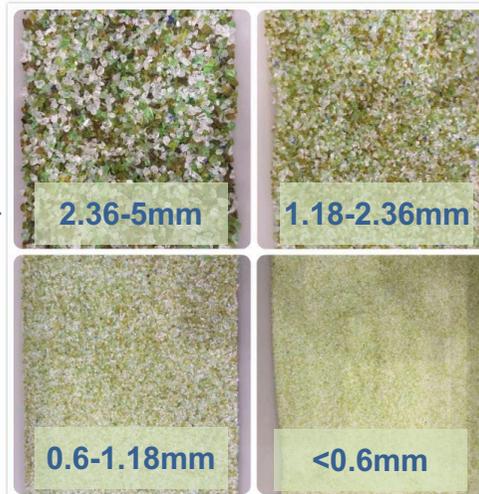
Glass Bottles

2. Crushing

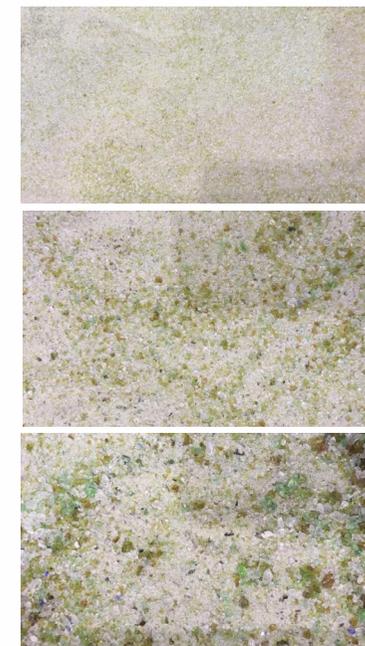


Mixed Glass Cullet (GC)

3a. Sieving



Glass Powder (GP)



3b. grinding

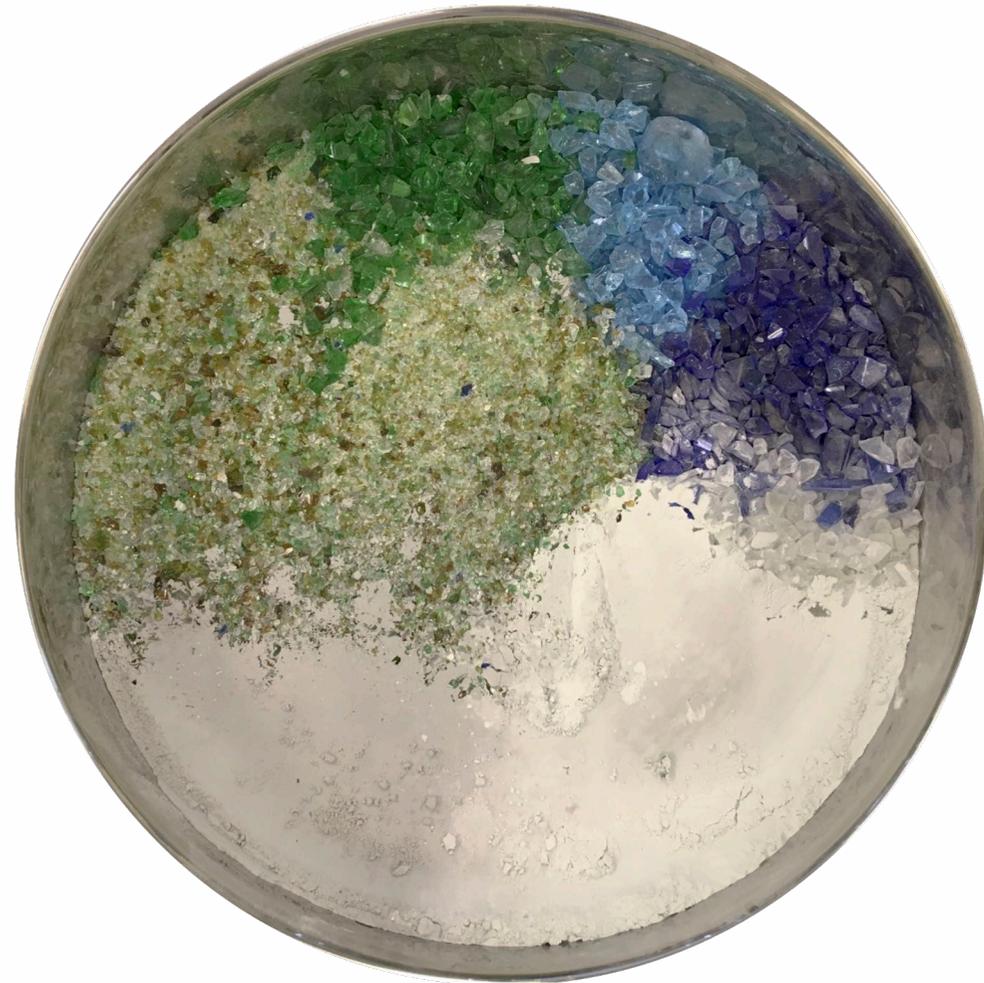
# Recycled Glass Ready for Use



River sand & GC

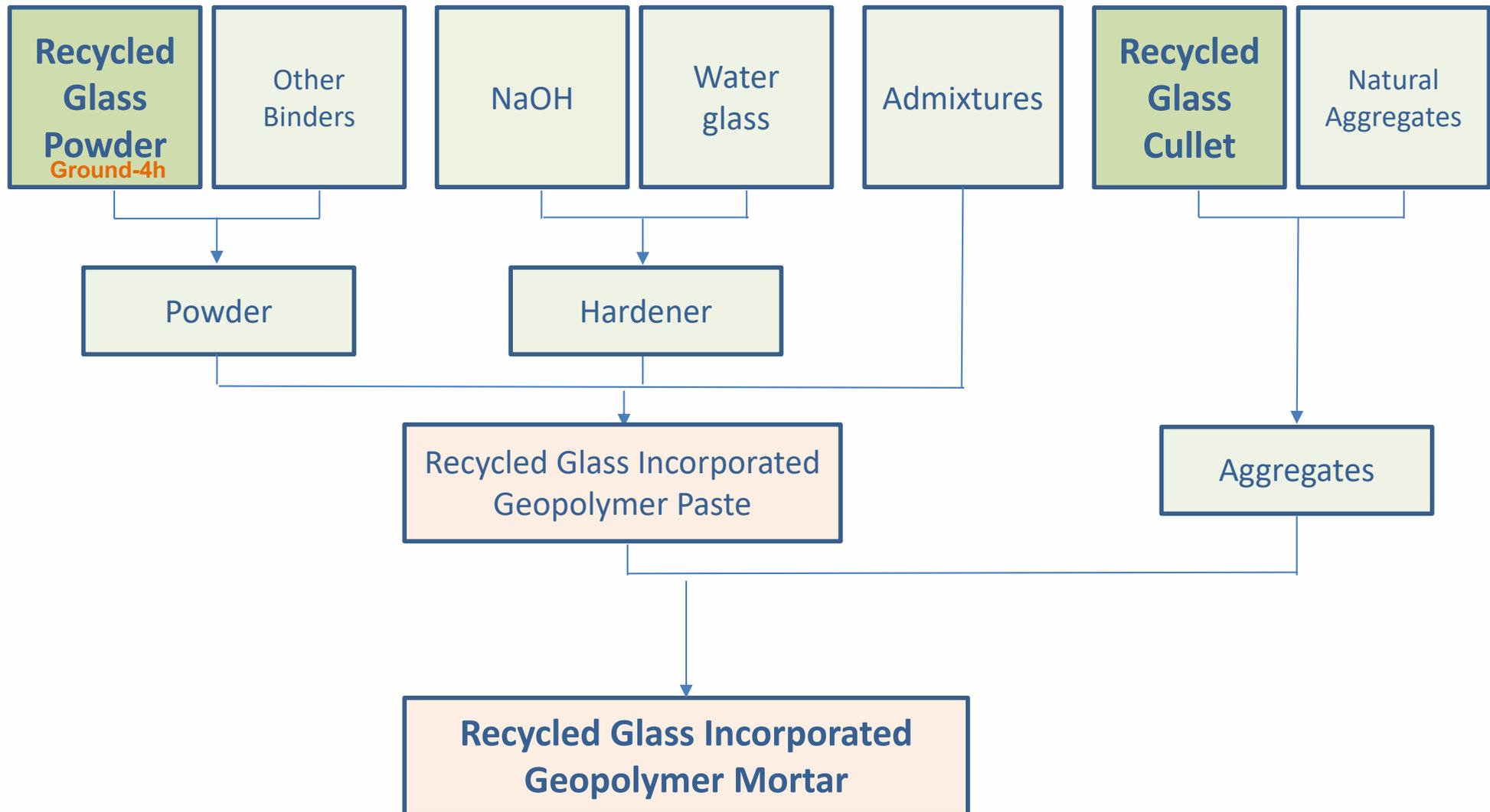


GP & Cementitious materials



- ✓ Optical transparency
- ✓ High impermeability
- ✓ Chemical inertness
- ✓ High intrinsic strength

# Maximizing Glass in Geopolymer



# Glass Incorporated Geopolymer

## Two Mixing Schemes



### Wet mix scheme

- Flowable
- Casting under vibration



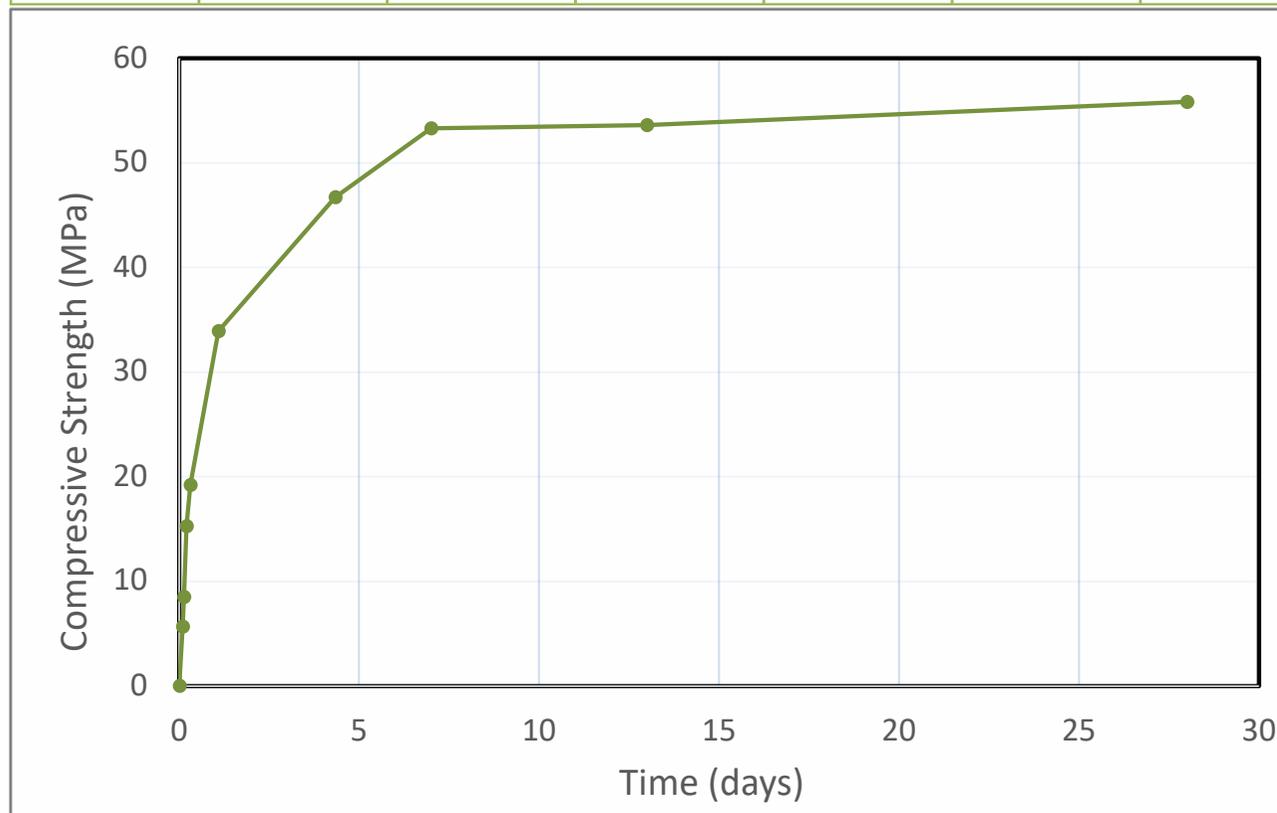
### Dry mix scheme

- Non-flowable
- Casting under compression (60kN)

# High Early Strength Development

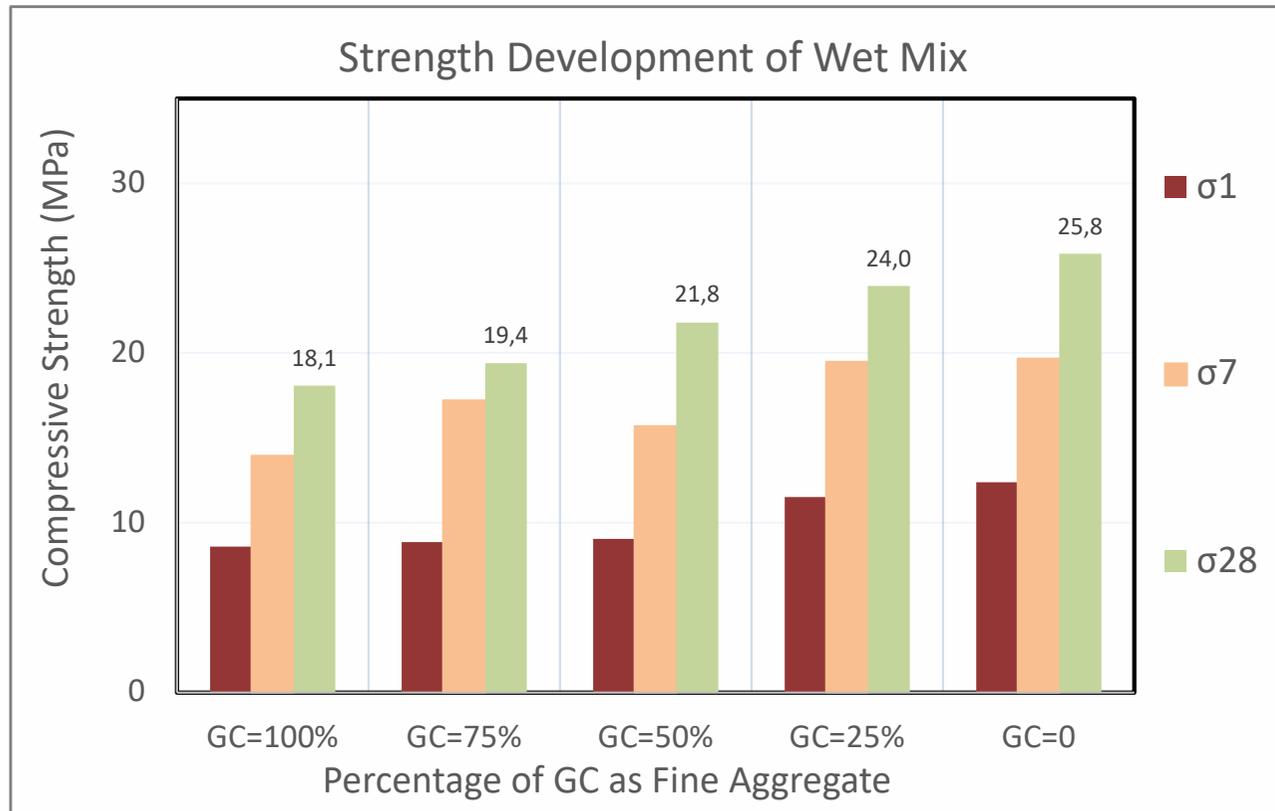
## Dry mix – Pre-cast Applications

Mix Proportion (wt%)						Strength Development (MPa)			
Glass powder	Glass cullet	Total Glass content	Other powder	Natural aggregate	Hardener	$\sigma$ -3h	$\sigma$ -6h	$\sigma$ -1 day	$\sigma$ -28 day
18.0	51.9	69.9	18.0	0	12.1	8.5	19.2	33.9	55.8



# Strength Development

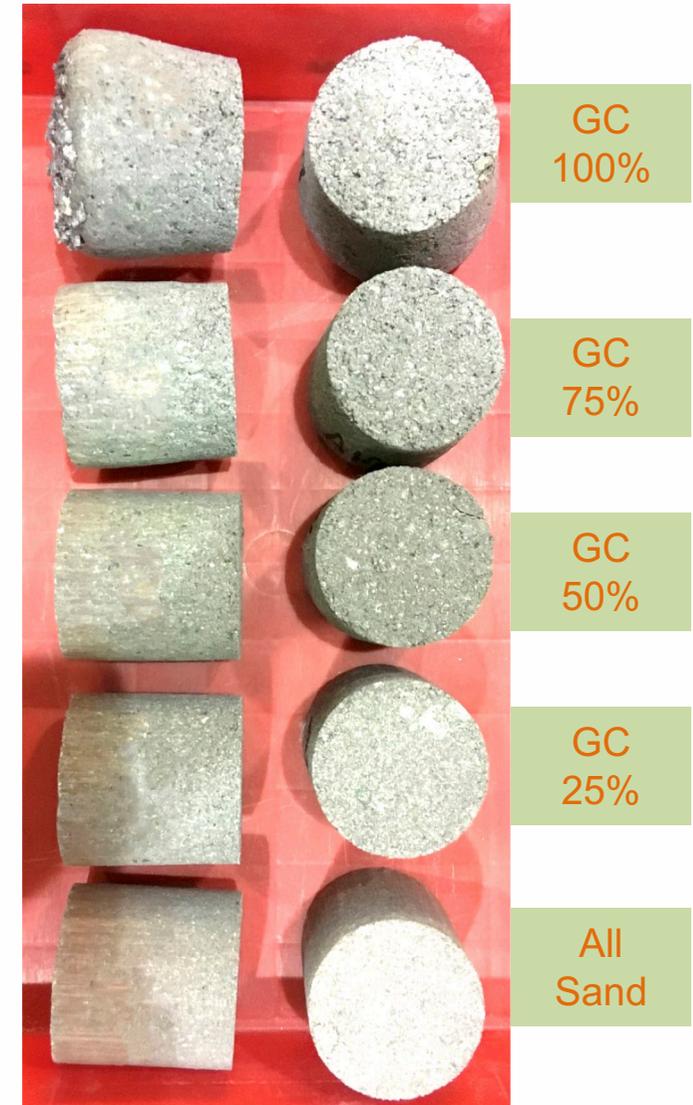
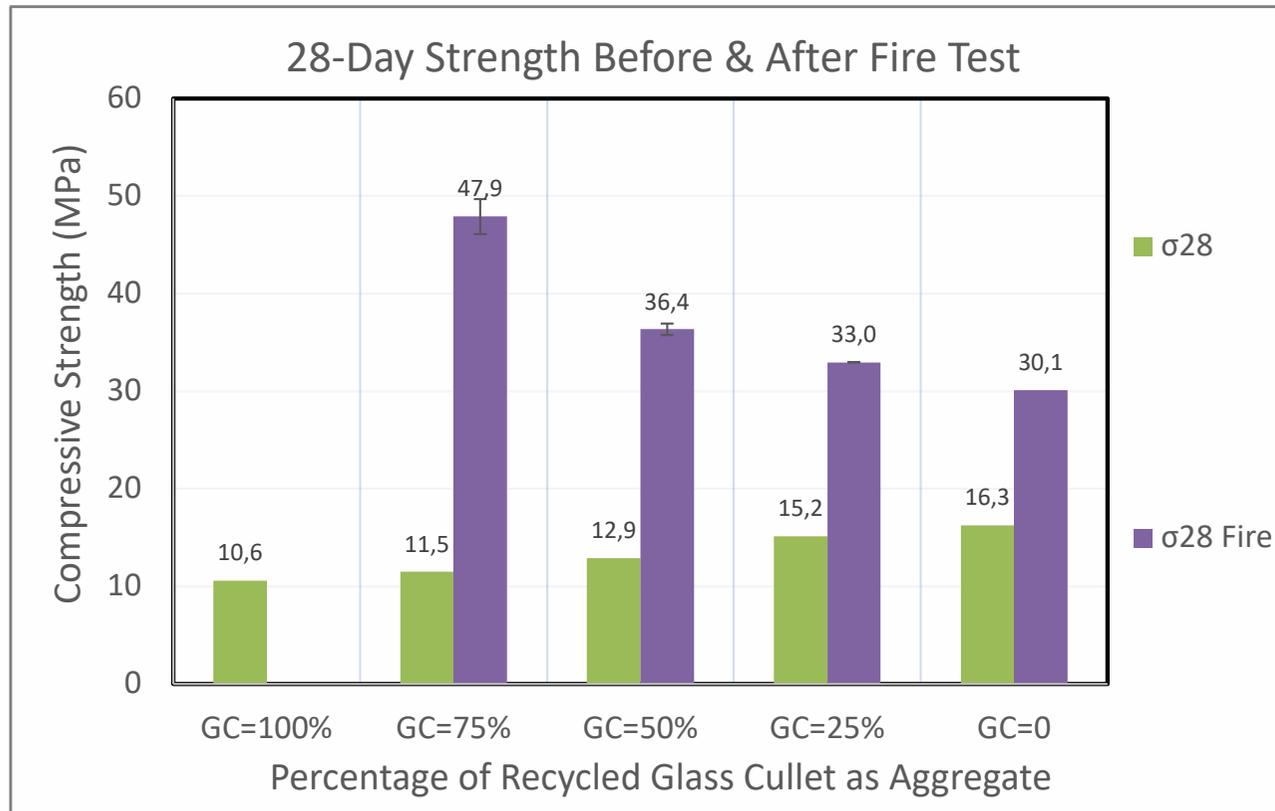
## Wet Mix – Non-Structural Applications



- Cylindrical specimens D50mm\*H50mm casted for compressive strength test;
- Slightly **strength loss** occurred due to recycled glass cullet incorporation;
- Strength of mixture incorporating 100% GC was higher than **15MPa**.

# Fire Resistance

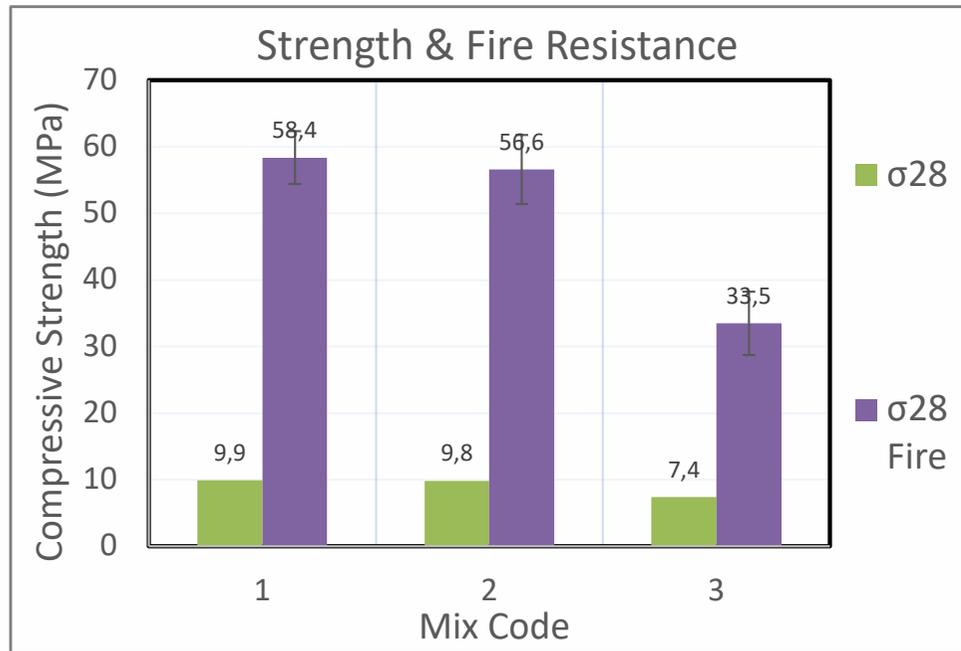
## Issue 1-Deformation



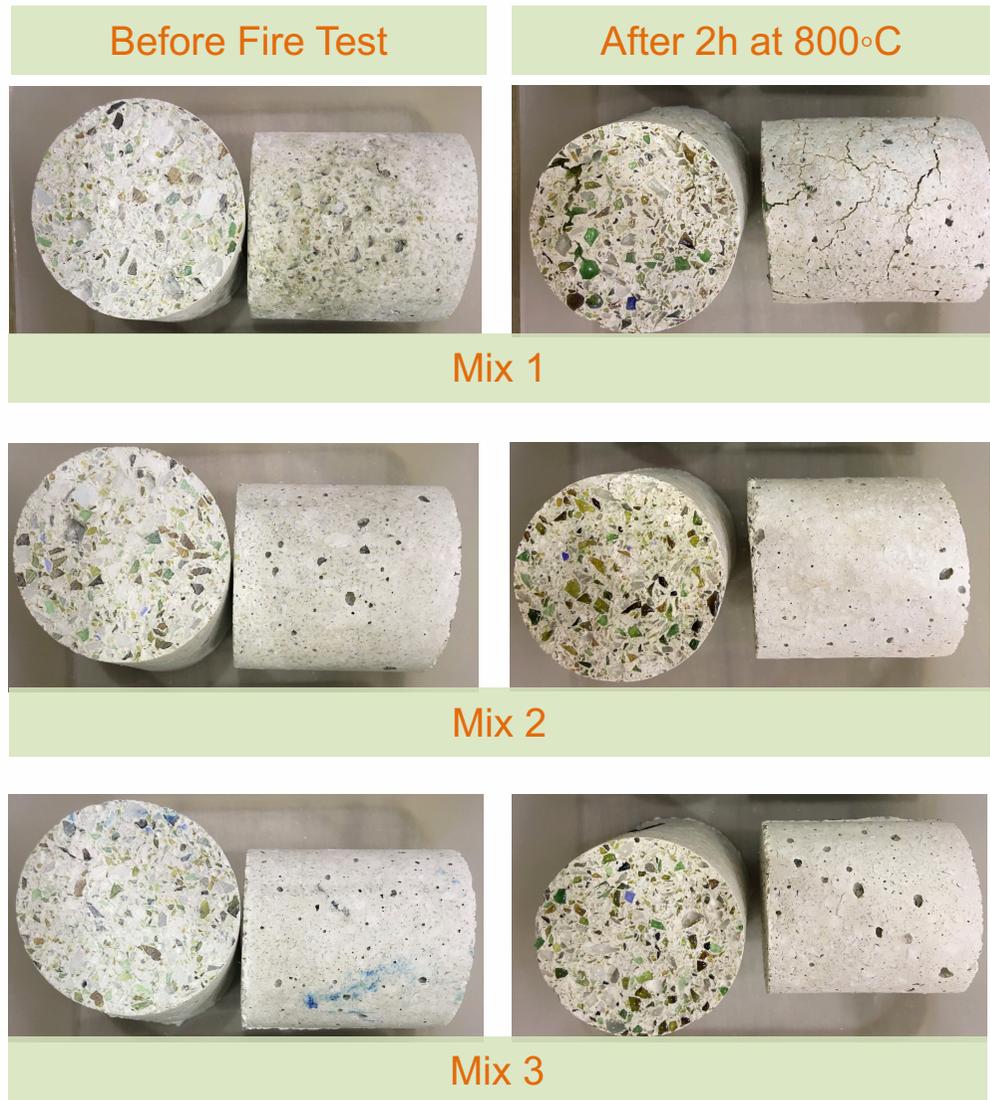
- More obvious **deformation** occurred with increased proportion of recycled glass cullet in geopolymer

# Fire Resistance

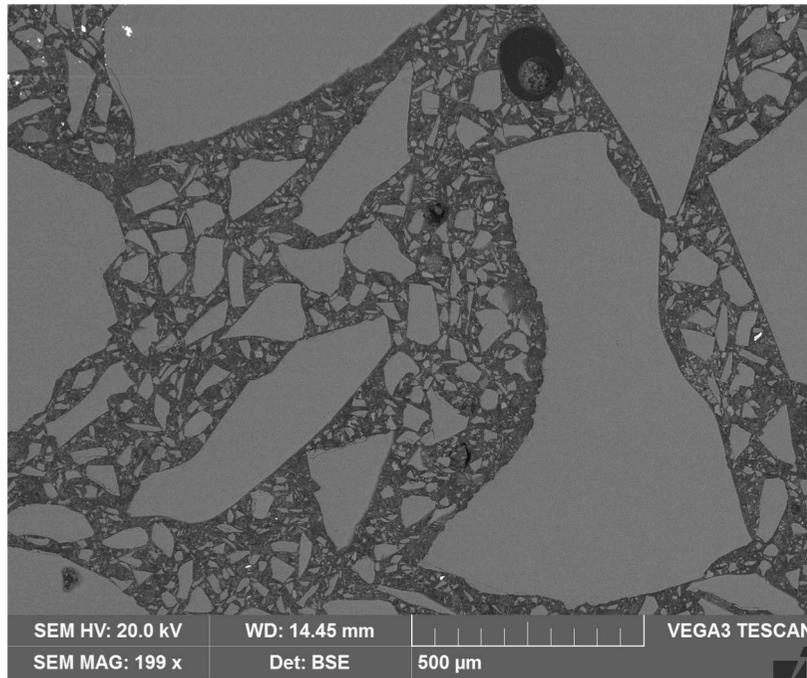
## Issue 2-Surface Cracks



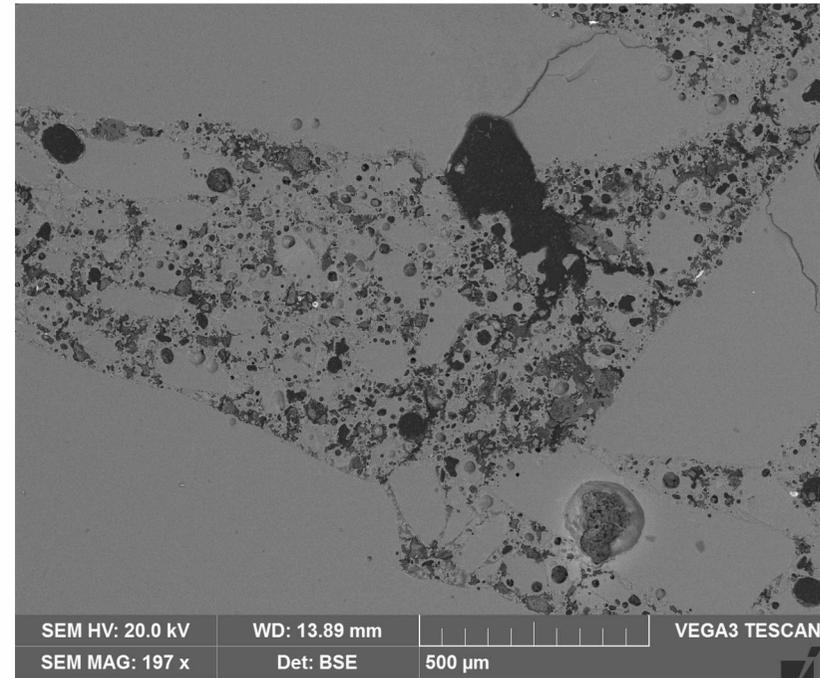
- When all fine aggregates were recycled glass cullet, cracks appeared at some mixture proportions



# Back Scattered Electron Imaging

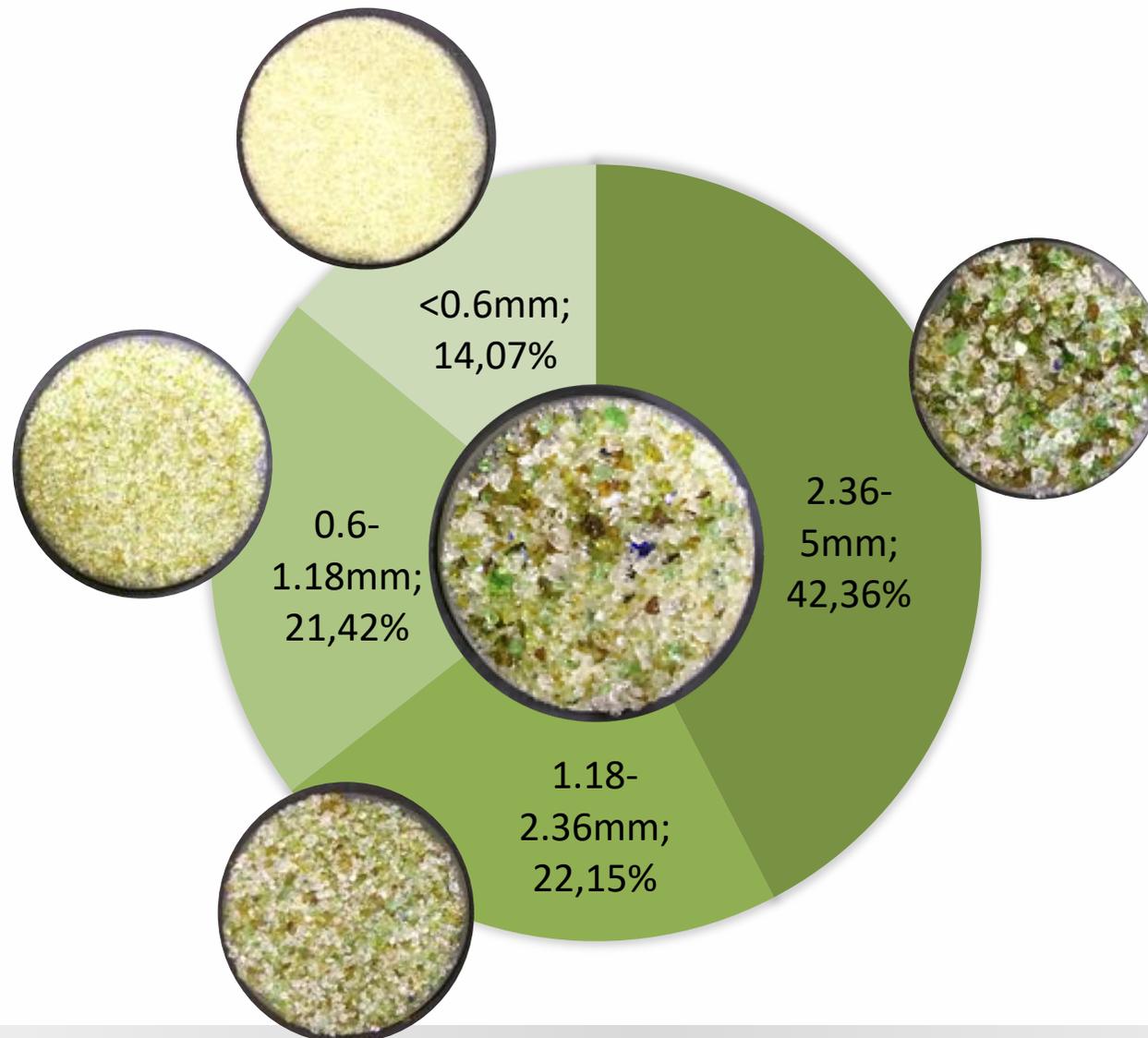


Before Fire Test  
Glass cullet distributed in paste

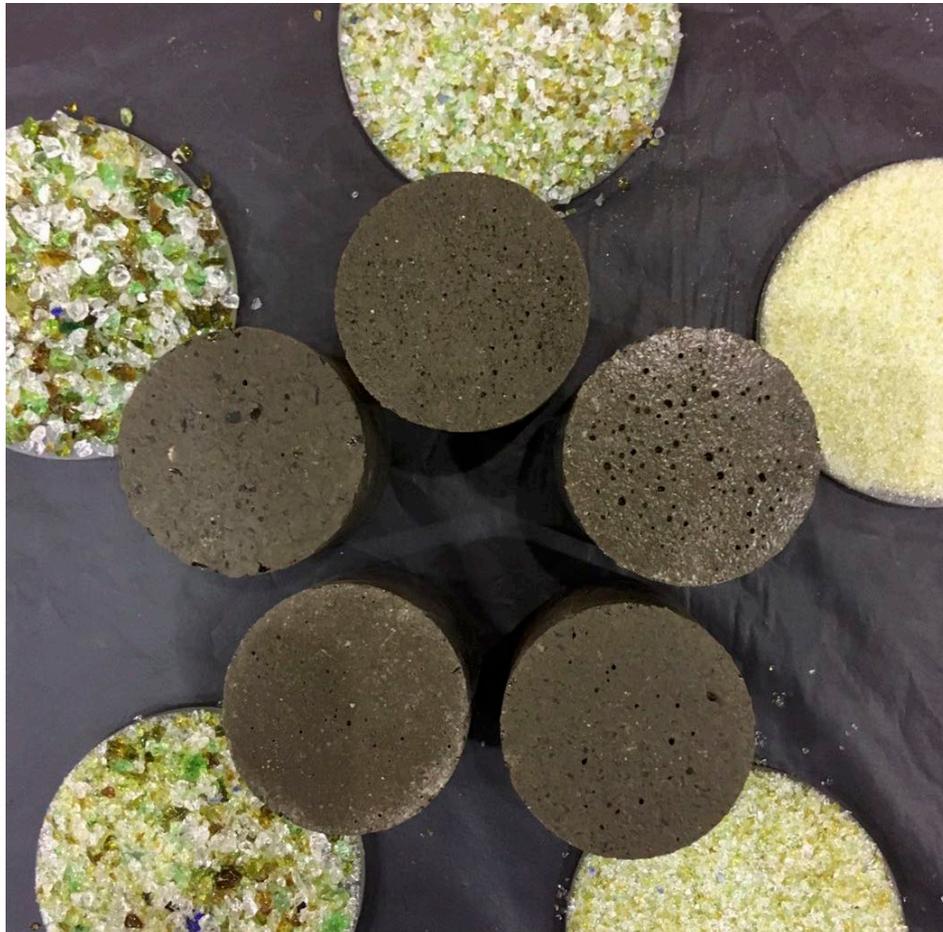


After Fire Test  
Glass particles melted together

# Glass Cullet Sieving



# Before & After 800°C



# Conclusions

- Incorporation of glass cullet in geopolymer mortar led to **reduced strength;**
- High early strength development can be achieved via employing different mixing schemes;
- Incorporation of glass cullet resulted in significantly increased strength after fire test, though **cracks and deformation** appeared after exposure to high temperature;
- Coarser particles (**2.36mm-5mm**) glass cullet resulted in surface **post-fire cracks.**

# Problems to be Solved

- ❖ How to effectively avoid **deformation**, especially when glass cullet is added to mass construction elements?
- ❖ How to **avoid cracks** without high labour cost pre-treatment of recycled glass materials? (e.g., sieving)

# More Than Waste Glass

## More Than Recycling, More Than Innovation

C&D Waste



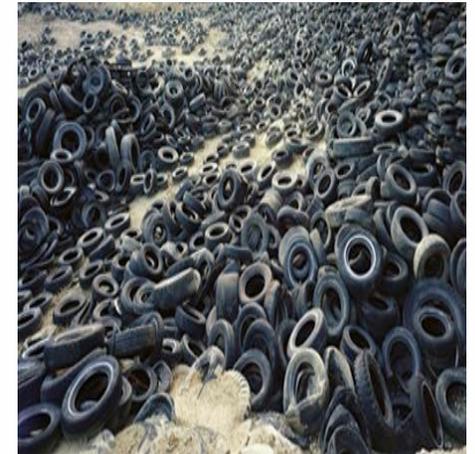
Incinerator Ash



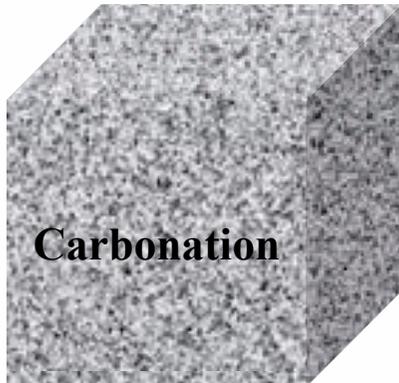
Waste Timber



Waste Tyres



Carbonation



GHGs  
Sequester

Decorative  
Tiles



Waste wood-MOC  
slab



Rubberized  
Geopolymer





# Thank You!

[binyu.z.zhang@polyu.edu.hk](mailto:binyu.z.zhang@polyu.edu.hk)

