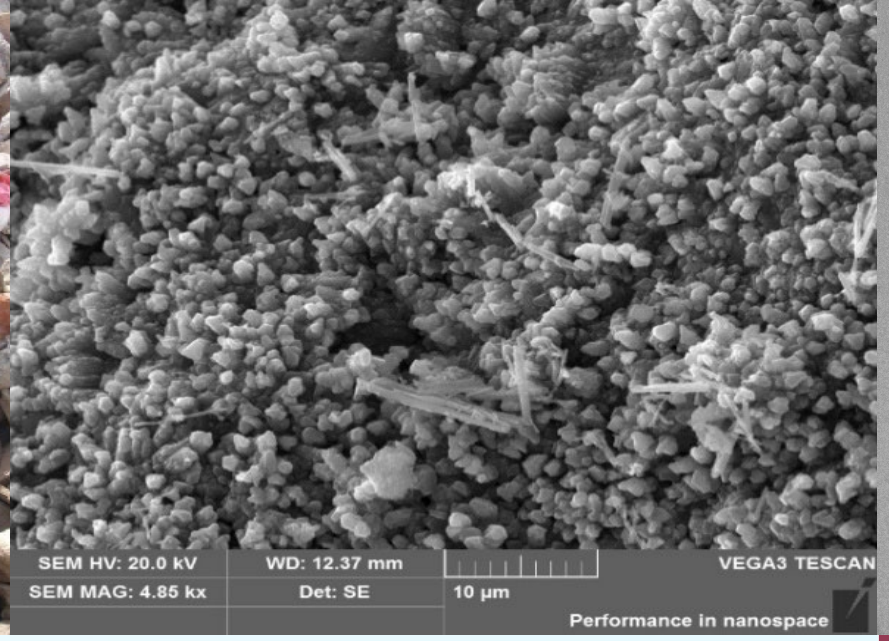
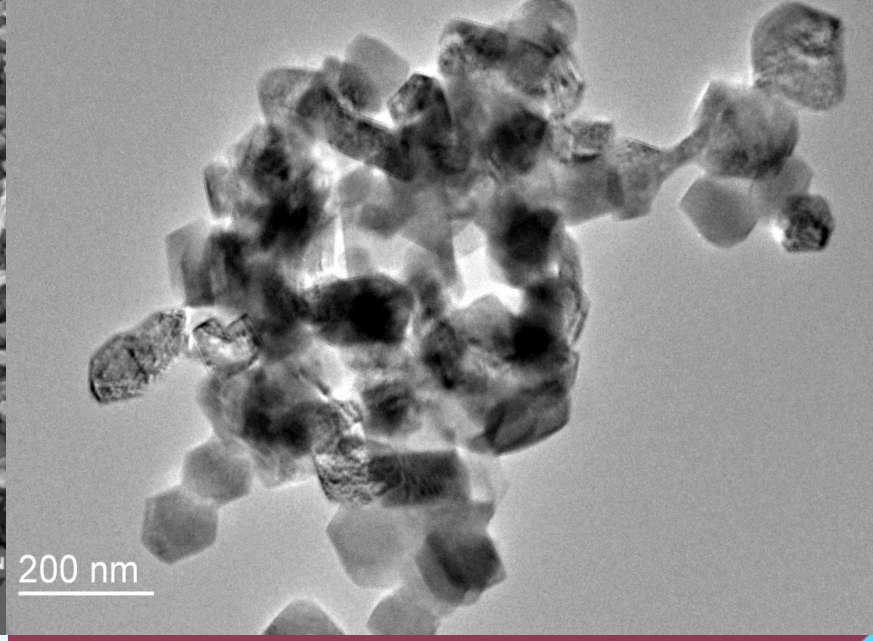



# Concrete Materials Laboratory

*ZS1110, Block Z,*

*Department of Civil and Environmental Engineering,*

*The Hong Kong Polytechnic University*

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
土木及環境工程學系

Opening Minds • Shaping the Future
啟迪思維 • 成就未來

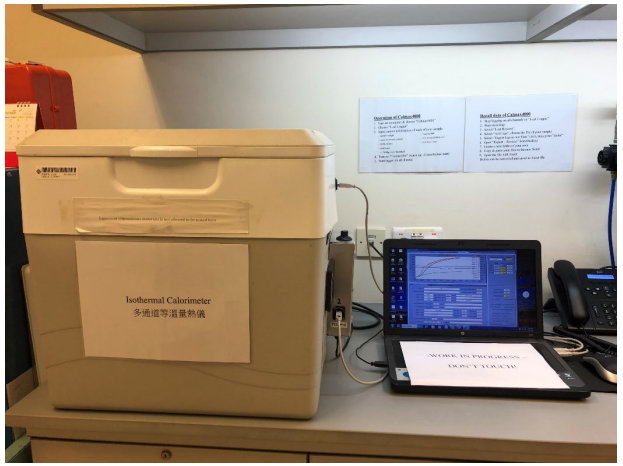
# Introduction

This laboratory focuses on characterisation of physical, chemical and microstructural properties of cement-based and eco-friendly construction materials on macro- and micro- levels.

It houses advanced equipment including:

- Ace Technology MHVX-1000A Micro-hardness Tester
- Bruker's TI 950 TriboIndenter (Located at ZS1107)
- Calmetrix I-Cal 4000 Isothermal Calorimeter
- Calmetrix I-Cal 8000 Isothermal Calorimeter
- Cole Parmer Five-Element Flame Photometer
- Malvern Mastersizer 3000 Particle Size Analyser
- Micromeritics ASAP2020 PLUS Porosity and Surface Area Analyser
- Micromeritics AutoPore IV Mercury Intrusion Porosimetry
- Micromeritics AutoPore V 9620 Mercury Intrusion Porosimetry
- Microtrac MRB BELPYCNO L Gas Pycnometer
- Nikon SMZ1270 Stereomicroscope
- Rigaku Supermini200 X-ray Fluorescence
- Rigaku Thermo Plus EVO2 Thermalgravimetry Analyser
- Tescan Vega 3 XMU Scanning Electron Microscope
- TA Instruments TAM Air
- Shimadzu DTG-60A Simultaneous Thermal Analyzer System with Auto Sampler

# Main Equipment



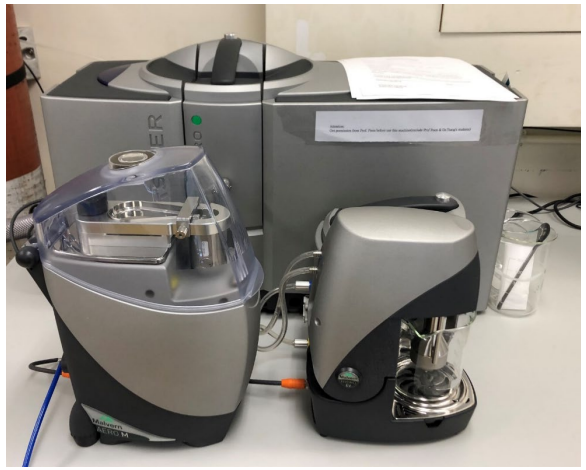

## Calmetrix I-Cal 4000 Isothermal Calorimeter

Isothermal calorimeter is used to investigate the heat of hydration of cement in different conditions such as water content, cement type, admixtures, cement alternatives, etc.

## Micromeritics AutoPore IV

Mercury intrusion porosimetry is one of the latest developed techniques for pore size analysis.

Determination of pore-size distribution of a porous material is an important step in the investigation of its microstructure of concrete materials.

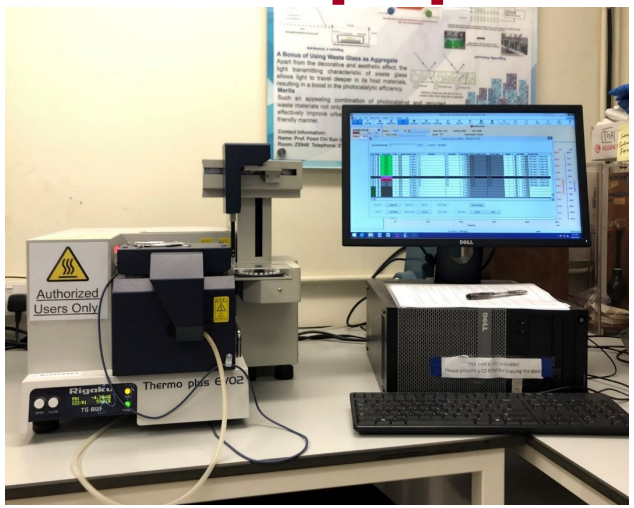


## Malvern Mastersizer 3000

The laser diffraction technique measures the particle size distribution of materials as solid or dispersed in liquid.

By measuring the intensity of light scattered as a laser beam passes through a dispersed particulate sample, the size of the particles that created the scattering pattern can be calculated.

# Main Equipment



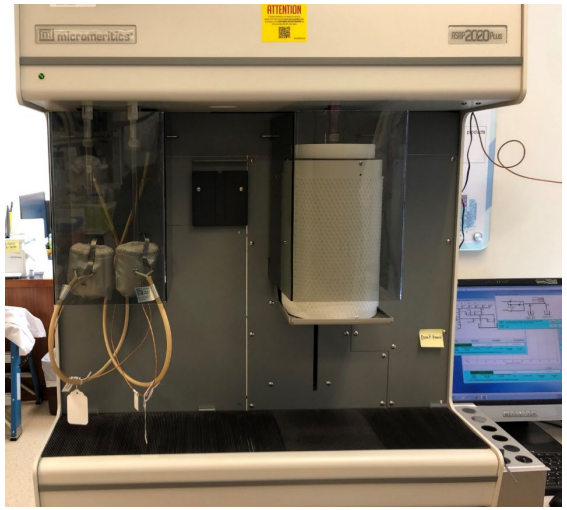

**Rigaku Thermo Plus EVO2**

Thermogravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis and commonly used to determine specific characteristics of materials that exhibit either mass loss or gain due to decomposition, oxidation, or loss of volatiles (such as moisture).


**Rigaku Supermini200**

X-ray fluorescence (XRF) is the emission of characteristic "secondary" (or fluorescent) x-ray from a material that has been excited by bombarding with high-energy X-rays or gamma rays.

The phenomenon is widely used for elemental analysis and chemical analysis, particularly in the investigation of ceramics and building materials.



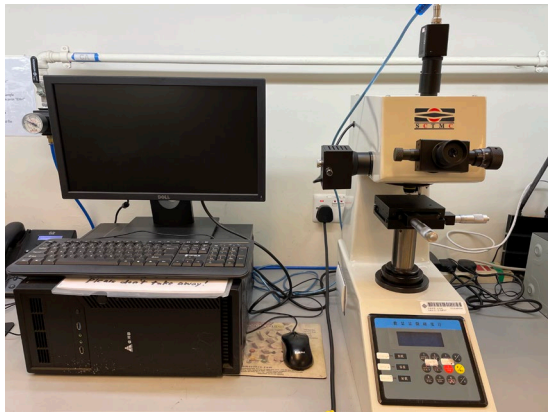

**Micromeritics ASAP2020 PLUS**

BET is an important analysis technique for the measurement of the specific surface area and pore size distribution of a material by physical adsorption under a high vacuum condition.

# Main Equipment

**Nikon SMZ1270 Stereomicroscope with NIS Element BR Imaging Software**

The stereomicroscope provide excellent optical performance such as high magnification, high zoom ration and high resolution images for standard research applications. With the help of the imaging software, morphology data of the materials can be acquired.



**Ace Technology MHVX-1000A Micro-hardness Tester**

Vickers hardness test is the indentation of test material with a diamond indenter subjected to a load of 0.0981N to 9.8N.

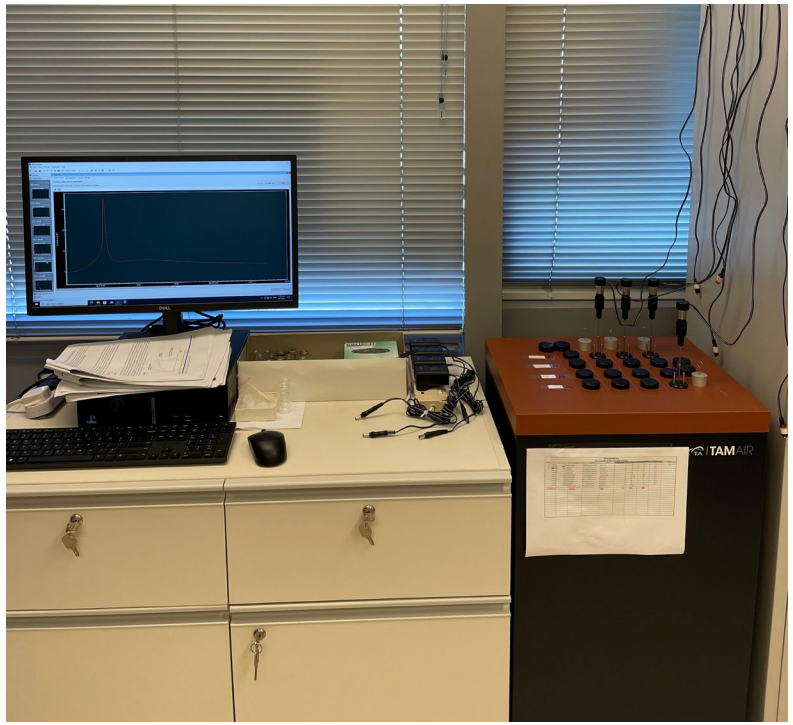
The two diagonals of the indentation left on the surface are measured and the Vickers Hardness is the quotient obtained by dividing the load by area of indentation.

**Microtrac MRB BELPYCNO L Gas Pycnometer**

This is a fully automated gas pycnometer for the determination of volume and skeleton density of powders, granulates, porous materials, mixtures, pastes and liquids.

The instrument utilizes a probing gas (Helium) which can reach even the smallest pores with less than one nanometer in diameter. Thus, the density of powders and porous materials can be determined exactly.

# Main Equipment

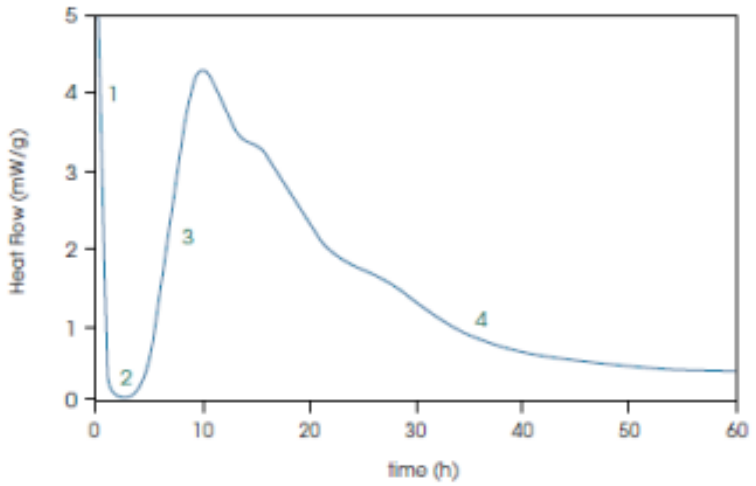



TA Instruments - TAM Air

The TAM Air isothermal calorimetry system provides the sample flexibility and measurement sensitivity to accurately characterize heat flow in a wide variety of materials. The 8-channel calorimeters are widely recognized as the instrument of choice for cement hydration analyses using ASTM C1702 and C1679.

This is a tool for large-scale isothermal calorimetry experiments. Capable of measuring several samples simultaneously under isothermal conditions, the TAM Air with its air-based thermostat and easily interchangeable 8-channel standard volume, is especially well-suited for characterizing processes that evolve or consume heat over the course of days and weeks.

# Main Equipment




**Phase 1:** Rapid Intial process - Dissolution of ions and initial hydration
**Phase 2:** Dormant period - Associated with a low heat evolution and slow dissolution of silicates
**Phase 3:** Acceleration period - Silicate hydration
**Phase 4:** Retardation period - Sulphate depletion and slowing down of the slicate hydration process

Isothermal calorimetry is an excellent tool to measure the total heat of hydration as well as to continuously follow the reaction rates in the different phases of the complex cement hydration process.

The heat flow profile from a hydrating cement or concrete sample is information-rich and can give insight and knowledge for:

> The development of new cements and admixtures

> Dosing and formulation optimization

> The impact of temperature on the hydration process

> The detection of any incompatibility of materials

> Production and quality control

# Main Equipment

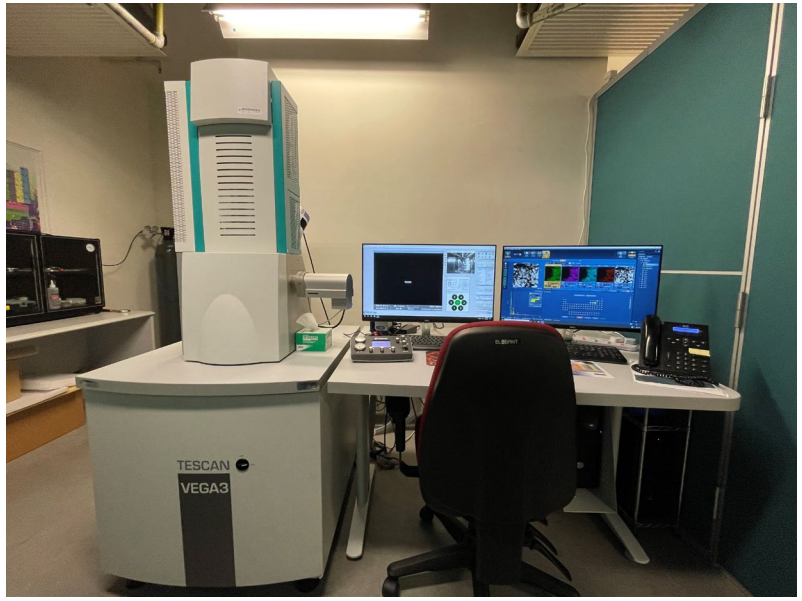

**Bruker's TI 950 TriboIndenter**

Nanomechanical testing delivers quantitative mechanical and tribological characterization at nanoscale. It meets specific research needs, from soft polymers to concrete and steel.

Young's modulus, hardness, fracture toughness and other mechanical properties can be measured via nanoindentation, and wear properties of various materials can be tested.

In-situ SPM imaging in Bruker's TI950 allows the observation of post-test deformation behaviour.

# Main Equipment



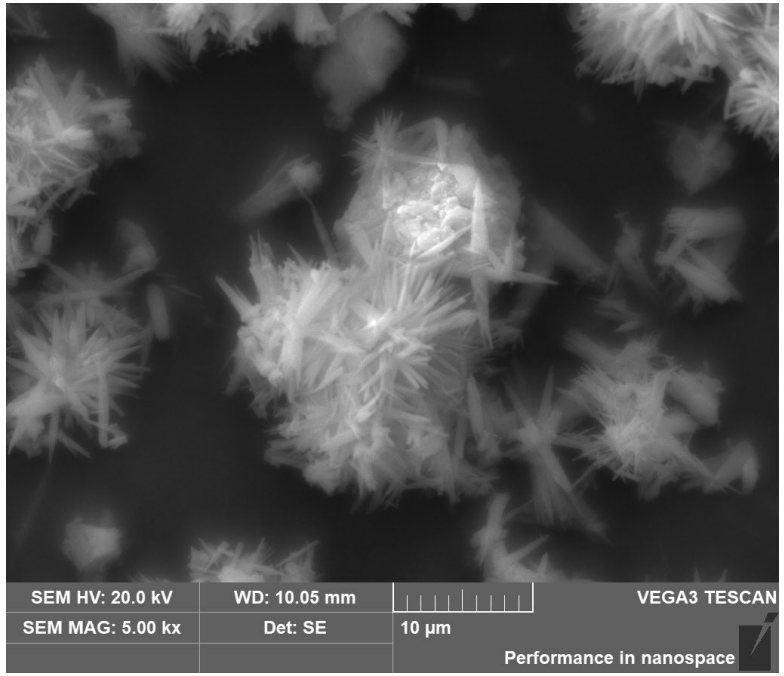

**Tescan Vega 3 XMU**
**Scanning Electron Microscope**

This tungsten thermionic emission SEM system, equipped with Oxford EDX System, is suitable for low- and high-vacuum operations.

A high spatial resolution with secondary electron (SE) and backscatter (BSE) detector allows the observation with fine surface details, whilst the EDX detector provides elemental and chemical analysis.

The SEM is designed for comprehensive materials characterization down to nanoscale. This instrument is best suited to imaging and analysis of coated samples that are stable under the electron beam, e.g. concrete, rocks, metals and alloys.

# Main Equipment




**Micrograph acquired from Tescan Vega 3 XMU SEM showing Aragonite, the carbonation product of hydrated cement paste**

- An extra-large analytical chamber with a full 5-axis motorized stage
- Detector: SE, BSE, EDX
- Imaging up to 50,000X
- Accelerating voltage: 200V to 30 kV
- 5 Electron Optics Working Modes: Resolution, Depth, Field, Wide Field, Channeling
- Rotation: 360°continuous / Tilt: -30° to +90°
- IR TV Camera for the “Chamber View”

# Academic Staff

**Prof. Poon, Chi Sun (潘智生)**

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Assistant Professor

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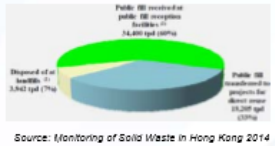
# Research Spotlight

## Carbon Neutral Construction Products Manufactured with Cement and Concrete Wastes

### Facts of Construction Waste in HK



Source: Monitoring of Solid Waste in Hong Kong 2014

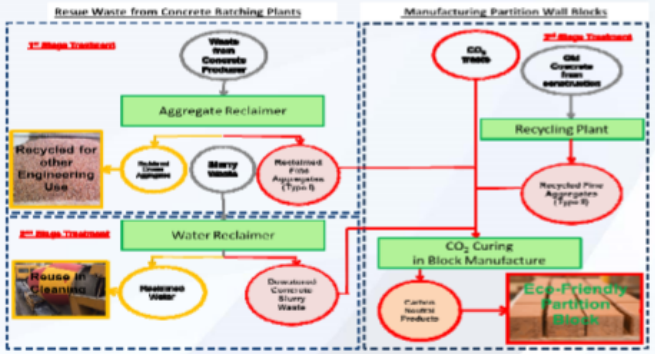
Recycled Concrete Aggregates

Concrete Slurry Waste

*Construction Sector* **in HK**
- Consume *40% of materials* entering the economy
- *2nd* largest carbon footprint contributor
- *85%* of the carbon emission embodied in upstream materials and services

- Construction waste is the *No. 1 solid waste* stream in HK about *57,000 ton/day*
- *Recyclable concrete waste* is estimated at *3,000 - 6,000 ton/day*
- *Concrete slurry waste* from concrete plants is estimated at *about 400 ton/day*

### Innovative Recycling and Reuse of Construction Waste




### Impacts and Benefits

RCA + CSW

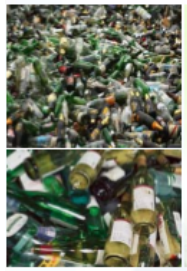
Turning construction wastes to construction products; and products may be produced by up to *97% waste materials*:
- CSW to *replace 40-80% cement*;
- RCA as aggregates to *replace 100% natural aggregates*.


**$CO_2$ curing of eco-blocks:**
- Accelerated strength development (*12 hours $CO_2$ curing ≈ 28 days air curing*);
- Reduced *50% shrinkage*;
- *$CO_2$ uptake* of block is *5.2% by weight*

## Maximize the recycling of waste glass

### Introduction

Waste glass has become an important part in the municipal solid waste (MSW) stream. Due to its low commercial values and the lack of glass manufacturing industry in Hong Kong, the recovery rate of waste glass is less than 10%. For this reason, it is very important to develop viable recycling technologies to recycle more waste glass.



| Hong Kong (2014) | |
|---|---|
| Waste glass containers | 250 tonnes daily |
| Recovery rate | Less than 10% |
| Reason | No glass manufacturing industry |
| Management | Mostly landfilled |



✓ **Glass action:** Good aesthetic property of glass → recycle waste glass to produce architectural products.

Glass wastes

Mix glass cullet (as fine aggregates)

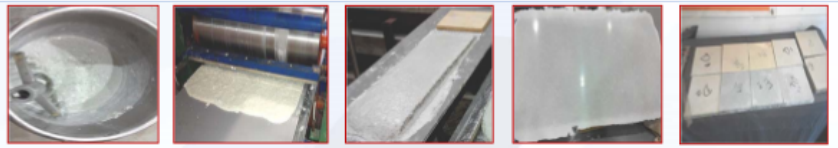
Waste glass powder (as SCM)

Production of waste glass powder


Maximize the use of the waste glass in architectural mortar

✓ Fully replace natural aggregates
✓ Partially replace cement.

✓ **Innovative forming method:** Calender Extrusion Method can effectively improve the production process.



Mixing → Rolling → Curing → Cutting → Polishing

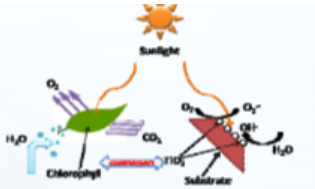
✓ **Glass-based Architectural Tile:** Attractive appearance, Cost-effective, High-quality.

# Research Spotlight

## Photocatalytic Cement-based Materials Combination of $TiO_2$ and Waste Glass

### Similarity between Photocatalysis and Photosynthesis

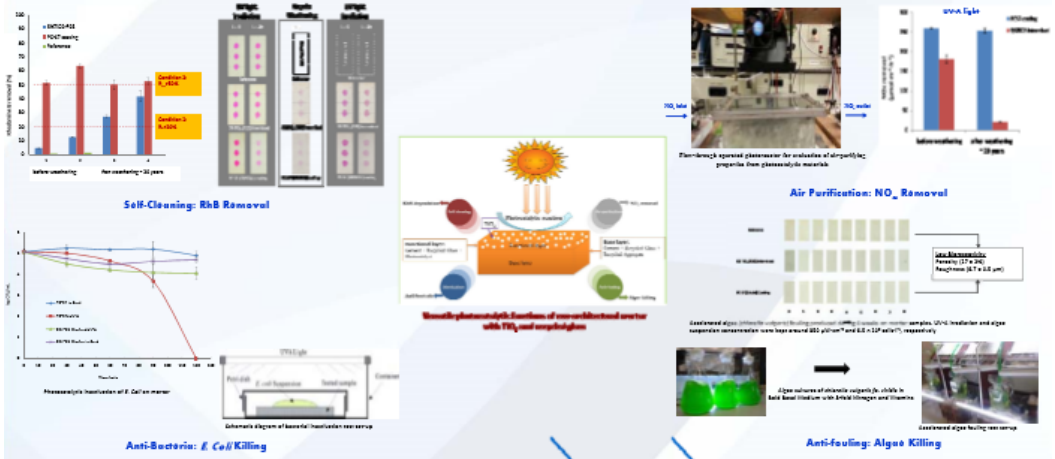
In plants, chlorophyll plays a catalytic role in converting light energy into chemical energy through the process of photosynthesis. $TiO_2$ is the equivalent of chlorophyll in photocatalysis. During the photocatalytic process, one or more reaction steps occur by means of electron-hole pairs photogenerated on the surface of $TiO_2$ illuminated by light of suitable energy. As an advanced oxidation technology, $TiO_2$-mediated heterogeneous photocatalysis garners increasing interest.




Comparison of photosynthesis in plants and photocatalysis mediated by $TiO_2$ under irradiation of sunlight

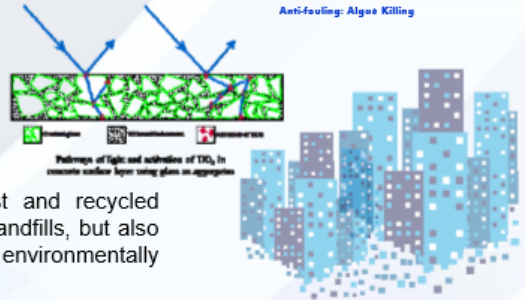
### Combination of Photocatalysis and Cement-based Materials

Drawing inspiration from photosynthesis, we try to harness solar energy by introducing $TiO_2$-mediated photocatalysis into recycled cementitious materials. Under only solar light irradiation, the $TiO_2$-incorporated products are able to deliver various value-added functions such as air-purification, self-cleaning, bacteria killing, and anti-fouling.




### A Bonus of Using Waste Glass as Aggregate

Apart from the decorative and aesthetic effect, the light transmitting characteristic of waste glass allows light to travel deeper in its host materials, resulting in a boost in the photocatalytic efficiency.



### Merits

Such an appealing combination of photocatalyst and recycled waste materials not only alleviates the burden on landfills, but also effectively improve urban living conditions in an environmentally friendly manner.

## Fundamental Research on Recycling Contaminated Marine Sediments and Incinerated Sewage Sludge Ash In HK

Sludge

T-park incinerator

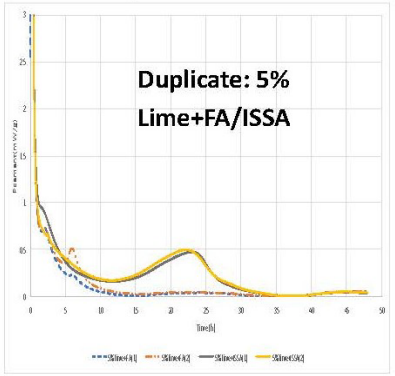
ISSA

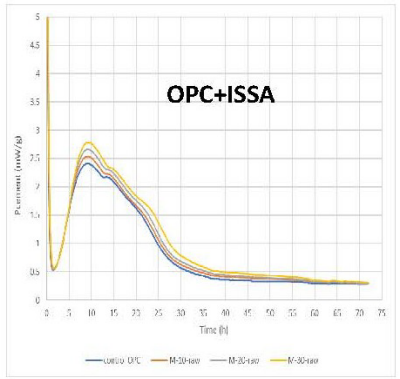
**Aim:** use of **as-received, ball-milled and acid-extracted ISSA** combined with **lime**/cement to solidify/stabilise contaminated marine sediments for providing a novel way to reuse marine sediments as filling materials .

**Preliminary work:** Characterisation (SEM, XRD, XRF, BET & PSD) **&** Compressive strength of paste samples

**Characterisation** and **compressive strength.**

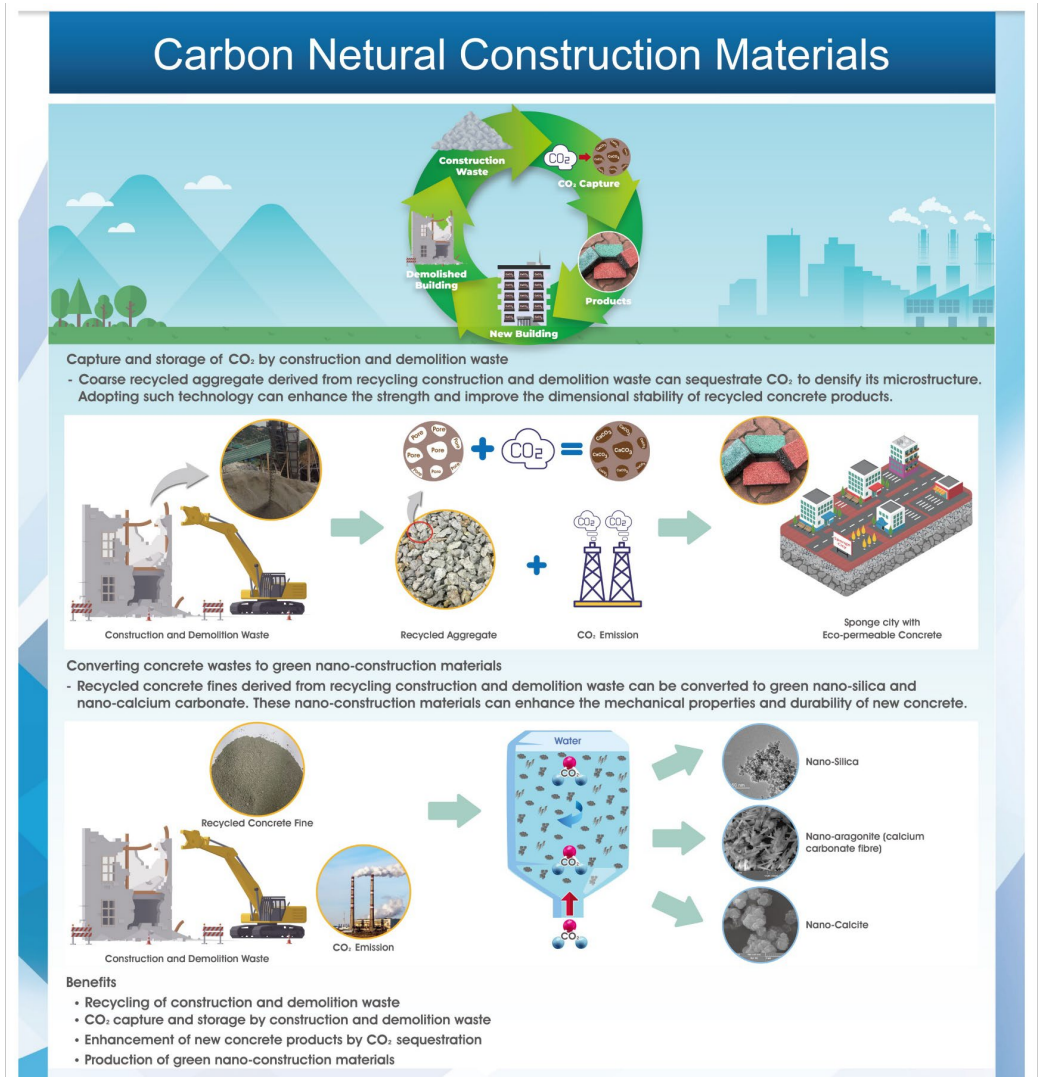

### Heat of Hydration:



# Research Spotlight

**Carbon Neutral Construction Materials**



# Lab-in-charge and Technical Staff

## Lab-in-Charge

**Prof. Poon Chi Sun (潘智生)**

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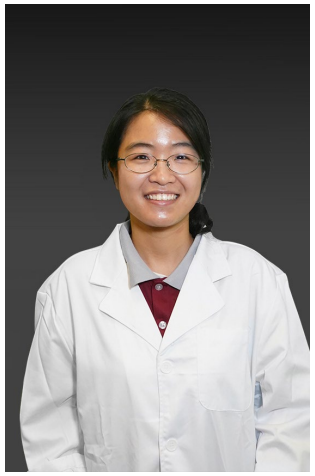

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Tuesday to Friday 8:45am – 12:30pm, 1:30pm – 5:30pm
(excluding Saturday, Sunday & public holidays)