

Concrete Materials Laboratory

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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

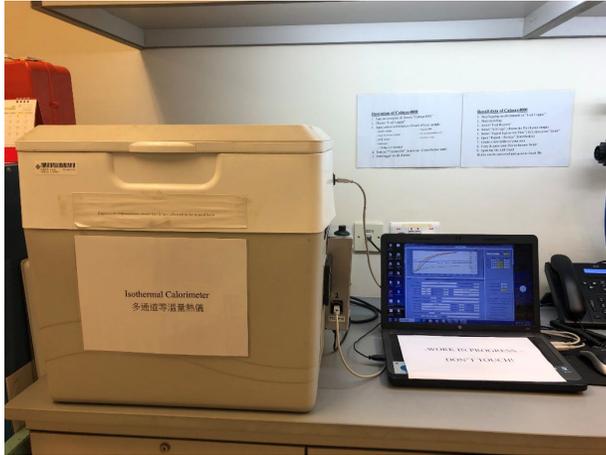
This laboratory focuses on characterisation of physical, chemical and microstructural properties of cement-based and eco-friendly construction materials on macro- and micro- levels.

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
- > 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
- > 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



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.

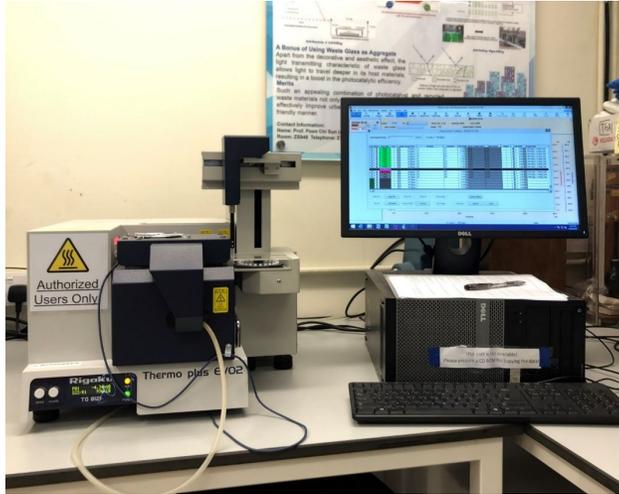


Malvern Mastersizer 3000

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

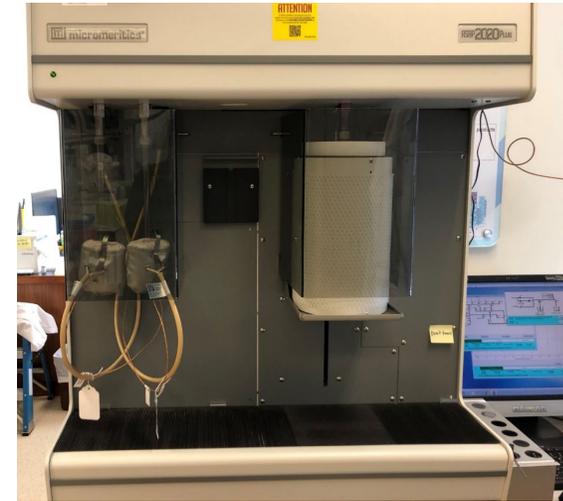
Thermogravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis and commonly used to determine specific characteristics of materials that exhibit either mass loss or gain due to decomposition, oxidation, or loss of volatiles (such as moisture).



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

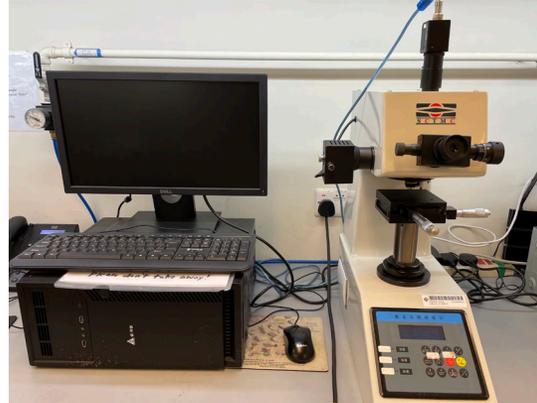
BET is an important analysis technique for the measurement of the specific surface area and pore size distribution of a material by physical adsorption under a high vacuum condition.

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.

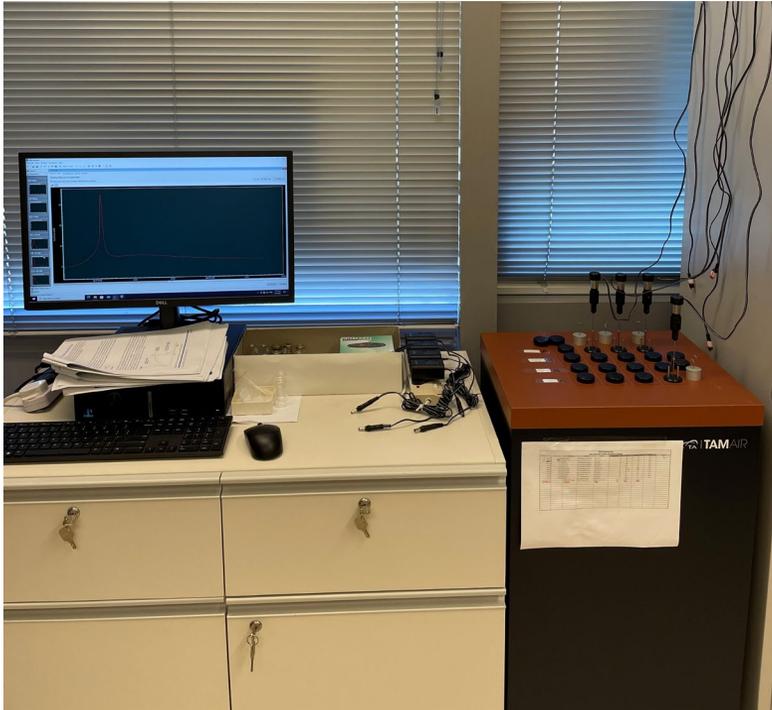


**Microtrac MRB BELPYCNO L
Gas Pycnometer**

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

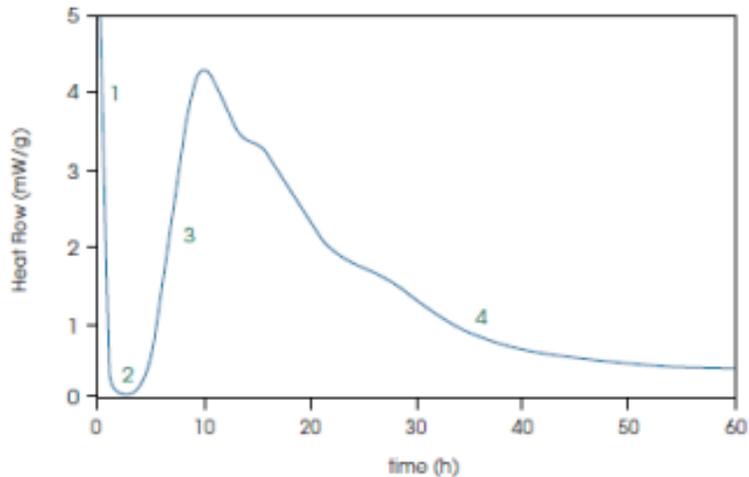


TA Instruments - TAM Air

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 Initial 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 silicate 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



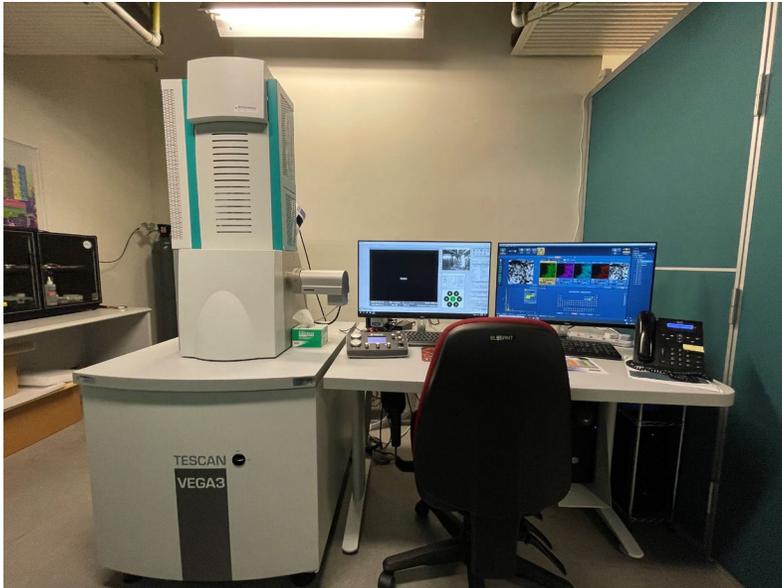
Bruker's TI 950 TriboIndenter

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



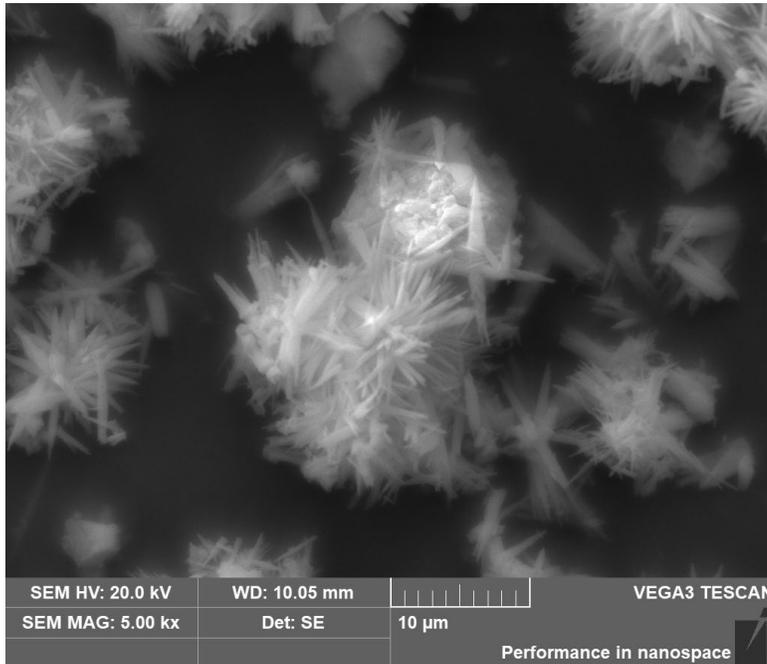
Tescan Vega 3 XMU
Scanning Electron Microscope

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



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Research Spotlight

Carbon Neutral Construction Products Manufactured with Cement and Concrete Wastes

Facts of Construction Waste in HK

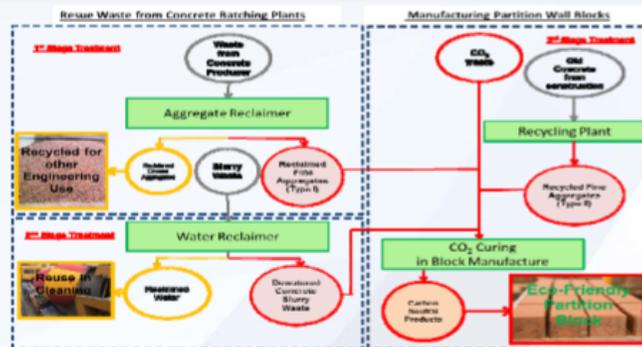


Construction Sector in HK

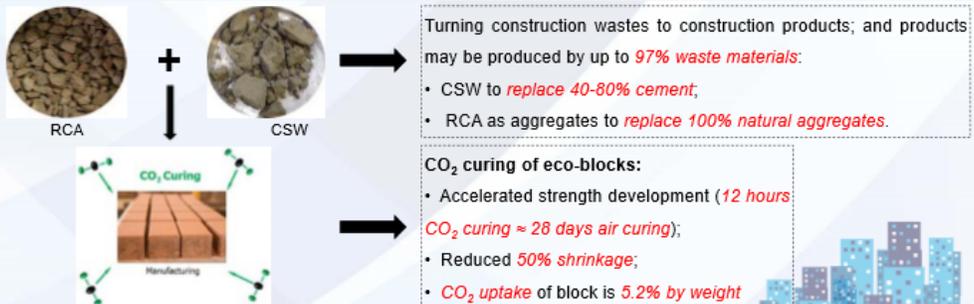
- Consume **40% of materials** entering the economy
- 2nd largest carbon footprint** contributor
- 85% of the carbon emission embodied** in upstream materials and services

- 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



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.

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.

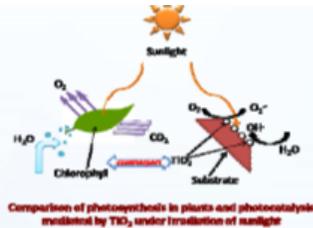
✓ **Glass-based Architectural Tile:** Attractive appearance, Cost-effective, High-quality.

Research Spotlight

Photocatalytic Cement-based Materials Combination of TiO_2 and Waste Glass

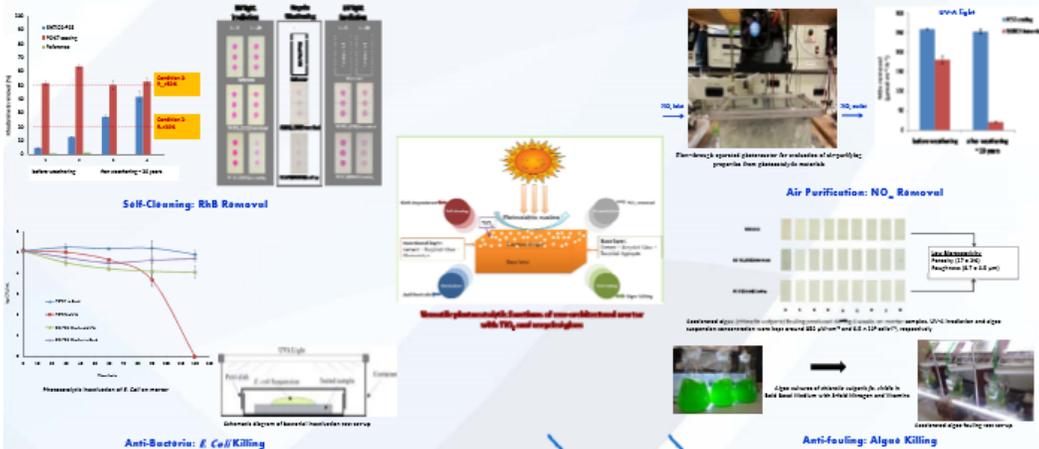
Similarity between Photocatalysis and Photosynthesis

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.



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.

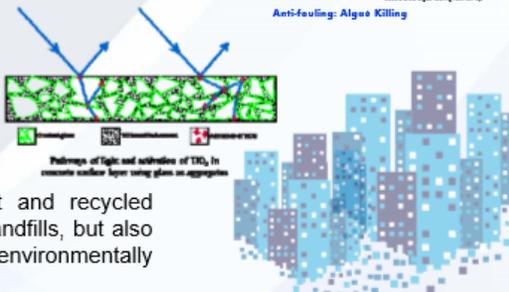


A Bonus of Using Waste Glass as Aggregate

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



T-park incinerator



Sludge

ISSA

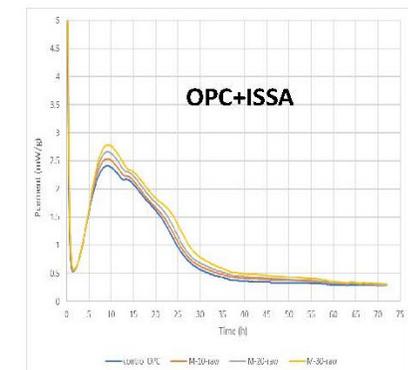
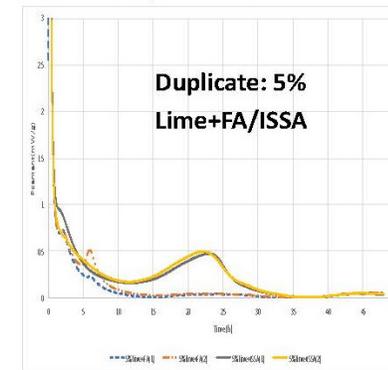
Aim: use of as-received, ball-milled and acid-extracted ISSA combined with lime/cement to so-lidify/stabilise contaminated marine sediments for providing a novel way to reuse marine sediments as filling materials.

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

Characterisation and compressive strength.



Heat of Hydration:



Research Spotlight

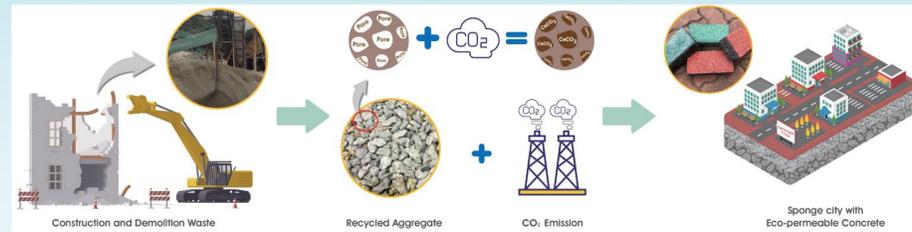
Carbon Neutral Construction Materials

Carbon Neutral Construction Materials



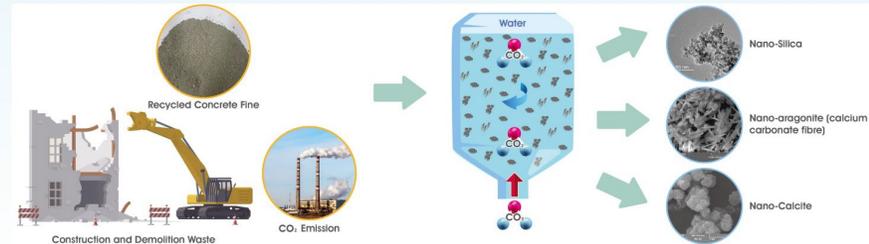
Capture and storage of CO₂ by construction and demolition waste

- Coarse recycled aggregate derived from recycling construction and demolition waste can sequestrate CO₂ to densify its microstructure. Adopting such technology can enhance the strength and improve the dimensional stability of recycled concrete products.



Converting concrete wastes to green nano-construction materials

- Recycled concrete fines derived from recycling construction and demolition waste can be converted to green nano-silica and nano-calcium carbonate. These nano-construction materials can enhance the mechanical properties and durability of new concrete.



Benefits

- Recycling of construction and demolition waste
- CO₂ capture and storage by construction and demolition waste
- Enhancement of new concrete products by CO₂ sequestration
- Production of green nano-construction materials

Lab-in-charge and Technical Staff



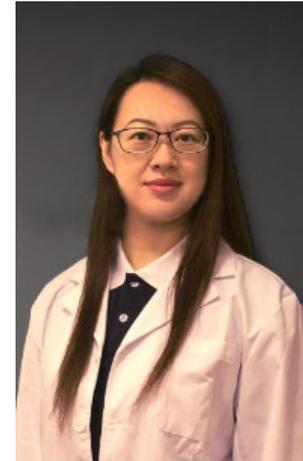
Lab-in-Charge

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