THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Resources Engineering towards Carbon Neutrality : Opportunities for the Hong Kong Cement and Concrete Industry

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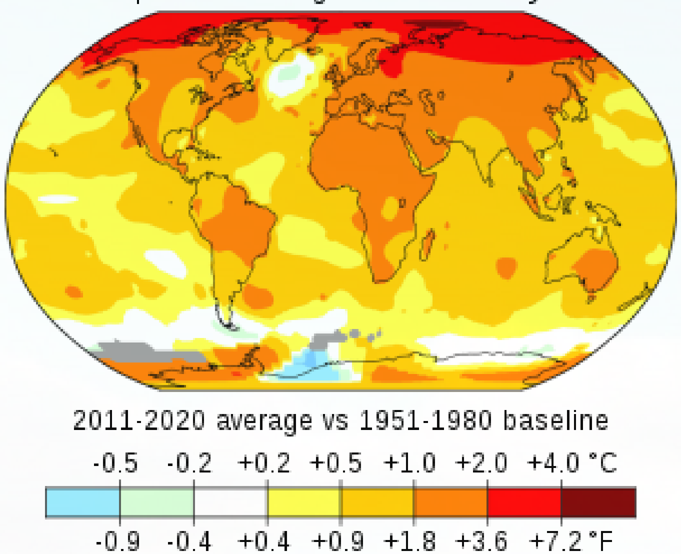
±RCRE
RESEARCH CENTRE FOR RESOURCES ENGINEERING TOWARDS CARBON NEUTRALITY
碳中和資源工程研究中心

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

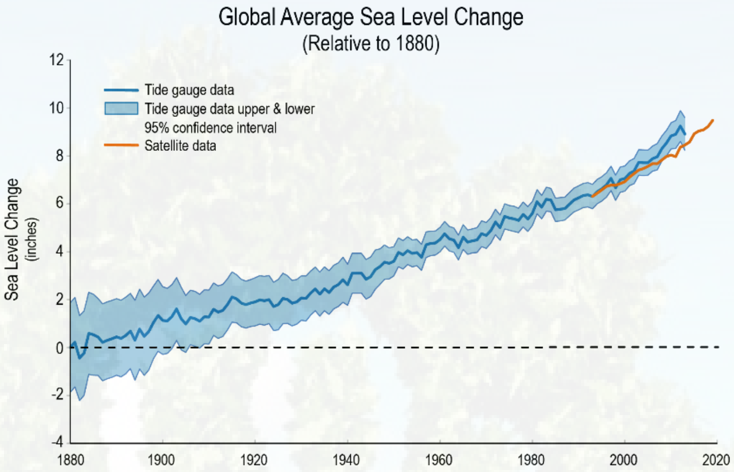
1. Background

Temperature Rise



The global average temperature has increased by 1.1 C since Industrialization, and will continue to increase at a rapid rate.

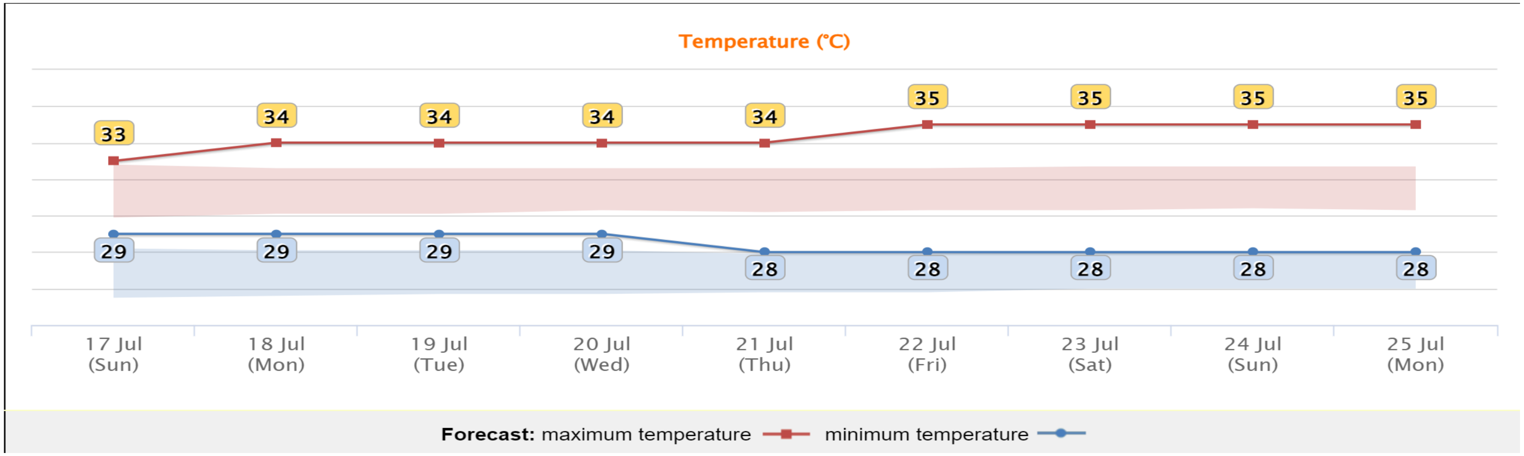
Sea levels Increase



The sea levels are currently rising at 3.4mm per year, and most models forecast a global sea-level rise 0.5-1.4 m by 2100

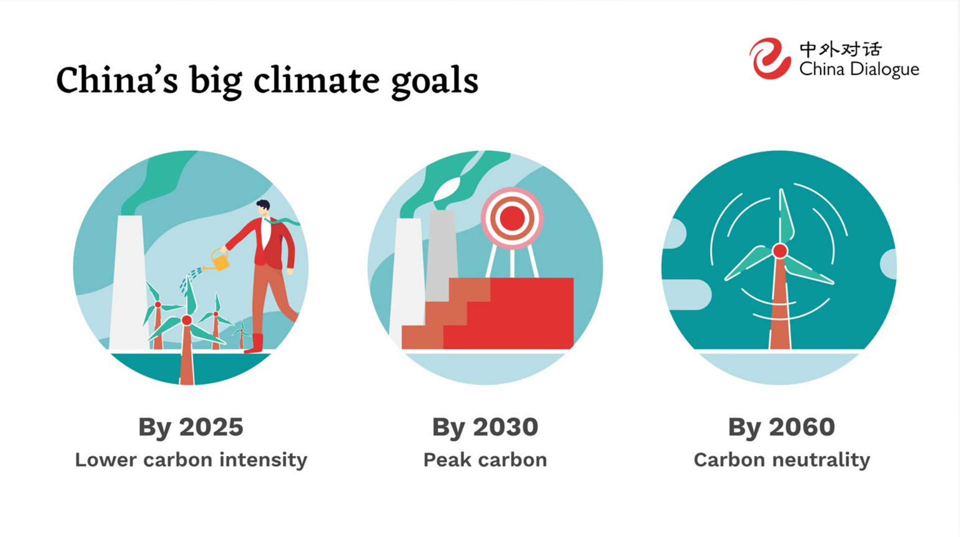
- **Threat to humanity if >1.5 C**

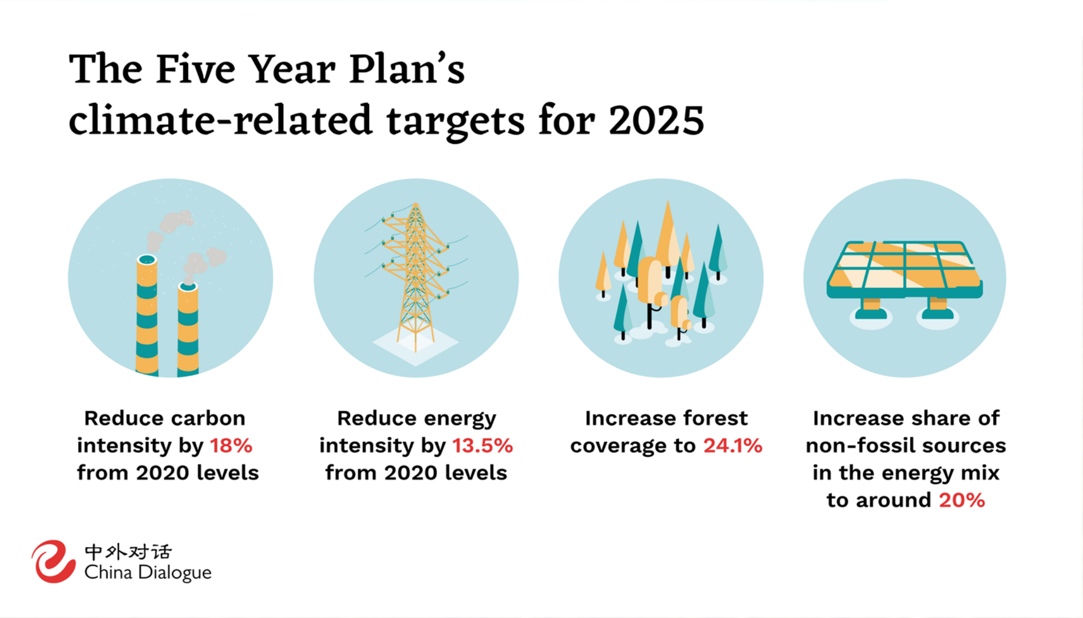
Temperature in Hong Kong July 2022



Situation in Europe July 2022

National Policy 14-5 Plan





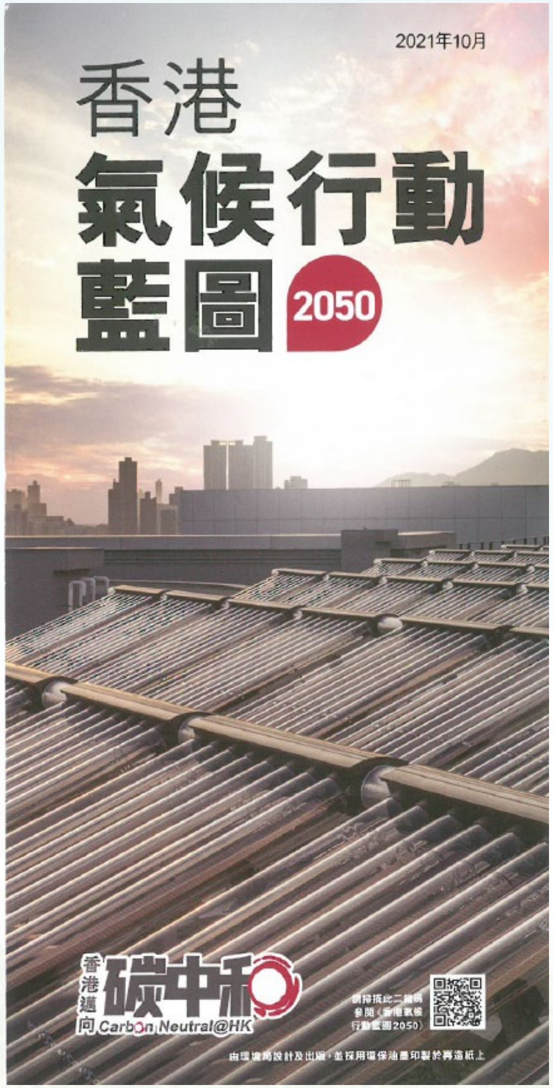
Background

- The 2020 Policy Address announced that Hong Kong would strive to achieve carbon neutrality before 2050. HK is moving towards the 2030 target of reducing carbon intensity by 65% to 70% compared to 2005 based on Hong Kong's Climate Action Plan 2030+.

Government Strategies

2021政府公布《香港氣候行動藍圖2050》

News, Gov.hk, Carbon neutrality strategies in place, https://www.news.gov.hk



Waste Reduction

Waste accounted for about 7% of total carbon emissions in 2019. Developing waste-to-energy facilities and promoting waste reduction and recycling will enable us to move away from reliance on landfills for municipal waste disposal

Waste Blueprint for Hong Kong 2035

2035

Implement the Waste Blueprint for Hong Kong 2035 to realise the vision of "Waste Reduction · Resources Circulation · Zero Landfill"

Municipal Solid Waste Charging

2023

Prepare for implementation of waste charging, encourage waste reduction and recycling, and strengthen community facilities and support

Regulation of Disposable Plastic Tableware

2025

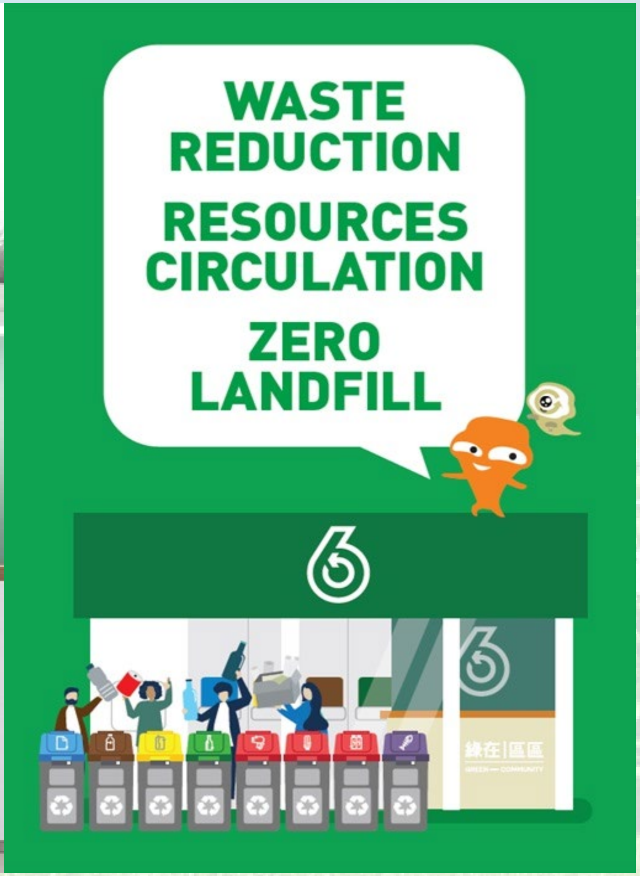
Regulate disposable plastic tableware, etc. in phases, reduce plastic at source

Waste-to-energy

2035

Develop adequate waste-to-energy facilities, move away from reliance on landfills for municipal waste disposal

HK Government Policy



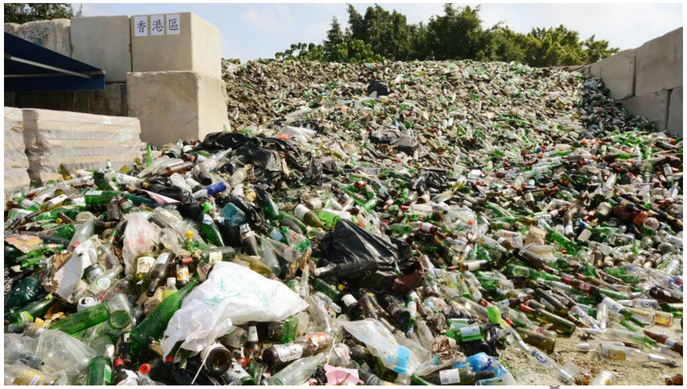
New HK Government initiatives

Set up an Office of Climate Change and Carbon Neutrality to co-ordinate actions under the "Hong Kong's Climate Action Plan 2050"

Make preparations to implement municipal solid waste charging effectively

Introduce a new producer responsibility scheme on plastic beverage containers and regulate disposable plastic tableware

Legco greenlights bill to tax glass bottle makers
3 Nov 2022



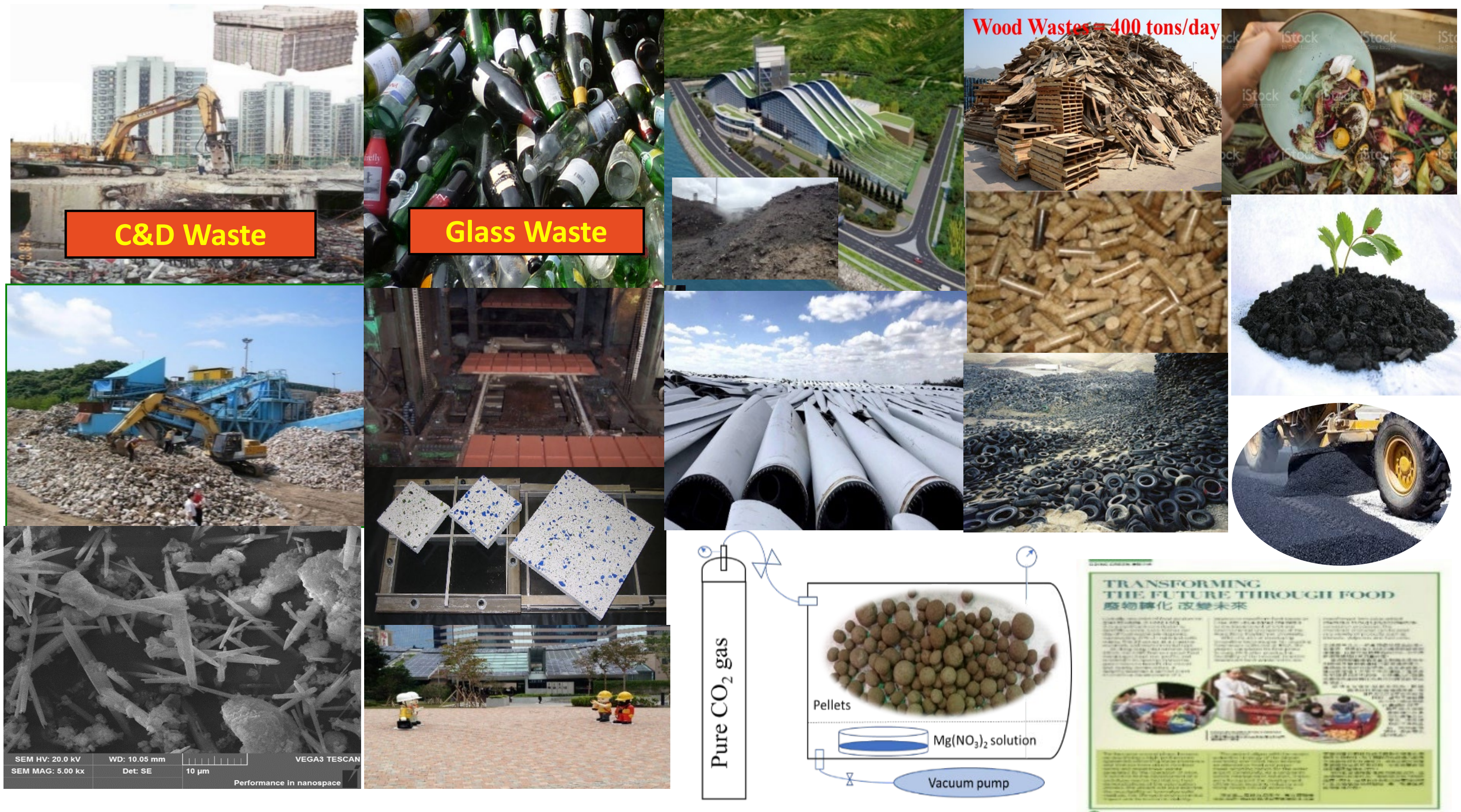
Vision of RCRE

- Establish HK PolyU as a forefront global research institution in solid waste recycling issues.
- Support the Hong Kong Government's policy in achieving carbon neutrality in 2050 and minimizing waste required to be disposed of at landfills.
- Support the Hong Kong and Central Governments initiatives in promoting Hong Kong and the Greater Bay Area as models of Resources Engineering towards Circular Economy.

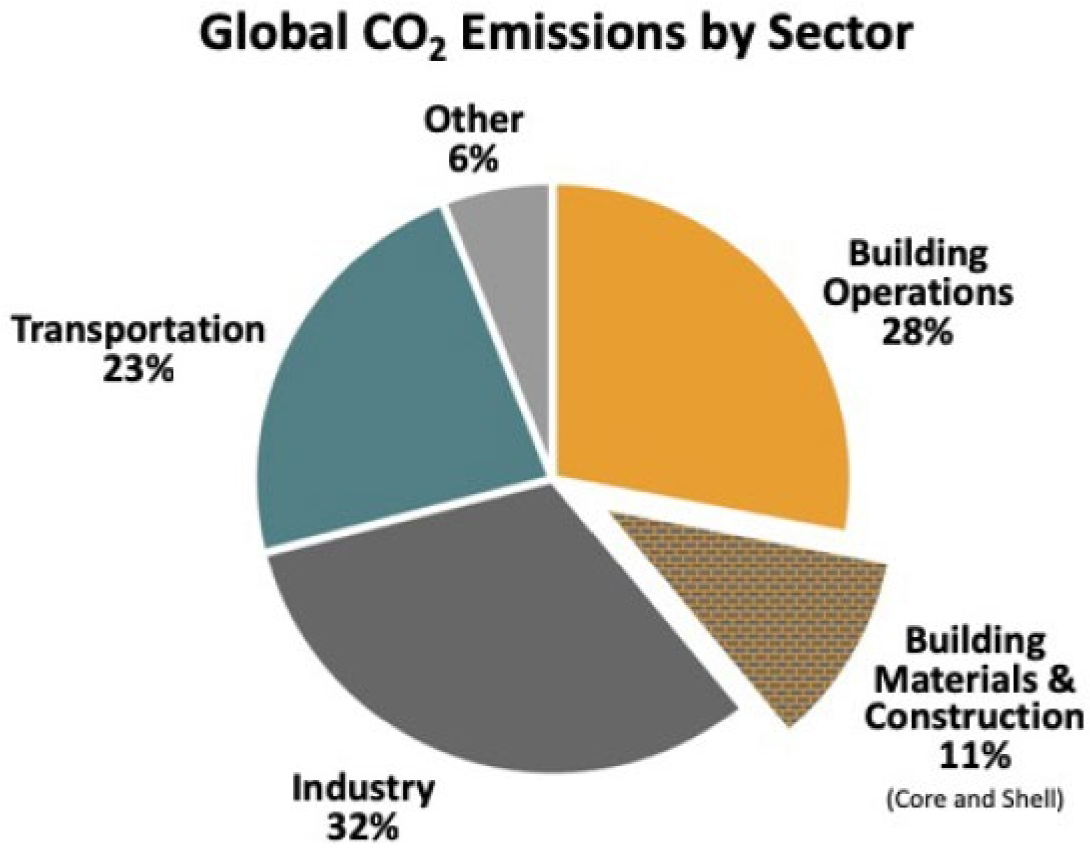
Research Directions

- **Policy and social** perspective studies;
- **Environmental and financial impact** studies;
- **Waste valorization technology** studies :
  - *Biological waste – food waste, wood waste and algae*
  - *Valued added materials derived from construction and demolition waste via CO_2 sequestration*
  - *Rubberized asphalt*
  - *Waste incineration residues*
  - *Other wastes with strategic importance for HK and the mainland (e.g. waste glass and mining waste).*

Research at PolyU RCRE in Turning Wastes to ECO Products

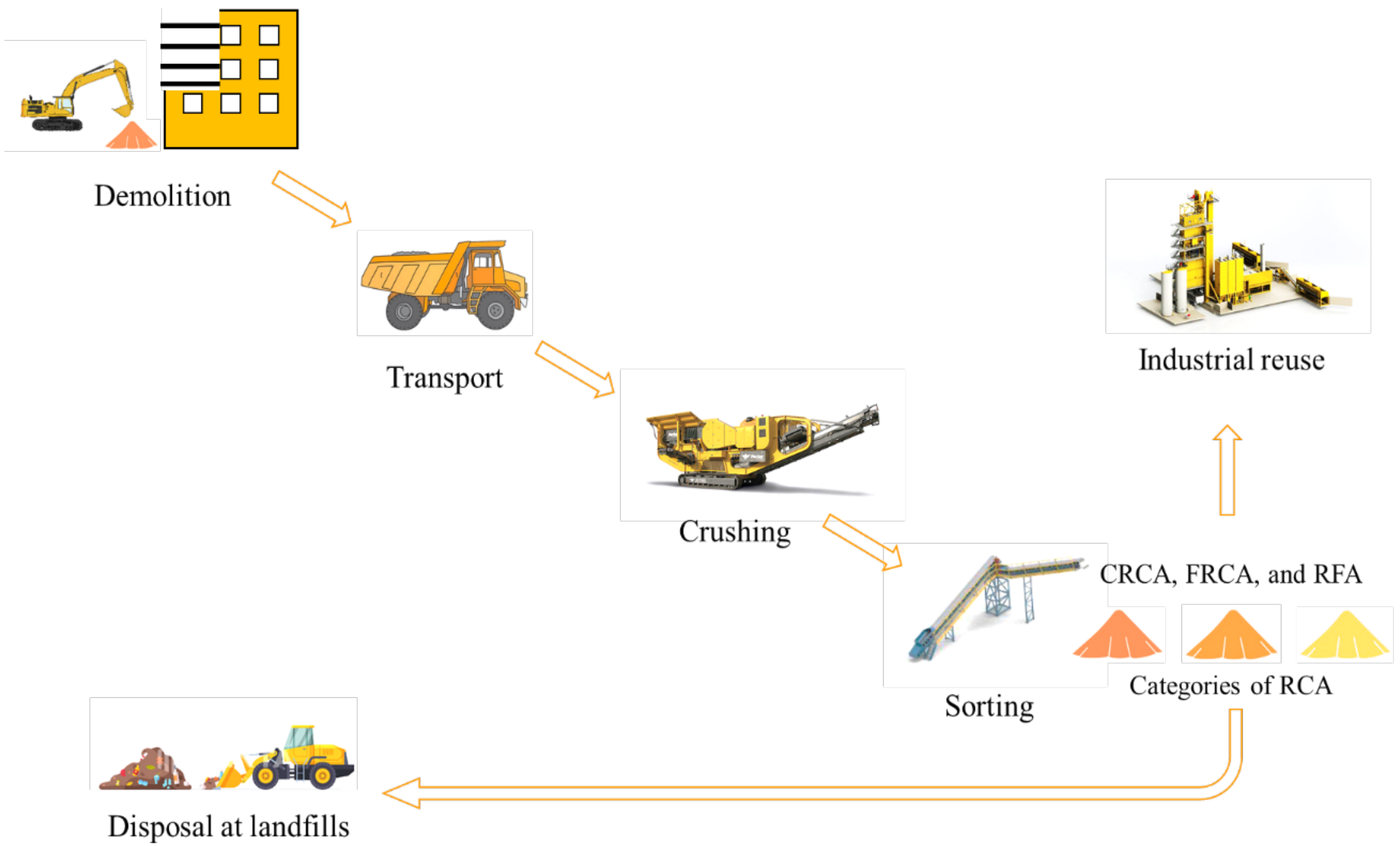


Carbon Emissions by Sector



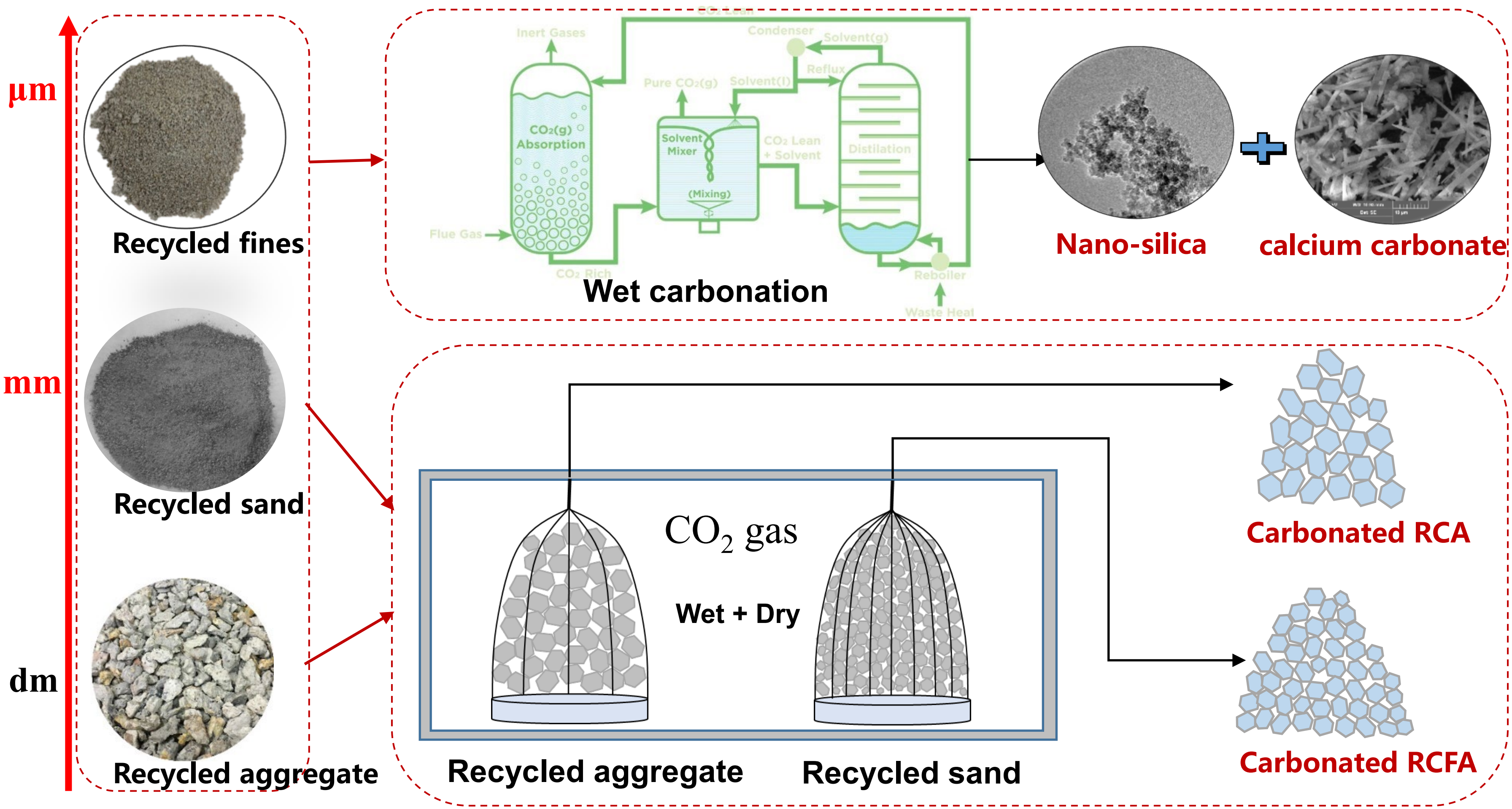
https://www.serverfarmllc.com/sustainability/modernization-vs-new-build-data-centers/

Material Flow of Demolition of Concrete Structures



CRCA-coarse recycled aggregate
FRCA- fine recycled aggregate
RFA- recycled fine powder

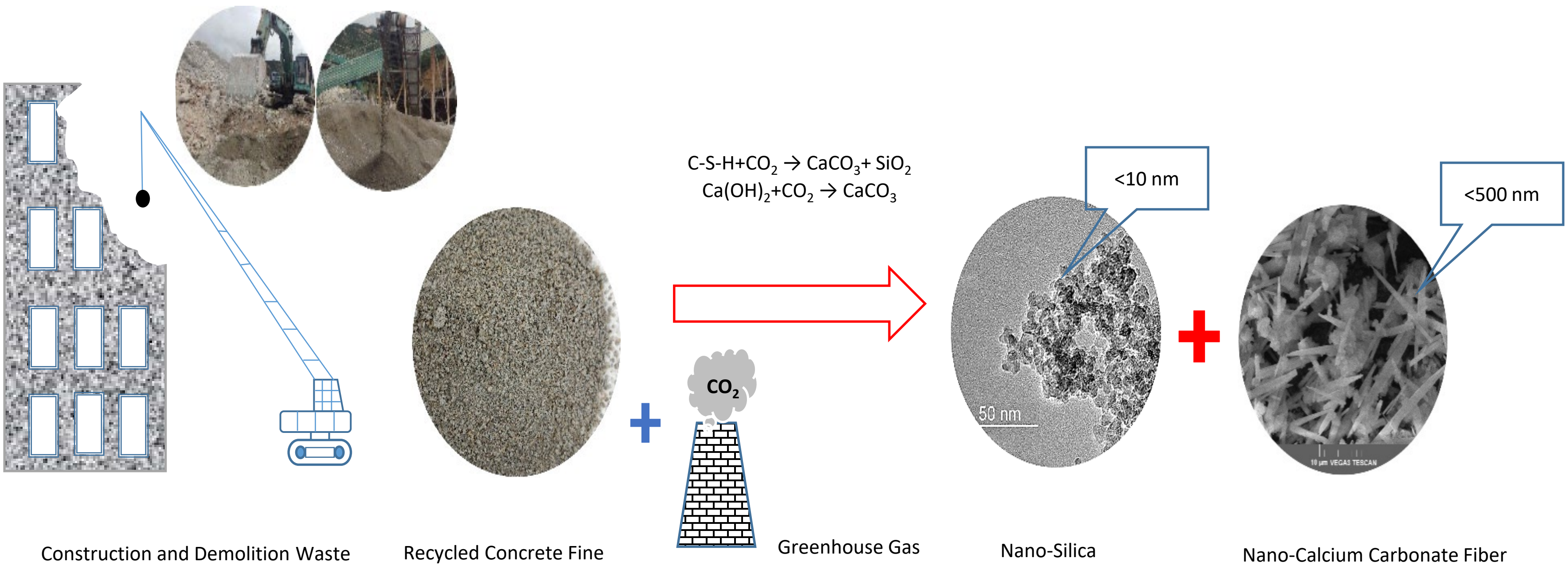
1.1 Accelerated carbonation for total recycling of C&D waste



- **Different accelerated carbonation strategies were designed for different sizes of waste**

*BJ Zhan, DX Xuan, CS Poon, KL Scrivener, **Cement and Concrete Research**, 2021, 144, 106448*
一种利用废弃混凝土砂粉制备纳米二氧化硅的方法，Chinese Patent 2021030235109.

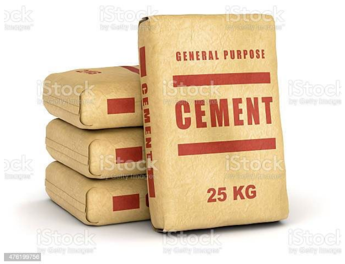
Carbonation of recycled aggregates to produce nano construction materials



一种利用废弃混凝土砂粉制备纳米二氧化硅的方法，Chinese Patent 2021030235109.

Shen Peiliang, Jian-xin Lu, Poon C. S. (2021). ***Cement and Concrete Research****, 106526;*
Multi-scale investigation on mechanical behavior and microstructural alteration of CSH in carbonated Alite paste
BJ Zhan, DX Xuan, CS Poon, KL Scrivener, ***Cement and Concrete Research****, 2021, 144, 106448,*
Characterization of interfacial transition zone in concrete prepared with carbonated modeled recycled concrete aggregates, BJ Zhan, DX Xuan, CS Poon, KL Scrivener, ***Cement and Concrete Research****, 2020, 136, 106175*
Mechanism for rapid hardening of cement pastes under coupled CO2-water curing regime, BJ Zhan, DX Xuan, CS Poon, CJ Shi, ***Cement and Concrete Composites****, 2019, 97, 78-88*

Supplementary Cementitious Materials in Concrete



High environmental impacts/CO_2 emission

SCMs → Fly ash | Granulated blast furnace slag | Silica fume

Construction sustainability

GGBS and PFA Concrete

55% GGBS

115kg CO_2/ton

↓

60kg CO_2/ton

30% PFA

115kg CO_2/ton

↓

85kg CO_2/ton

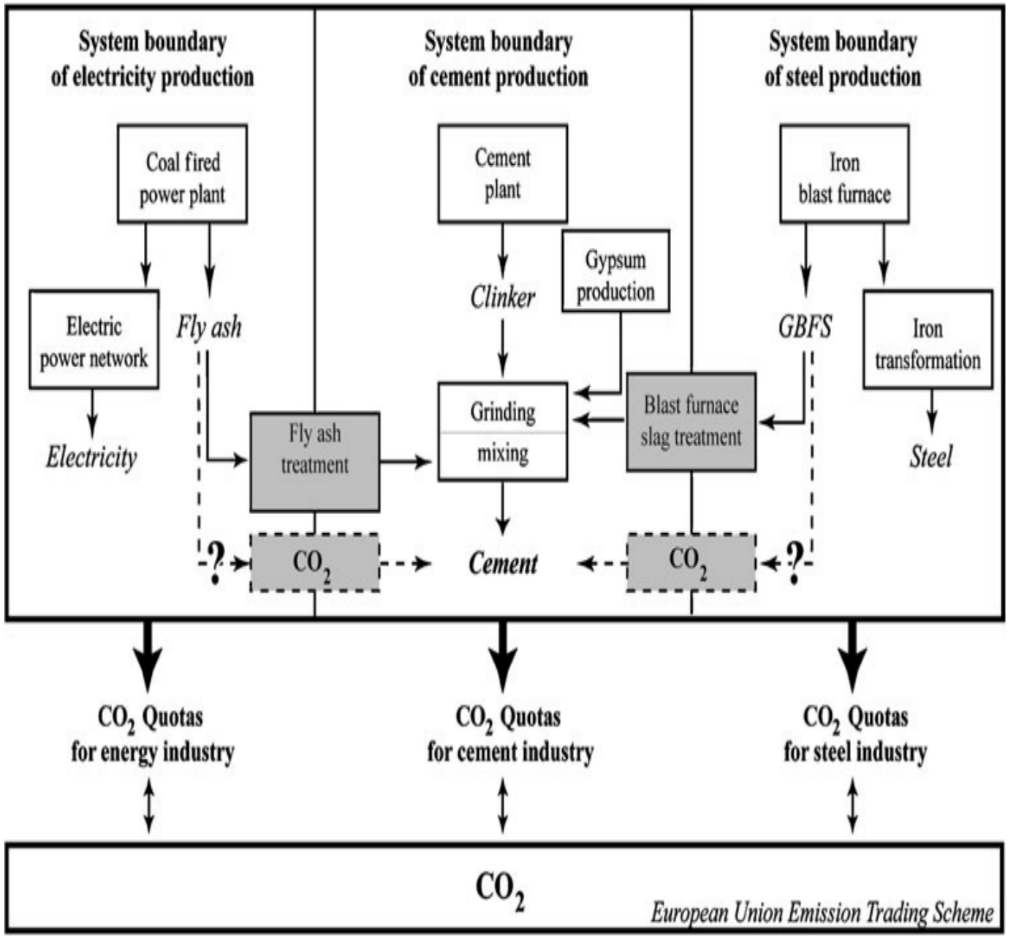
LCA of Supplementary Cementitious Materials

SCMs are waste or by-products?

According to Directive of the European Union, a substance or object can be regarded as a co-product or by-product (rather than waste), if it fulfills the following conditions:

1. It further use is certain,
2. It can be used directly without any further processing other than normal industrial practices,
3. It is produced as an integrated production process, and
4. It will not lead to adverse environmental or human health impacts

(EU Directive 2008)



LCA of Supplementary Cementitious Materials

According to ISO, when a production system produces more than one product, it is necessary to attribute an environmental burden to each product.

As GGBS and PFA met the above criteria, they should NOT be considered as waste!!!!

THUS, the environmental impacts (e.g., CO_2 emission) of such materials SHOULD follow the proper LCA methodology (ISO, 2006), rather than so-called "WASTE"

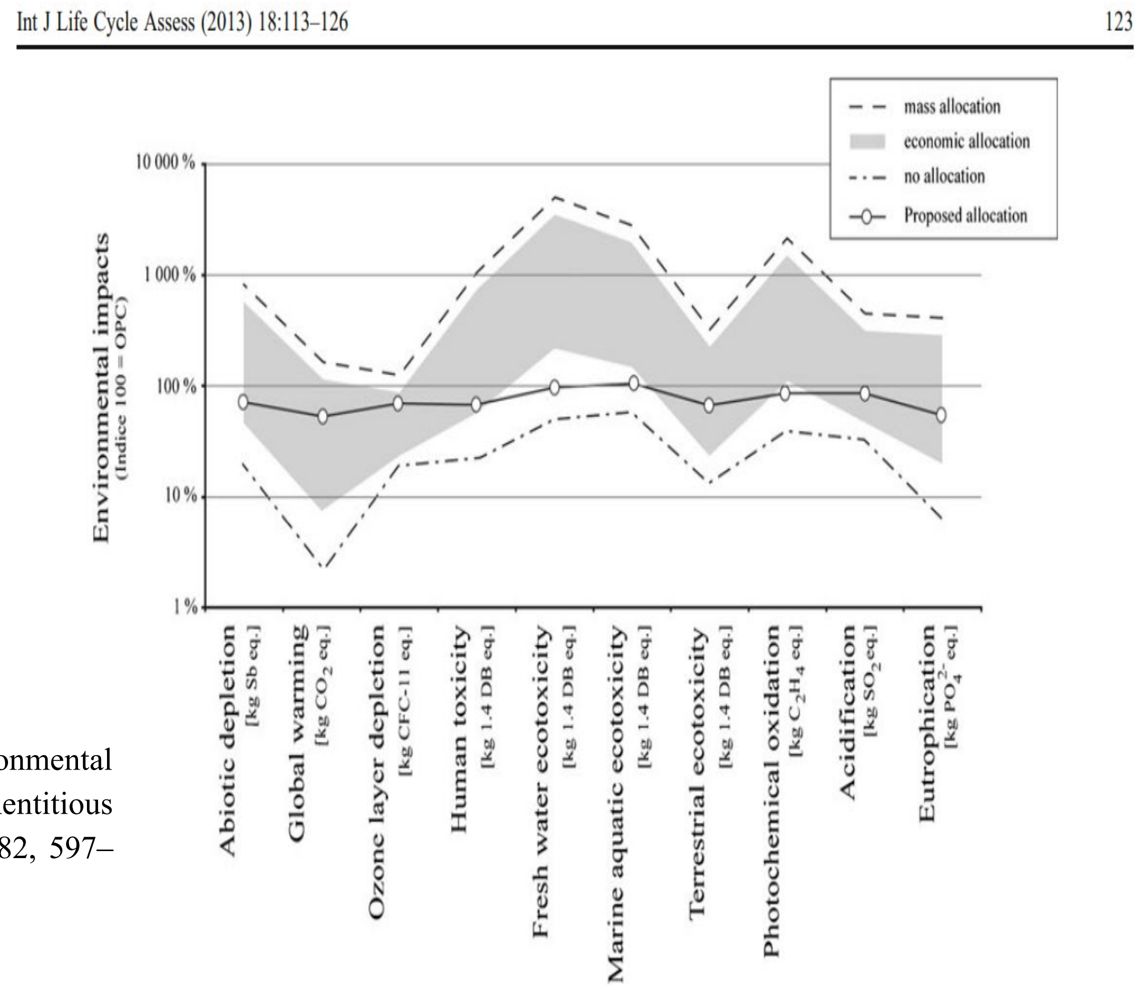
LCA of Supplementary Cementitious Materials

According to ISO 14044 environmental impact of by-products should be distributed:

System expansion approach

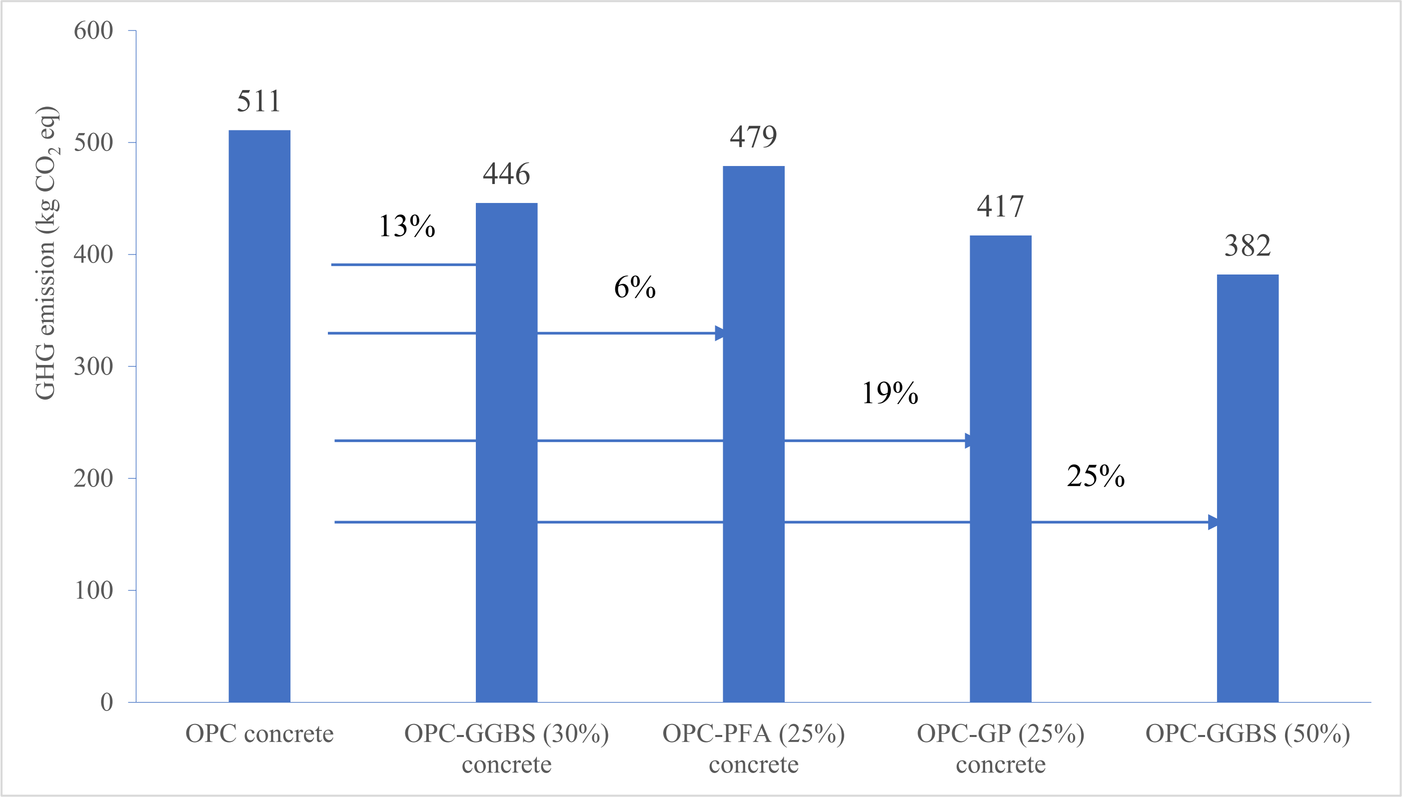
1. Allocation by mass
2. Allocation by economic values

M.U. Hossain, C.S. Poon, Y.H. Dong (2018). Environmental impact distribution methods for supplementary cementitious materials. *Renewable and Sustainable Energy Reviews* 82, 597–608.



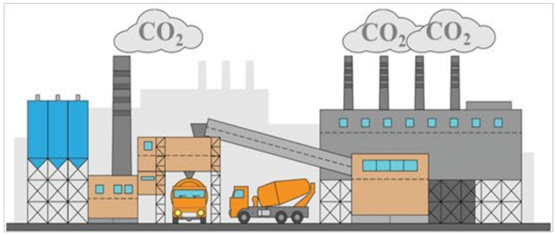
Guillaume Habert, 2013

GGBS, PFA and GP Concrete for HK



Decarbonisation using waste glass

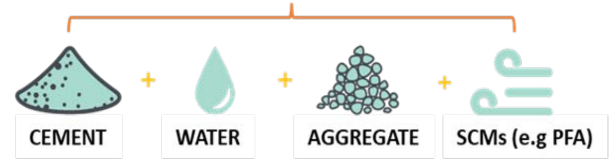
- **Cement** is one of the largest sources of building material-related CO_2 emissions. Globally, total cement production is responsible for around **8% CO_2** emissions.



High CO_2 emissions of cement production

Concrete production

High CO_2 embodied energy



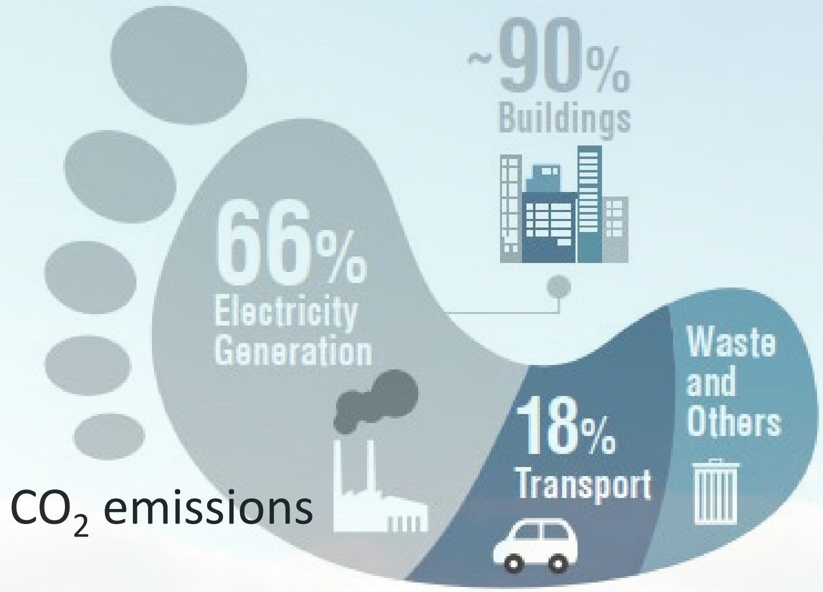
Development of low-carbon local alternatives for cement & aggregates & PFA

Technology and strategy for low-carbon materials

Substitutions of cement & aggregates for production of construction materials

- The reuse of waste glass can reduce embodied carbon of construction materials and produce high performance low-carbon construction products.

Decarbonisation using waste glass



Hong Kong Carbon Emission Sources @ 2019

No Coal for Electricity Generation

Cease using coal for daily electricity generation, to be replaced by low to zero-carbon energy

Electricity saving in making cement

Seeking alternative pozzolanic materials

Valorization of Waste Glass in Low Carbon Cement

HK waste glass

Milled →

Glass powder

Replace →

Cement

Ordinary Portland Cement

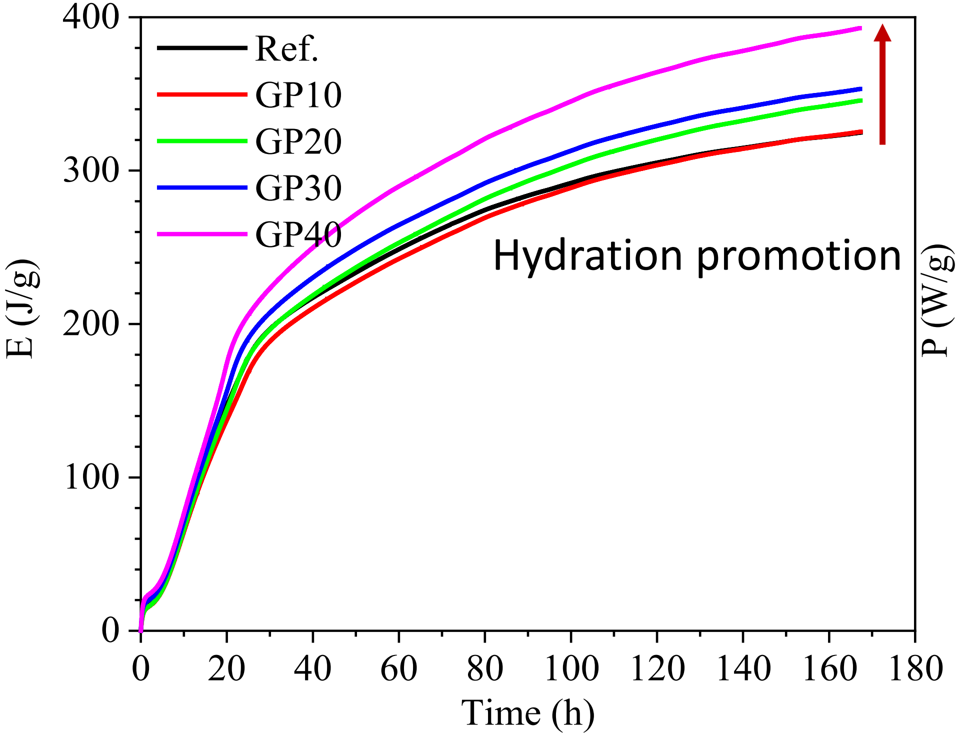
Clinker	+ Limestone	+ Gypsum
~90%	~5%	~5%

Waste glass powder (20~30%)

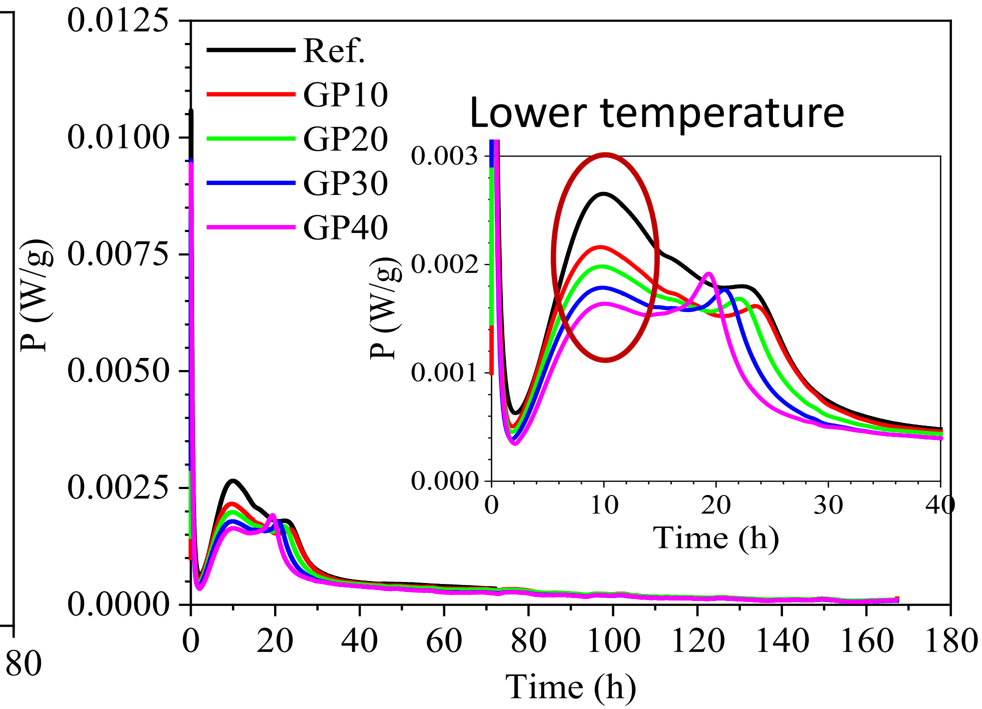
Replace Fly Ash

Advantages of low carbon cement

Hydration heat of cement



Hydration heat rate of paste



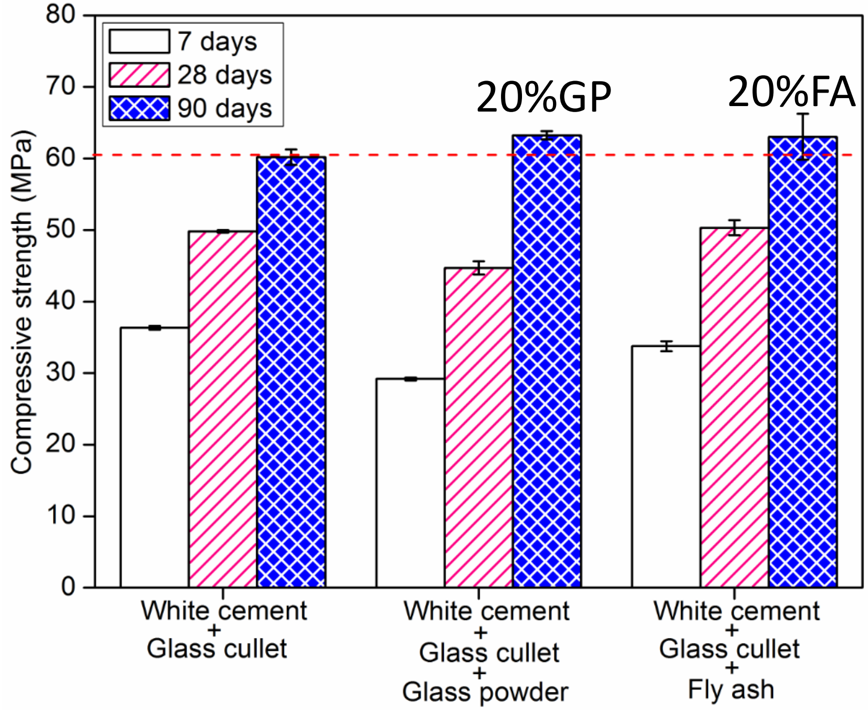
✓ **The use of GP promoted the cement hydration and the low carbon glass cement had lower heat peak than pure cement.**

J.X. Lu, C.S. Poon, Construction and Building Materials 131 (2017) 793–799.

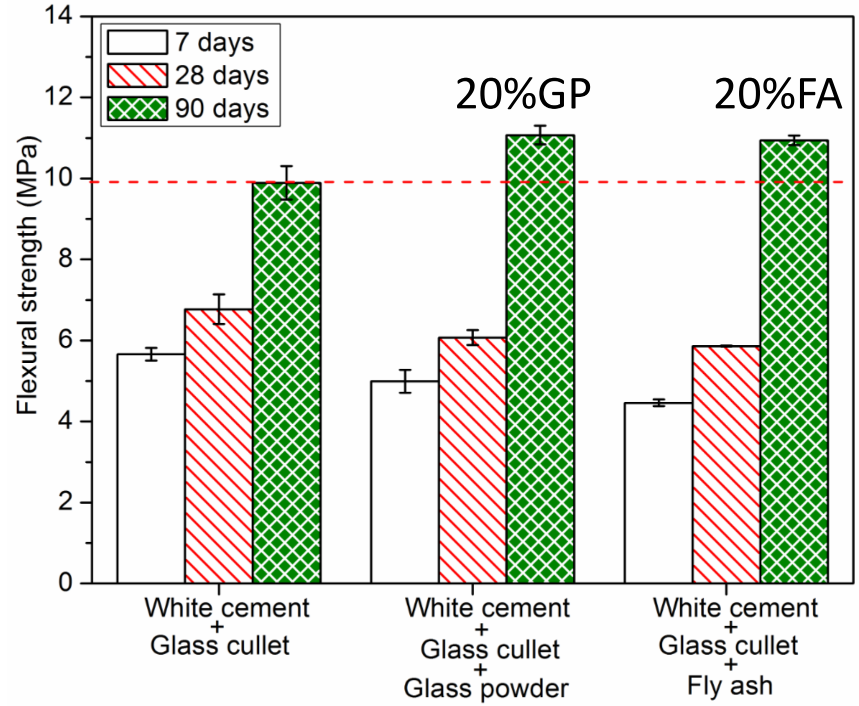
Advantages of low carbon cement

❖ The waste glass powder will be used as a partial replacement of cement, with a view to reducing the consumption of cement, cost and CO_2 emission.

Compressive strength



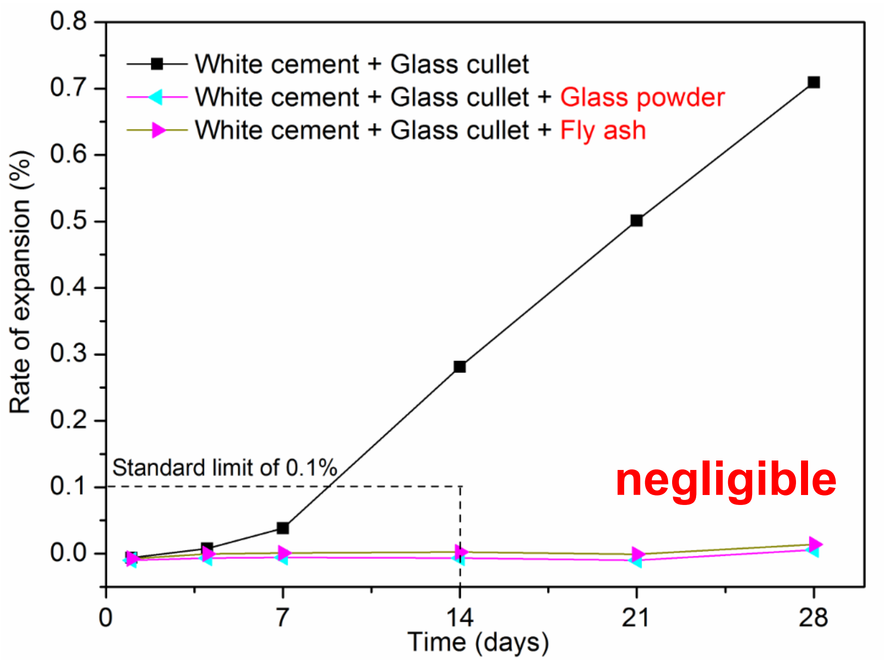
Flexural strength

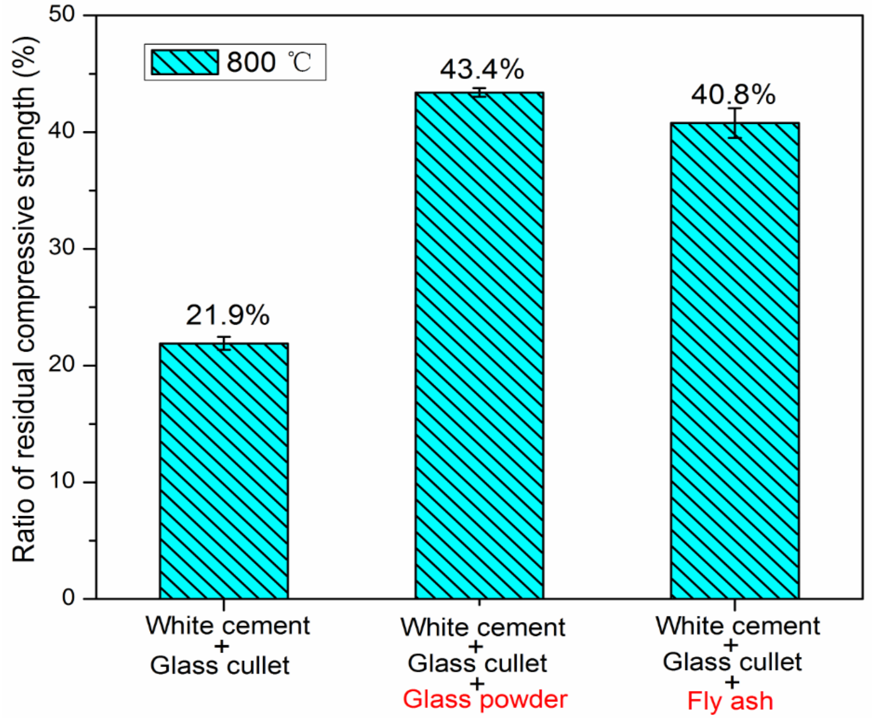


✓ **Low carbon glass cement had similar strength to pure cement and fly ash cement.**

J.X. Lu, C.S. Poon, Cement and Concrete Composites 82 (2017) 34e44.

Advantages of low carbon cement





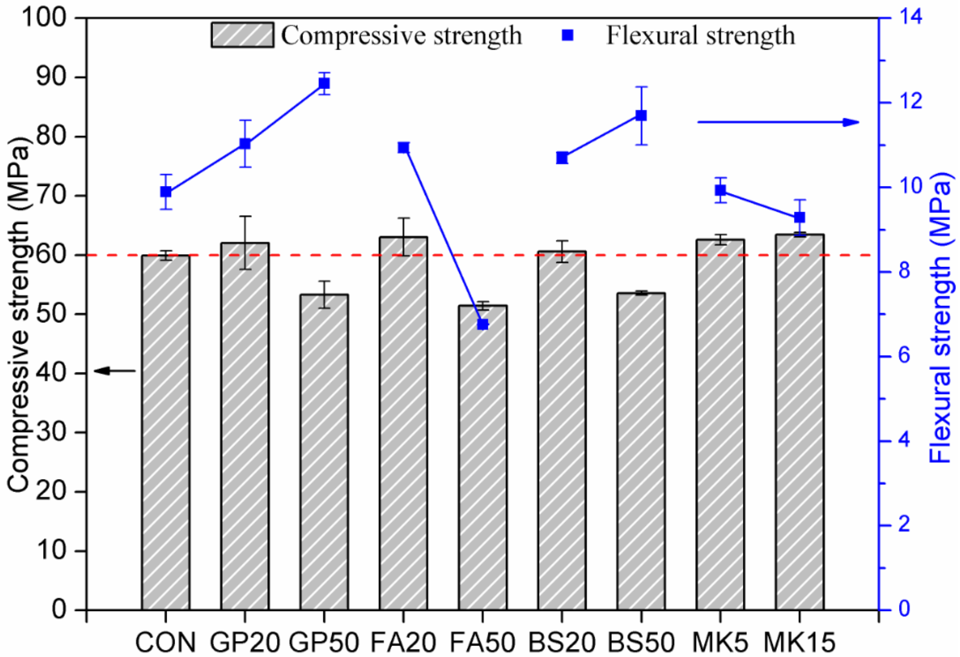
✓ **Low carbon glass cement had good durability in terms of ASR and fire resistance.**

J.X. Lu, C.S. Poon, Materials and Design 135 (2017) 102–111.

Advantages of low carbon cement

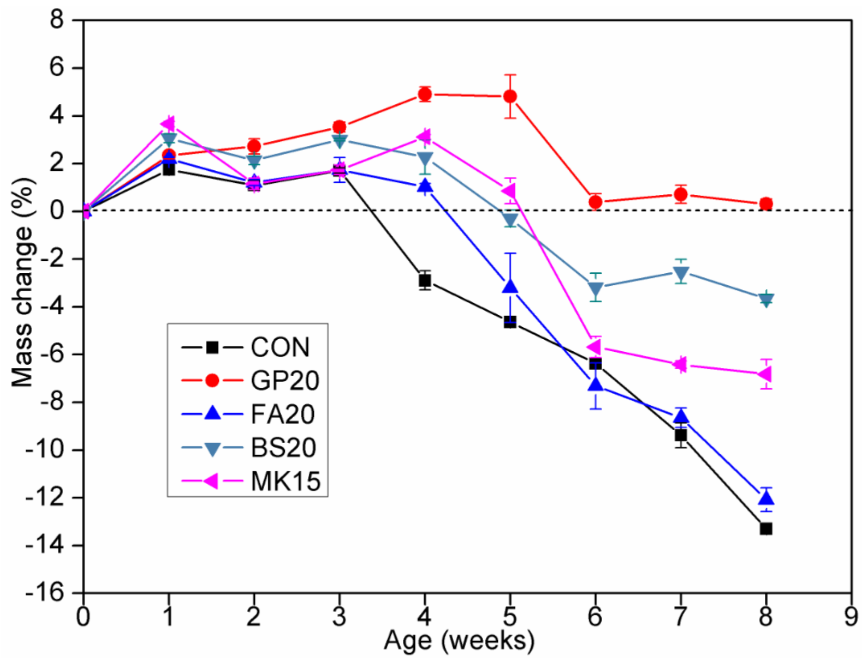
Compared to other pozzolanic materials

Strength



GP PFA Slag Metakaolin

Acid resistance



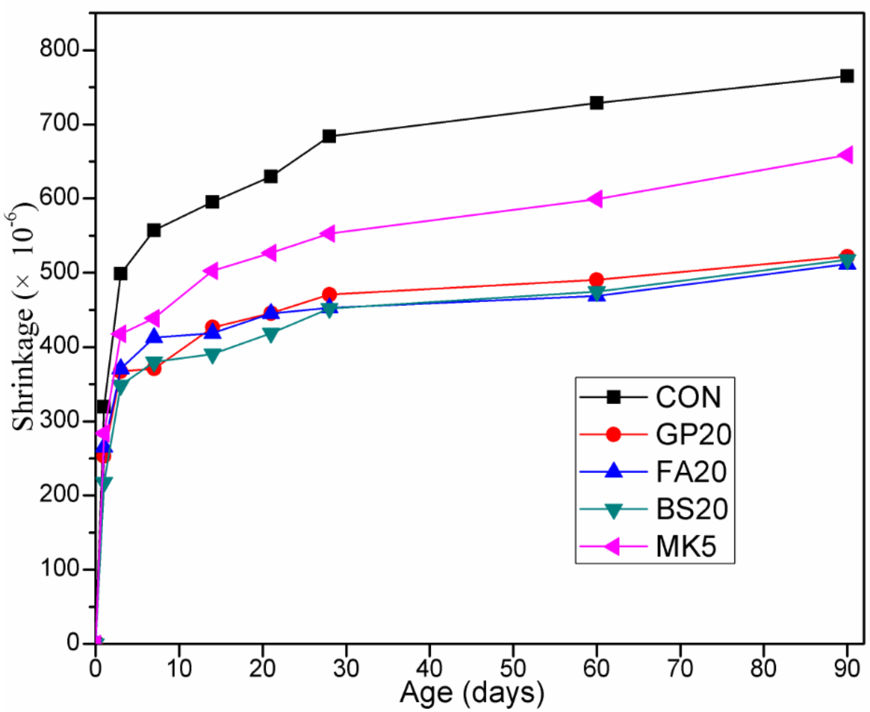
✓ **Waste glass powder led to comparable strength with other pozzolanic materials.**

J.X. Lu, C.S. Poon, Construction and Building Materials 153 (2017) 975–985.

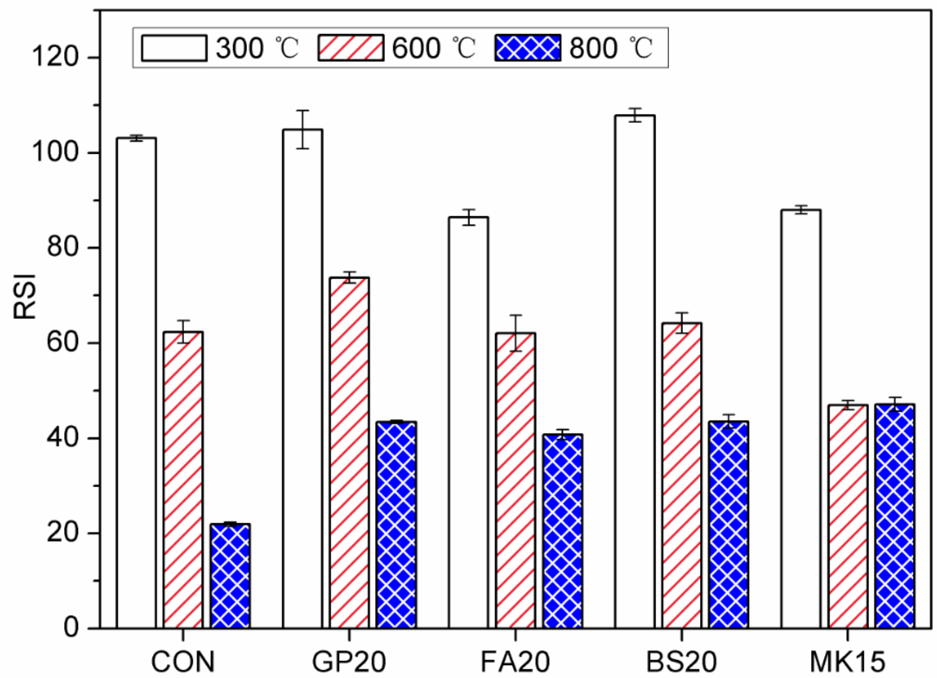
Advantages of low carbon cement

Compared to other pozzolanic materials

Drying shrinkage



Fire resistance

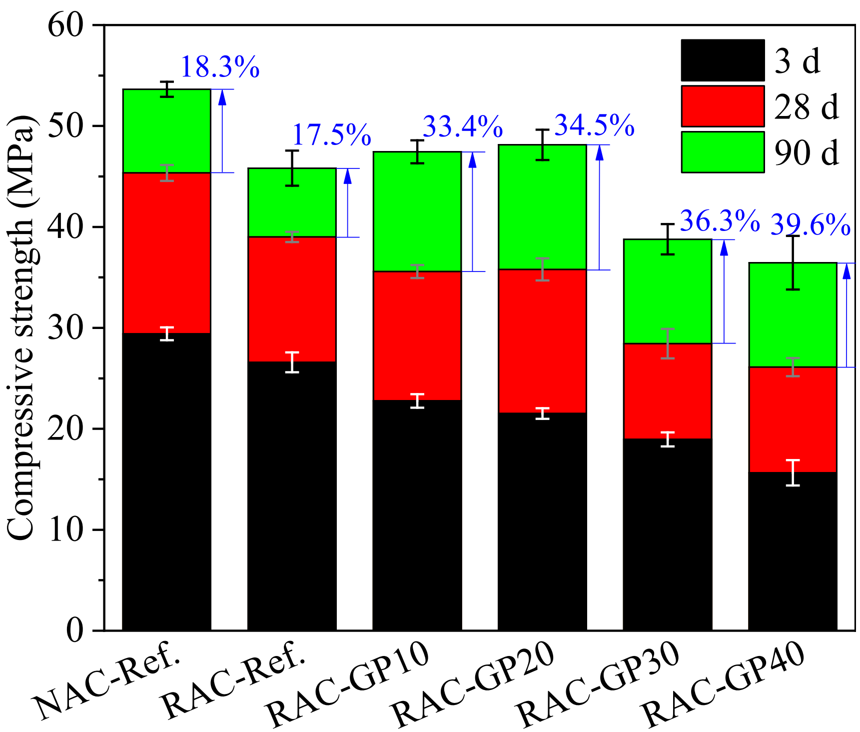


✓ **Low carbon glass cement had comparable durability with other pozzolanic materials cement**

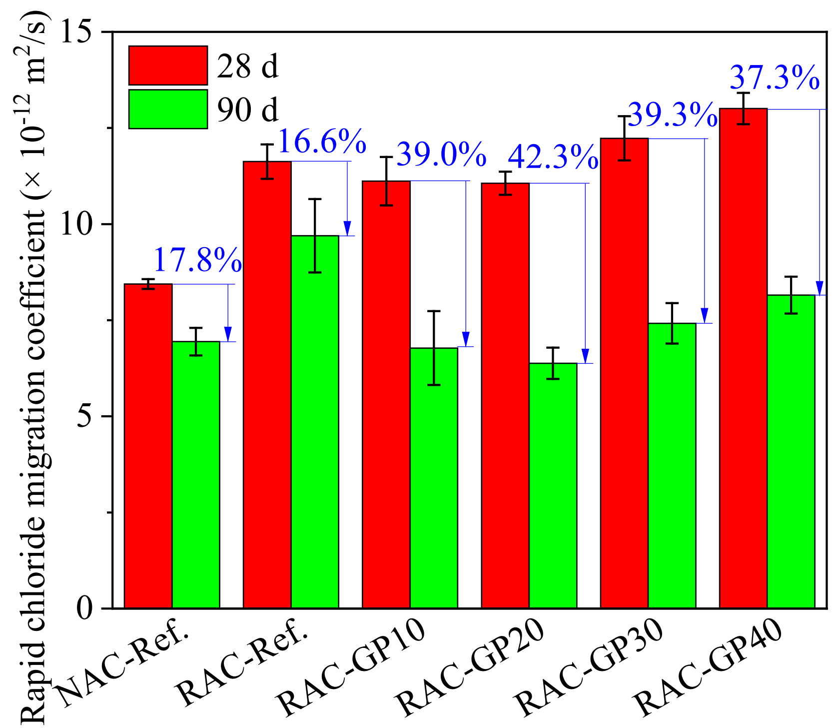
J.X. Lu, C.S. Poon, Construction and Building Materials 153 (2017) 975–985.

Advantages of low carbon cement

❖ **Chloride penetration resistance of GP-RAC (GP + recycled concrete aggregates)**



Mechanical strength



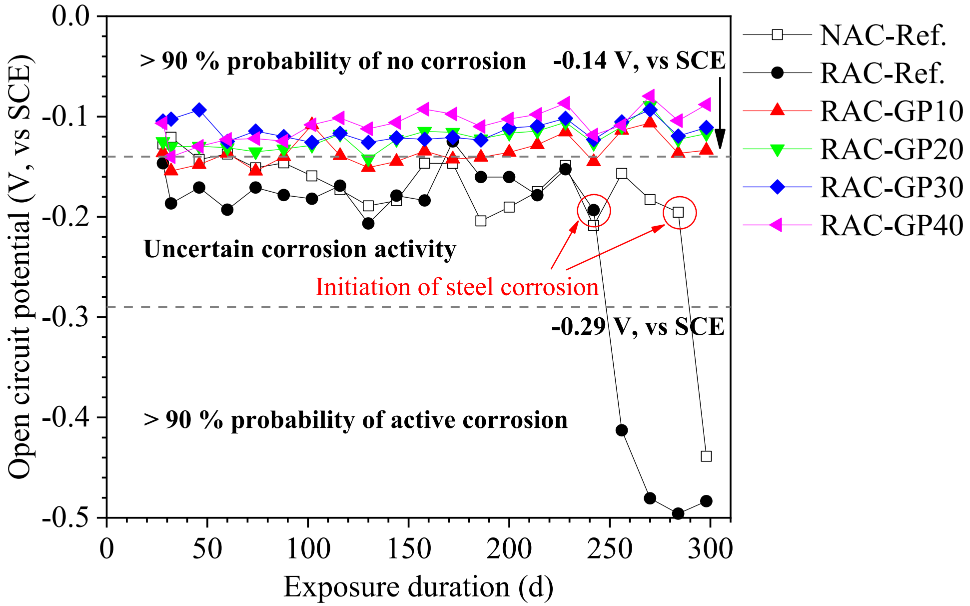
Permeability

- ❑ The compressive strength of GP-RAC achieved a significant increase at late age.
- ❑ The chloride penetration resistance was largely improved by using GP.

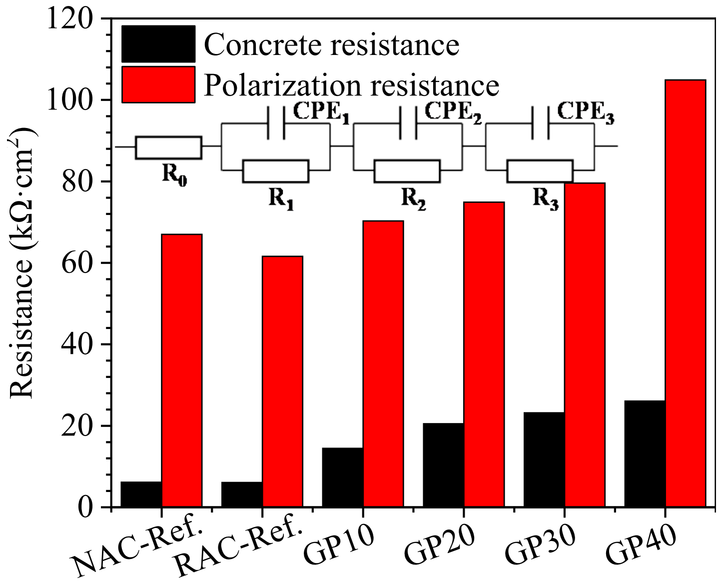
A/B=5.6, W/B=0.5

Advantages of low carbon cement

Benefit of GP for steel corrosion prevention



Open circuit potential

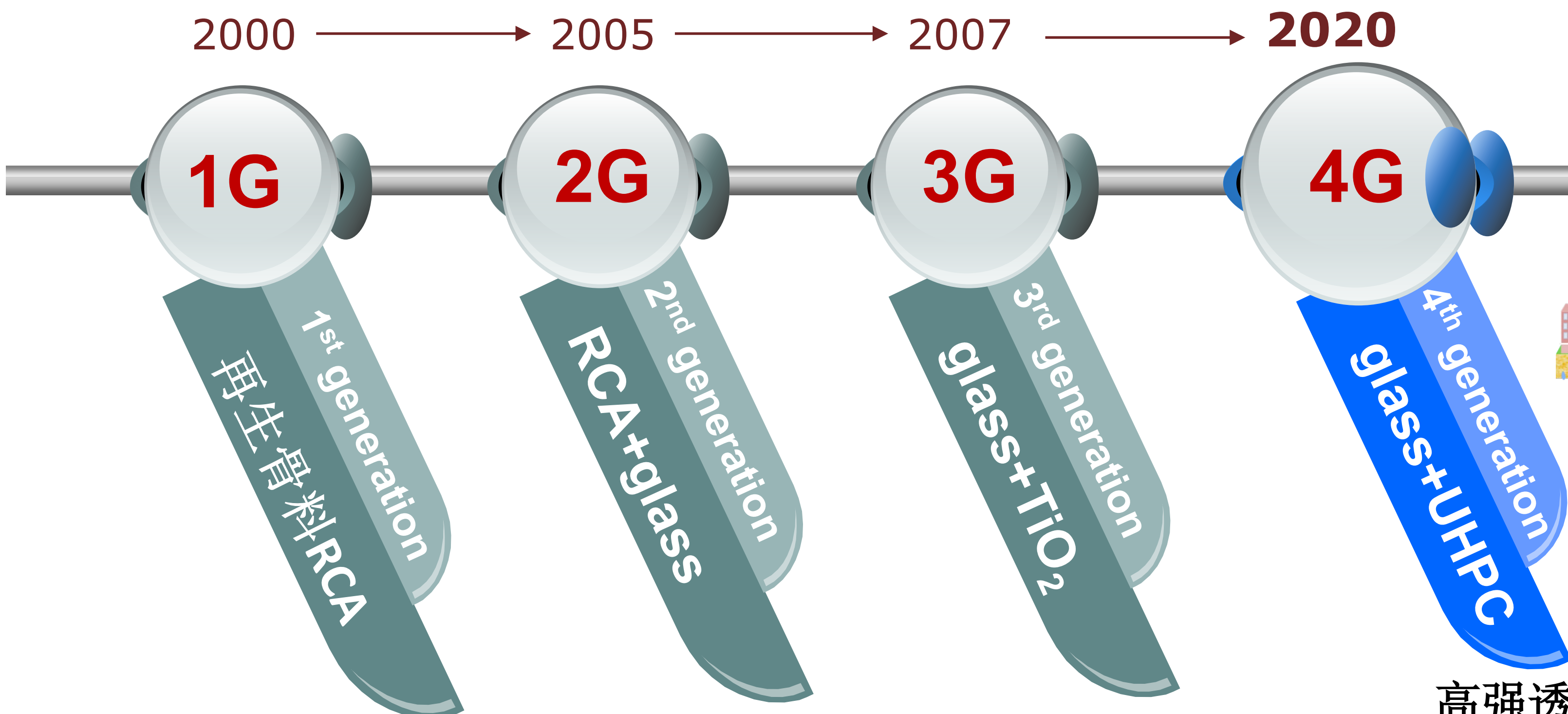


Polarization resistance

- The use of GP increased open circuit potential and polarization resistance, indicating the lower corrosion probability of concrete.
- The higher volume of GP led to a lower corrosion probability even though the compressive strength was lower.

Cleaner production with waste glass

Dry-mixed glass concrete




Sponge City

高强透水混凝土

1) T.C. Ling et al., Resources, Conservation and Recycling, 2013
2) P. Shen et al., Cement and Concrete Composites, 2020
3)Patent: 陆建鑫，申培亮，潘智生. 固碳型多功能高强透水混凝土及其制备方法和路面, 202110723100.7

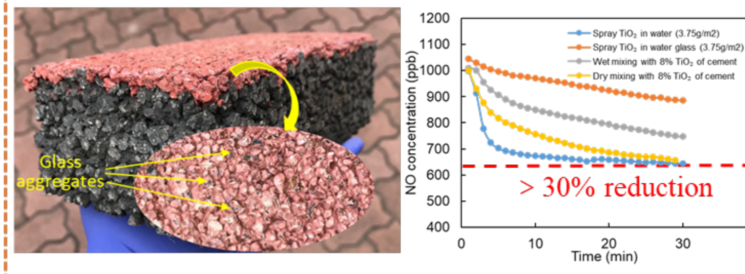
Low carbon glass cement products

Sustainable Permeable Concrete for Urban Drainage

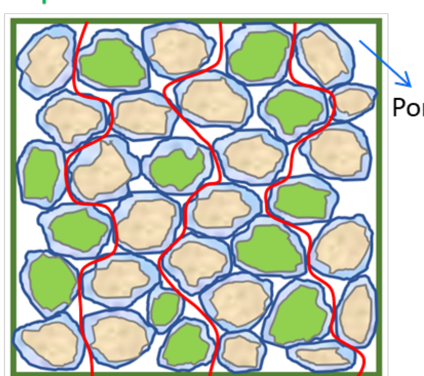
香港綠色創新大獎
Hong Kong Green Innovations Awards

Eco-permeable concrete

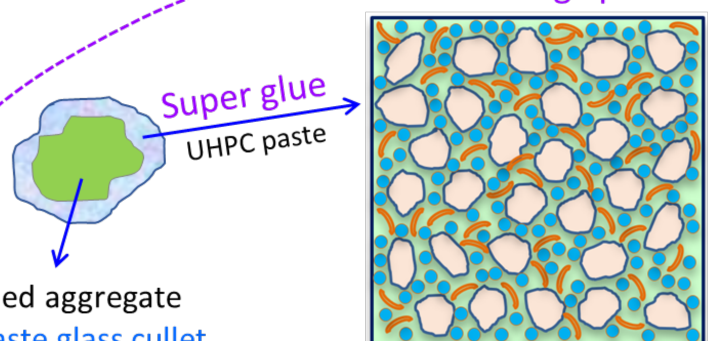
1. Aesthetic surface with photocatalytic effect



2. High-performance permeable sub-base



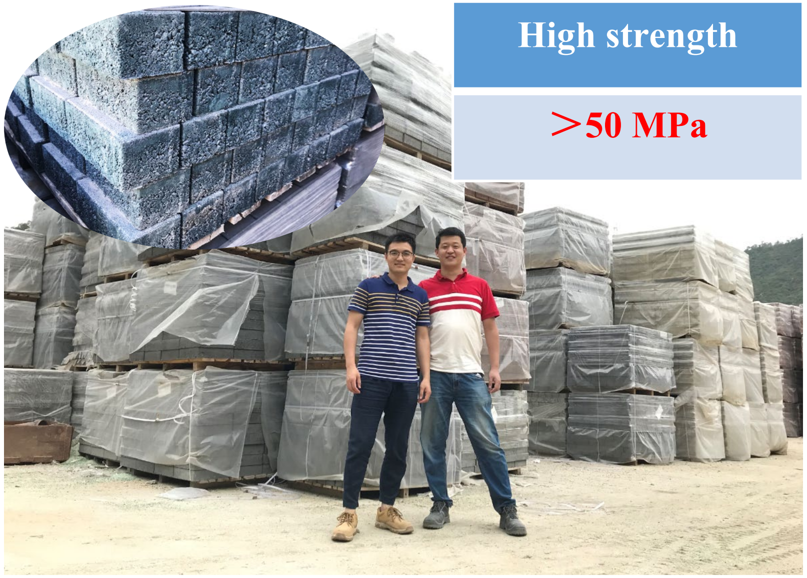
3. Glass ultra-high performance concrete



Recycled aggregate
- Waste glass cullet
- Recycled concrete aggregates
- Waste incineration bottom ash

1) J.X. Lu, C. S. Poon, et al., Journal of Cleaner Production, 2019
2) P. Shen, J.X. Lu, C. S. Poon, et al., Cement and Concrete Composites, 2020
3) P. Shen, J.X. Lu, C. S. Poon, et al., Construction and Building Materials, 2021

Pilot-scale production in a local factory



Past: CIC 2015 Innovation Award

Carbon Neutral Construction Products Manufactured with Cement and Concrete Wastes

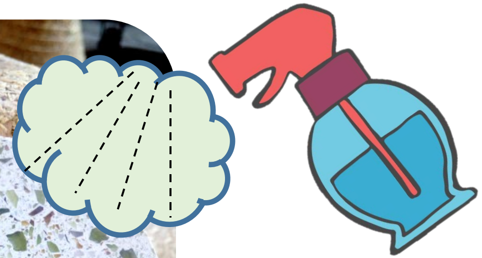
CIC Innovation Award 2015

The Hong Kong Polytechnic University and Gammon Construction Ltd.

THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學

Low carbon glass cement products

Architectural Product for Anti-virus (anti-COVID19)



Coating of antiviral agents

Benefits	Cleaning with disinfection agents	Antiviral Architectural Products
Chances of contamination to cleaner	High	Low
Sustainability	No	Eco-friendly
Maintenance effort	High	Low

1) J.X. Lu, C. S. Poon, et al., Cement and Concrete Composites, 2020
2) J.X. Lu, C. S. Poon, et al., Cement and Concrete Composites, 2018
3) J.X. Lu, C. S. Poon, et al., Materials and Design, 2017

✓ **Glass-based Architectural Tile： Anti-COVID19, Attractive appearance, Cost-effective, High-quality.**

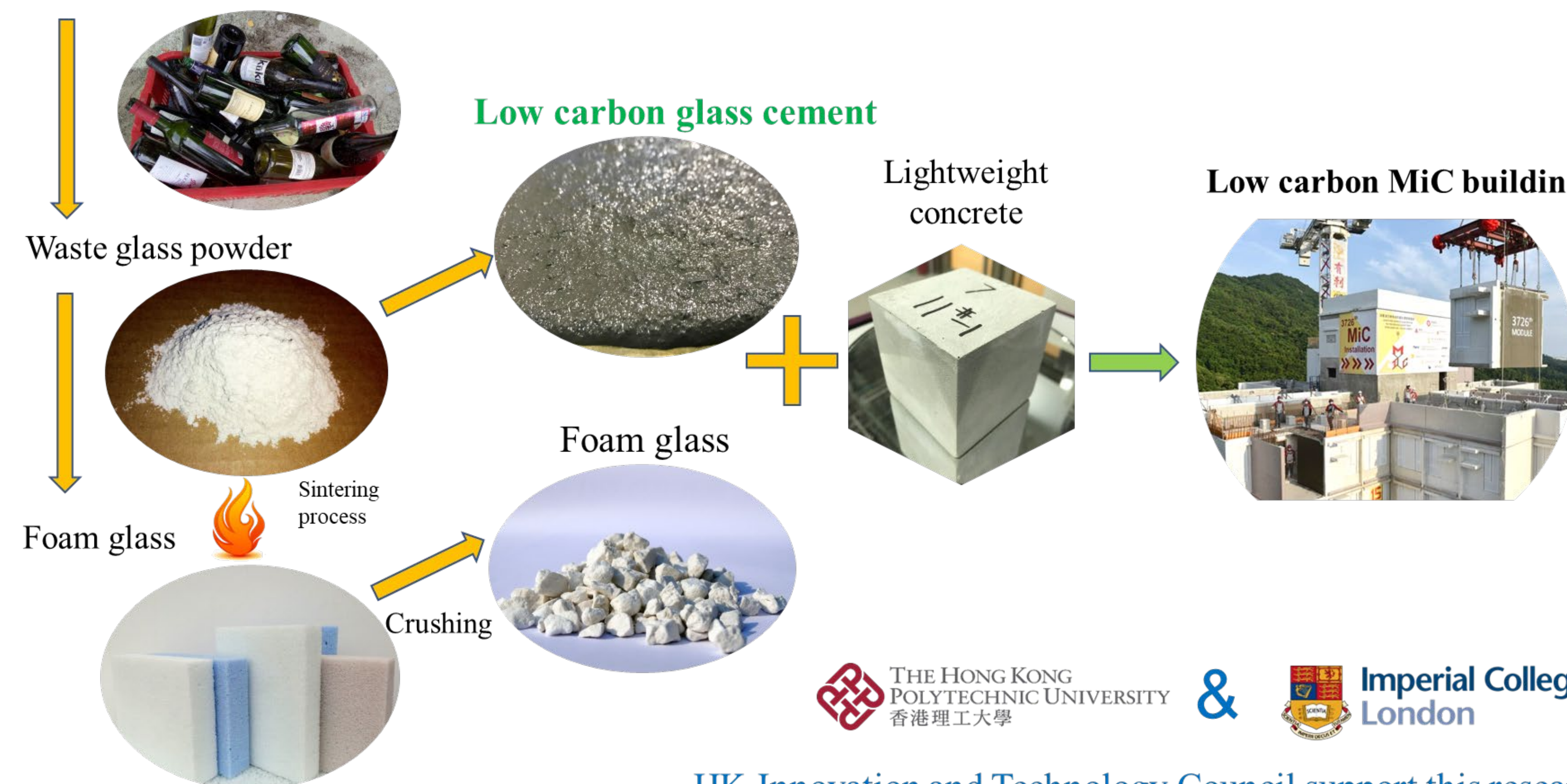
Green Innovations Award: Merit Award (2016) & Silver Award (2020)

Low carbon glass cement products

Permeability test video

Low carbon glass cement products

Low Carbon Lightweight Concrete for MiC

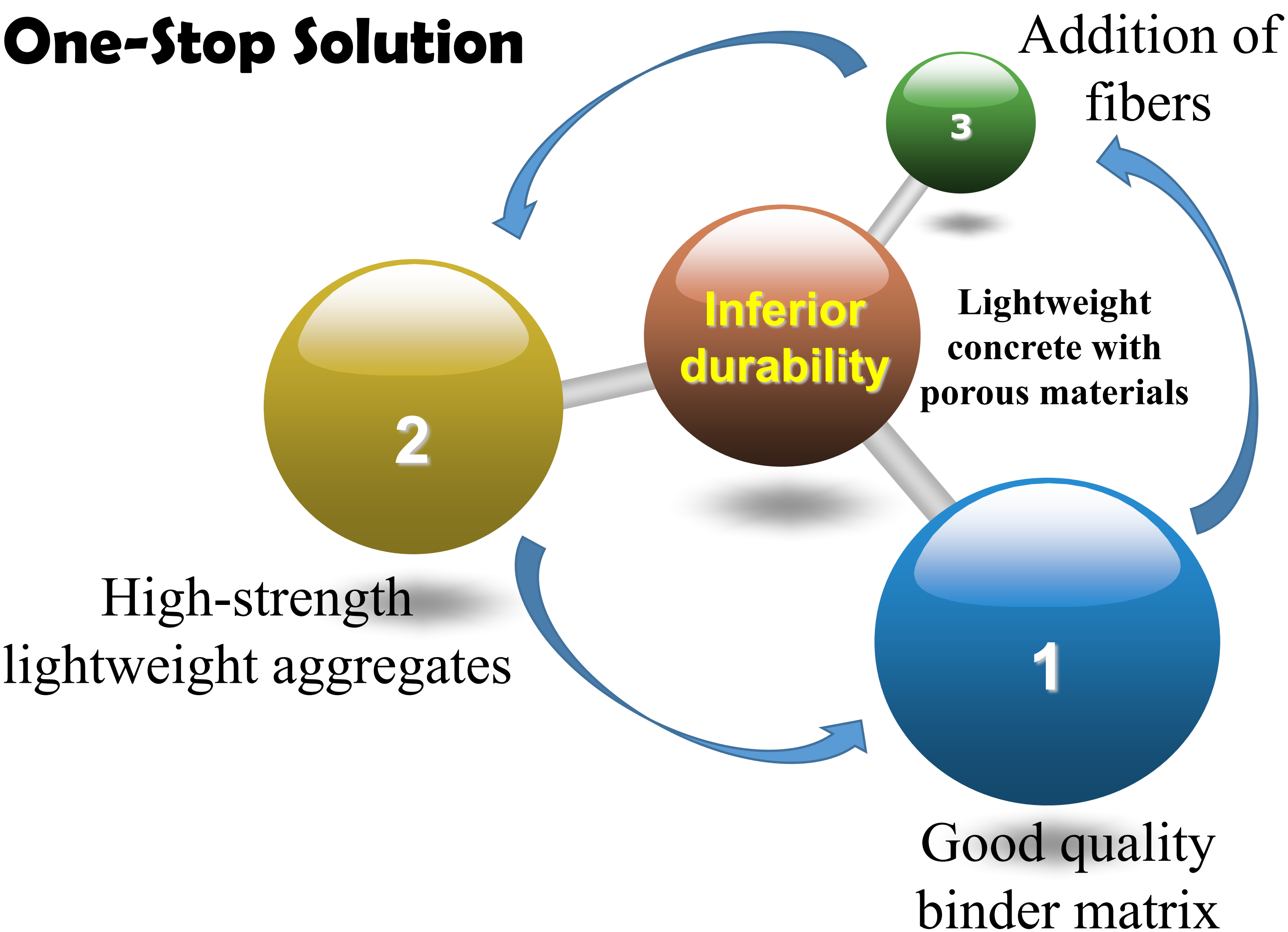


The Hong Kong Polytechnic University 香港理工大學 & Imperial College London

HK Innovation and Technology Council support this research

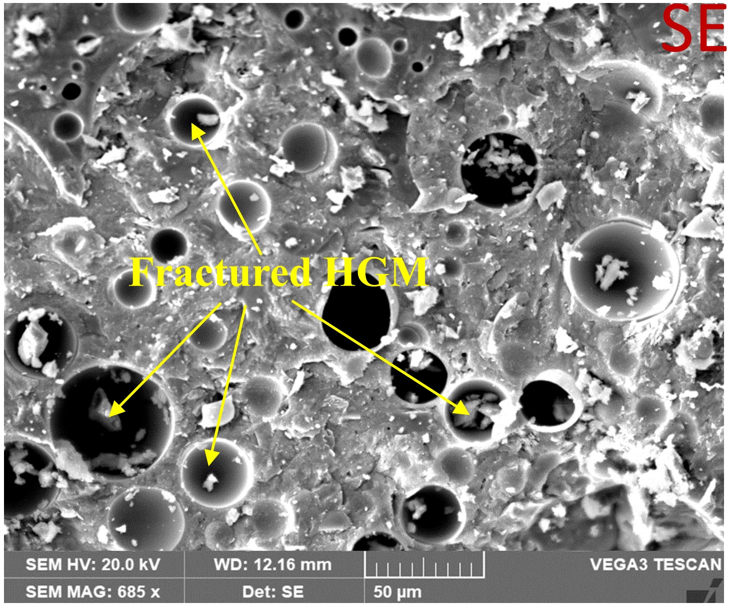
Strategies for producing HSLWC

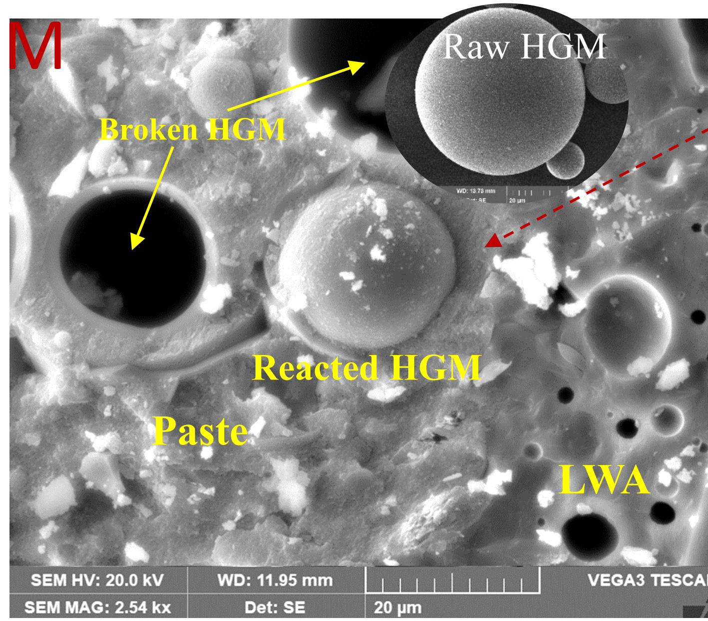
One-Stop Solution



UHP-LWC: Mix design and Performance

SEM

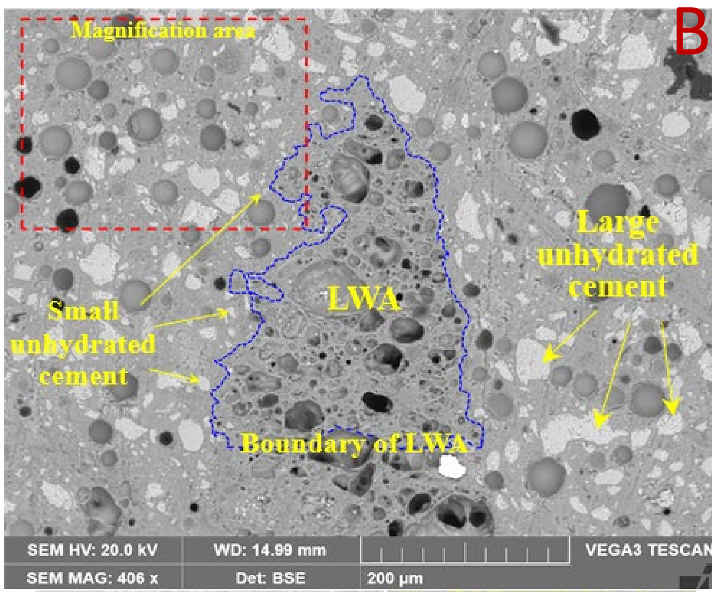


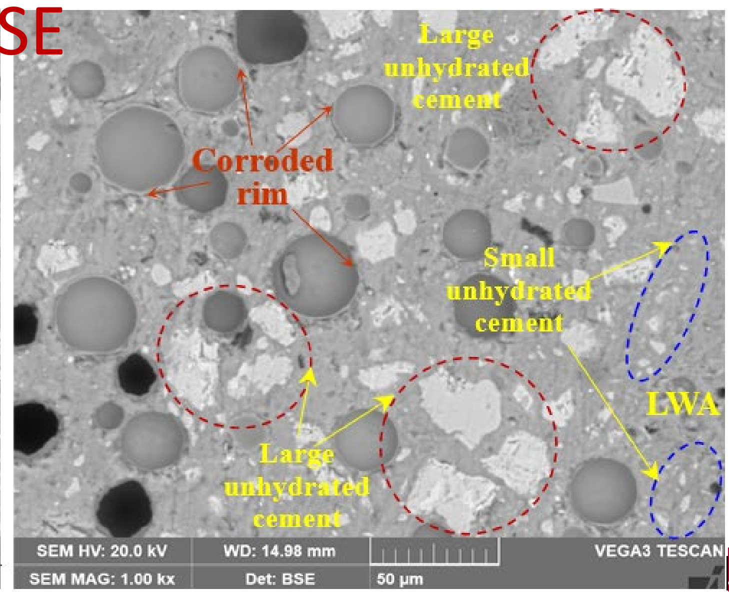


i: Dense interface of paste and LWA and

ii: High interfacial toughness of the HGM-paste due to the chemical reaction of HGM

BSE



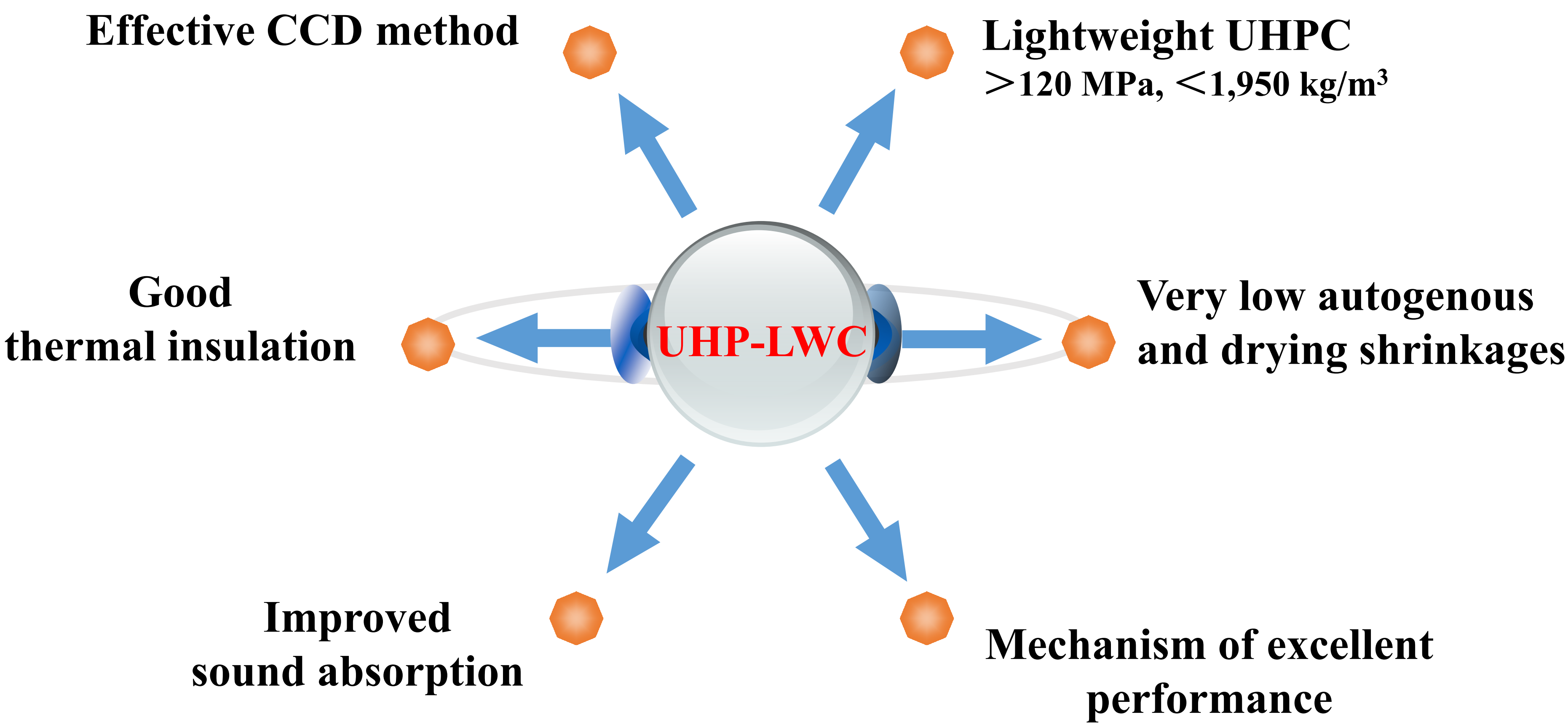


i: Smaller size cement particles around LWA

ii: Interlocking bonding of LWA and paste

iii: Pozzolanic reactivity of HGM

UHP-LWC: Mix design and Performance



Thank you for your attention

Our Vision
願景

RESEARCH CENTRE FOR
RESOURCES ENGINEERING TOWARDS CARBON NEUTRALITY
±RCRE 碳中和資源工程研究中心

香港邁向碳中和
Carbon Neutral@HK

Zero-carbon Emissions	•	Sustainable Development	•	Liveable City
零碳排放		持續發展		綠色宜居

Waste recycling → Low carbon concrete → Green construction