Greening the Concrete Jungle - Why Structural Engineers Hold the Keys

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China State Construction Engineering (Hong Kong) Limited

China State Construction International Medical Industry Development Co., Ltd.

2023-12-05 Hong Kong

1. Background

2. Material – Structure – Project

3. The Ecosystem

1. Background


Extreme Weather
is becoming
The New Normal

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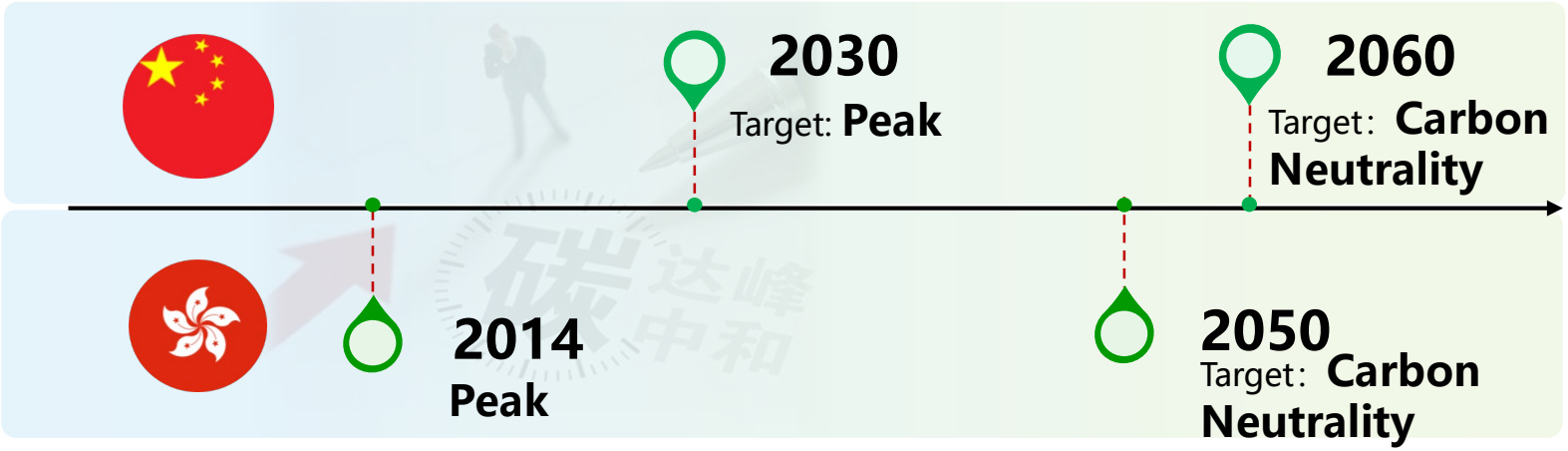
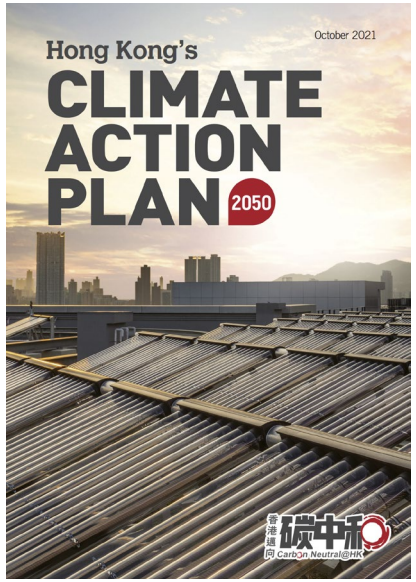
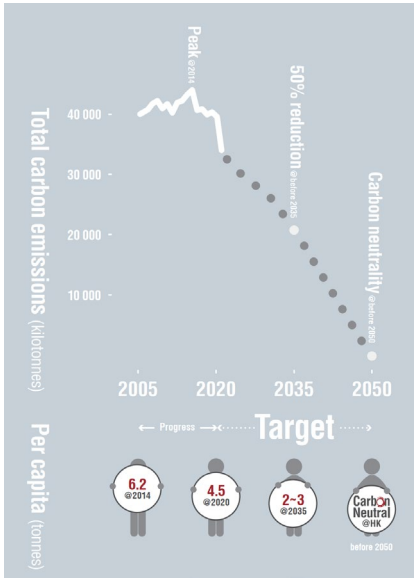
Moving Forward to Carbon Neutrality

Roadmap to Carbon Neutrality



"30/60"
National "Dual Carbon" Strategic Plan





Climate Action Plan 2050

- Zero-carbon Emission
- Liveable City
- Sustainable Development

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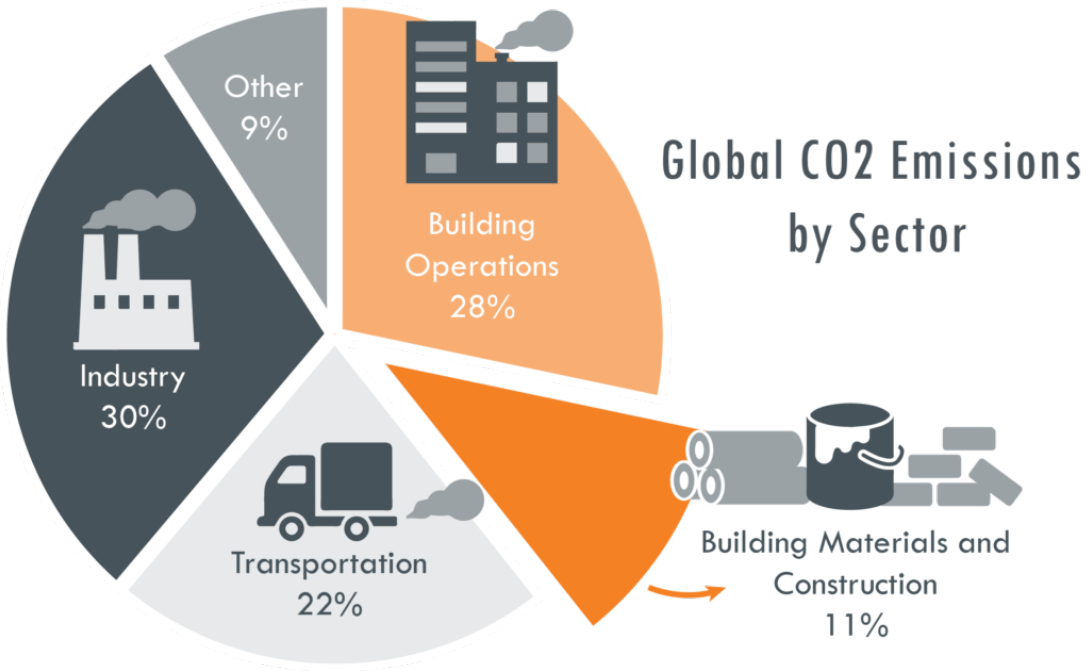
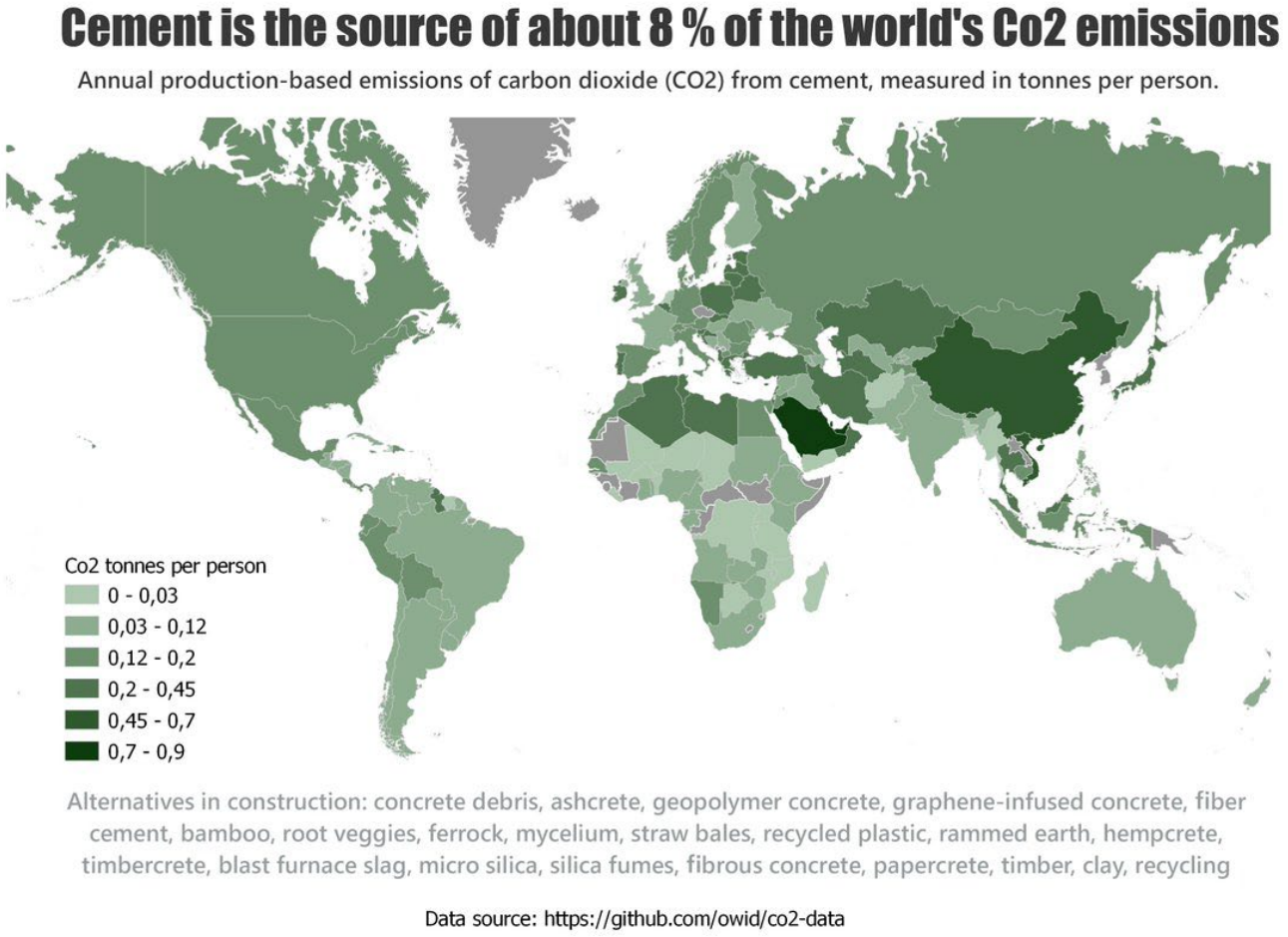
The Statistics



The carbon emissions from building operations and construction activities account for **39%** of the total global carbon emissions.

Source：UN Environment Global Report 2017



2. Material – Structure – Project

The Formula

Embodied Carbon ($kgCO_2e$) ↓

=

↓ **Material Quantity** (kg) x **Carbon Factor** ($kgCO_2e/kg$) ↓

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Material – Structure – Project

The Holistic Approach

I. Material-level

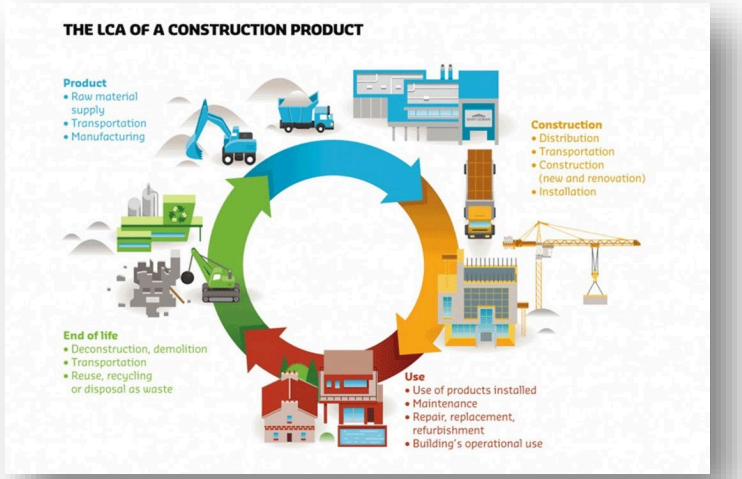
- Mechanical Properties
- Durability
- Carbon coefficient
- Local market availability

II. Structure-level

- Structural Efficiency
- Construction Cost
- Structural System/ Element/Connection
- Design Contingency
- Structural optimization

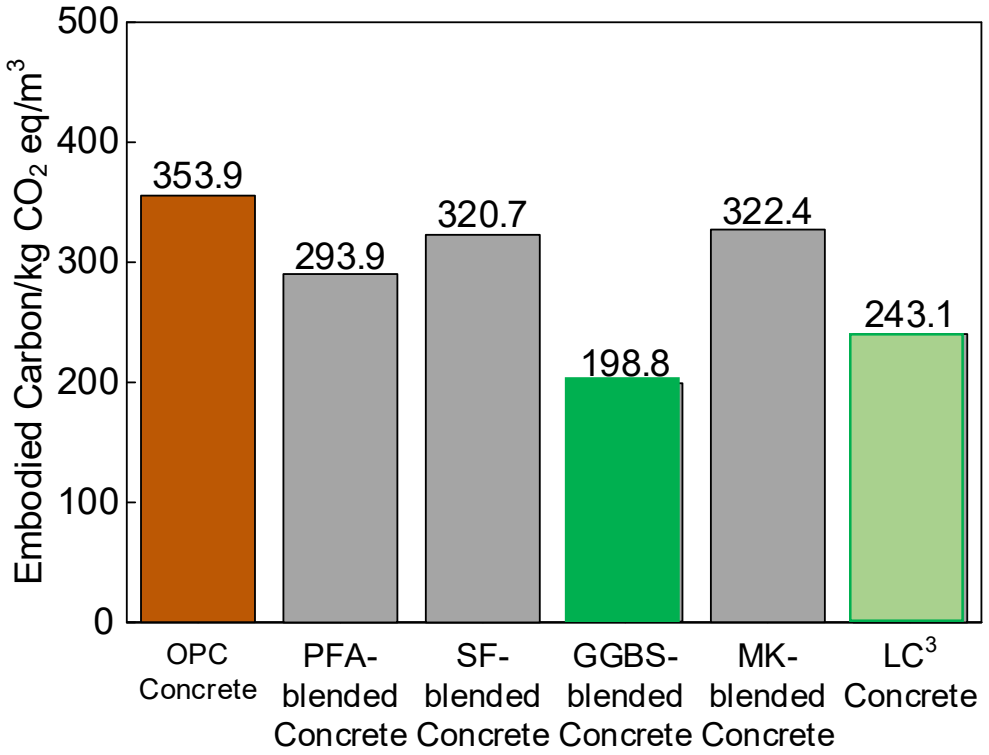
III. Project-level

- Multi-disciplinary Collaboration
- Life-cycle Analysis
- Performance of Durability and Sustainability
- Smart Construction
- Construction Digitalization
- Green and low-carbon Development



Material - Level

The Comparisons



SCM Type	Replacement Level	Carbon Reduction
PFA	25%	17.0%
SF	10%	9.4%
GGBS	50%	43.8%
MK	10%	8.9%
LC^3	50%	31.3%

SCM: Supplementary Cementitious Material
LC^3: Limestone Calcined Clay Cement
MK: Metakaolin
GGBS: Ground Granulated Blast-furnace Slag
SF: Silica Fume
PFA: Pulverized Fly Ash

SCMs are promising in reducing embodied carbon of RC by replacing ordinary Portland cement (OPC)

Ji, Xin-Lin et al. “A Review on FRP Bars and Supplementary Cementitious Materials for the next Generation of Sustainable and Durable Construction Materials.” *Construction & building materials* 383 (2023): 131403-. Web.

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GGBS Concrete in the Projects Worldwide

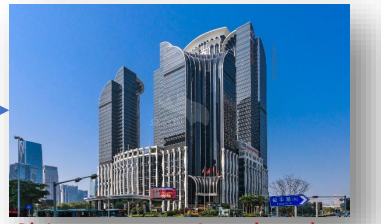
Blavatnik School of Government
Oxford, UK (Completion:2016)
GGBS ratio= 40%

Gatwick Airport Station
London, UK (Completion: 2023)
GGBS ratio= 70%

Hekla Tower
Paris, France (Completion:2022)
GGBS ratio= 50%

Three Gorges Dam
Yichang, China
(Completion:2012)
GGBS ratio= 40%

Hangzhou Bay Bridge
Hangzhou, China (Completion:2007)
GGBS ratio= 40%



Great China International Exchange Square
Shenzhen, China (Completion:2005)
GGBS ratio= 35%

One World Trade Center
New York, US
(Completion: 2014)
GGBS ratio= 40%

Central Park Tower
New York, US
(Completion:2020)
GGBS ratio= 30-70%

Tuas Undersea Cable Tunnel,
Singapore (Completion:1998)
GGBS ratio= 70%

Stonecutters Bridge
Hong Kong, China
(Completion:2009)
GGBS ratio= 60-70%

Tsing Ma Bridge
Hong Kong, China
(Completion:1997)
GGBS ratio= 65%

Material - Level

Comparison of Standards of GGBS Concrete

Regions	Standard	GGBS Ratio (OPC Replacement Level)
Hong Kong SAR	• Code of Practice for Structural Use of Concrete 2013 (2020 Edition)	**35-75%**
Mainland China	• **GB/T 18046-2017** Ground Granulated Blast Furnace Slag Used for Cement, Mortar and Concrete; • **GB 175-2007** Common Portland Cement	**20-70%**
UK, Europe	• **BS EN 15167-1/2:2006** Ground Granulated Blast Furnace Slag for Use in Concrete, Mortar and Grout; • **BS 8500-1:2015+A2:2019** Concrete – Complementary British Standard to BS EN 206	**20-80%**
US	• **ASTM C989/C989M-22** Standard Specification for Slag Cement for Use in Concrete and Mortars ; • **ASTM C595/C595M-23** Standard Specification for Blended Hydraulic Cements	**30-70%** (Depending on application)
Japan	• **JIS A 6206:1997** Ground Granulated Blast Furnace Slag for Concrete; • Recommendation for Construction of Concrete Containing Ground Granulated Blast Furnace Slag as an Admixture (JSCE)	**30-70%**

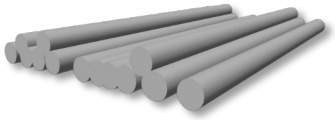
*In 2005, SCCT endorsed BS 6699 as the standard for GGBS in Hong Kong. BS 6699 was later superseded by EN 15167-1/2

Wider Adoption of Low Carbon Material

Basalt FRP bar

+

OPC blended with SCM (GGBS/PFA/LC³) Concrete

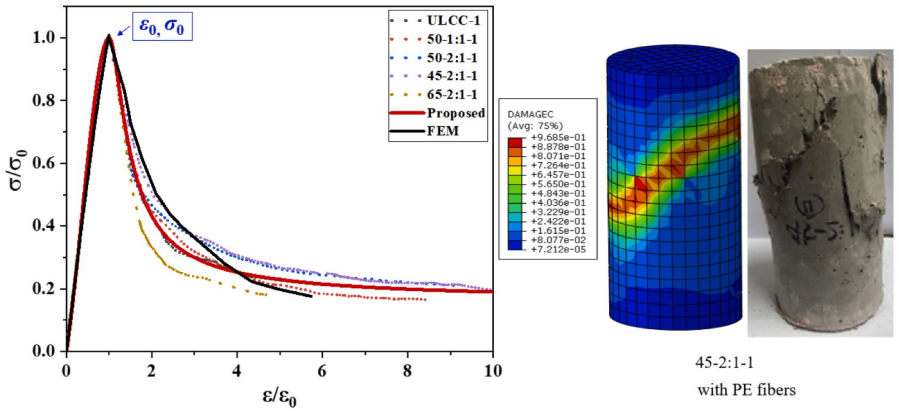


Recycled Aggregates

Seawater Sea Sand

Ji, X.-L., Chen, L.-J., Liang, K., Pan, W., & Su, R.-KL. (2023). A review on FRP bars and supplementary cementitious materials for the next generation of sustainable and durable construction materials. Construction & Building Materials, 383, 131403-.

Ultra-lightweight Concrete LC3



Liang, T.-T, Chen, L.-J, Huang, Z.-Y, Zhong, Y., & Zhang, Y. (2023). Ultra-lightweight low-carbon LC3 cement composites: Uniaxial mechanical behaviour and constitutive models. *Construction & Building Materials*, *404*, 133173-.

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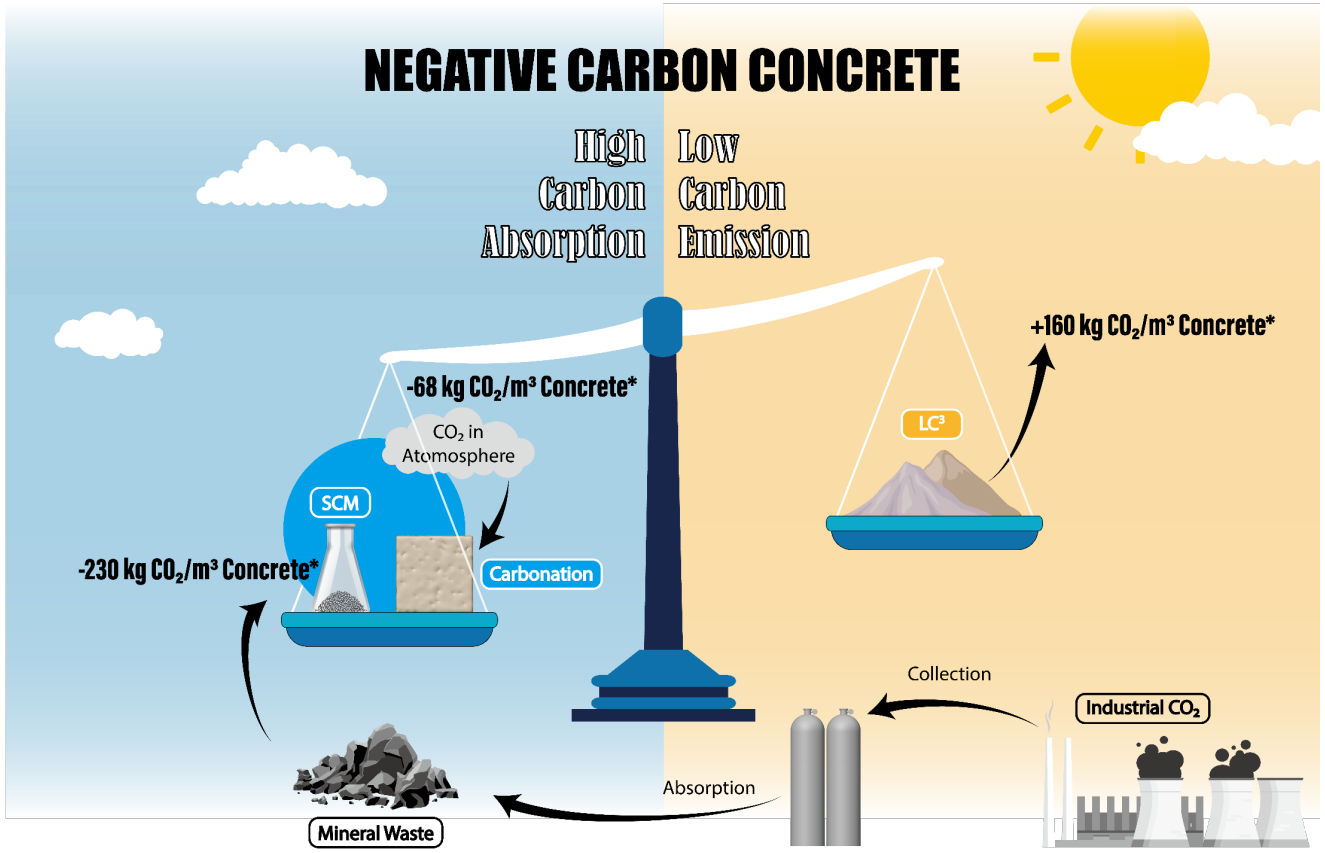
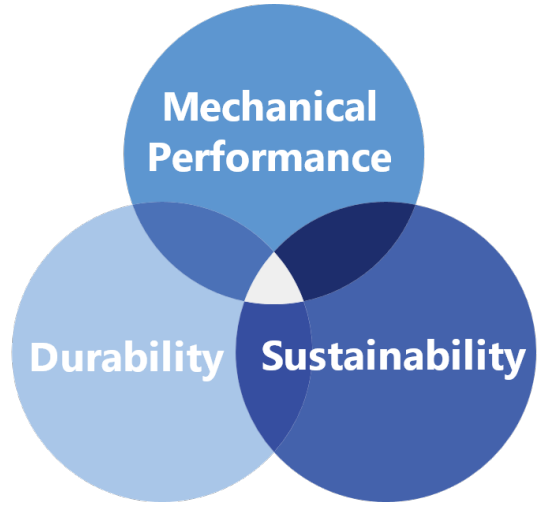
Material - Level

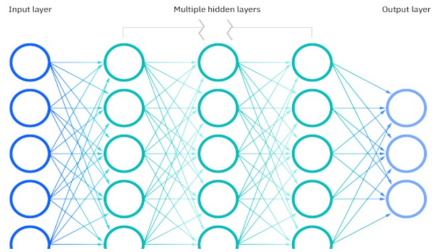
Next Generation of Negative Carbon Concrete



Xinlin JI, Lijie CHEN, Ying ZHONG, Yi ZHANG, Jiayi LI, Wei PAN, Ray Kai-Leung SU, "Negative Carbon Concrete For Achieving Next Generation Of Sustainable And Durable Modular Integrated Construction (MiC): A Review", 2023 Creative Construction Conference, Keszthely, Lake Balaton, Hungary, 20 to 23 June 2023.

Pillai, Radhakrishna G., et al. "Service life and life cycle assessment of reinforced concrete systems with limestone calcined clay cement (LC3)." Cement and Concrete Research 118 (2019): 111-119.





Improved annual sustainability with longer service life

Lijie CHEN, Xinlin JI, Jiayi LI, Ray Kai-Leung SU, "Integrated concrete mix design with sustainability, cost and durability based on artificial intelligence", 2023 Creative Construction Conference, Keszthely, Lake Balaton, Hungary, 20 to 23 June 2023.

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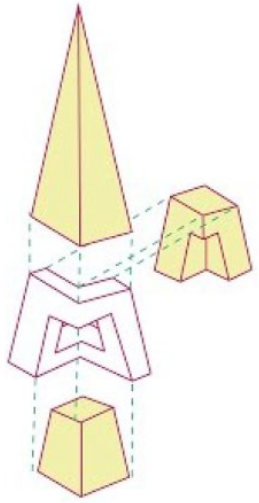
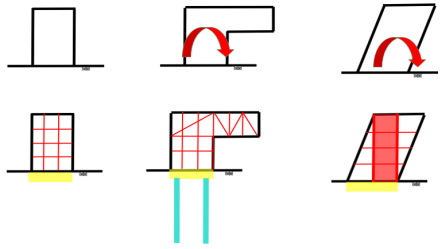
Structure - Level

Structural Morphology

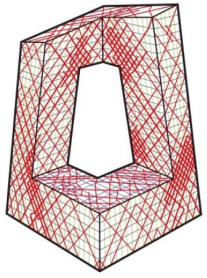
- Statical Performance
- Wind-resistant Performance
- Seismic-resistant Performance
- Global Stability

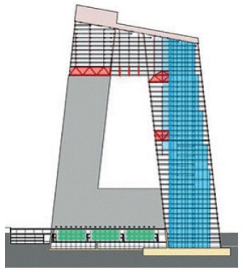




Structural System

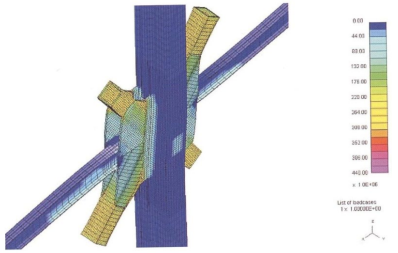
- Structural Efficiency
- Design Intent
- Construction Cost
- Functionality
- Load Path



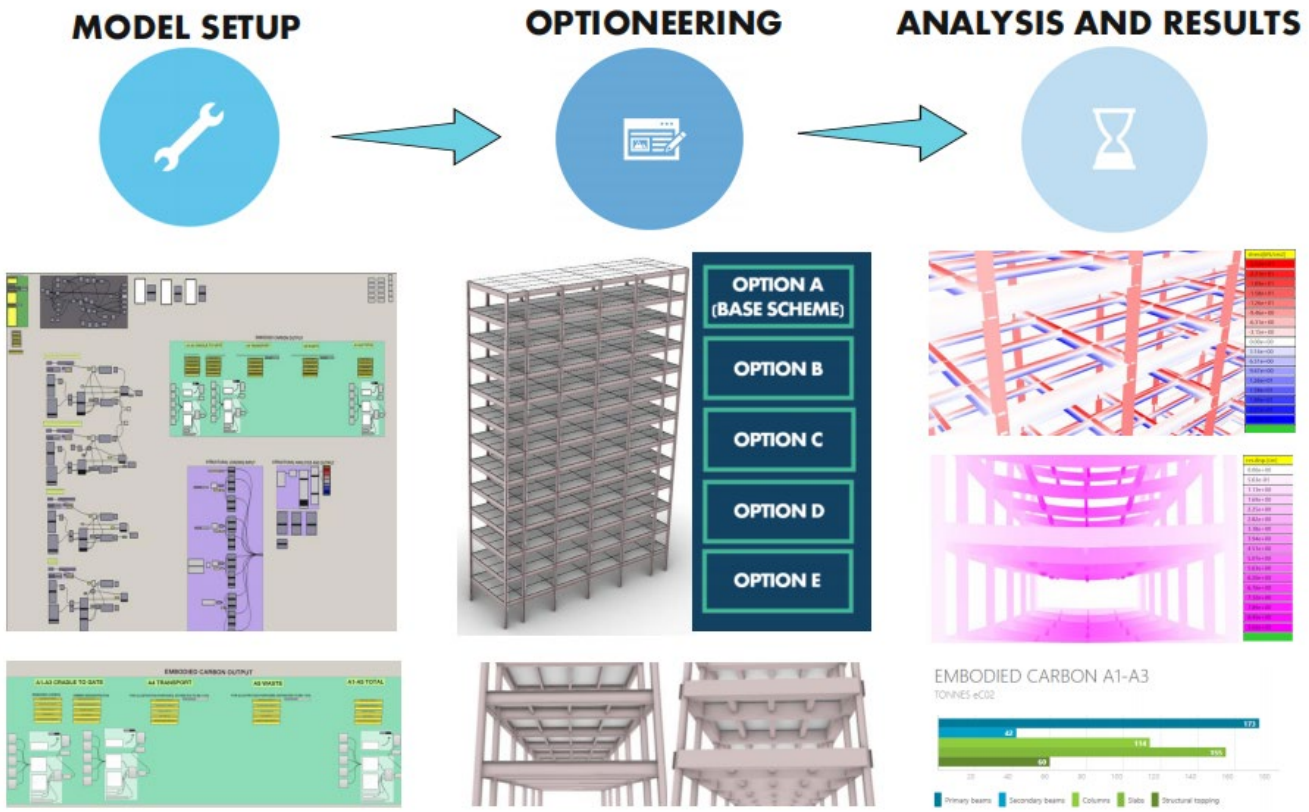


Structural Components

- Structural Element/Connection
- Design Contingency
- Constructability & Buildability
- Construction Cost



Parametric Modelling & Design



Parametric design:
Design Response = f (Design Intent)

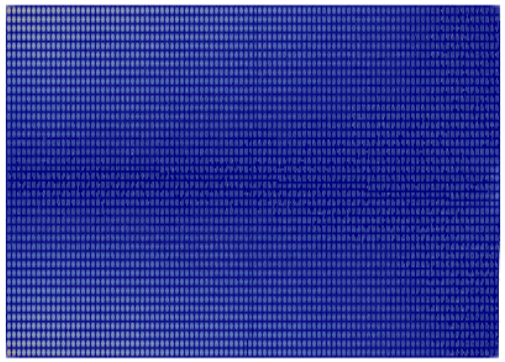
Integrated Design Platform

- **Interaction** between Architecture and Structure
- **Parameter-based** interactive design pattern
- **Real-time** performance evaluation of the scheme
- **Dynamic** challenges of design schemes

To generate more Insightful and Faster Engineering Solutions for Decision-making!!

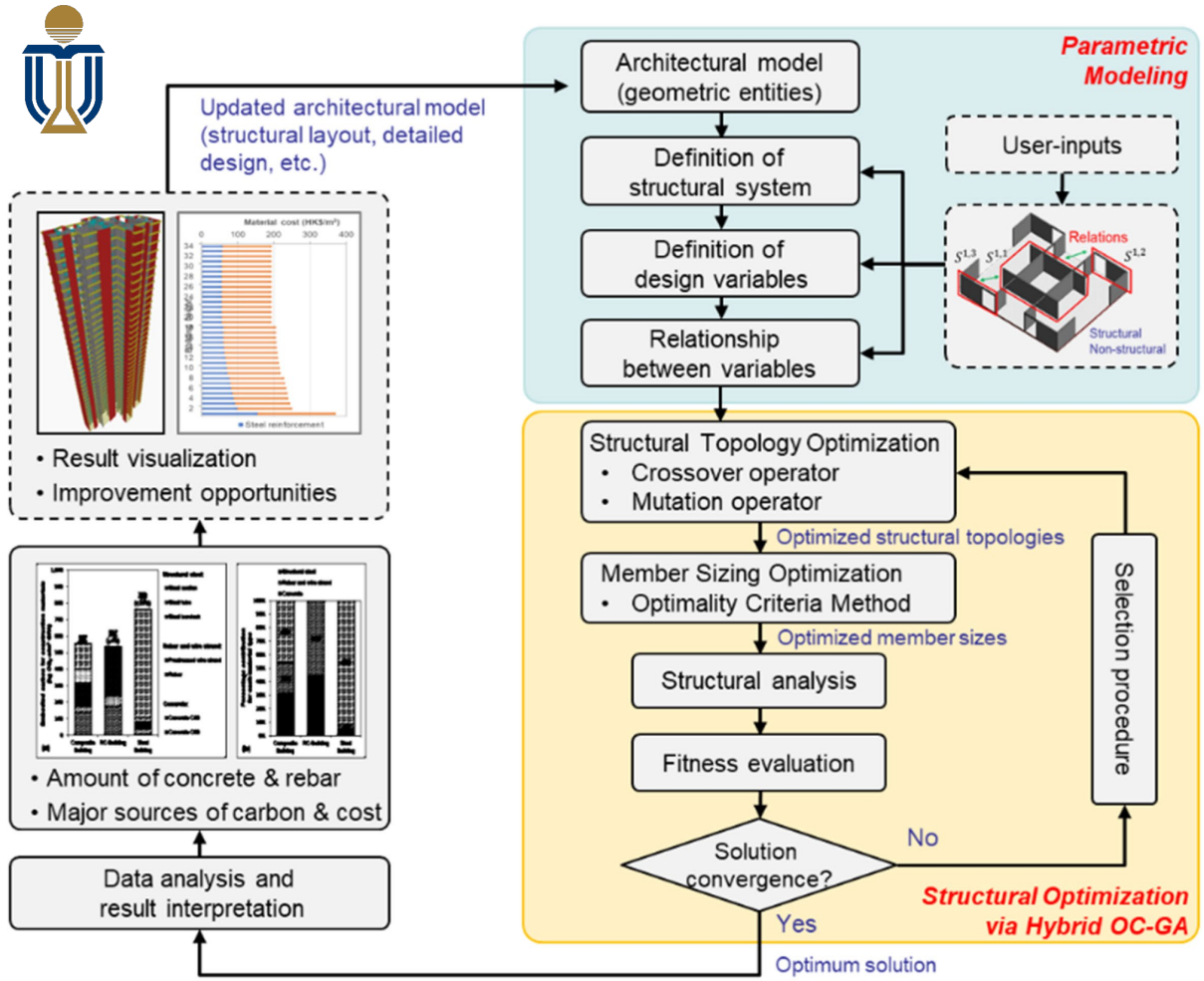
Topology Optimization

Yan, Xin et al. “Detail Control Strategies for Topology Optimization in Architectural Design and Development.” *Frontiers of architectural research* 11.2 (2022): 340–356. Web.

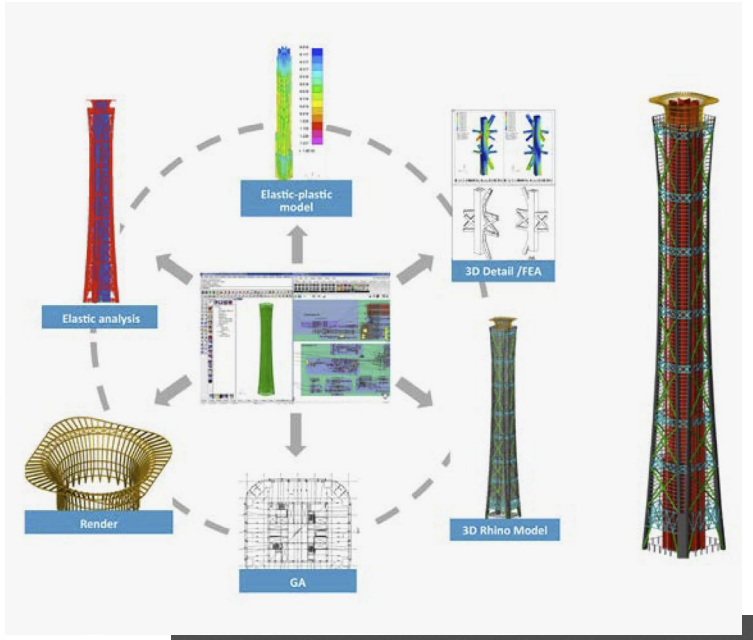


Less Material
More Design

Systematic Structural Optimization

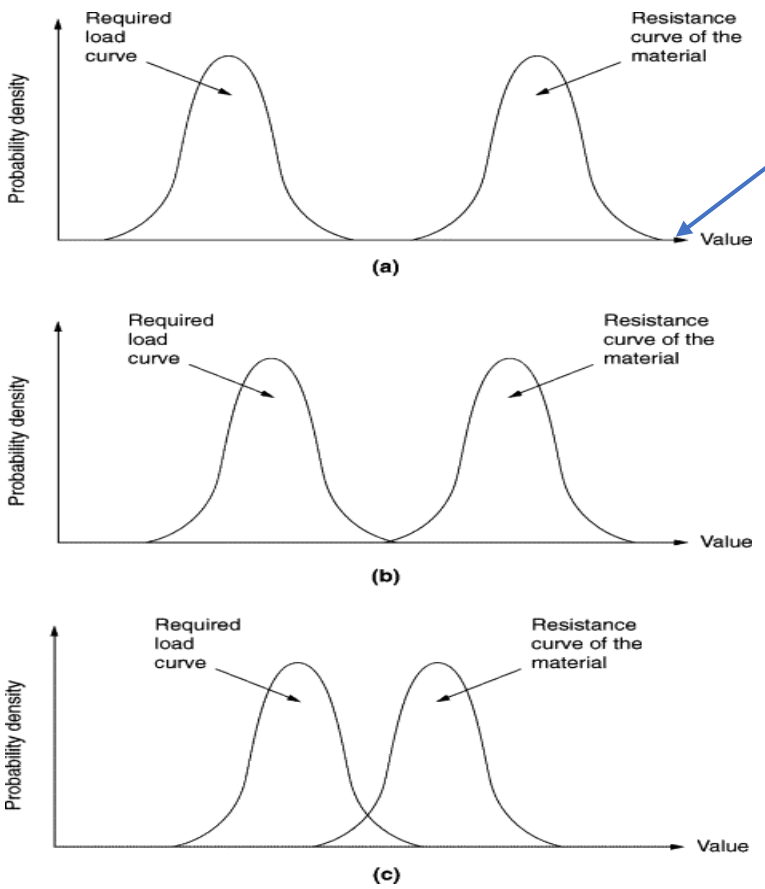


Gan, Vincent J.L. et al. "Parametric Modelling and Evolutionary Optimization for Cost-Optimal and Low-Carbon Design of High-Rise Reinforced Concrete Buildings." *Advanced engineering informatics* 42 (2019): 100962-. Web.



Cheng, Yu. et al. "A vessel for commerce." *The Arup Journal* 2 (2019)

The Mindset



Higher embodied carbon footprint,

Higher climate risk

Being Conservative in the structural design is NOT the solution to deal with climate emergency


Design for
Low Carbon / Net Zero
≥
Design for Safety

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Project - Level

Methodology

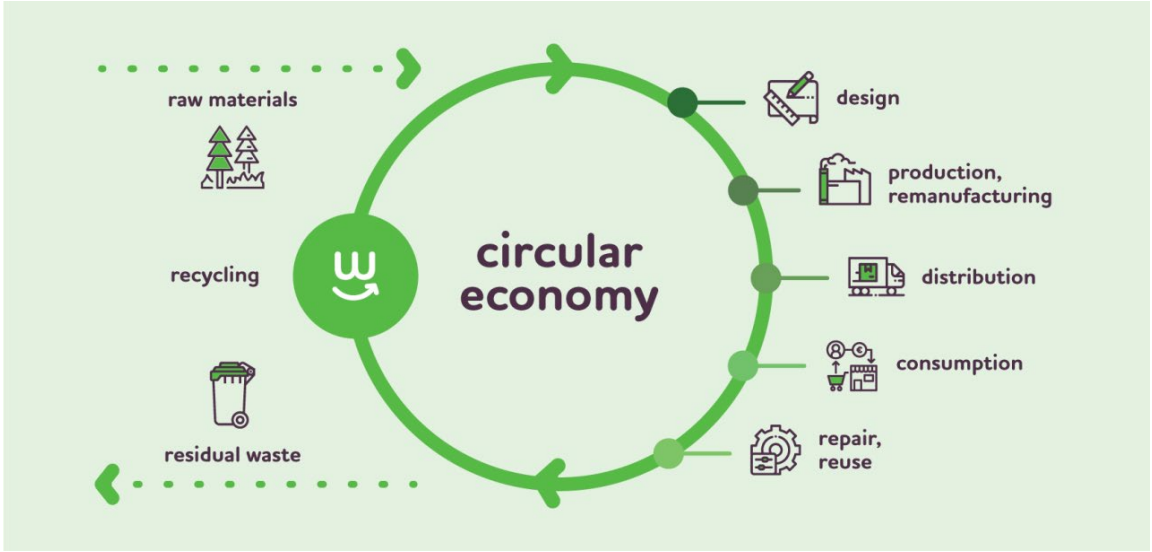
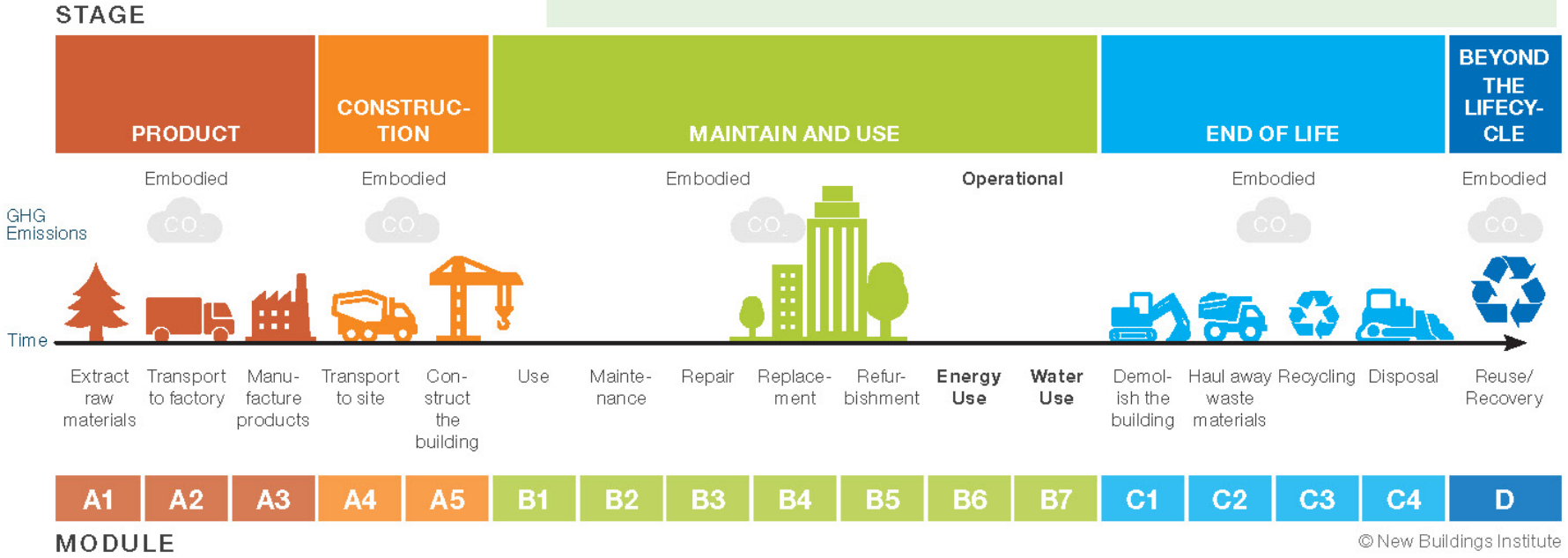


FIGURE 1: LIFECYCLE STAGES
Data source: BS EN 15978:2011



The **Circular Economy** offers a compelling vision for a sustainable Future.

Decarbonizing the built environment by addressing **whole life carbon**

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Project - Level

High-productivity Smart and Green Construction

Industrialized Construction

- DfMA Approach
- MiC, MiMEP, etc.

Construction Digitalization

- BIM-based Techniques
- Smart Construction

Low-carbon and Green Construction

- Green Building and Construction
- Net Zero Ready Building

Conceptual Framework of Design and Construction for Low Carbon

I. Architectural Geometry

Rhinoceros

AUTODESK® REVIT®

II. Structural Geometry

AUTODESK® REVIT®

Dynamo

III. Structural Analysis

ETABS®

SAP2000®

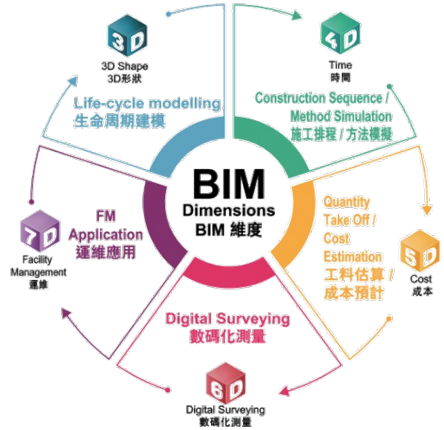
TEKLA® A TRIMBLE COMPANY

IV. Embodied Carbon Assessment

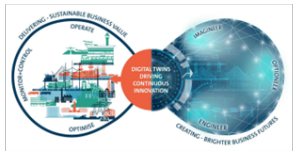
CONSTRUCTION INDUSTRY COUNCIL 建造業議會

CIC Carbon Assessment Tool 建造業議會碳評估工具

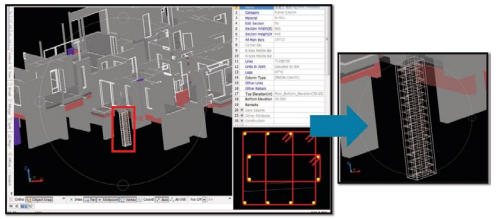
V. Documentation & Drawings, BIM+

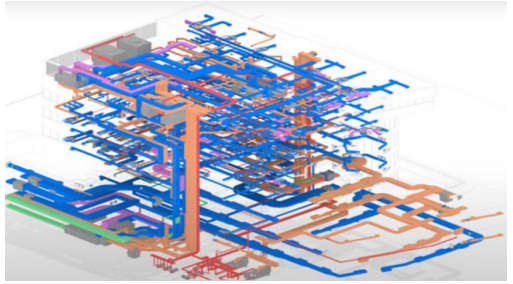


VI. Digital Management Platform

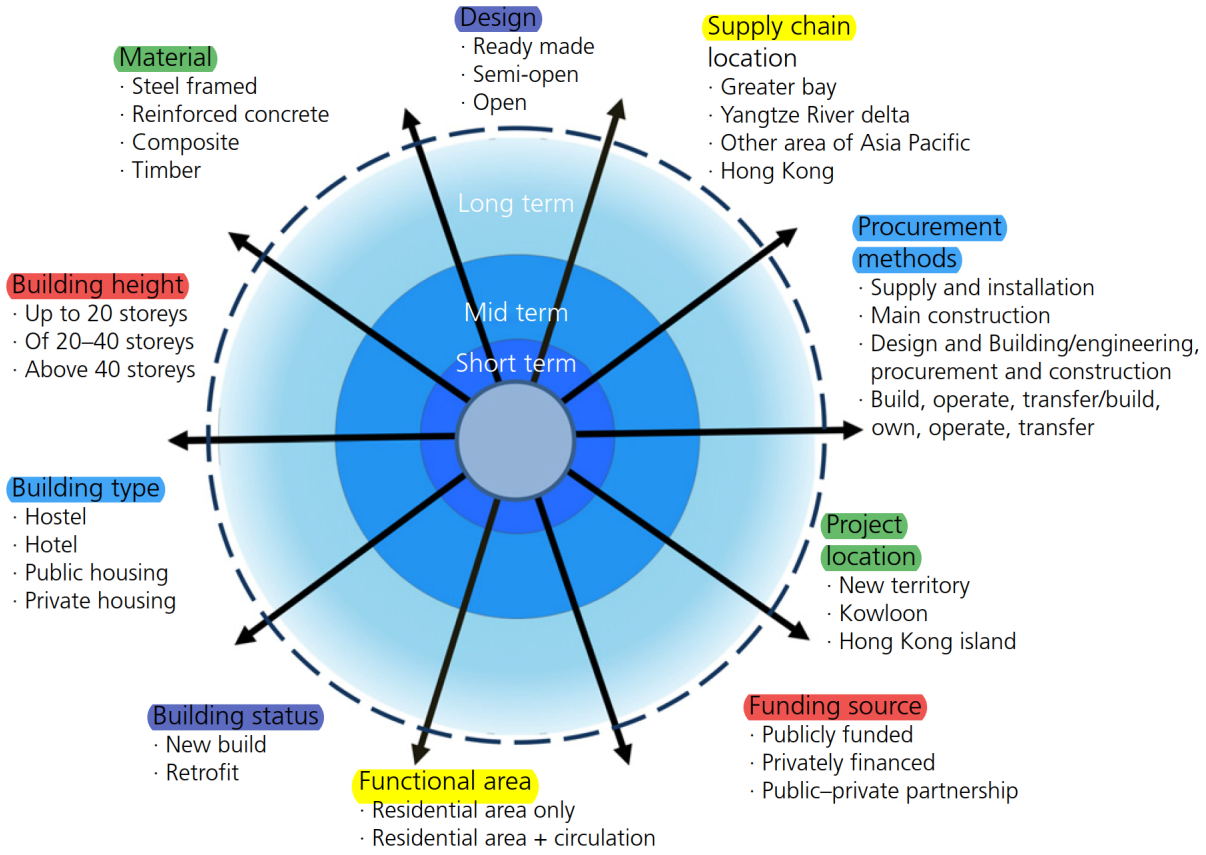


C-SMART





Systematic Framework of MiC Design, Construction and Development



A systems framework of MiC adoption scenarios in Hong Kong

Pan, Wei, and Chi Keung Hon. "Briefing: Modular Integrated Construction for High-Rise Buildings." *Proceedings of the Institution of Civil Engineers. Municipal engineer* 173.2 (2020): 64–68. Web.

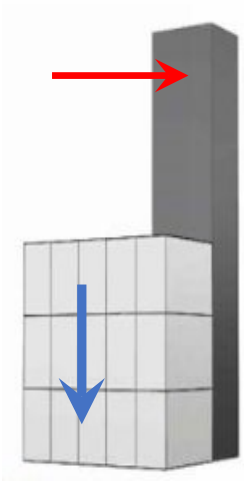
The design, construction, and development of MiC require

Systematic Thinking

that covers the entire supply chain of construction industry.

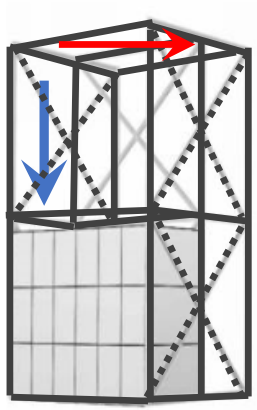
Project - Level

Better Synergy with MiC Structure



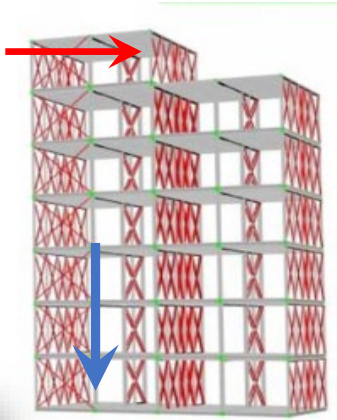
1. Independent System

MiC (Vertical Stability System only)



2. External System

MiC (Non-structural)

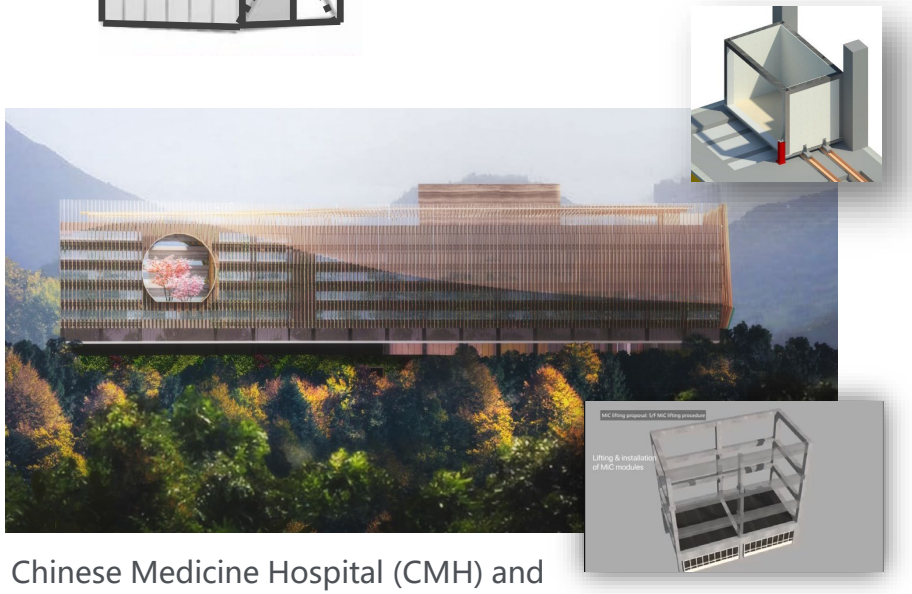


3. Combined System

MiC (contribute to both Vertical and Lateral Stability System)

HKU Student Residence at Wong Chuk Hang

(Source: HKU)



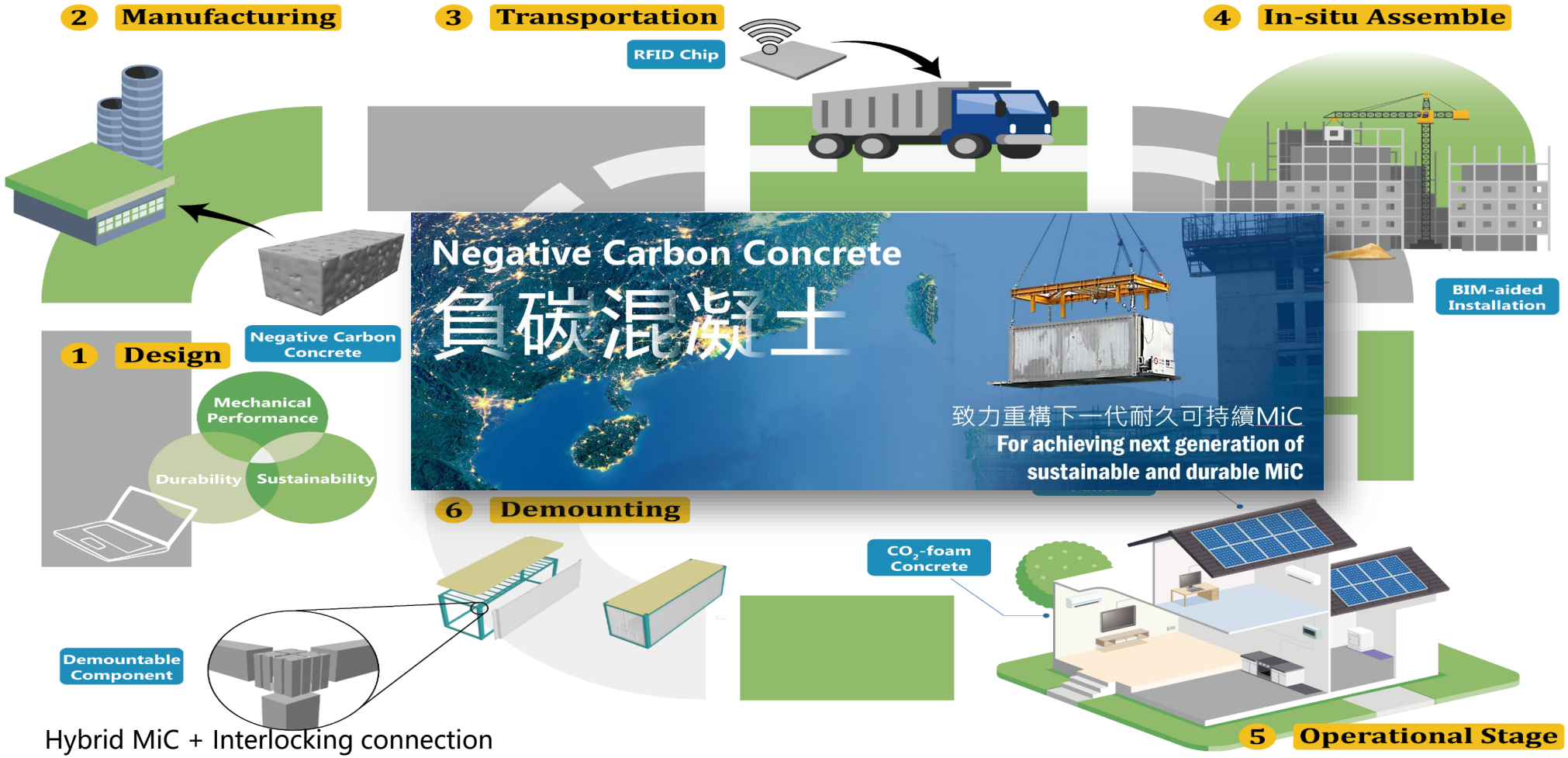
Chinese Medicine Hospital (CMH) and Government Chinese Medicines Testing Institute (GCMTI)

(Source: ArchSD)

Public Housing Development at Tung Chung Area 99

(Source: Housing Authority)

Next Generation of Sustainable and Durable MiC



Hybrid MiC + Interlocking connection

Xinlin JI, Lijie CHEN, Ying ZHONG, Yi ZHANG, Jiayi LI, Wei PAN, Ray Kai-Leung SU, "Negative Carbon Concrete For Achieving Next Generation Of Sustainable And Durable Modular Integrated Construction (MiC): A Review", 2023 Creative Construction Conference, Keszthely, Lake Balaton, Hungary, 20 to 23 June 2023.

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Project - Level

DBO Organic Resources Recovery Centre Phase 2 (O•PARK2)

The 1st engineering project in China to announce a carbon neutrality commitment during the construction stage

智慧工地管理平台

(C-smart Management Platform)

碳中和數據雲平台

(Carbon Neural Cloud Platform)

O·PARK2 Carbon Neutral Cloud Platform

Carbon Emission Management

AI Identification/ Verification

Blockchain

Big Data

Moving towards Carbon Neutrality

O•PARK2 Low-carbon Materials

Recycled Reinforcement

In supply chain management, using 100% recycled steel bars, reduces carbon potential by 67%*.

In concrete, using Ground Granulated Blastfurnace Slag (GGBS) to replace 60% of cement, reduces carbon potential by 53%*.

Low-carbon Concrete

CCUS Techniques

Developing Carbon Capture Utilization and Storage (CCUS) technology, using CO_2 captured from energy companies to produce low-carbon concrete blocks, achieves efficient sequestration and utilization of CO_2, reducing carbon potential by 78%*.

** For Information Only*

O·PARK2 Low-carbon Design

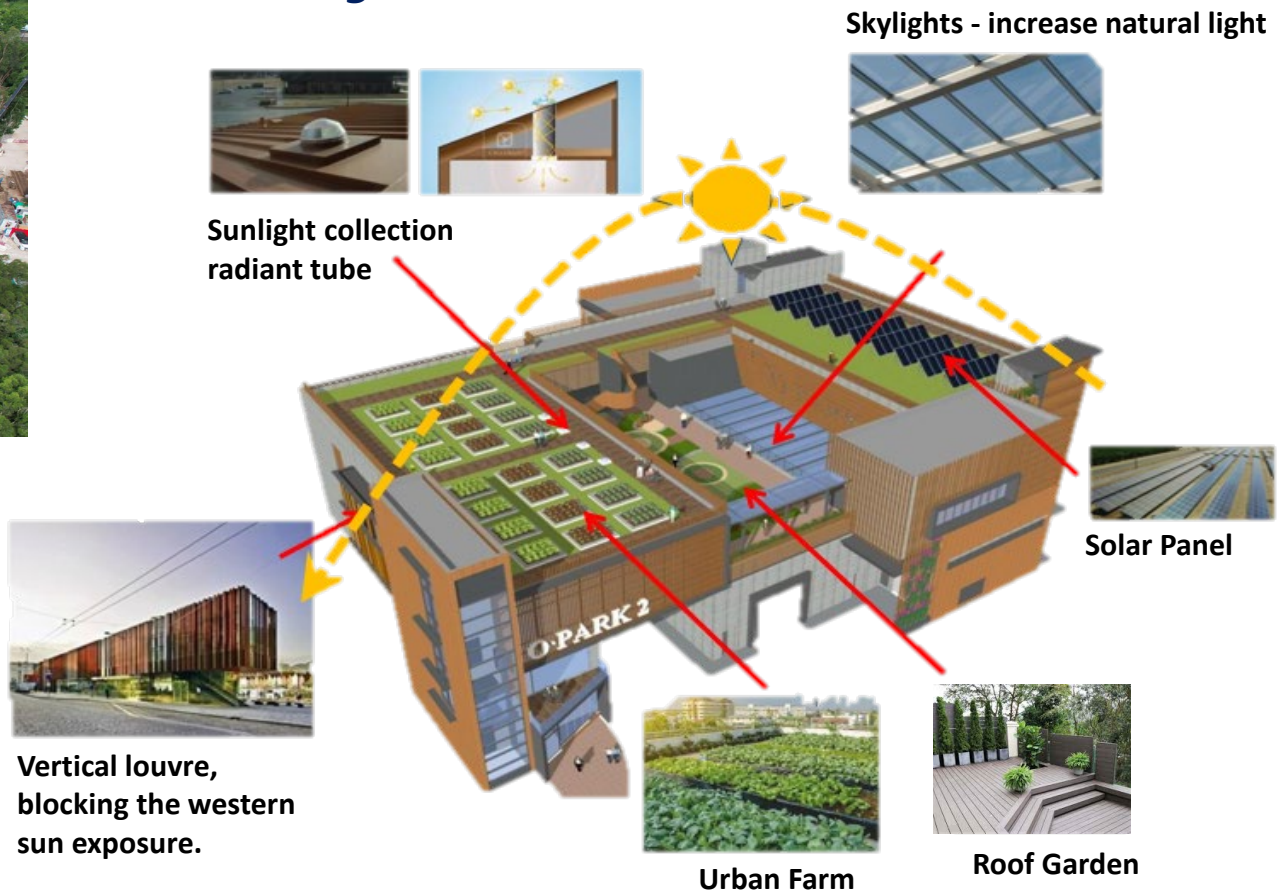
Structural Optimization

Reducing concrete usage by 7.8%* ,reduces carbon emissions by approximately 1,000 tons of CO_2 equivalent.

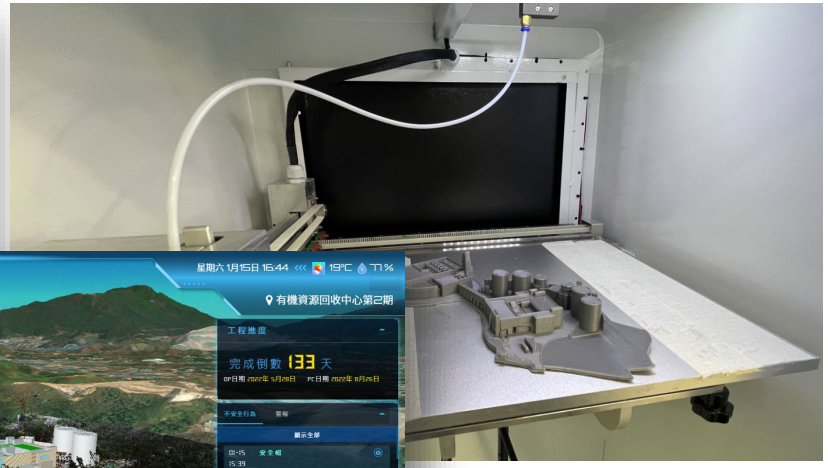
** For Information Only*

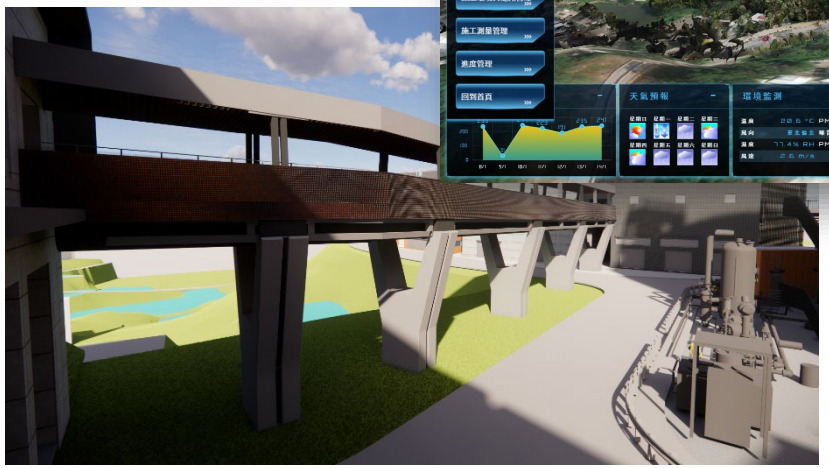
Passive Design

Embrace nature, make full use of natural light and natural wind.



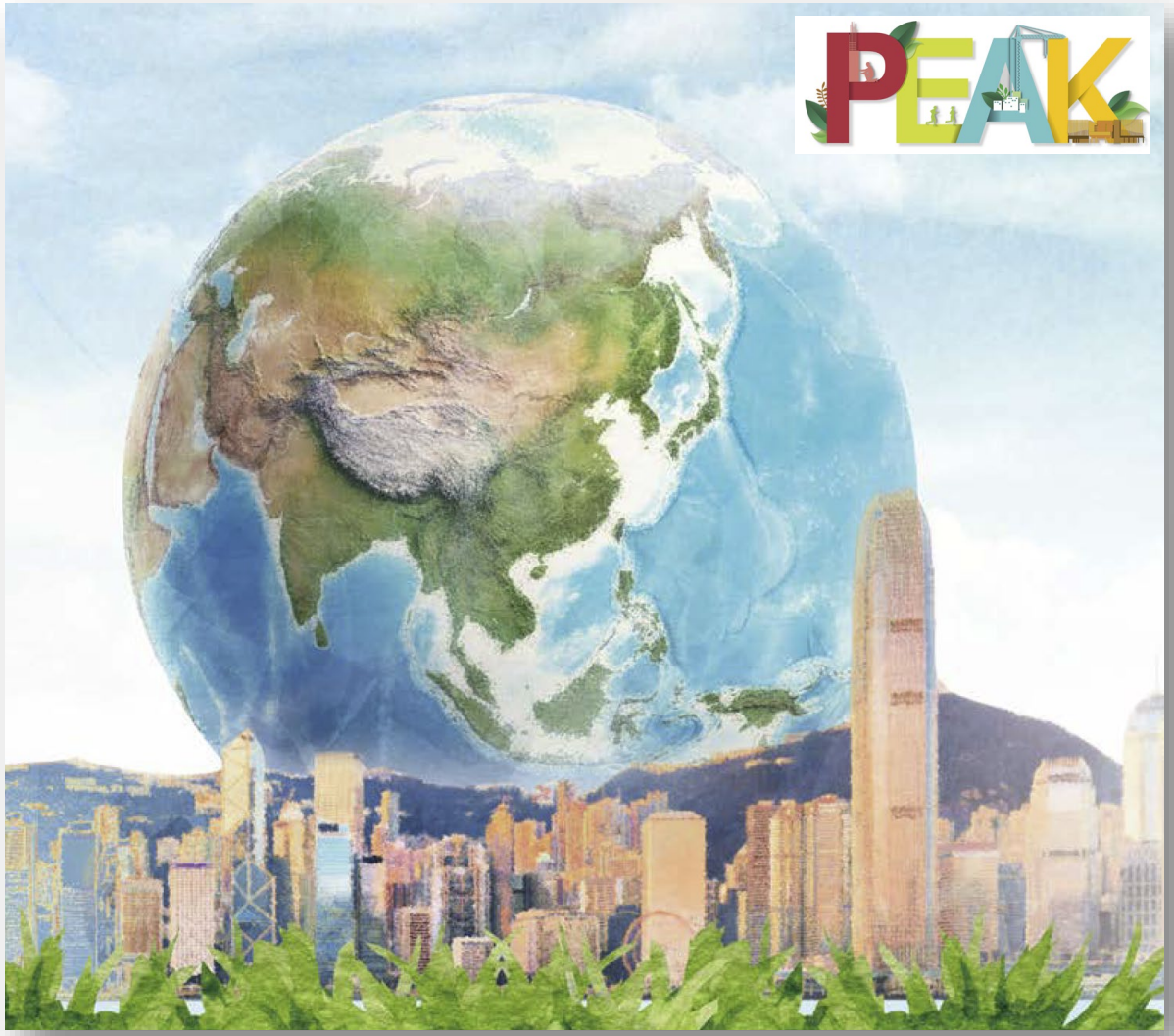
O·PARK2 Smart Construction & Construction Site Electrification





Project - Level

Eco-friendly Projects



建築署
Architectural Services Department

水務署
Water Supplies Department


Integrated Design
Smart Construction
Lower Carbon
Higher Performance


WHAT NEXT?


CO2

3. The Ecosystem

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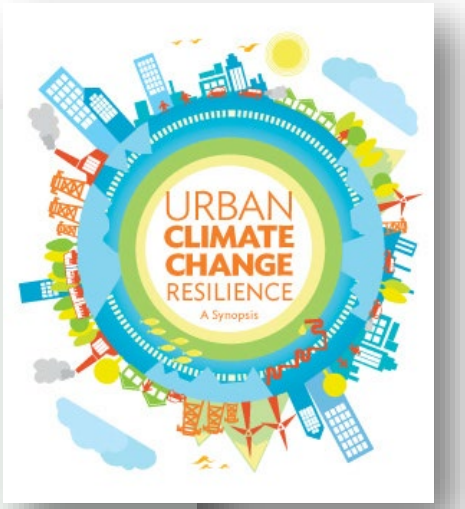
New Development Principle



Embedding the principles of Circular Economy, Resilient Infrastructure, and ESG into the core of our development strategies.

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Policy Support

Incentives for Green Finance

Strengthening regulatory frameworks for ESG

Promoting Carbon Footprint Assessment and Labeling within the Region

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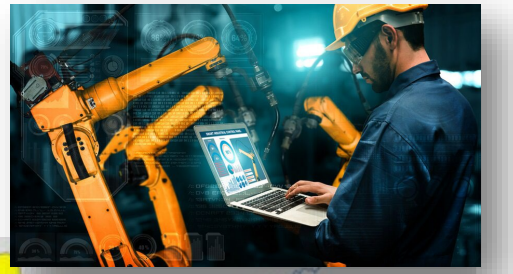
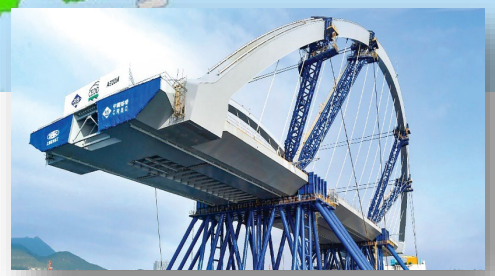
GBA Closer Collaboration





Cross-boundary Government-Academia-Industry Collaboration

Competitive Supply Chain

Transport and Logistics

Expanding Talent Pool

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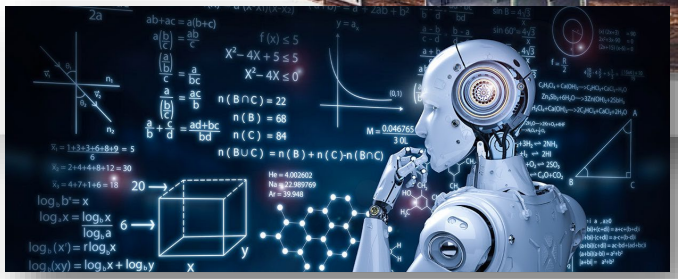
Innovation for Advancing Science & Technology

“Science and technology constitute a primary productive force”



Digital Transformation

Smart Construction

Robotics and Automation

New materials

AI. IoT

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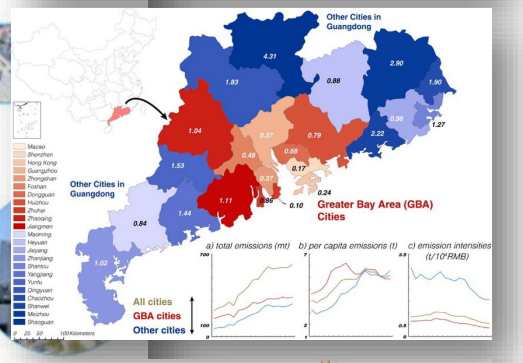
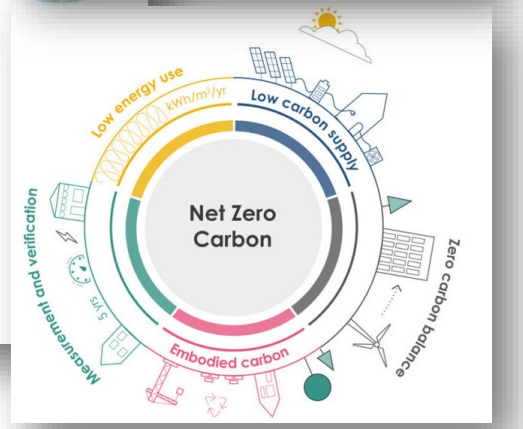
GBA Standards





To create and synergize GBA Carbon-relevant Standards.

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Youth Development

Attracting, Developing and Retaining Younger Generations in the Construction Industry.

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Leveraging Hong Kong's Strengths, to Shape a Sustainable Future of the Greater Bay Area Together.

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中國建築工程(香港)有限公司
CHINA STATE CONSTRUCTION ENGINEERING (HONG KONG) LIMITED

中建國際醫療產業發展有限公司
CHINA STATE CONSTRUCTION INT'L MEDICAL INDUSTRY DEVELOPMENT CO., LTD.

Change the Mindset
Adopt the Holistic Approach
Build the Ecosystem

Thank You!

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China State Construction Engineering (Hong Kong) Limited

China State Construction International Medical Industry Development Co., Ltd.

2023-12-05 Hong Kong

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