

# URBAN SOLUTIONS AND SUSTAINABILITY R&D CONGRESS 2023

BUILDING SUSTAINABLE, RESILIENT, AND LIVEABLE CITIES OF TOMORROW

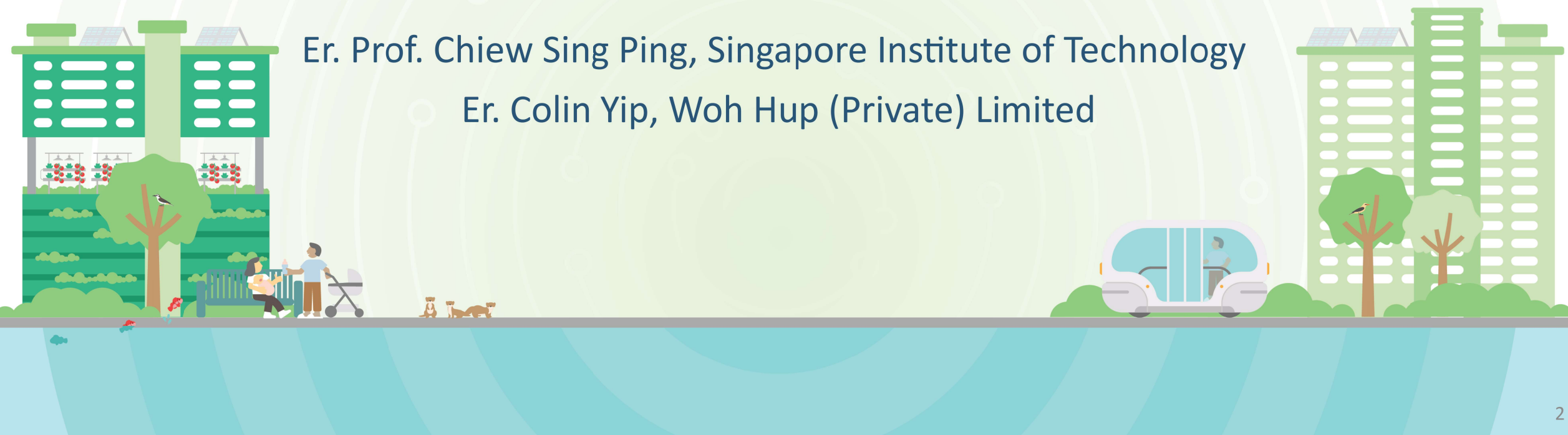
4TH - 5TH OCTOBER 2023



# Driving Applied Research with Industry Partners – An Alliance Approach

Er. Prof. Chiew Sing Ping, Singapore Institute of Technology

Er. Colin Yip, Woh Hup (Private) Limited



## Key Talking Points

**1**

**‘Bottom-up’  
Industry-Driven  
Research Model**

**Focusing on  
translation from  
laboratory to site**

**2**

**Case Studies &  
Technology  
Translation**

**CTIL’s collective  
efforts made in the  
three AR & I Pillars**

**3**

**Why SIT and  
CTIL?**

**Marry applied  
research and  
industry’s best  
practice. Build  
talent pipelines  
through AR & I  
upskilling  
programmes.**



# Challenges in Construction Industry

## Tackling embodied carbon is the next step of the green building journey

Without considering the upfront emissions from construction, the world could burn through its remaining carbon budget as the global population swells. Eco-Business asks Lisa Bate, chair of the World Green Building Council, for her thoughts on how to address the problem of embodied carbon. ST, 2 Jan 20



## Critically urgent to address the sustainability and climate change challenges

- Post Covid

- Sustainability

THE STRAITS TIMES

### Hold on or fold up: Singapore's construction, F&B players struggle to cope with crunch

ST, 8 Nov 20

Construction firms said the shortage of workers has led to an increase in subcontractor labour costs by about 20 to 30 per cent. ST PHOTO: ARIFIN JAHAN

THE STRAITS TIMES

CORALS CARBON RISING SEAS

CLIMATE CODE RED

## SAVING SINGAPORE'S SHORES



## A Platform for Applied Research

CTIL provides a platform for Singapore-based construction companies and SIT researchers to carry out applied research and develop innovative and cost-effective construction technologies for building structures and sub-structures.



## Start-Up Grant

Woh Hup (Private) Limited provides a \$2M start-up grant to set up CTIL and supports its operation over an initial period of 5 years (2021 -2026).

# Construction Technology Innovation Laboratory

(CTIL)

Building and Construction Authority



*Woh Hup - SIT Construction Technology Innovation Laboratory (CTIL) provides a platform for Singapore-based construction companies and SIT researchers to collaborate and develop innovative technologies for building structures and sub-structures with societal and economic impact.*

## VISION

- To advance construction technologies for building structures and sub-structures through innovation

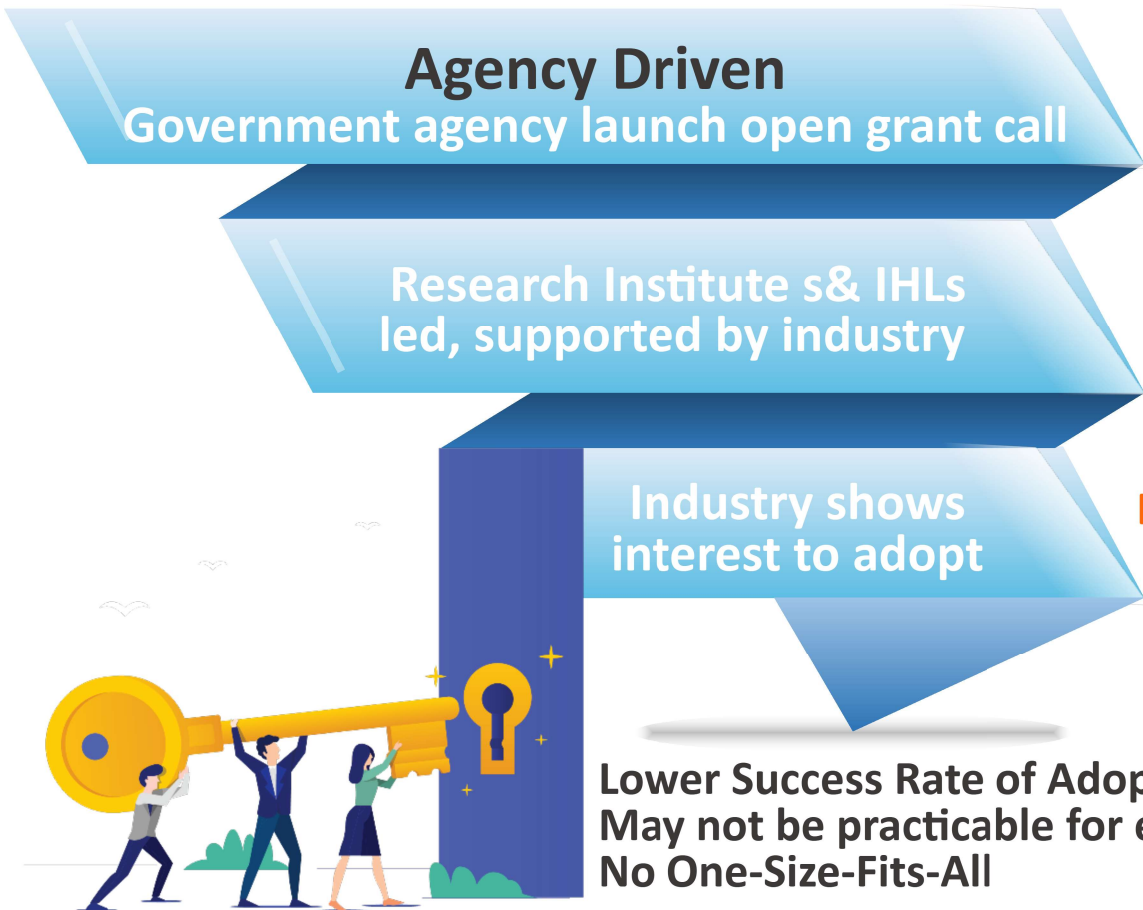
## MISSION

- To develop innovative and disruptive construction technologies through applied research.
- To translate innovative technologies from laboratory to site.
- To provide specialized training and support talent development.

# Top-Down v.s. Bottom-Up

## 'Top-Down' Agency Driven Applied Research

Aim for knowledge creation & building capability



## 'Bottom-Up' Industry-Focus Applied Research

Aim for test bedding & actual application

Higher Success Rate of Adoption  
Tailored to the industry needs



# Three Pillars of Collaboration and Activities

## Applied Research

Proof of Concept

Prototyping

Demonstration and Test-Bedding

Living lab

## Growing Industry

Industry Partnerships

Access to Labs

Consultancy and Advice

Commercialization platform

## Training

Student attachments

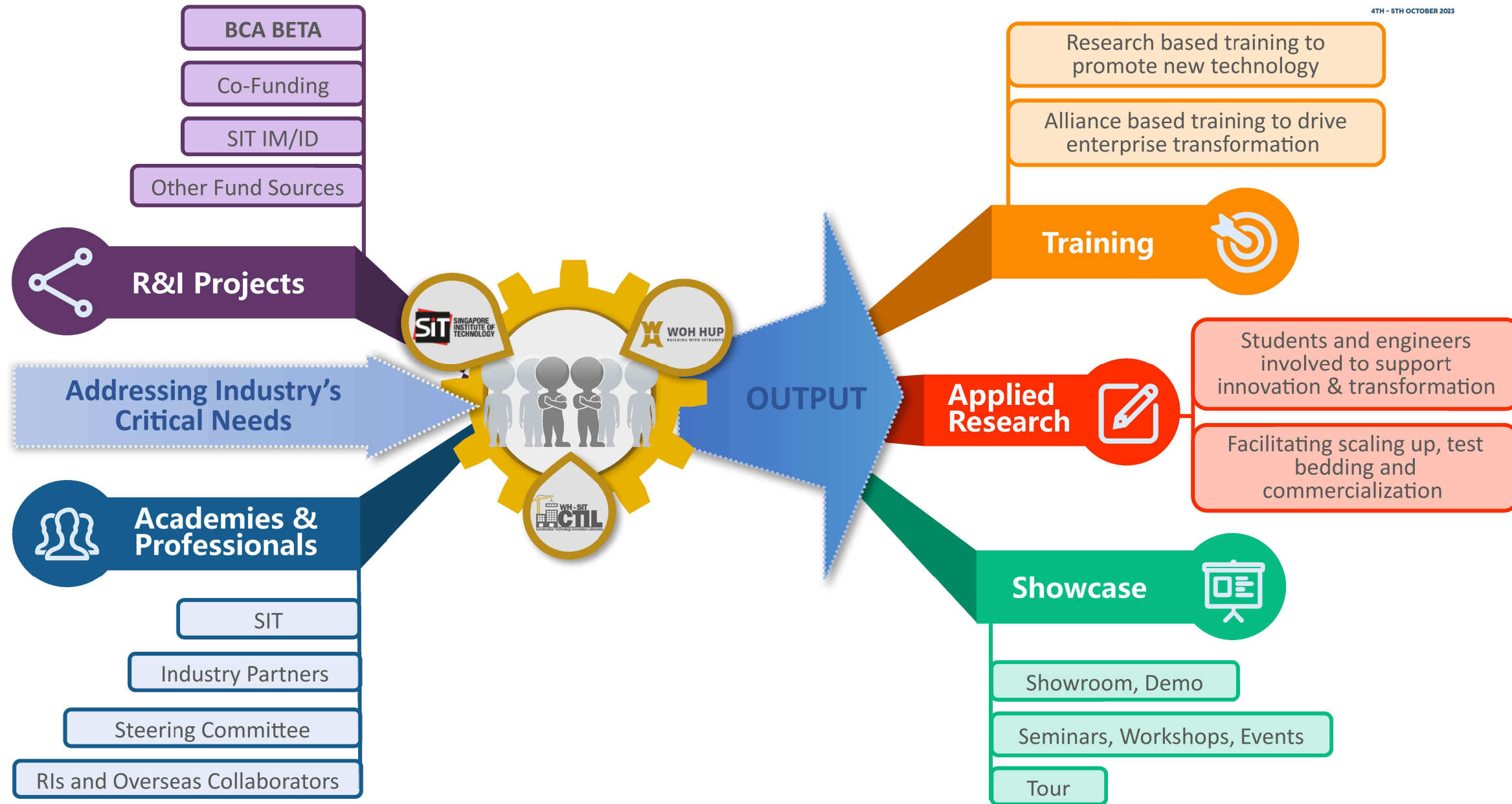
Postgraduate Training  
(Industrial Master/Doctorate)

Professional Training

And more....



# Collaboration and Activities



# CTIL Focus Areas

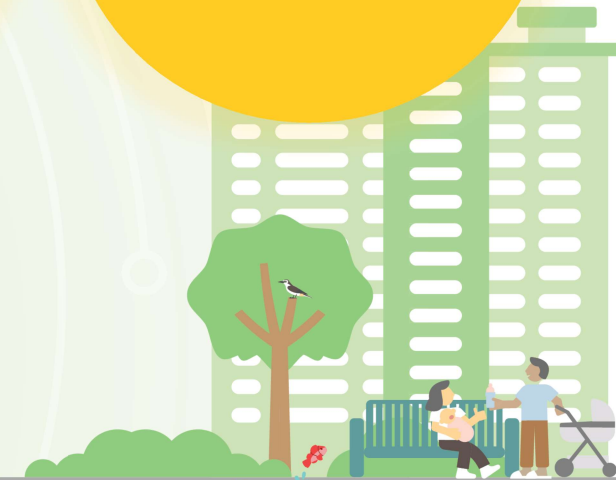
New Technology Creation, Test Bedding & Translation, Technology Adoption

## Focus 1 Productivity

(Innovative construction technologies)

## Focus 2 Sustainability (Alternative materials & decarbonization)

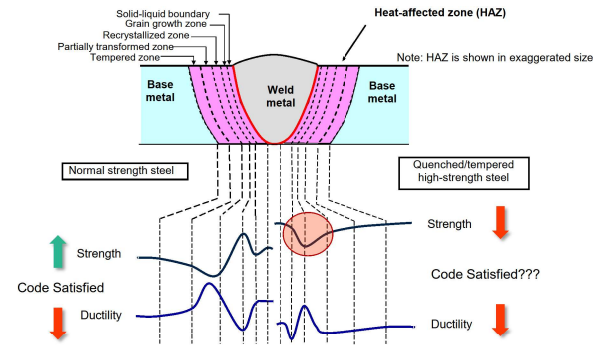
## Focus 3 Resilience (Blast mitigation and climate change)



# Prioritizing Our Efforts

## Project 2: High Performance Plunge-in King Post for Top-Down Building Construction

Securing the quality of welds (HAZ)



### Welding S690Q in Controlled Environment

The main reason that high strength steel (HSS) and normal strength steel (NSS) have similar chemical composition yet drastic different mechanical properties is that HSS usually goes through heat treatment hardening processes, more specifically, thermal-mechanical controlled rolling (TMCP) or quenching and tempering (QT) after rolling.

Everybody can weld S690, but can every work piece achieve yield strength of 690 N/mm<sup>2</sup> across the joint?

Base metal:  $f_y \geq 690 \text{ N/mm}^2$   
Electrode:  $f_y \geq 690 \text{ N/mm}^2$  ?  
Joint:  $f_y \geq 690 \text{ N/mm}^2$   
Must satisfy for direct tension members!

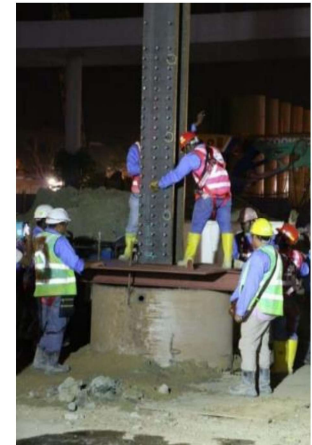
Welding procedures need to qualify Welding Procedure Specification (WPS)

FCAW - X profile  
Average heat input: 1.54kJ/mm

SAW - X profile  
Heat input: 1.4kJ/mm



Fabrication of the 1<sup>st</sup> S690 King Post in SG



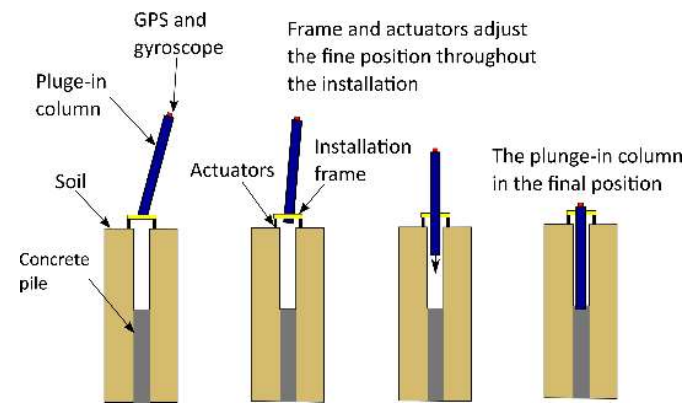
Conventional labour intensive installation of king posts



40% lighter S690 built-up king posts  
Source: DPM Heng Swee Keat's Facebook



Sensor box

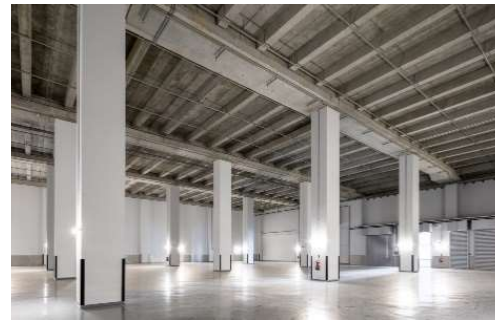


Positioning and verticality control system (under development)

# Prioritizing Our Efforts

## • P4: High Performance Pre-Engineered Steel Concrete Composite Beams for Sustainable Construction

**Aim: To reduce embodied carbon and improve construction productivity in modern industrial building construction with high-performance steel concrete composite beams.**



, 11.4m height, live load

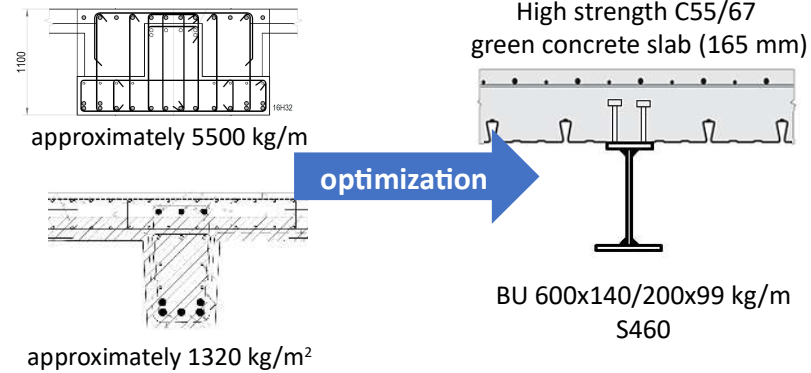


Photo by Woh Hup: Prof. Chiew and Asst/P Zhao supported Woh Hup during DPM's Visit on 13 Feb 23

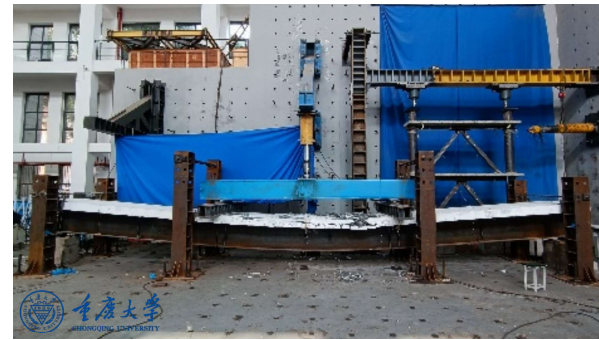
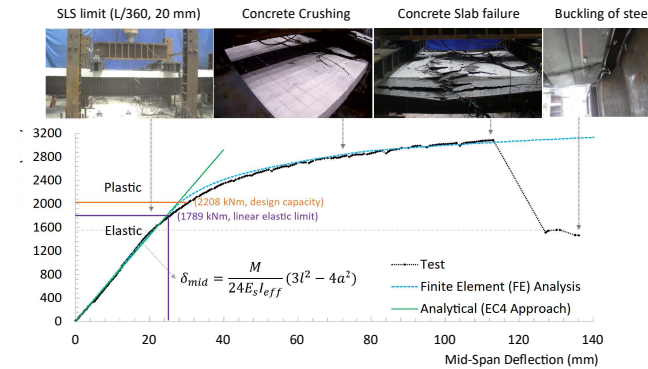


Photo by Prof Yang Bo: testing of full scale HPCB at Chongqing University



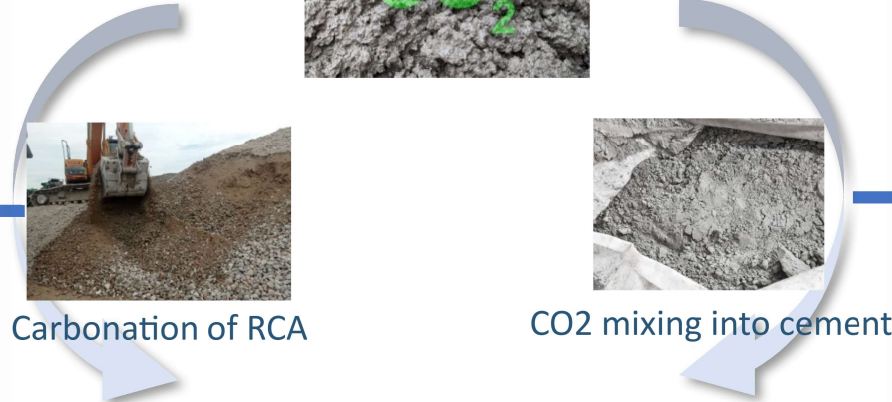
- 60% lighter
- 10% higher productivity
- 5-10% cheaper
- 40% less embodied carbon

# Prioritizing Our Efforts

## • P5: Waste Valorisation in Concrete Production via CO2 Sequestration



### CO2 Sequestration and Waste Valorisation in ready mixed concrete



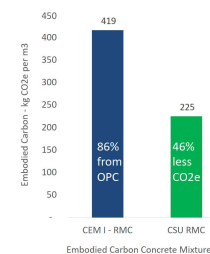
Carbonation of RCA



CO2 mixing into cement



Coming to market soon!



#### Carbonation of RCAs



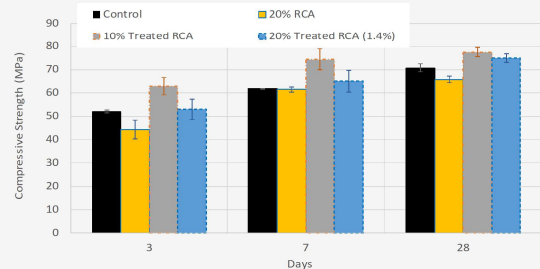
Local demolishing waste



Cross-section after cutting



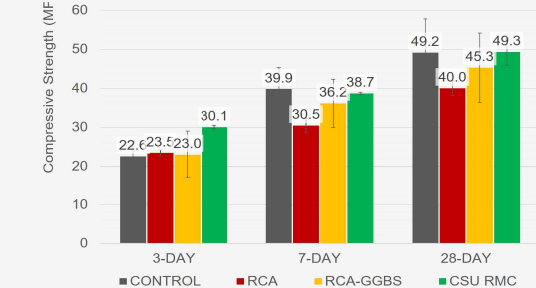
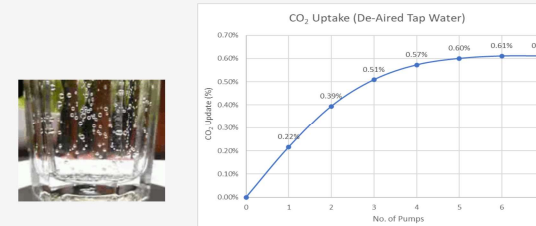
RCA after 4 hr carbonation (8.3 < pH < 10)



Strength of CRCA Concrete (C55/67) (1.4 wt% CO<sub>2</sub> uptake)

– exceed virgin concrete by 5.8% at 28 days

#### Mixing with carbonated water/solutions



Control: Commercial C32/40  
CW: 50% GGBS + 0.6% CO<sub>2</sub> mixing

- 30% higher 3-day strength
- Comparable 28-day strength
- 170 mm sump to ensure pumpability



Building with Integrity. Backed by more than nine decades of experience

A leading construction and civil engineering specialist behind Singapore's most iconic developments

**95**

Number of years since Woh Hup was founded

**2,725**

Number of talents working with Woh Hup

**548**

Number of awards we have won

**143**

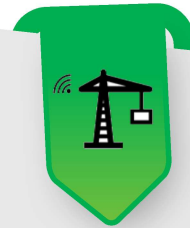
Projects in Singapore since 1927

# Alignment with the refreshed BE ITM 2025



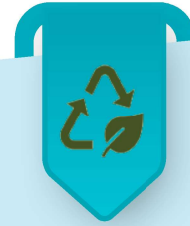
## Integrated Digital Environment

Improve  
productivity,  
quality and  
efficiency



## BE Automation

Improve  
productivity,  
reduce the  
reliance on labors



## Sustainable Urban Infrastructure

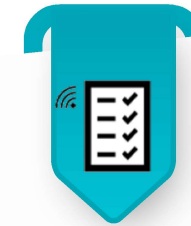
Critically urgent to  
address the  
sustainability and  
climate change  
challenges:

- Post Covid
- Decarbonisation
- Coastal  
protection



## Smart Inspection

Improve  
productivity,  
efficiency and  
safety



## Smart Approval

Improve  
productivity and  
efficiency

## Design for manufacturing and assembly (DfMA)

- A key strategic thrust to *raise construction productivity* (Construction Industry Transformation Map).
- Buildings are designed for ease of off-site manufacturing and efficiency of on-site assembly.

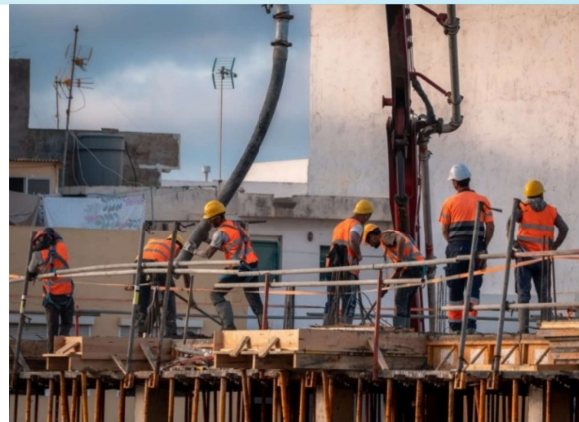
Conventional labor-intensive construction site

Construction Industry Transformation

High-productivity and efficiency DfMA construction site

Traditional

High performance steel/steel-concrete composite structures



Prefabricated prefinished volumetric construction (PPVC) for student hostel @NTU



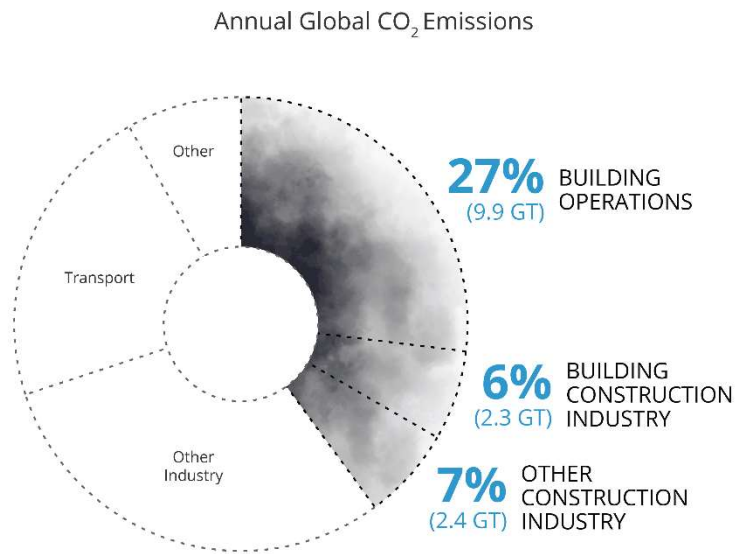
DfMA for multistorey inland container depot JTC logistics hub @Gul



# How to make Construction more Sustainable?

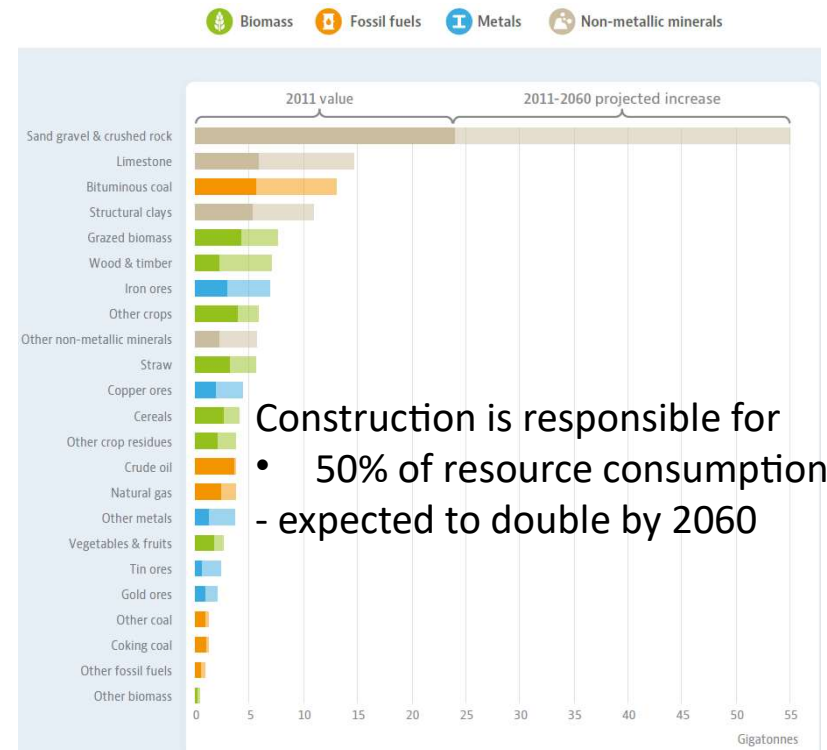
## (1) Tackling the embodied carbon (a.k.a. $eCO_2$ , $CO_2e$ , $CO_2eq$ )

WGBC: New developments and major renovations to reduce and compensate embodied carbon emissions by 2030



© Architecture 2030. All Rights Reserved. Data Source: IEA (2022), Buildings, IEA, Paris  
Building Construction Industry and Other Construction Industry represent emissions from concrete, steel, and aluminum for buildings and infrastructure respectively.

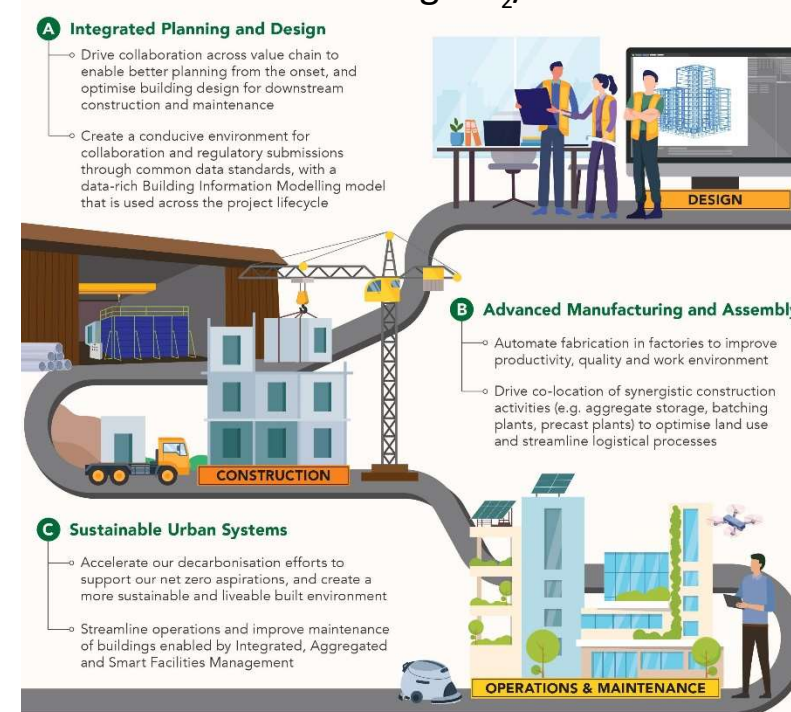
## (2) Reduce input of virgin materials



Source: OECD HIGHLIGHTS (2018). Global Material Resources Outlook to 2060. Economic drivers and environmental consequences

## (3) Improving productivity

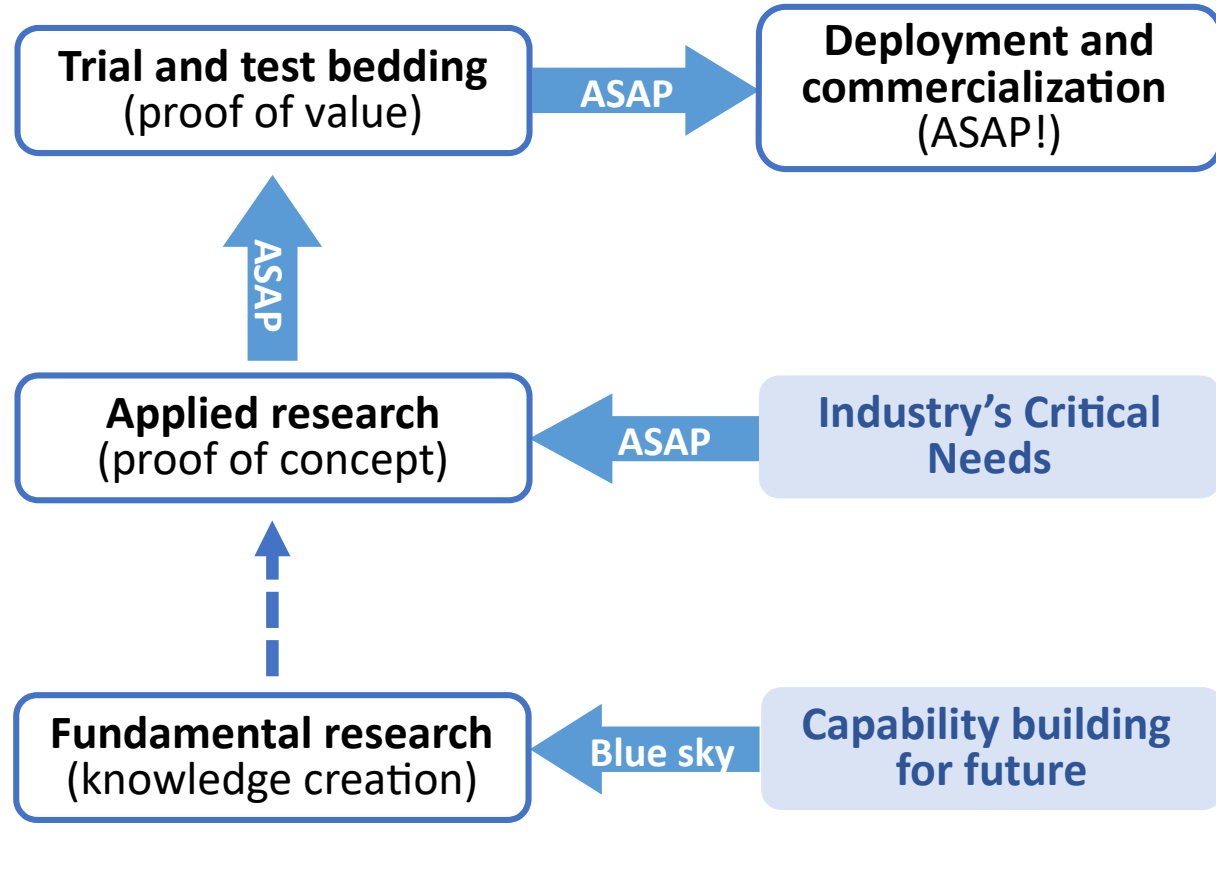
- Electricity = 0.41 kg CO<sub>2</sub>/kWh
- Diesel = 3186 kg CO<sub>2</sub>/tonne



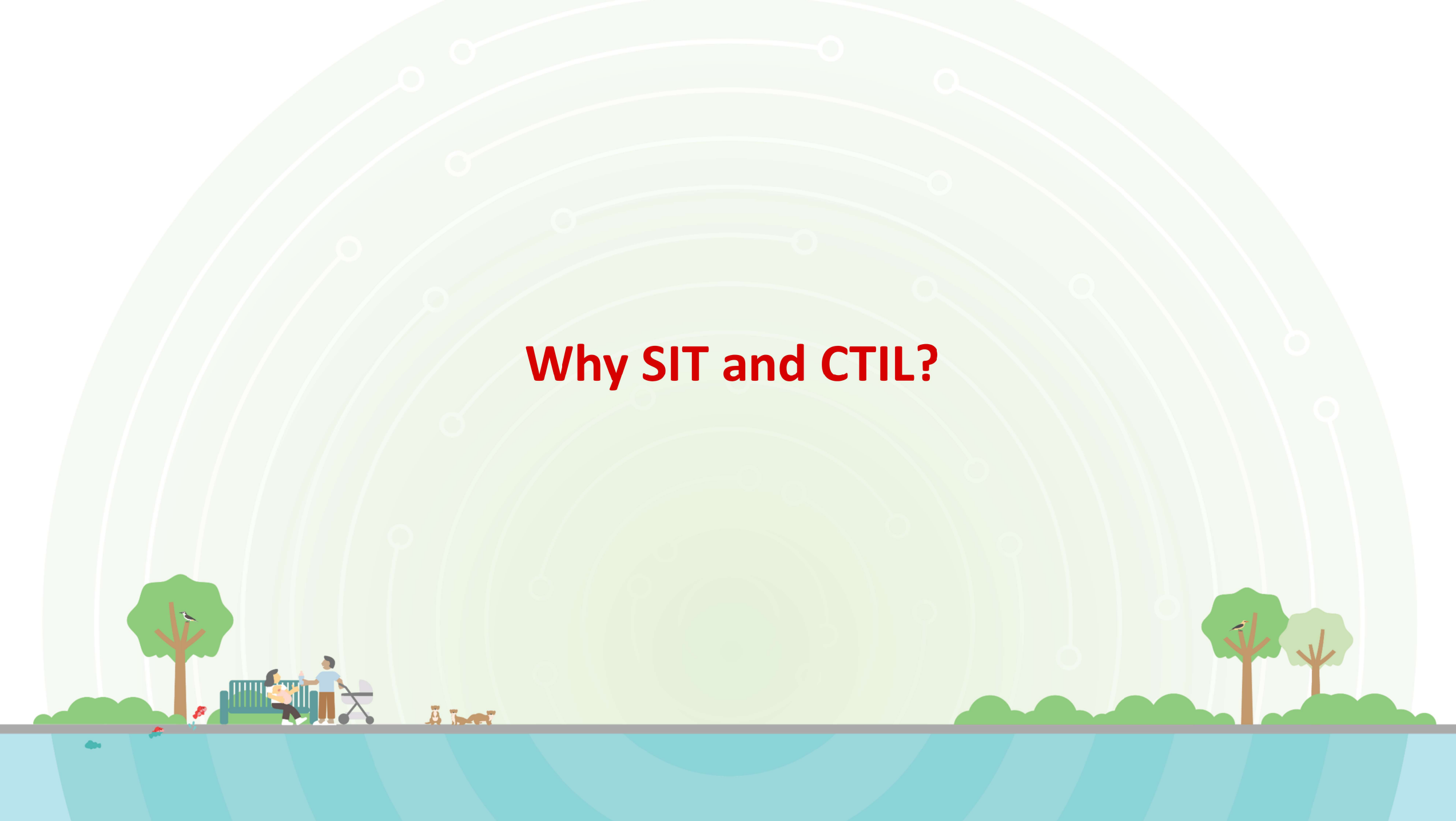
Source: BCA (2022). Built Environment Industry Transformation Map (ITM). Building a world-class and resilient sector. BCA (2021). Green Mark 2021 Carbon Technical Guide.

# Technology Readiness Level – Translation Speed

Level	Stage	Description
9	Production	Actual system, proven through successful mission operations
8	Full-scale development	Actual system completed and operationally qualified through test and demonstration
7	Exploratory development	System prototype demonstration in an operational environment
6		System/ sub-system model or prototype demonstration in a relevant environment
5	Technology development	Component and/ or basic sub-system validation in relevant environment
4		Component and/ or basic sub-system technology validation in laboratory environment
3		Analytical and laboratory studies to validate analytical predictions
2	Technology development	Technology concept and/ or application formulated
1		Basic principles of technology observed and reported

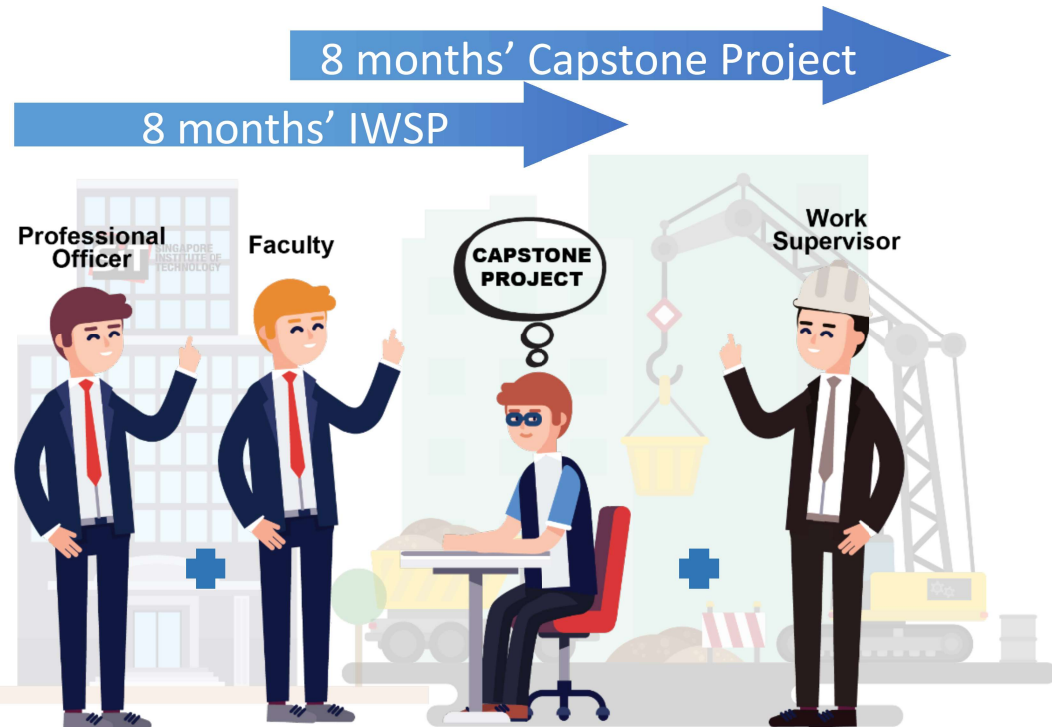


# Why SIT and CTIL?



# Integrated Work-Study Programme and Industry Capstone Project

- 11 students taken in 2020
- 14 students taken in 2021
- 17 students taken in 2022
- 11 students taken in 2023



## • Showcase IWSP posters from Woh Hup students

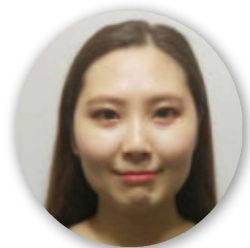
## Industrial Masters and Industrial Doctorate Programme (IM/ID)

- Designed to develop talent pipeline at postgraduate level
- To equip professionals with applied research skills
- Facilitate the test bedding and accelerate technology adoption



**Mr. Chua Guan Feng**

8 years working experience before joining IM  
Research topic: High performance pre-engineered steel-concrete composite beams for sustainable industrial buildings



**Ms. Cong Yuxiao**

10 years working experience before joining IM  
Research topic: Zero cement geopolymer concrete for sustainable coastal protection

## Annual CTIL Technical Seminar for disseminating the research findings



## Concluding Remarks

- **CTIL's modus operandi revolves around a 'Bottom-Up' approach, which provides a much-needed platform for industry partners to share expertise to develop capabilities to address key industry challenges. It also re-introduces and reinforces the value of collaboration not only among supply chain partners but also among government agencies, institutes of higher learning and industry players; marrying research with skills to create practical solutions for the BE sector.**
- **Deep involvement of practicing engineers in the applied research projects facilitate the trial and test bedding and eventually accelerate the translation of technology from laboratory to sites.**
- **The 12-month long Integrated Work-Study Programme and Industry Capstone Project allow students to hone their technical skills and gain new knowledge at workplace, and eventually build up talent pipeline for the companies. The Industrial Master and Industrial Doctorate Programmes also give current employees of companies an opportunity to upgrade themselves and review the current practice in the companies.**





**Thank You**