Research Institute for Sustainable Urban Development: a Brief Overview

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Ko Jan Ming Professor of Sustainable Structures and Materials &

Chair Professor of Structural Engineering

6 January 2017

Opportunities for Hong Kong

- ✓ **Hong Kong is a unique model of high-density cities characterized by high-rise residential blocks**
- ✓ **Most large cities in the mainland are becoming like Hong Kong**
- ✓ **Hong Kong is ahead of the Chinese mainland in urbanization by at least two decades**
- ✓ **Hong Kong's dense urban environment is a living laboratory for R & D**
- ✓ **World-class research at PolyU in related areas**
- ✓ **Examples of Hong Kong's areas of opportunity:**
  - ➢ **Public transport systems**
  - ➢ **GPS navigation of vehicles**
  - ➢ **Management of underground assets**

network.nationalpost.com http://leadership.uoregon.edu/upload/images/hongkong.jpg

Vision:

To be a world leader in the development and dissemination of innovative solutions for sustainable high-density urban development

RISUD was officially inaugurated in June 2013

Mission:

- ✓ To create innovative solutions to problems generated by high-density urban development through multi-disciplinary, collaborative research;
- ✓ To engage in knowledge transfer activities by collaborating with industry and government; and
- ✓ To make an impact on societal cultures of urban sustainability through community engagement and services.

Organizational Chart

Innovative Solutions for Sustainable Cities

Key Characteristics of RISUD

- ✓ Aimed at high-impact solutions for pressing socio-economic problems
- ✓ Integration of expertise for multi-disciplinary and/or collaborative research
- ✓ Incentive funding from RISUD to encourage multi-disciplinary/collaborative research
- ✓ Collaboration with government and industry for real-world impact

University-Government-Industry (UGI) Consortium for Sustainable Urban Development

(Initiated and currently hosted by RISUD)

Government Departments

- ✓ Architectural Services Department
- ✓ Buildings Department
- ✓ Civil Engineering and Development Department
- ✓ Drainage Services Department
- ✓ Electrical and Mechanical Services Department
- ✓ Environmental Protection Department
- ✓ GLTS Section of the Development Bureau
- ✓ Highways Department
- ✓ Hong Kong Observatory
- ✓ Housing Department
- ✓ Planning Department
- ✓ Transport Department
- ✓ Water Supplies Department

Universities (8 members)

- ✓ CityU
- ✓ CUHK
- ✓ HKBU (2 centres)
- ✓ HKU
- ✓ HKUST (2 centres)
- ✓ PolyU

Industry (26 members)

- ✓ AECOM Asia
- ✓ CLP Power
- ✓ Gammon Construction
- ✓ Hongkong Electric
- ✓ MTR Corporation
- ✓ Ove Arup & Partners
- ✓ Siemens Limited
- ✓ Sun Hung Kai Properties
- ✓ ……

Strategic Focus Areas

(Selected/under consideration)

- Smart and grid-responsive buildings (selected)
- Urban water management (selected)
- Urban simulation (tentatively selected)
- Air quality and urban health
- Innovative land supply
- Robotics in construction
- Industrialization of construction
- Sustainable urban infrastructure

Sustainable Marine Infrastructure: Challenges and a Promising Solution

Jin-Guang TENG

Ko Jan Ming Professor in Sustainable Structures and Materials,

Chair Professor of Structural Engineering &

Director of Research Institute for Sustainable Urban Development (RISUD)

The Hong Kong Polytechnic University

Needs for Marine infrastructure

Hong Kong-Zhuhai-Macau Bridge

http://www.arounddb.com

Hong Kong Airport Third Runway

Artificial islands

http://www.construction-post.com

Land reclamation in Hong Kong

https://commons.wikimedia.org
/

Marine Infrastructure Projects

Belt and Road Initiative

http://politicsinn.com/belt-and-road-takes-new-route/

Wind energy farm

http://ppm5d.ie/ppm-and-the-energy-industry/

Floating island

https://www.youtube.com/

Offshore drilling platform

http://www.offshoreenergytoday.com

Very Large Floating Structures

- **Floating wind farms**
- **Floating solar farms**
- **Floating airports**
- **Floating islands/cities**

Offshore wind energy

The world's first full-scale floating wind turbine, Hywind

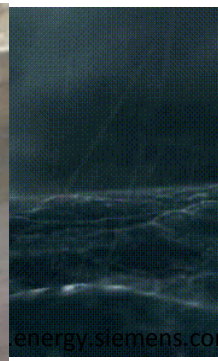
en.wikipedia.org

Offshore solar energy

The Kyocera Corporation’s Kagoshima Nanatsujima Mega Solar Power Plant can generatie enough electricity to power roughly 22,000 homes.

www.smithsonianmag.com

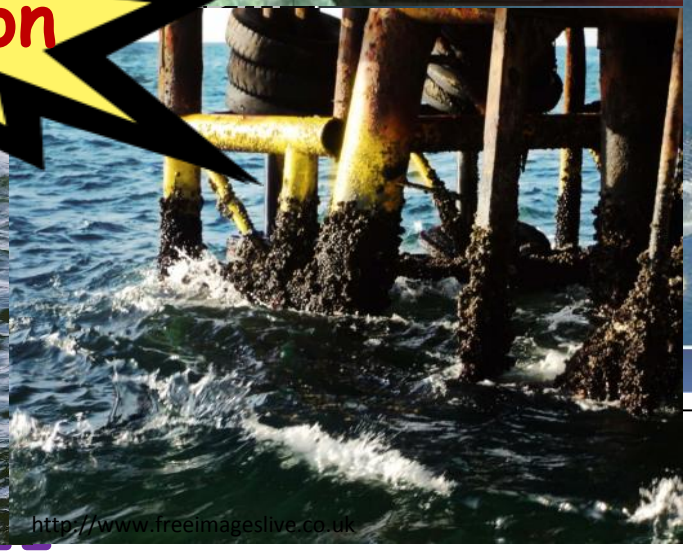
Marine environment



Steel-re

of

Steel corrosion



Challenge posed by steel corrosion

High maintenance costs of steel-RC structures

Steel corrosion costs about 3% of GDP (https://www.nace.org/)

United States (ASCE 2013):

- ✓ The US would need to invest US$3,600 billion over eight years to maintain a state of good repair for its infrastructure

The challenge for Hong Kong and the Chinese mainland is similar (Jin et al. 2007):

- ✓ About 24% of bridges in costal regions suffered from steel bar corrosion and corrosion-induced cracking.

FRP products for new construction

What is FRP?

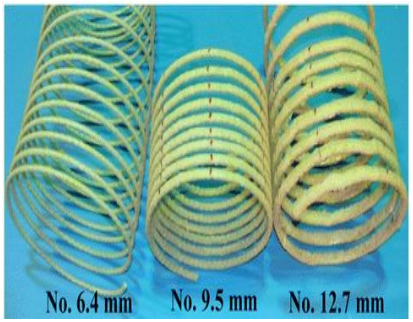
In North America, many bridges have been built with FRP reinforcing bars (rebars)

(Courtesy of Prof Mufti)

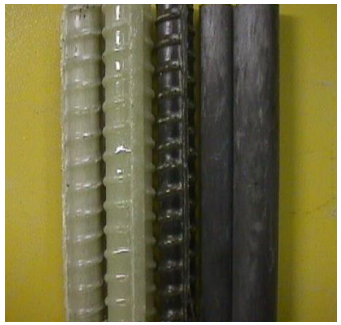
FRP products for use in civil engineering

FRP profile

FRP bridge deck



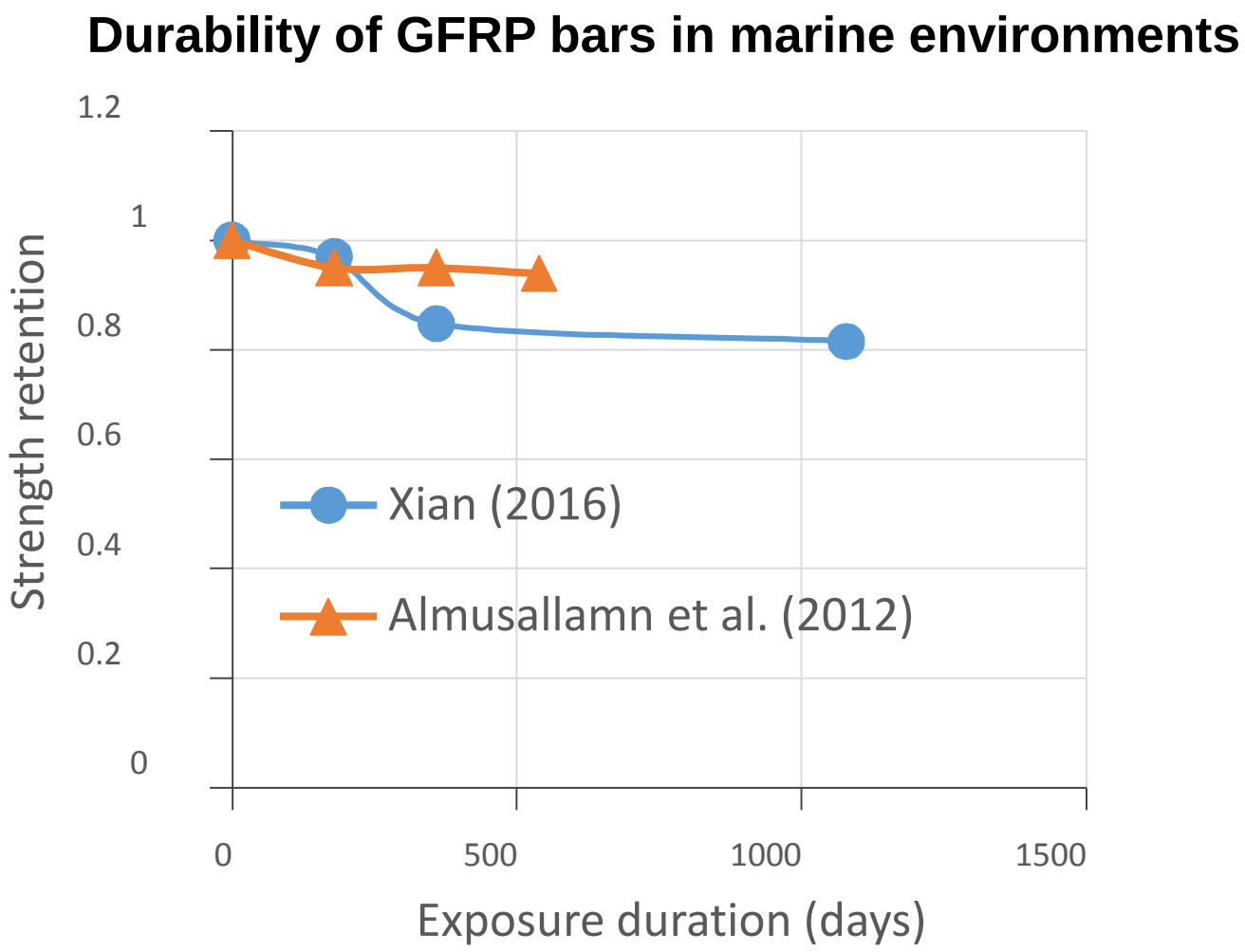
FRP stirrups



FRP rebars

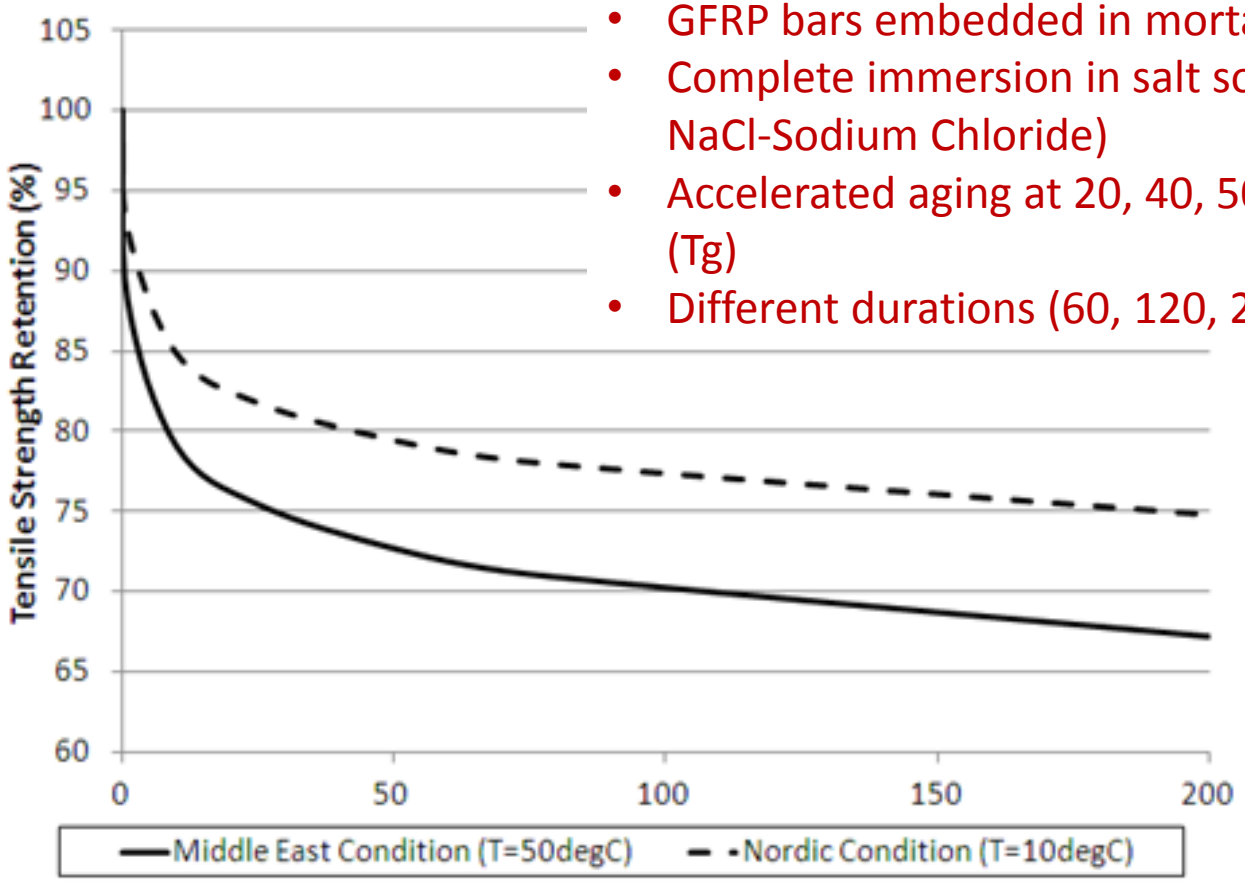
FRP tube

Durability of FRP Composites



Durability of FRP Composites

Durability of GFRP bars in marine environments

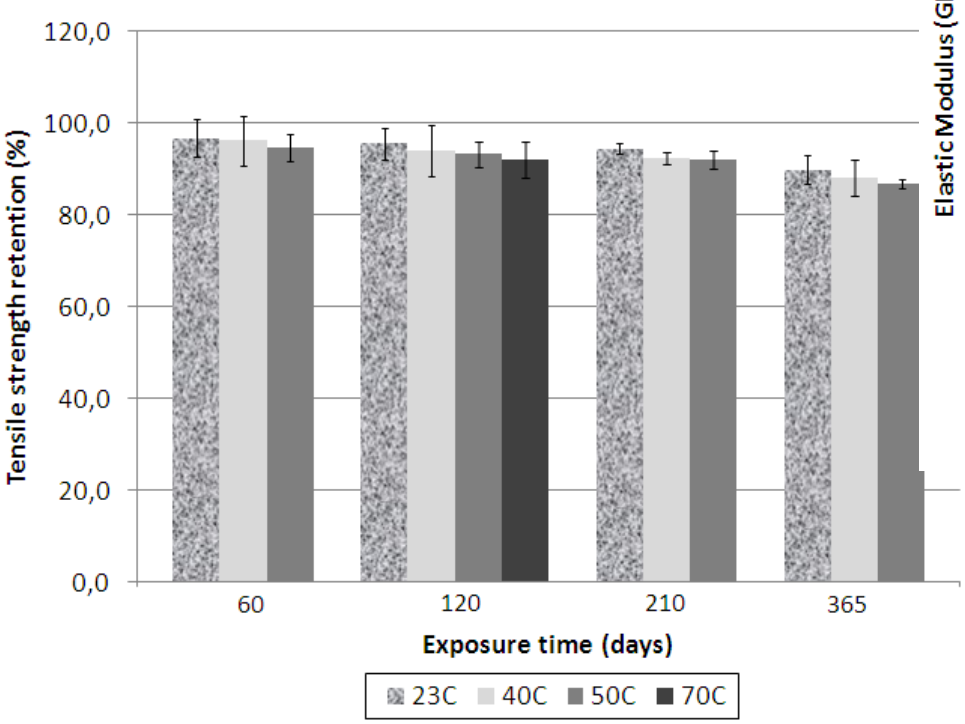


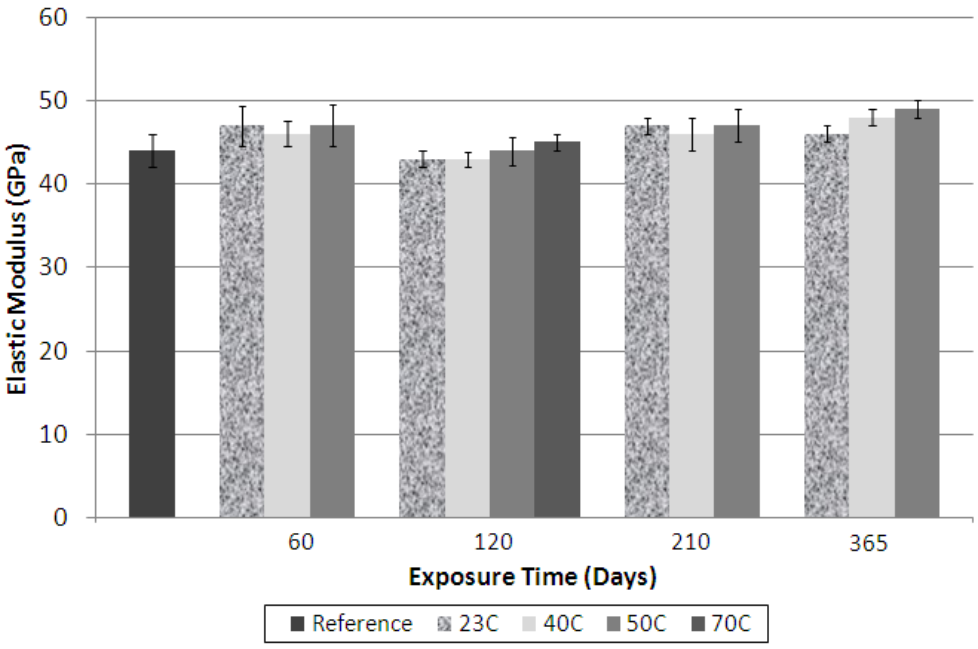
- GFRP bars embedded in mortar
- Complete immersion in salt solution (3% NaCl-Sodium Chloride)
- Accelerated aging at 20, 40, 50 and 70oC (Tg)
- Different durations (60, 120, 210, 365 days)

Courtesy of Prof. Brahim Benmokrane, University of Sherbrooke, Canada

Durability of FRP Composites

Durability of GFRP bars in marine environments





Courtesy of Prof. Brahim Benmokrane, University of Sherbrooke, Canada

International Workshop on Seawater Sea-sand Concrete (SSC) Structures Reinforced with FRP Composites, 13 December 2016, Hong Kong Polytechnic University

Long-Term Exposure Performance of FRP Composites in Marine Environments

Itaru Nishizaki, Iwao Sasaki & Hiroki Sakuraba

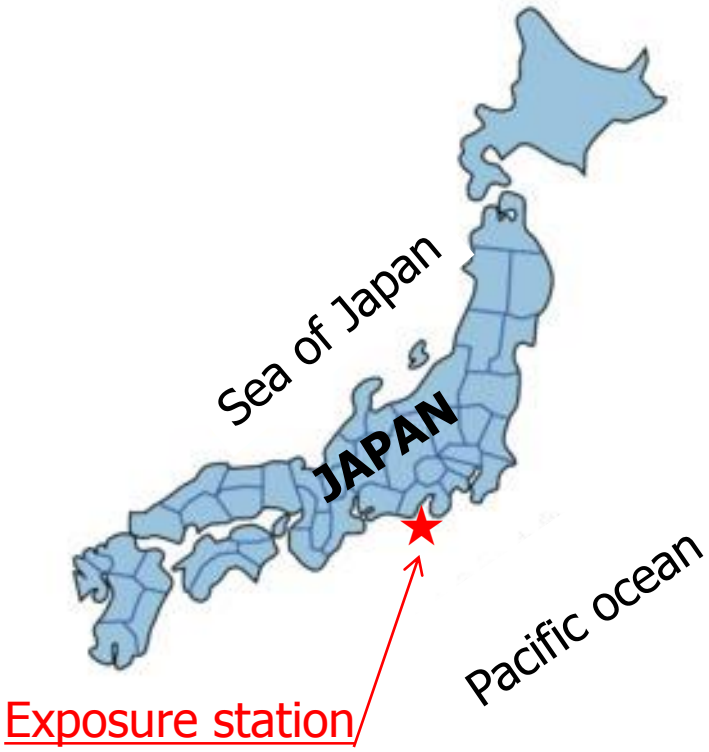
Public Works Research Institute, Japan

Innovative Materials & Resources Research Center (iMaRRC)

(Extracted slides with some adaptations by JG Teng)

Exposure location used in this test

Facilities for exposure tests: 8.9 meters from the tidal level



Climate: Typical mainland Japan
Annual mean temp.: 16.6 ℃; Annual rainfall: 2016 mm/y; Global solar radiation 14.7MJ/m^2.
Corrosivity based on ISO9223: C-4 (High) (3rd deck)

(Courtesy of Dr Itaru Nishizaki, Public Works Research Institute, Japan)

Sample name	CFRP1	CFRP2	AFRP1	AFRP2	GFRP	VFRP
Shape	Strand	Rod	Rod	Braided	Rod	Rod
Fiber type	Carbon	Carbon	Aramid	Aramid	E-glass	Vinylon
Matrix resin	Epoxy	Epoxy	Vinyl ester	Epoxy	Vinyl ester	Epoxy
Vf (%)	64	65	66	65	65	72
Diameter (mm)	12.5	8.0	6.0	8.0	6.0	6.0
Ultimate load (kN)	141	70.6	52.4	65.7	36.3	19.6
Modulus (GPa)	145	168	55.6	62.1	52.9	28.6
Anchor system	Adhesive	Wedge	Adhesive	Adhesive	Adhesive	Adhesive

Note: The GFRP & VFRP bars used in the testing programme were **not** developed for the reinforcement of concrete members

(Courtesy of Dr Itaru Nishizaki, Public Works Research Institute, Japan)

Specimens exposed to open marine environment: water, salt, sunlight, thermal cycles etc.

Exposure Condition

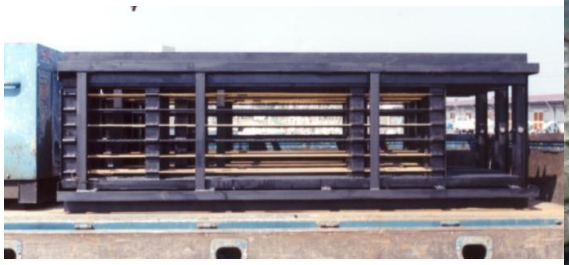
With/without direct sunlight

Specimens with tension

(in a stainless steel flame, 1m)

Two initial load levels were adopted for each FRP type

Specimens without tension

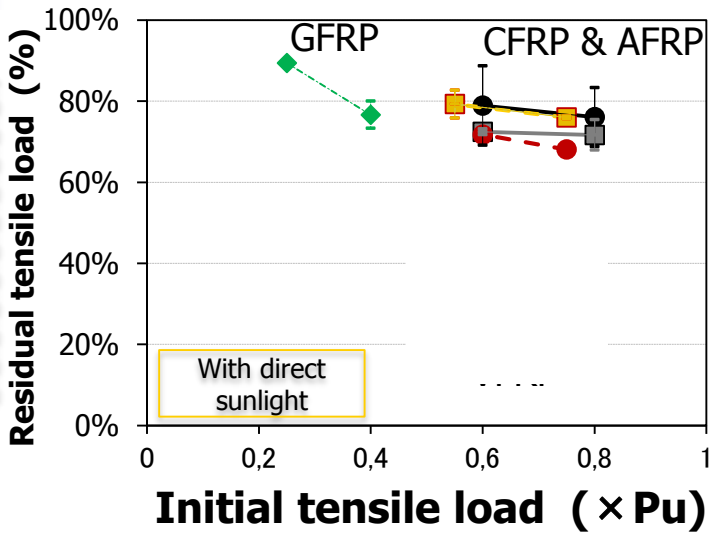


(Courtesy of Dr Itaru Nishizaki, Public Works Research Institute, Japan)

Results of residual tensile resistance

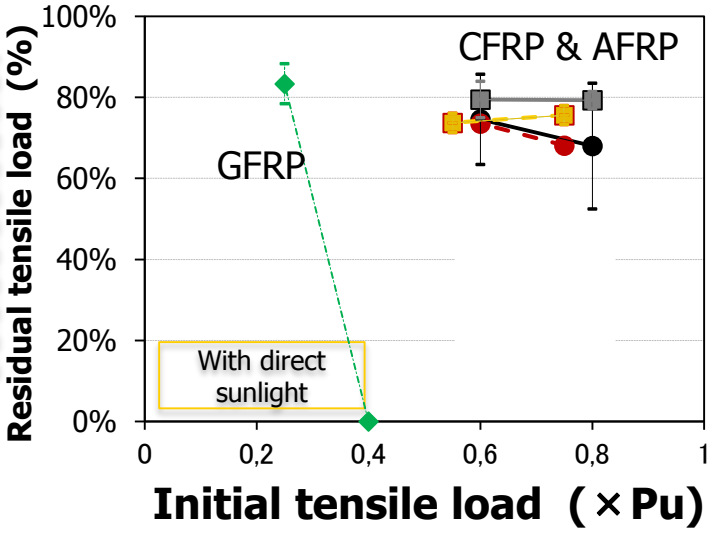
3.5years in tension

1993.5 – 1996.11



17years in tension

1993.5 – 2010.5



- Influence of the initial load level

- **Residual tensile resistance**
  - CFRP/AFRP: 70-80% retained after 17 years (at 0.6-0.8Pu)*
  - GFRP: 80% retained (at 0.25Pu) after 17 years; Creep ruptured at 0.4Pu after 17 years

(*For AFRP2, at 0.55-0.75Pu)

(Courtesy of Dr Itaru Nishizaki, Public Works Research Institute, Japan)

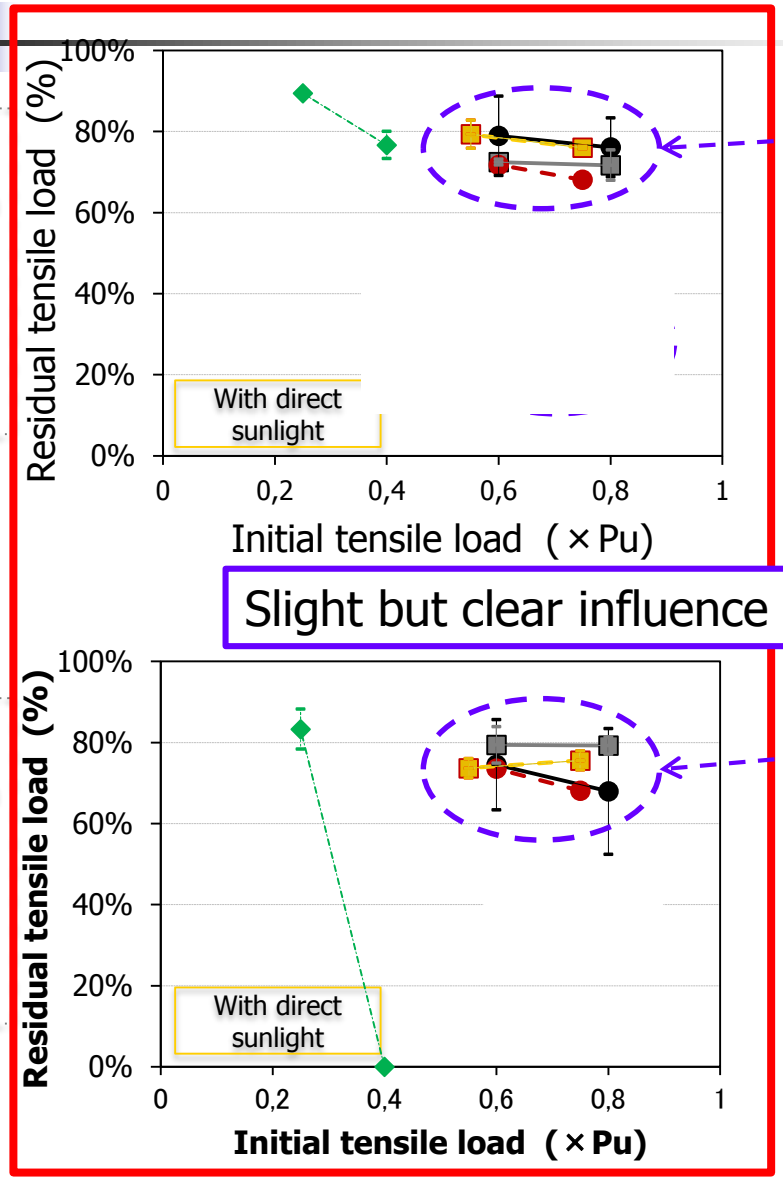
Effect of direct sunlight on residual tensile resistance

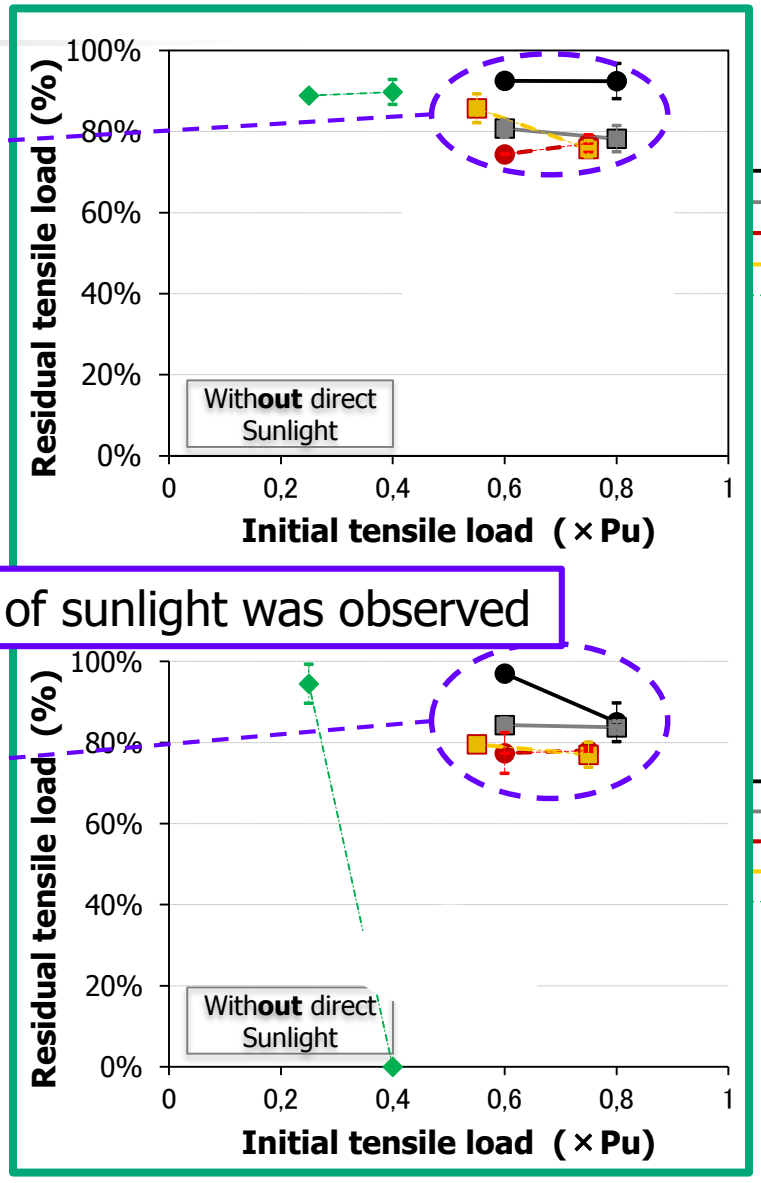
3.5years in tension

1993.5 – 1996.11

17years in tension

1993.5 – 2010.5





Slight but clear influence of sunlight was observed

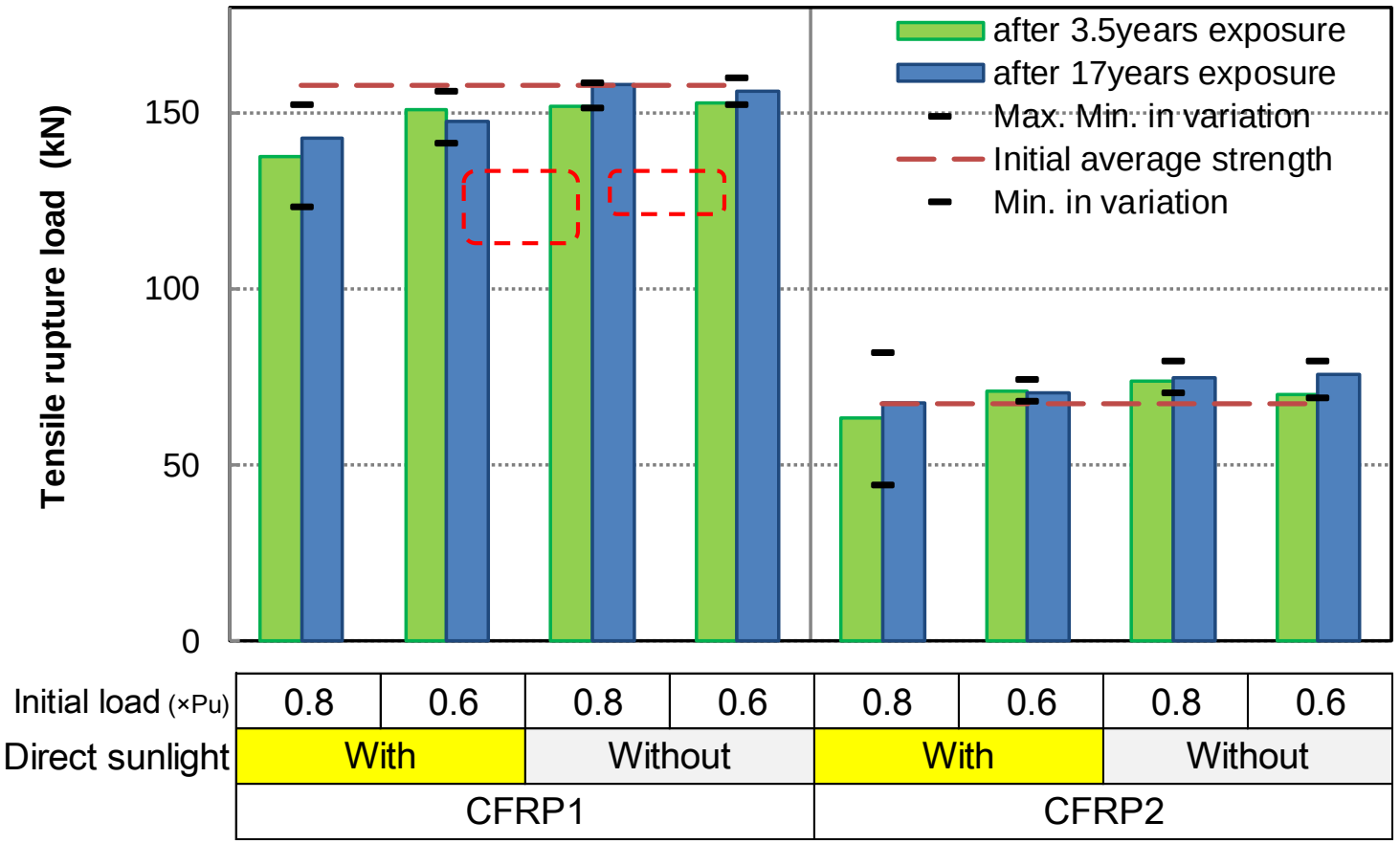
With direct sunlight

Without direct sunlight

(Courtesy of Dr Itaru Nishizaki, Public Works Research Institute, Japan)

Results of residual tensile resistance: CFRP

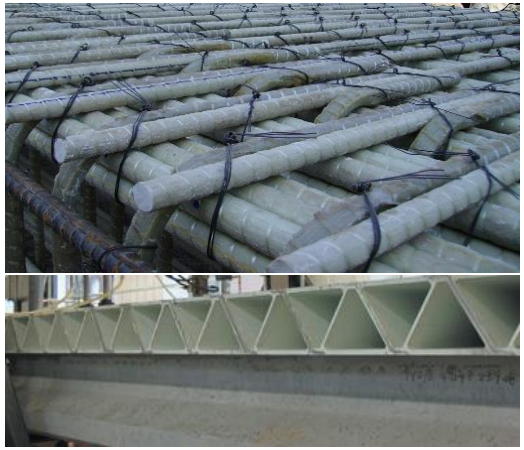
- Pre-stressed specimens, outdoor open exposure
- Overall findings: almost no major change
- CFRP1 under direct sunlight and a high prestress ratio: slight reductions



(Courtesy of Dr Itaru Nishizaki, Public Works Research Institute, Japan)

Sea-sand seawater concrete (SSC) + FRP

Sea-sand and seawater



FRP products

2 BIRDS 1 STONE

If steel is no longer used as the reinforcing material, then sea-sand and seawater can be used to make concrete

Steel	⇒	FRP
River sand	⇒	Sea sand
Fresh water	⇒	Seawater

Sustainability benefits: I

We can save fresh water, river sand, and energy

Protect the environment; Reduce carbon emissions

Damage to rivers and mountains by sand and gravel mining

Sustainability benefits: II

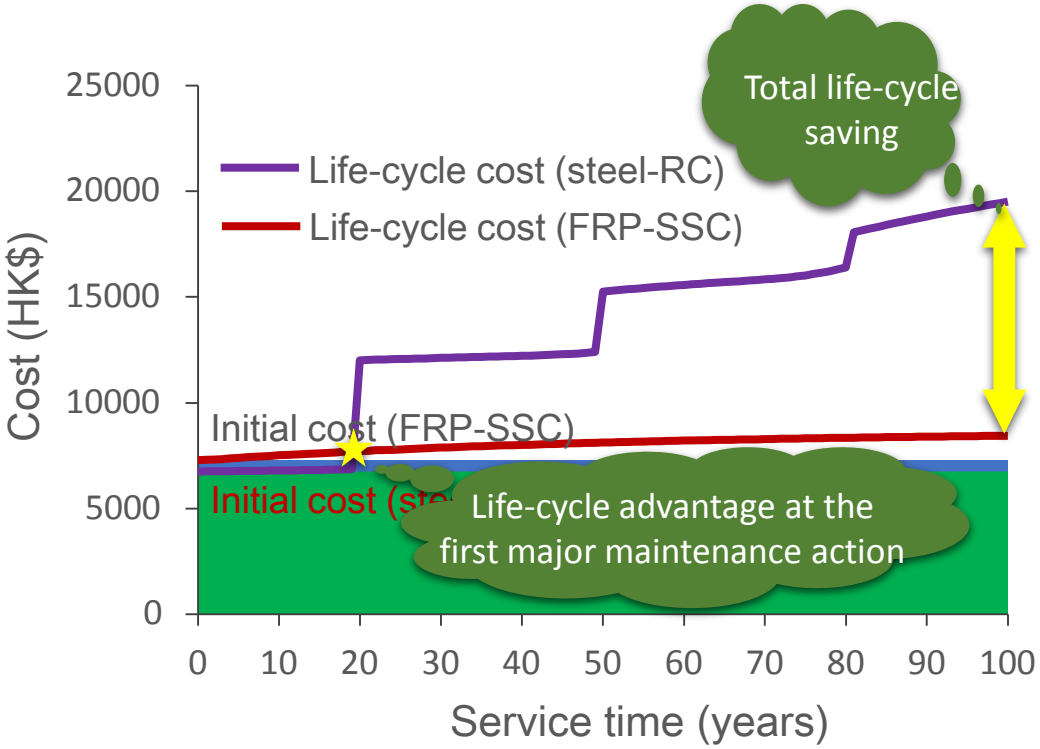
Cement production consumes great amounts of energy and accounts for about 5% of global CO_2 emissions

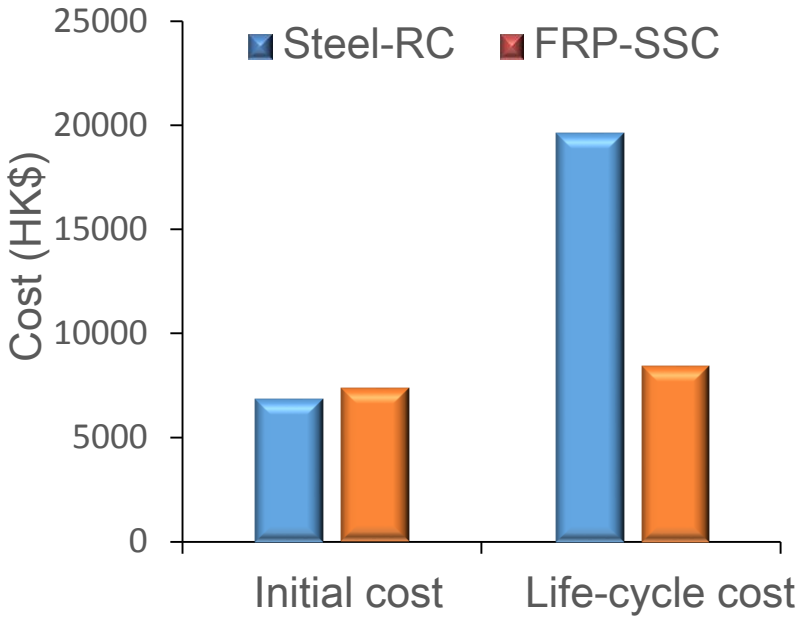
Relaxing chloride limits for cement allows the use of waste materials as fuels in cement production

Combining wastes incineration with energy recovery!

Life-cycle cost analysis

The life-cycle cost of FRP-SSC is only **half** that of steel-RC for a large structural member with a service life of 100 years





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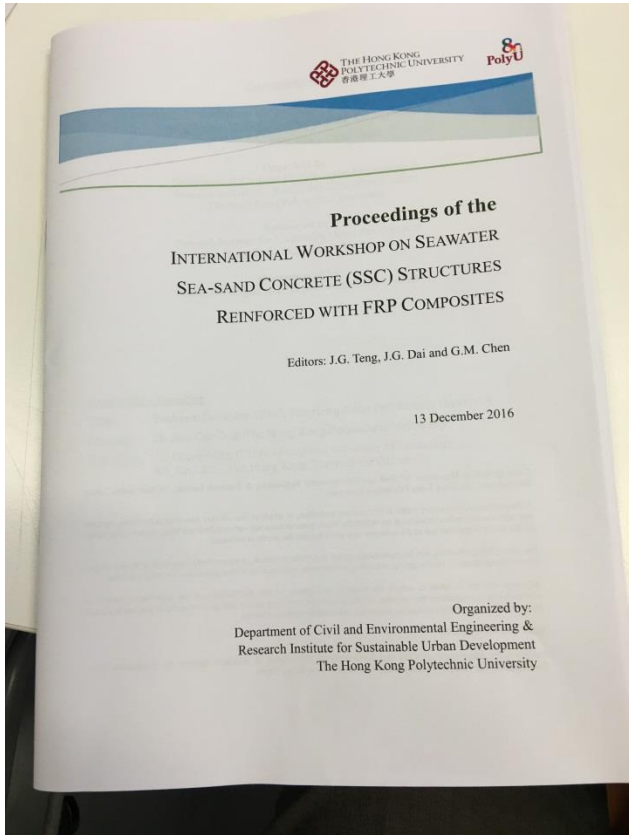


Grand challenge

How well will the new type of structures perform in 50 years, 100 years or even longer?

Accelerated aging tests

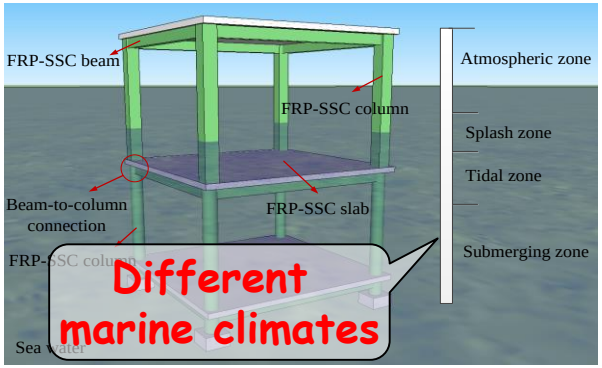
Artificial environmental chamber

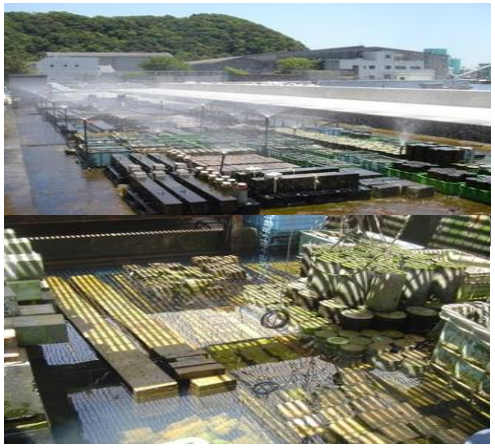
Key issues:

(i) Simulation of a sub-tropical climate like that in Hong Kong and nearby regions

(ii) Combined mechanical and environmental actions.

Field exposure tests





Accelerated laboratory tests

?

Field performance

Concerns with accelerated durability tests

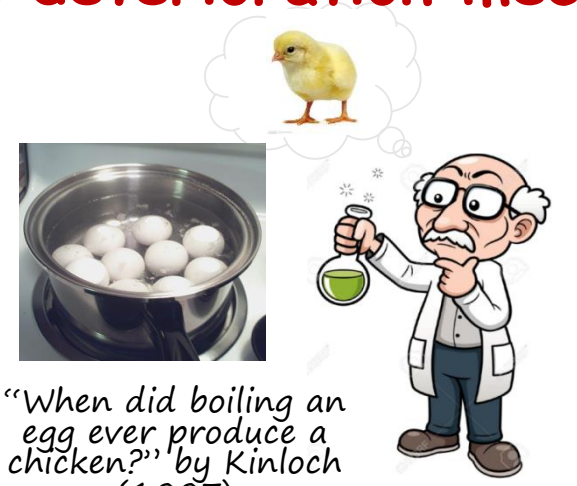
Traditional ways of accelerated laboratory durability tests

Increase temperature

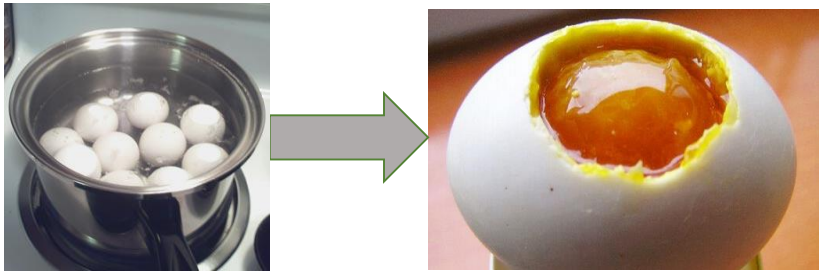
Increase concentration

Lower concentration Higher concentration

Simplistic empirical extrapolation must be avoided as the deterioration mechanism may change!

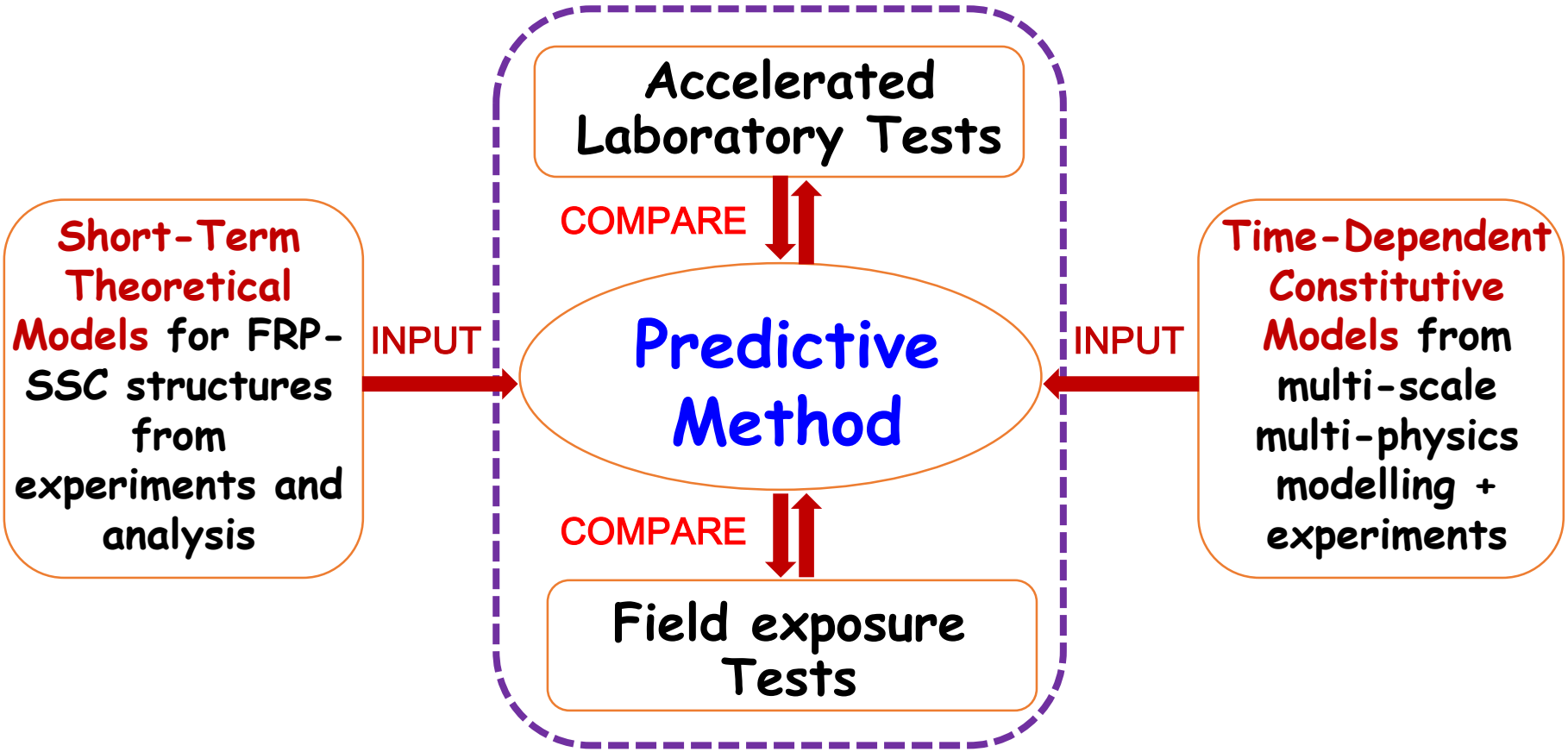


"When did boiling an egg ever produce a chicken?" by Kinloch (1997)

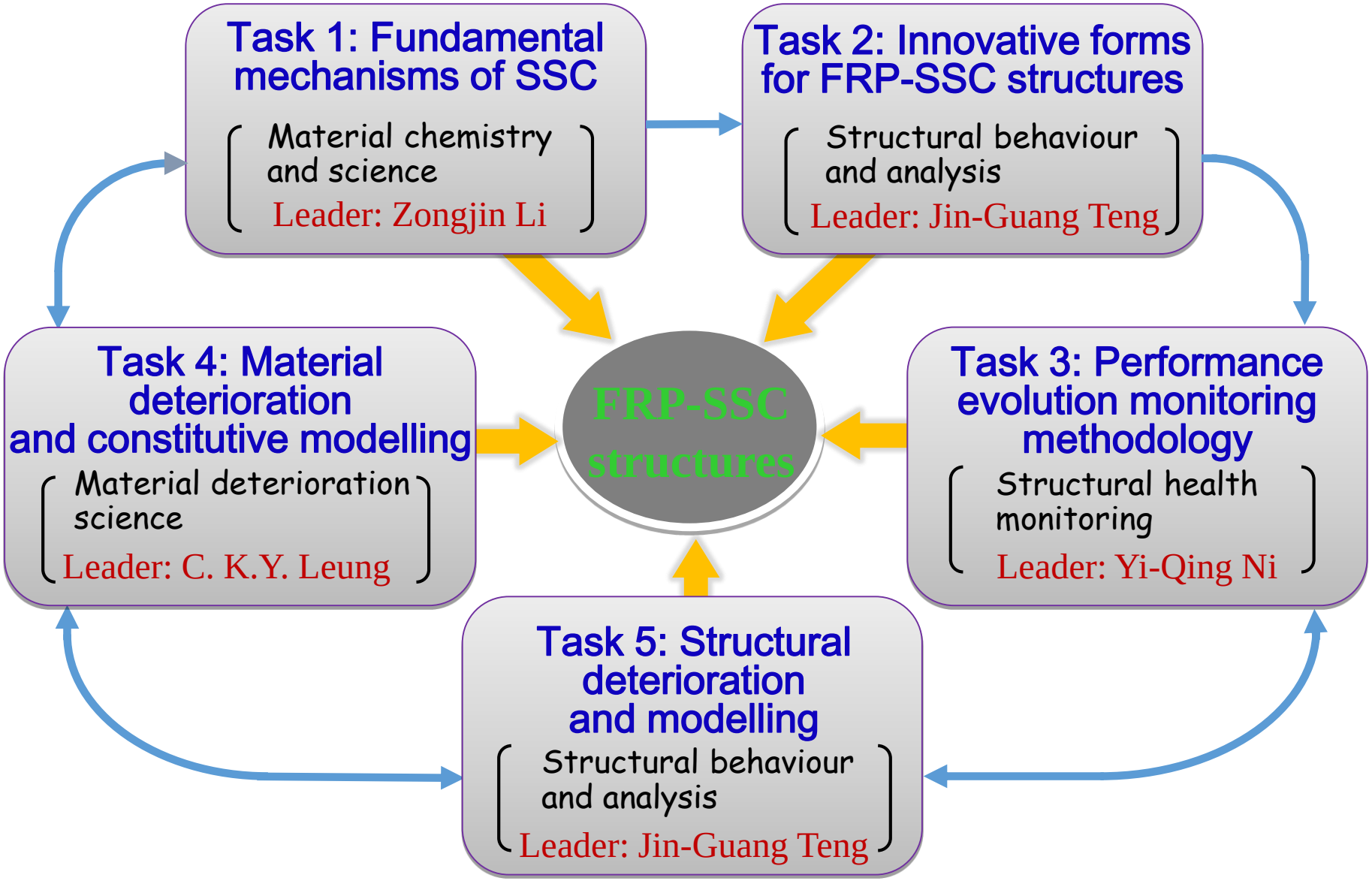


Grand scientific challenge

From molecular dynamics to structural behaviour: *A multi-scale multi-physics approach for predicting life-cycle performance*



Research programme



Thank you for your attention!

Questions?