Boosting Concrete with Ground Granulated Blast Furnace Slag (GGBS) For Sustainable and Low-carbon Solutions

Ir Thomas Lau
Head of Civil Engineering

Background

GO

- Reduce Carbon Emission
- Improve Durability
- BD's COP 2013: 35% to 75%

STOP

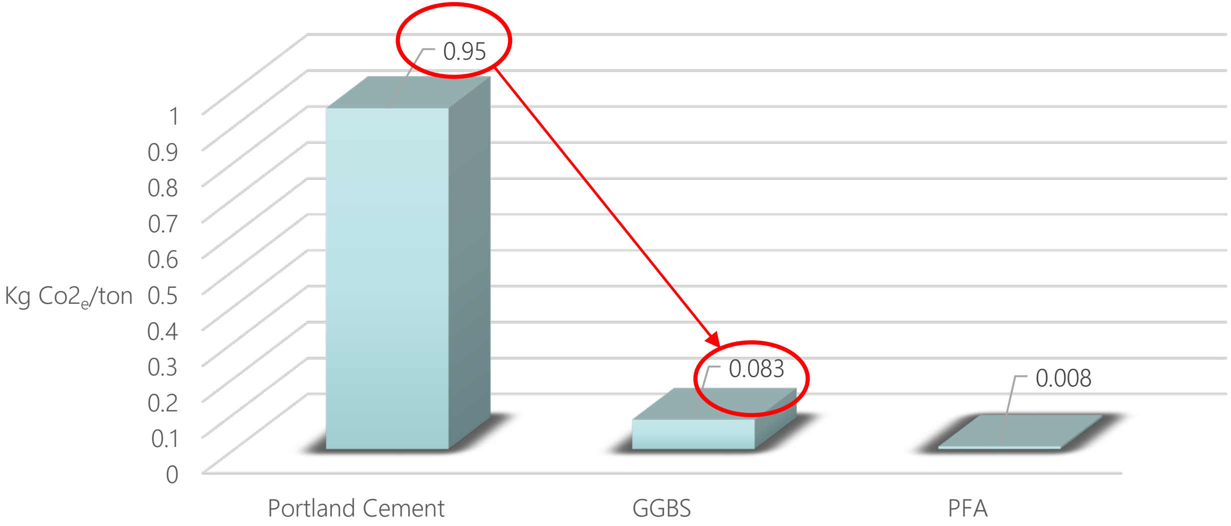
- Supply
- Early strength

ESG Benefits

The cement industry is one of the primary producers of green gas

(7% of annual global greenhouse gas)

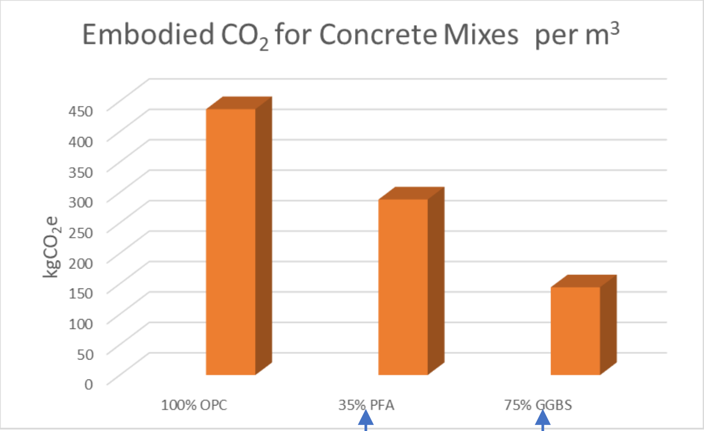
Embodied Carbon Emission of Cementitous Materials



Default value taken from University of Bath

ESG Benefits

GGBS: Reduction in carbon footprint



PFA: capped at 35% replacement

GGBS: capped at 75% replacement

Concrete Volume	Assuming 1M m^3
Approx. Carbon Footprint by using 100% Ordinary Portland Cement (OPC)	436,750 t CO_2e
Approx. Carbon Footprint of by using 35% PFA (Normally used in Government & MTR Civil jobs)	288,385 t CO_2e
Approx. Carbon Footprint of by using 75% GGBS (Rare usage in high dosage GGBS recently)	144,137 t CO_2e
Reduction in Carbon Emissions (Compared to 100% OPC)	**292,613 t CO_2e (67% reduction)**
Reduction in Carbon Emissions (Compared to 35% PFA Concrete)	**144,248 t CO_2e (50% reduction)**

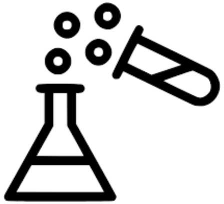
Background

MTR has demonstrated a dedication to sustainability by the early adoption of PFA and GGE 1998

But still not Common in high dosage

No sufficient test data to relieve the concern of early strength

In collaboration with HKIE-Materials Division, CEDD, Hong Kong Construction Material Association to carry out a research



Results and findings published in MaSTEC in Nov 2023

Research Methodology

To ease the concern of early strength development an
to verify the benefit in durability, different concrete m
were batched and tested

1. Category: Cat A (Durable) & Cat C (Foundation)

2. Concrete mixes of 50%, 65%, 75%, 85% GGBS replacement, 35% PFA replacement and 100% Portland Cement as control

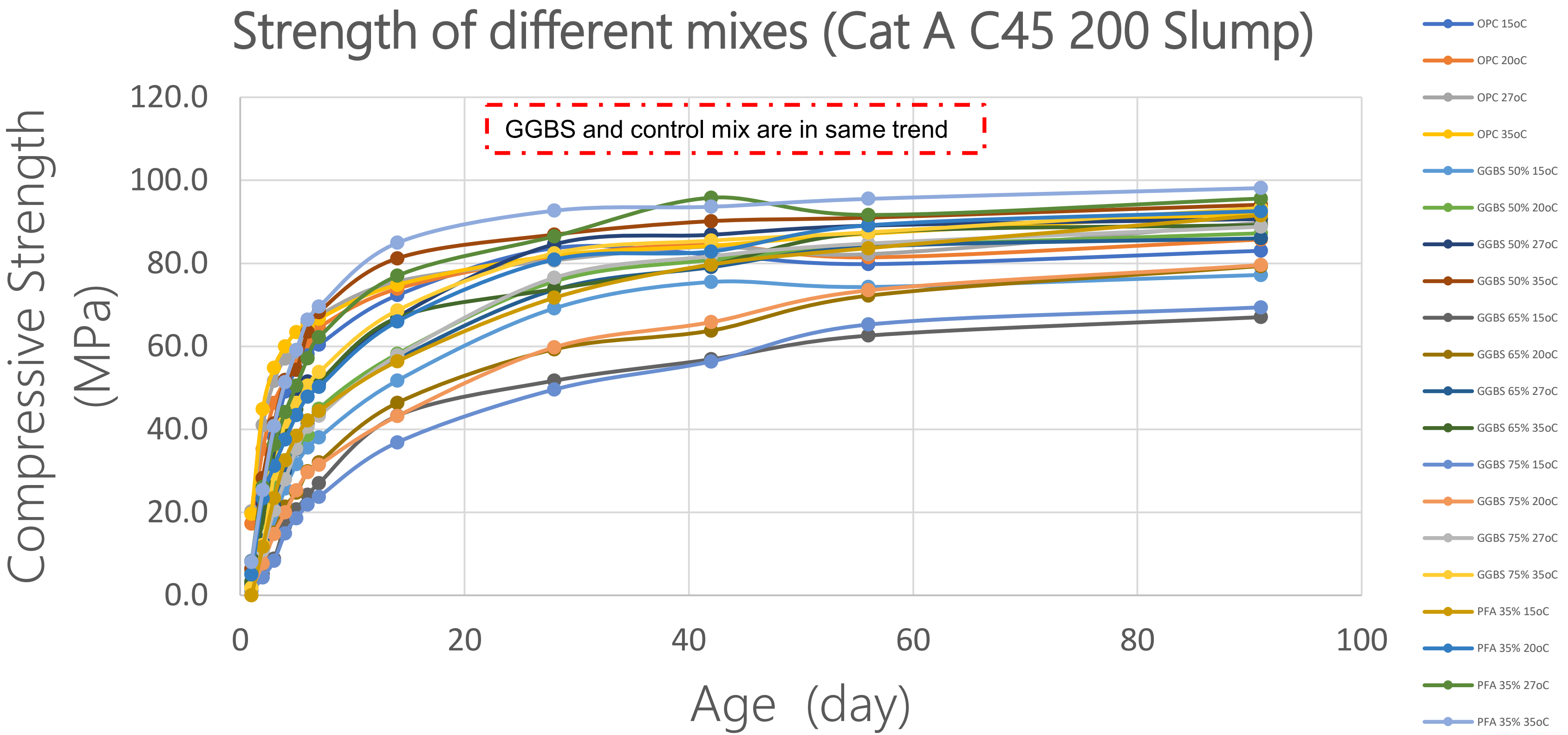
3. Different curing temperature to simulate different ambient temperature (15°C, 20°C, 27°C, 35°C) to observe the early strength development

4. Concrete workability, initial and final stiffening time and strength at different ages

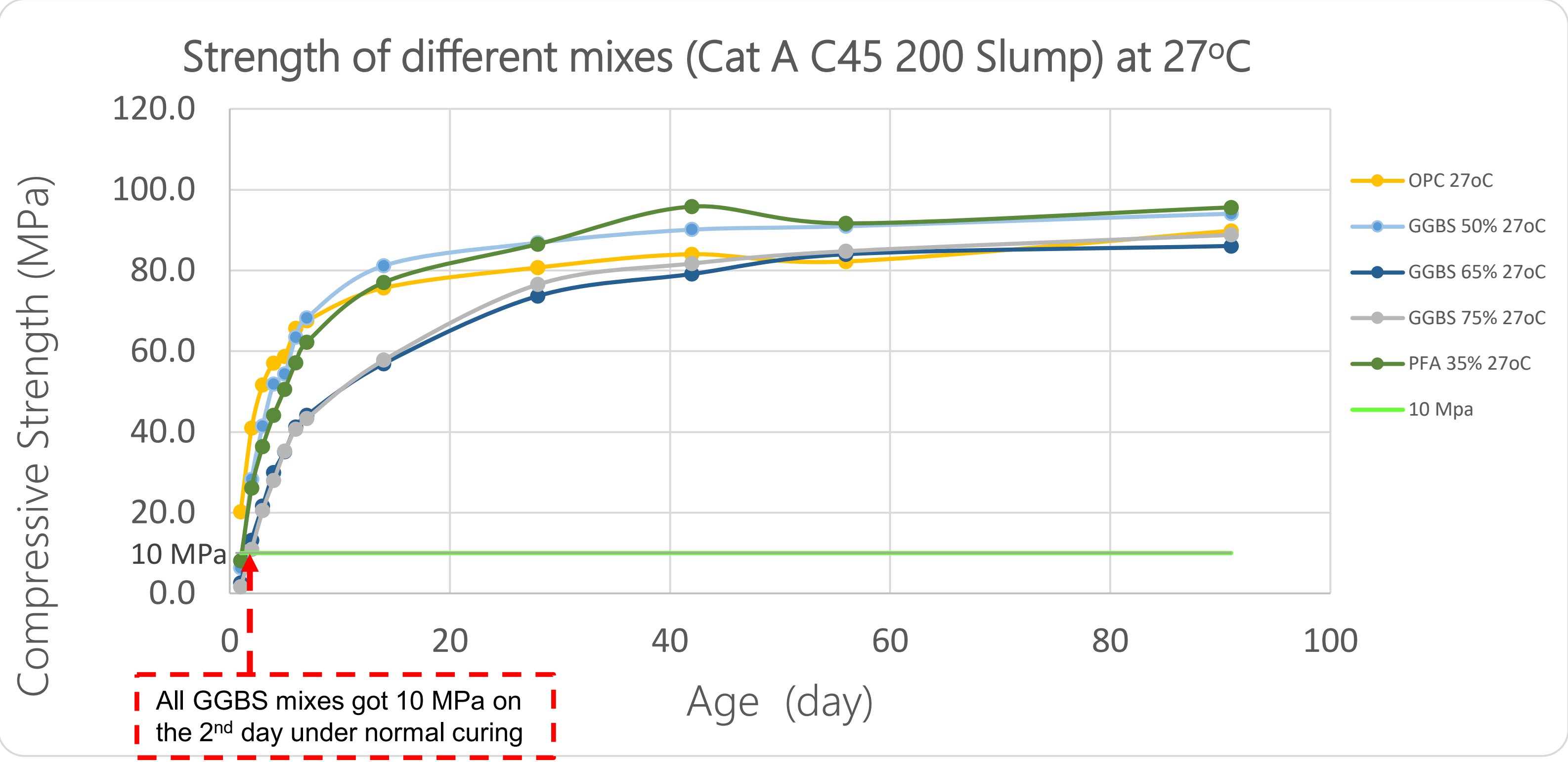
5. Concrete durability test (Resist Chloride Ion Penetration Test and water absorption test)

Highlight of Results

General Strength Development



Early Strength Development



GGBS strength go slowly in early strength and catch up in long term

Highlights of Findings in Strength Development

1. Under normal curing conditions (27°C), the GGBS concrete mixes with increased percentages of GGBS replacement exhibited lower early-age strength compared to the PFA control mix.

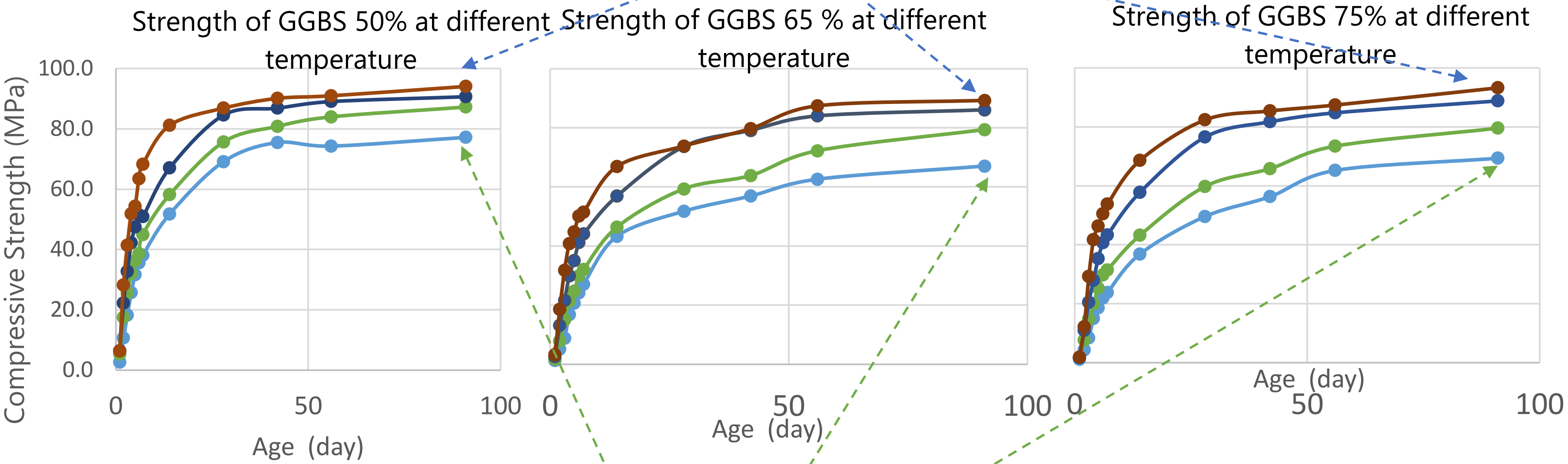
2. All GGBS concrete mixes were able to attain a normal demolding strength of 10 MPa on the 2nd day, as per the requirements set out by the Authority.

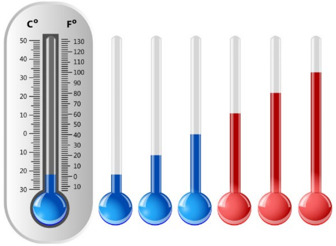
3. All the concrete mixes satisfied the 28-day strength requirement under normal curing conditions.

4. The divergence in concrete strength between control mixes and GGBS mixes was diminished significantly, particularly starting from 28th days.

Highlights of Effect of Various Ambient Temperatures on Strength Developmen

Under warm/hot temperature, GGBS mixes got similar long term strength





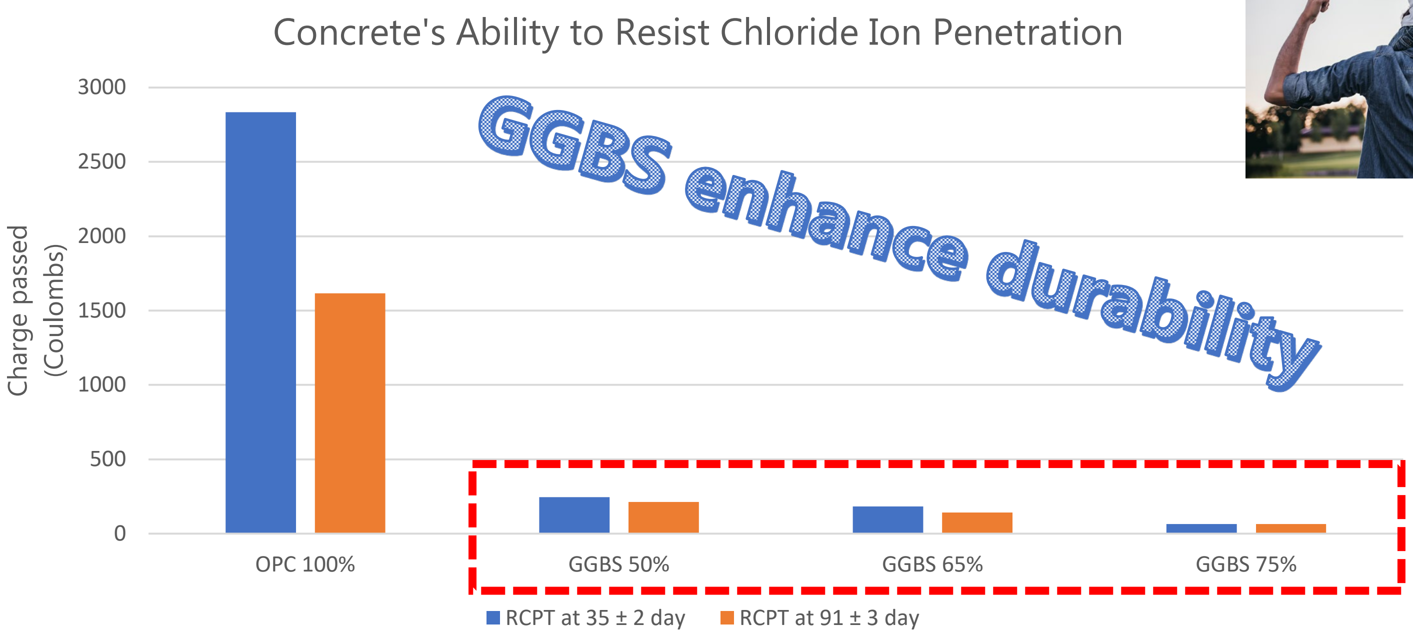
Under cooler temperature of 15 c, high % GGBS mix got lower long term strength

Table 1. Comparison of strength growth of different mixes at curing temperature of 15°C and 27°C

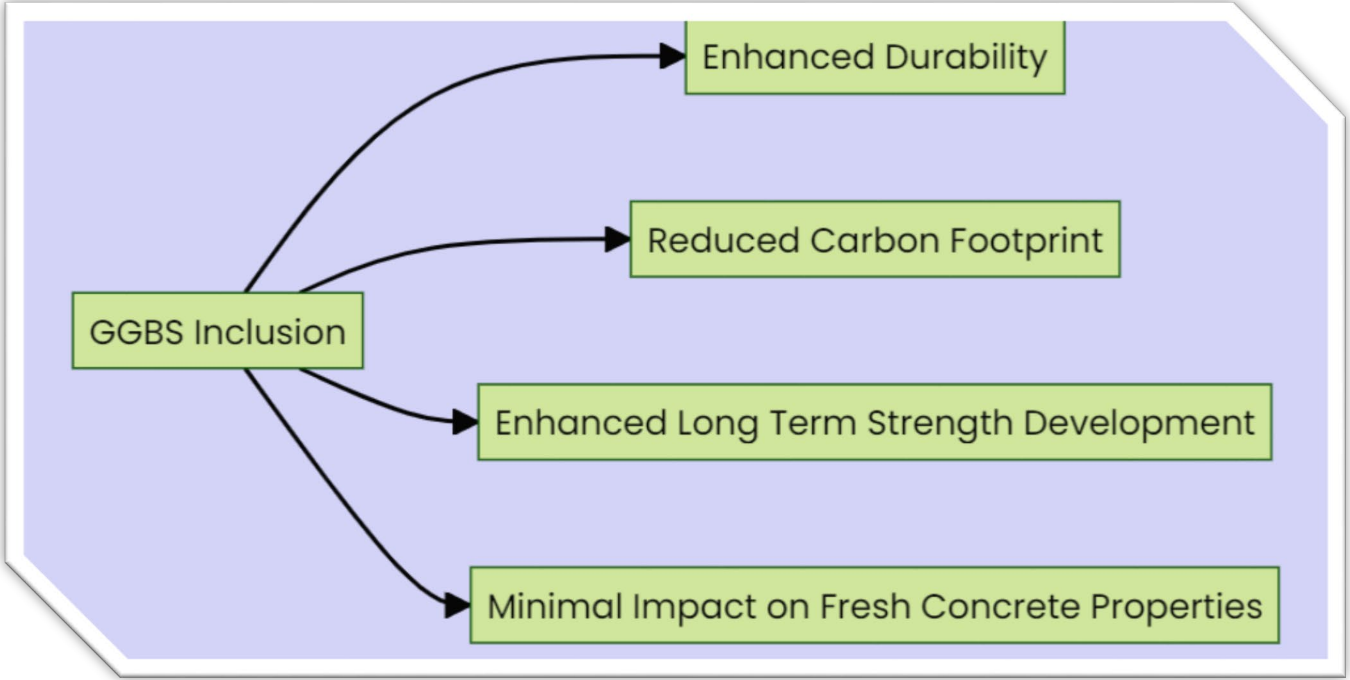
Mix	Comparison in strength = $\frac{\text{Strength at 27°C}}{\text{Strength at 15°C}}$			
	4th day	5th day	6th day	7th day
OPC	116%	108%	113%	112%
GGBS 50%	164%	150%	145%	134%
GGBS 65%	178%	170%	170%	163%
GGBS 75%	187%	190%	186%	182%
PFA	136%	132%	135%	140%

GGBS sensitive to low temperature in early strength

Highlights of Effect of GGBS on Durability



Conclusion and Recommendation

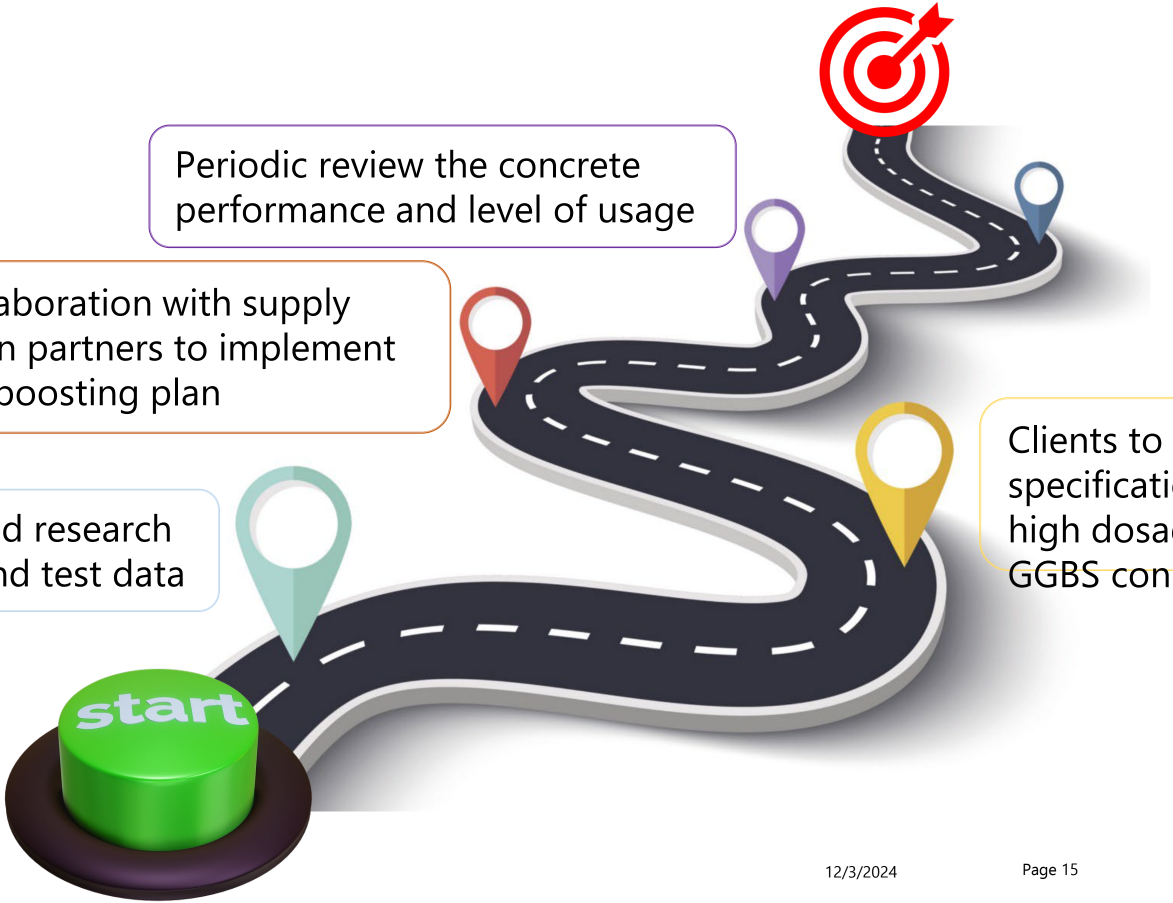


Conclusion and Recommendation

With the consideration of the results and the environmental benefit of GGBS concrete, the following concrete elements are recommended to adopt high percentage GGBS :

- Structures with less concern on early strength
- Structures to be cast in warm/hot temperature
- Structures with higher concern on durability and water proofing

Roadmap of Boosting GGBS Concrete



MTR shared research findings and test data

Collaboration with supply chain partners to implement the boosting plan

Periodic review the concrete performance and level of usage

Clients to revise specification to boost the high dosage and usage of GGBS concrete

Acknowledgement

Technical Advisor – Hong Kong Institution of Engineers – Materials Division

Their guidance and expertise have been critically shaping the direction of our research and ensuring its technical accuracy.

Civil Engineering and Development Department (CEDD)

Sharing valuable information and exchange of engineering ideas on the research

Hong Kong Construction Material Association

Sponsoring supports and raw materials

Q & A