Green Island Cement
青洲英坭

Quality Assurance in the Production of GGBS

Annual Concrete Forum 2023 – Towards Climate-friendly Concrete Construction

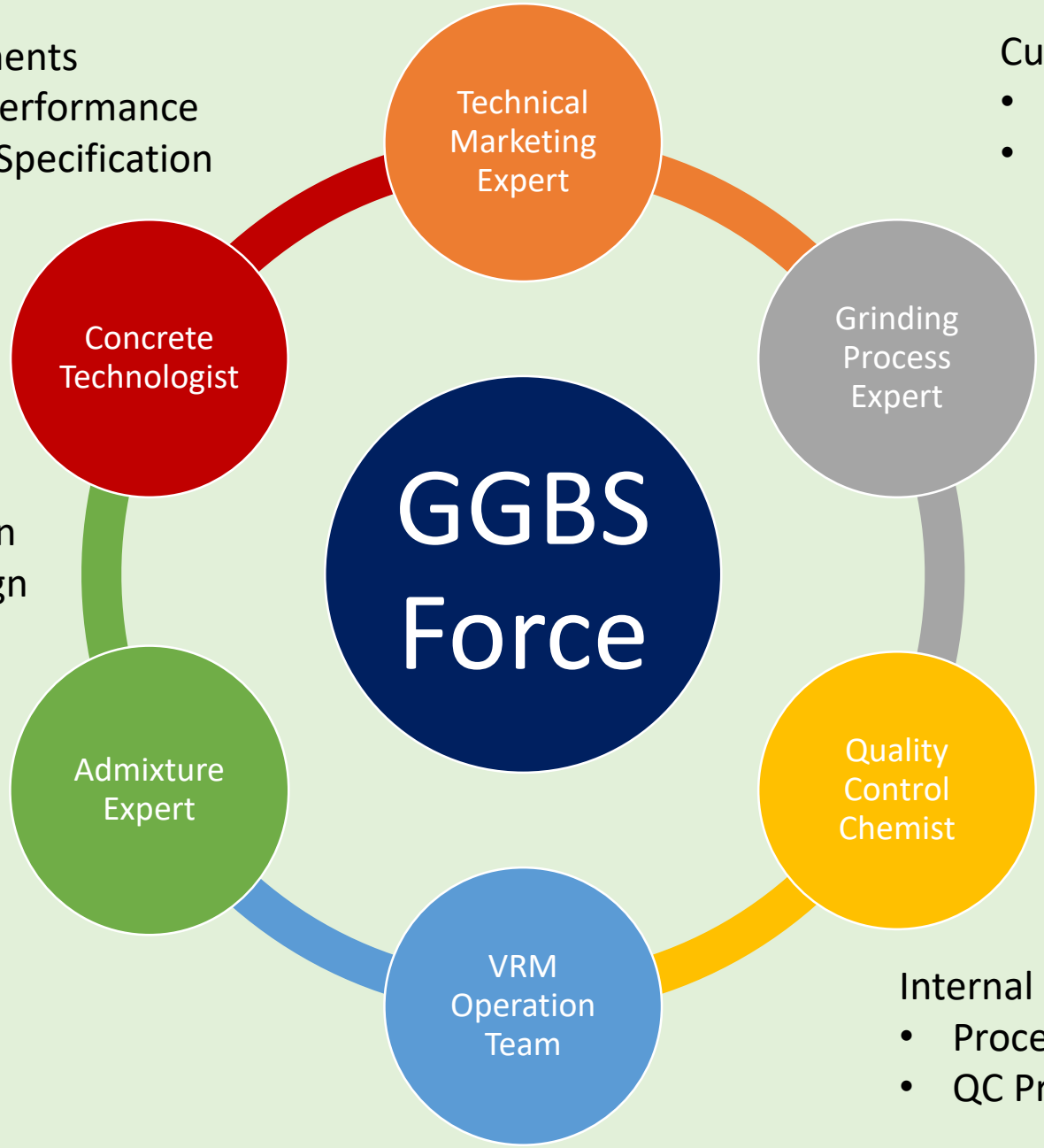
5 December 2023

Ir Raymond Wai-Man CHEUNG

Division Manager – Green Island Cement Co. Ltd.
Director – Green Island Environmental Technologies Ltd.

Continuous Improvements
- Review Product's Performance
- Fine Tune Product Specification

Customers' Needs
- Product Specification
- Functional Specification



Build a Milling System
- Response to the Needs

Customer Service
- Technical service on Concrete Mix Design
- Fulfil Functional Specification

Consistent Product Quality
- Set Up Control Parameters
- Apply Operation Know-How

Internal Quality Control Targets
- Process Specification
- QC Procedures

Green Island Cement 青洲英坭

Working Together to Build a Green Island

Scope of Presentation

- 137 years' of GIC
- Benefits of GGBS
- Product Quality and Acceptance Criteria
- Grinding Experience in GIC's Plant
- Grinding Process Control
- Plant Visit (6/Dec)

Green Island Cement
青洲英坭

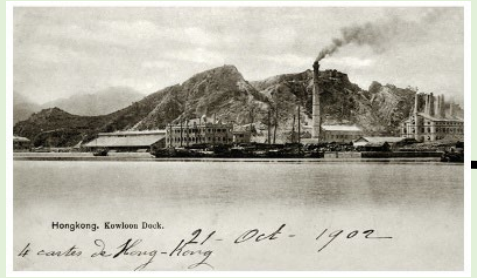
137 Years' of Green Island Cement

The Green Island Cement

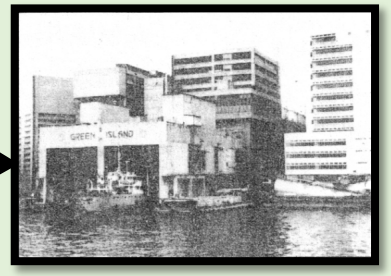
Macau Factory 1886-1936

May 11 1886
Established in Macau

Jan 3 1887
Incorporated in Hong Kong



1900



Hok Un Factory 1900 -1987, Hong Kong
Sales office at present

Sai Wan Depot, Hong Kong

1976

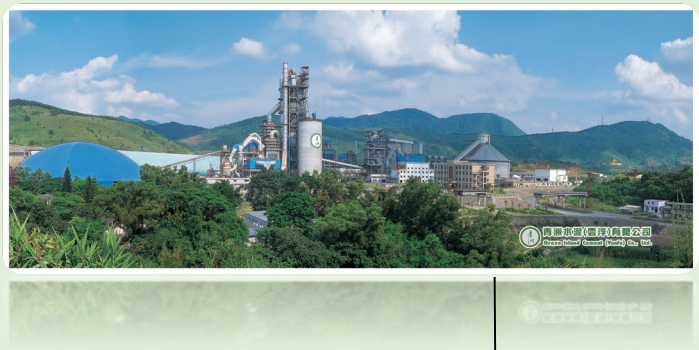
Tap Shek Kok Plant, Hong Kong, 1982

1982

1997

Siquijor Limestone Quarry, Philippines, 1997

GIC Yunfu Plant, Yunfu, China, 2013



1998

GITIC Green Island Plant, Yunfu, China, 1998

2013

2018

Xiangli Plant, Yunfu, China, 2018

GGBS Plant, in TSK, 2020

2020

Green Island Cement 青洲英坭

Working Together to Build a Green Island

Pioneer: Importing Cement Technologies to China

- GIC's Macau factory (1886) is the first **cement plant in China.**
- GIC's TSK plant is the first **4500t class precalciner-kiln** system installed in China
- First **rotary packer** and **auto-pelletizer** installed in China
- First **POLAB** (Automatic Laboratory) system in China
- Provided **Specialized Cement (CPJ55), a low alkali blended cement with 15% PFA,** to China's first nuclear plant to construct its "Nuclear Island".
- Provide **25% PFA Blended Cement** to HK's Port and Airport Development (PAD) projects
- Promoting the use **GGBS** in HKSAR, such as Stone Cutter Bridge Project.
- Produce **GGBS** in HKSAR – Made In Hong Kong

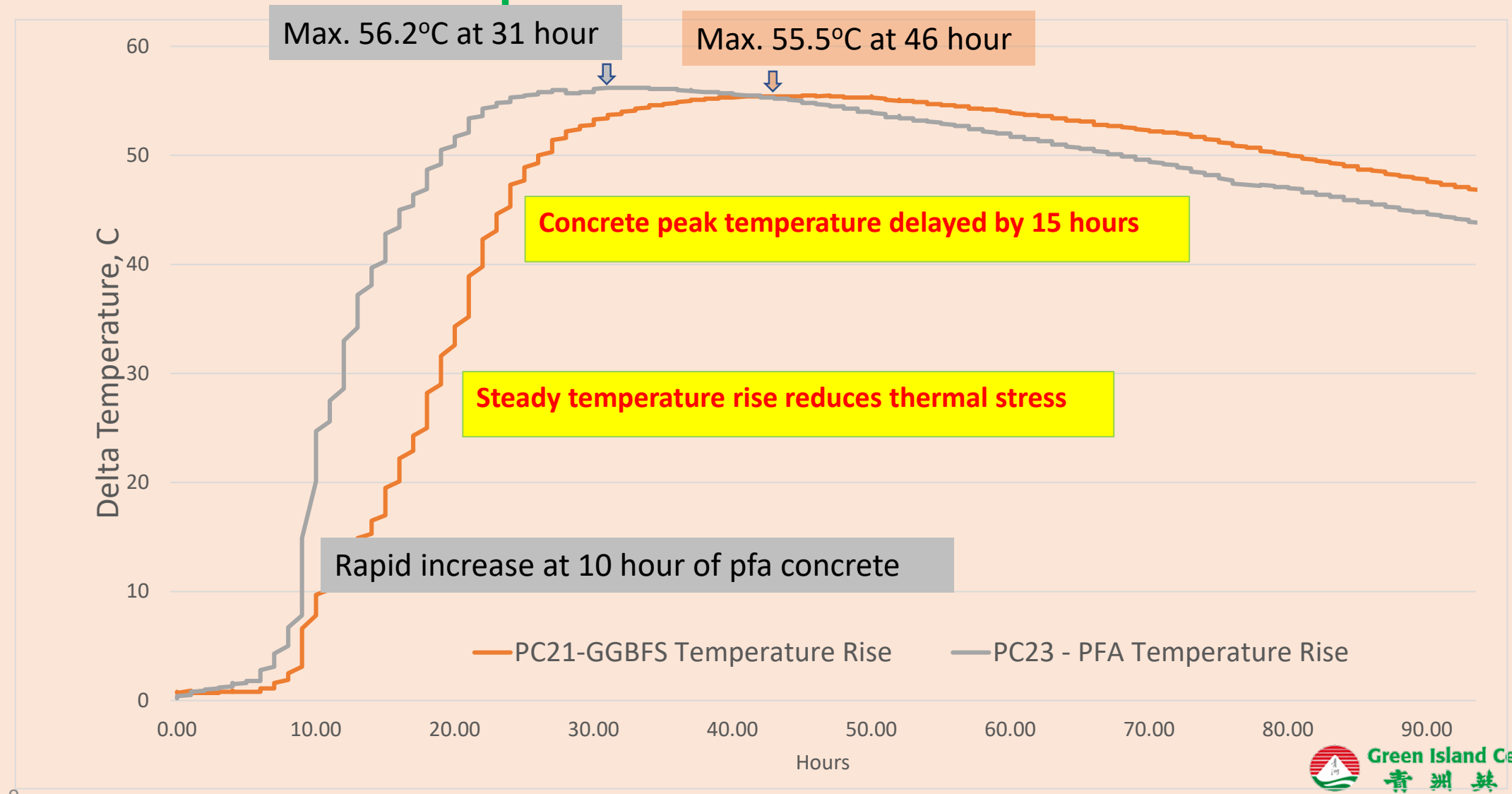
The Tap Shek Kok Plant

- Built in 1982 with Precalciner-Kiln technology
- The only full integrated cement manufacturing plant in HKSAR
- 1.5 Mtpa clinker/2.5 Mtpa cement
- 450k tpa PFA
- 360k tpa GGBS
- SP license granted to use Alternative Fuels derived from
  - Rubber
  - Plastic
  - Wood
  - Polyurethane residue

Green Island Cement
青洲英坭

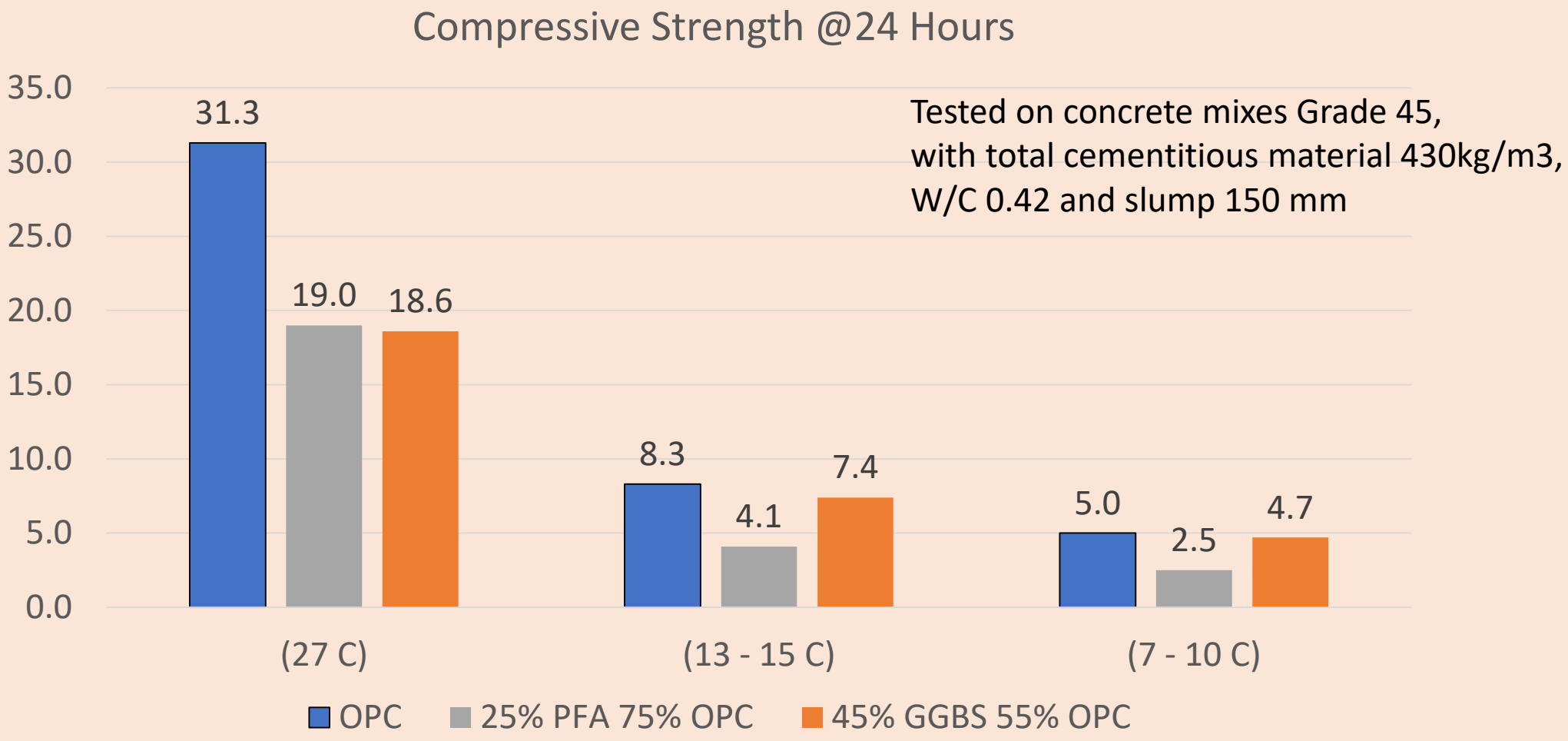
Benefits of GGBS – Local Experience

PFA and GGBS concrete in mass concrete – Core Temperature
Pile Cap of size 11 .4m x 4.6m x 2.0m



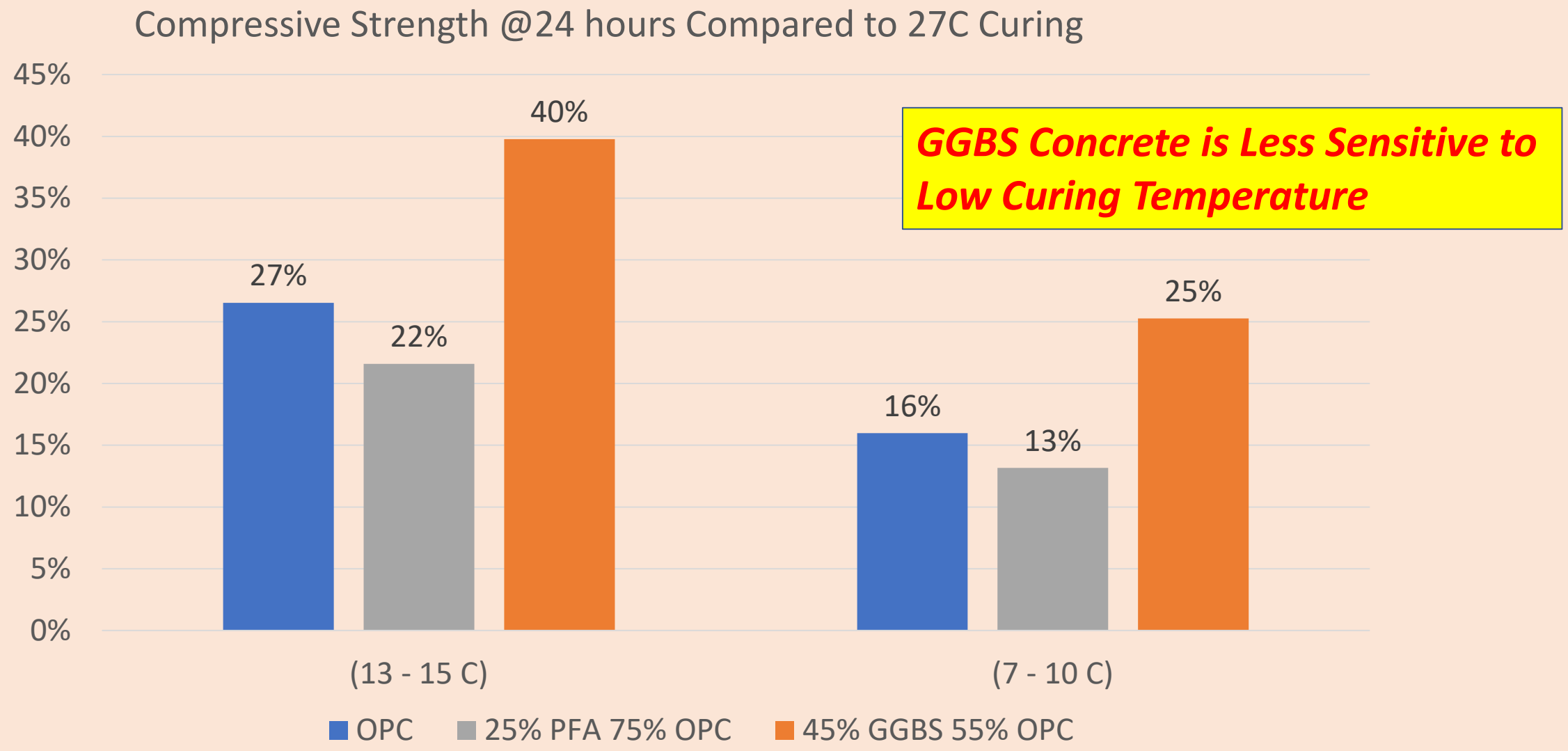
Green Island Cement
青洲英坭
Working Together to Build a Green Island

Sensitivity Test Against Curing Temperatures



Tested on concrete mixes Grade 45,
with total cementitious material 430kg/m3,
W/C 0.42 and slump 150 mm

Green Island Cement
青洲英坭
Working Together to Build a Green Island



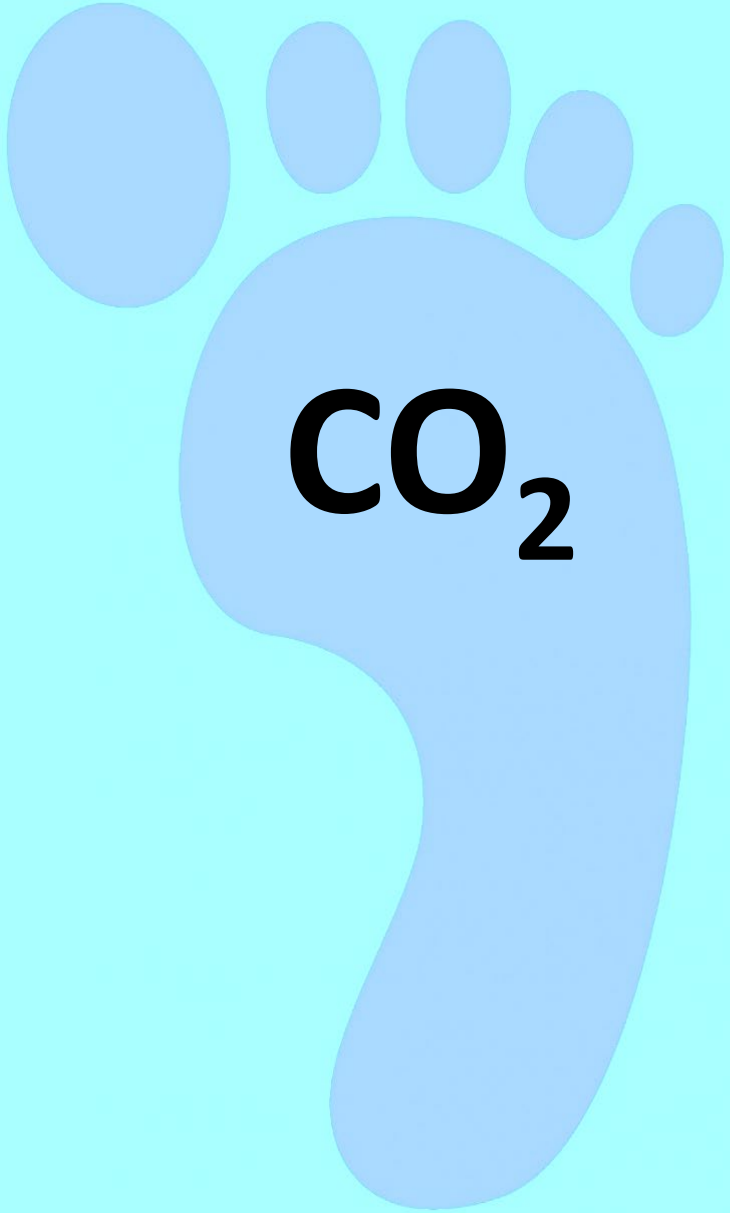
GGBS Concrete is Less Sensitive to Low Curing Temperature

Protection Against Chloride Ingression

GGBS concrete provides Excellent Protection Against Chloride Ingression

GGBS content	Charge Passed, (Coulombs)	Chloride Ion Permeability (defined by ASTM C1202)
0%	2,951	Moderate
35%	1,291	Low
45%	1,075	Low
55%	787	Very Low
65%	762	Very Low

Total cementitious material : 450 kg/m3
W/C : 0.4
Age of RCPT test: 28 days



Embodied Carbon*

OPC
800-900

GGBS
25-60

PFA
10-20

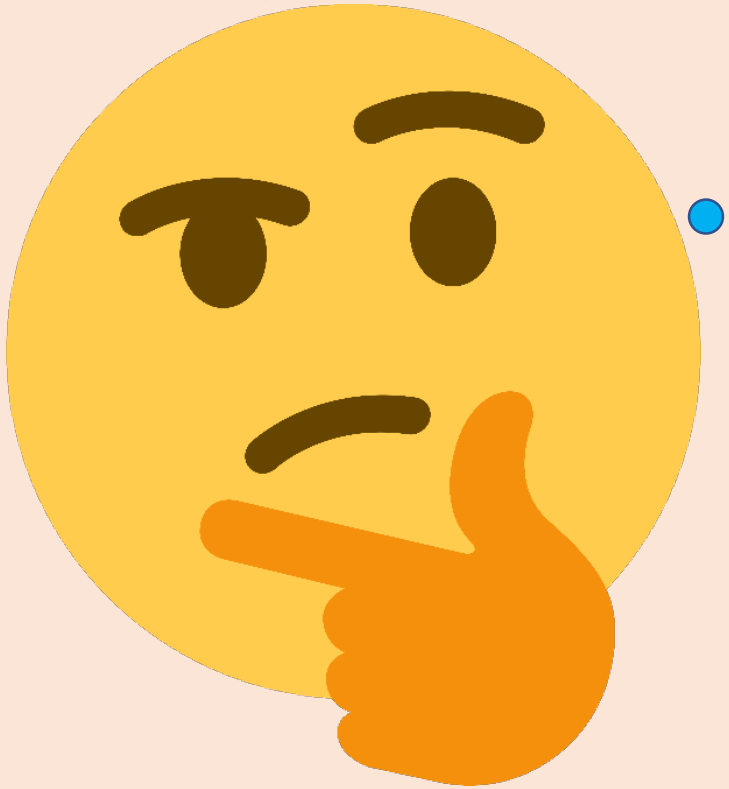
Embodied carbon reduction in concrete:
PFA concrete : ~25%
GGBS concrete : 50%+

Green Island Cement
青洲英坭
Working Together to Build a Green Island

** kg CO_2 / MT Cementitious Material*

It is so Good,
so…

How do we :
Specify GGBS in the concrete, and
Control its performance



Benefits of GGBS concrete:

- *Low embodied carbon*
- *Excellent protection Against Chloride*
- *Improved thermal developing profile*
- *Less sensitive to curing temperature*

Which Standard?

BS EN 15167-1
or
GB/T 18046

What are their major requirements?

Green Island Cement
青洲英坭

Product Quality and Acceptance Criteria

GGBS, as a materials for making structural concrete, is **ALREADY** specified in section 6.29B of **General Specification for Building** 2022 Edition as

*"Ground Granulated Blast Furnace Slag (GGBS) shall comply to **BS EN 15167-1:2006** except that the scheme for the evaluation of conformity of GGBS specified in BS EN 15167-2:2006 is not required. **The glass content ……. shall be not less than 67%**."*

BS EN 15167-1:2006

Section 4 : Constituents

*"Ground Granulated Blast Furnace Slag (GGBS) conforming to this European Standard shall contain **no added materials** except grinding aids to assist in the manufacture. The total quantity of grinding aid shall not exceed 1.0 % and the organic content of any grinding aid(s) shall not exceed 0.2%"*

BS EN 15167-1:2006

Section 4 : Constituents

"Ground Granulated Blast Furnace Slag (GGBS) conforming to this European Standard shall contain no added materials ***except grinding aids*** *to assist in the manufacture. The total quantity of grinding aid shall not exceed 1.0 % and the organic content of any grinding aid(s) shall not exceed 0.2%"*

BS EN 15167-1:2006

Section 5 : Specifications

5.1 General

5.2 Chemical requirements

5.3 Physical requirements

5.3.1 Fineness

"The specific surface determined in accordance with the air permeability method specified in EN 196-6, shall be ***not less than 275 m^2/kg****."*

5.3.2.2 Activity index

"The activity index shall be expressed as the ratio (in percent) of the compressive strength of the combination (by mass) of 50 % of ground granulated blastfurnace slag with 50 % of test cement, to the compressive strength of the test cement on its own. The compressive strengths shall be determined in accordance with EN 196-1 and ***the water:combination ratio and the water:cement ratio shall both be 0.50.***

The activity index at 7 days and at 28 days shall be not less than 45 % and 70 % respectively.

Note: The activity index gives no direct information *on the strength contribution of ground granulated blastfurnace slag in concrete, nor is the use of the ground granulated blastfurnace slag limited to the mixing ratio used in the activity index test."*

5.3.2.2 Activity index

$$A_d = \frac{100 \times R_d}{RC_d}$$

R_d ← Compressive Strength of Test Mortar at day d, MPa

RC_d ← Compressive Strength of Control Mortar at day d, MPa

A_d ↑ Activity Index at day d, %

Note: ***The activity index gives***

- ***no direct information on the strength contribution of ground granulated blastfurnace slag in concrete, nor***
- ***is the use of the ground granulated blast furnace slag limited to the mixing ratio used in the activity index test.***

GB/T 18046-2017

GGBS used in Cement, Mortar and Concrete

No other minor constituents ALLOWED

Section 4 : Constituents

4.1 *Granulated Blast Furnace Slag (GBS) conforming to GB/T 203 requirement*

4.2 Natural Gypsum conforming to GB/T 5483 requirement on type G and type M or above

4.3 Grinding aids conforming GB/T 26748 and shall not exceed 0.5 %

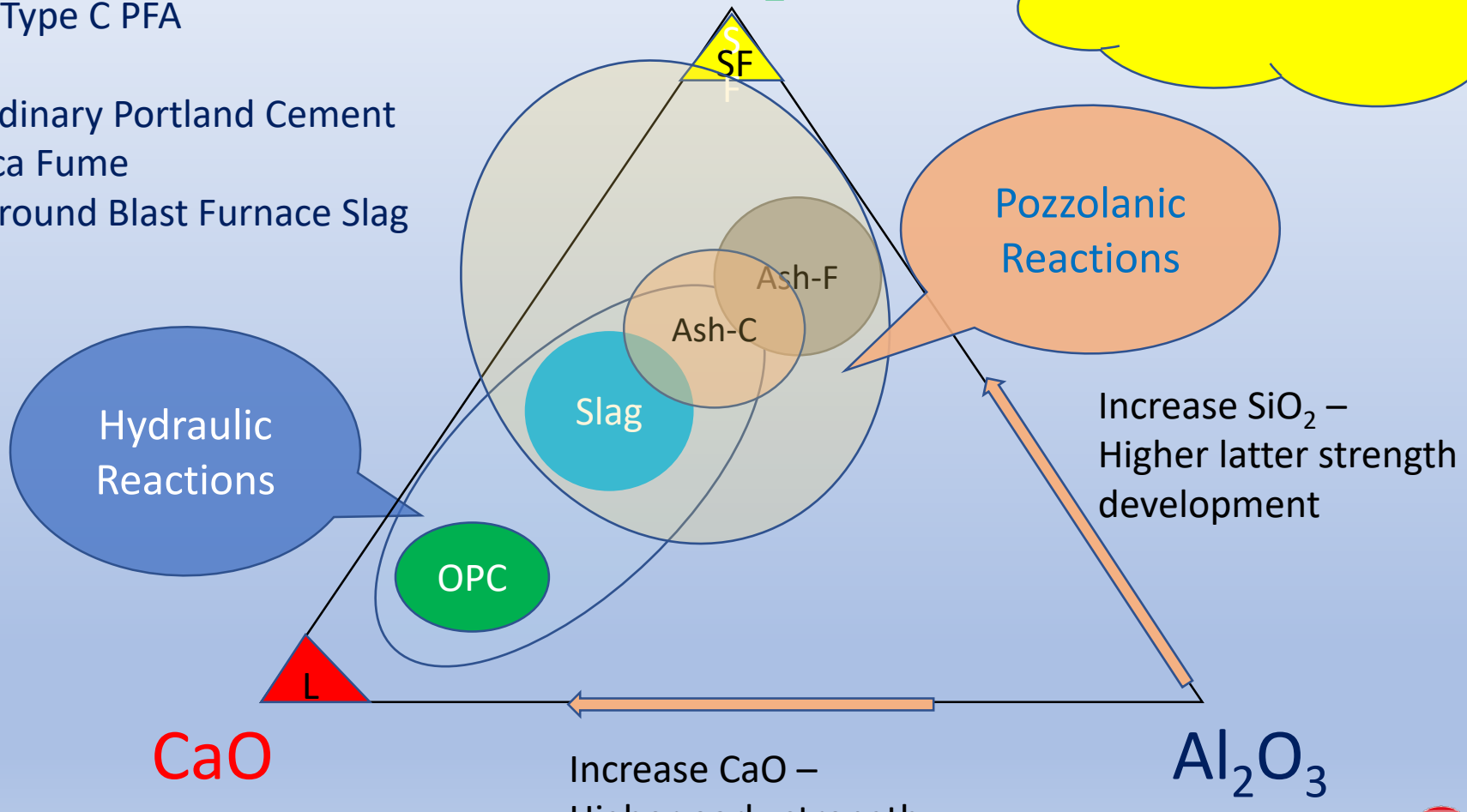
BS EN 15167-1:2006

- *"no added materials except grinding aids"*
- *"not less than 275 m^2/kg."*
- "The activity index at 7 days and at 28 days shall be not less than 45 % and 70 % respectively."

Ternary system CaO-Al_2O_3-SiO_2

Ash-F – Type F PFA
Ash-C – Type C PFA
L – Lime
OPC- Ordinary Portland Cement
SF – Silica Fume
Slag – Ground Blast Furnace Slag

GGBS Can replace both OPC and PFA



Increase SiO_2 – Higher latter strength development

Increase CaO – Higher early strength development

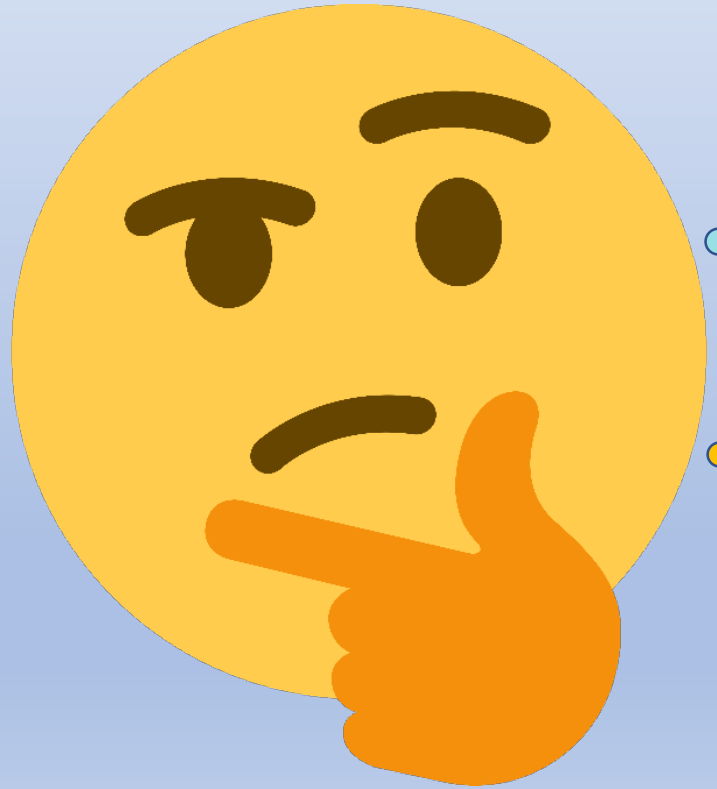
Green Island Cement 青洲英坭
Working Together to Build a Green Island

GGBS's Pozzolanic Activity needs to be activated

Use with OPC, and Grinding

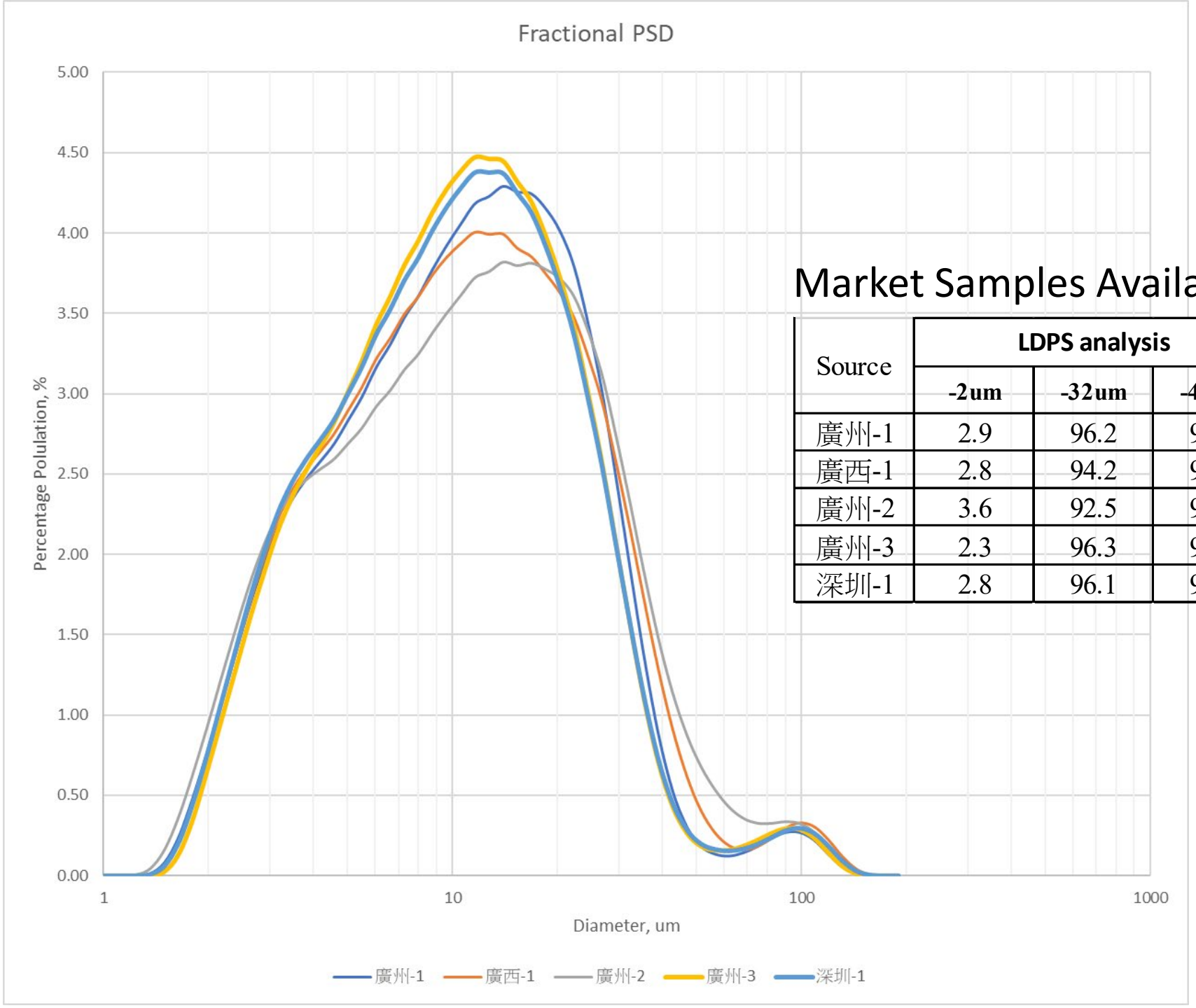
BS EN 15167-1 requirements:

- *Fineness: > 275 m2/kg*
- *Activity Index @ 7 day: > 40%*
- *Activity Index @28 day: >70%*



Do the fineness and activity index requirements in BS EN 15167-1 sufficient?

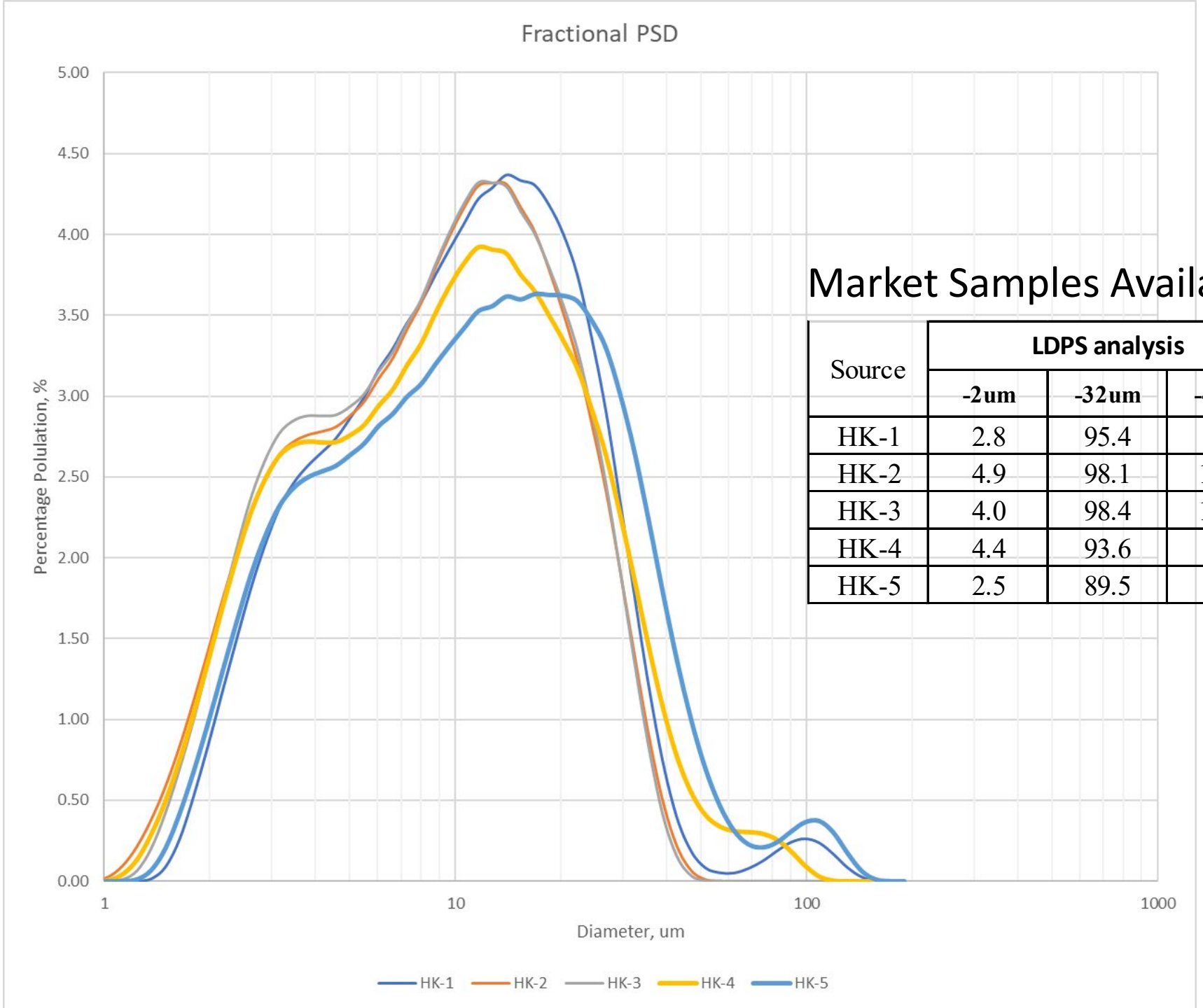
How do they affect my concrete performance?



Market Samples Available in Pearl River Delta

Source	LDPS analysis			Blaine	Activity, %	
	-2um	-32um	-45um	m2/kg	7 days	28 days
廣州-1	2.9	96.2	98.1	513	63-67	93-99
廣西-1	2.8	94.2	97.4	437		
廣州-2	3.6	92.5	96.5	503		
廣州-3	2.3	96.3	97.9	453		
深圳-1	2.8	96.1	97.8	447		

Green Island Cement
青洲英坭
Working Together to Build a Green Island



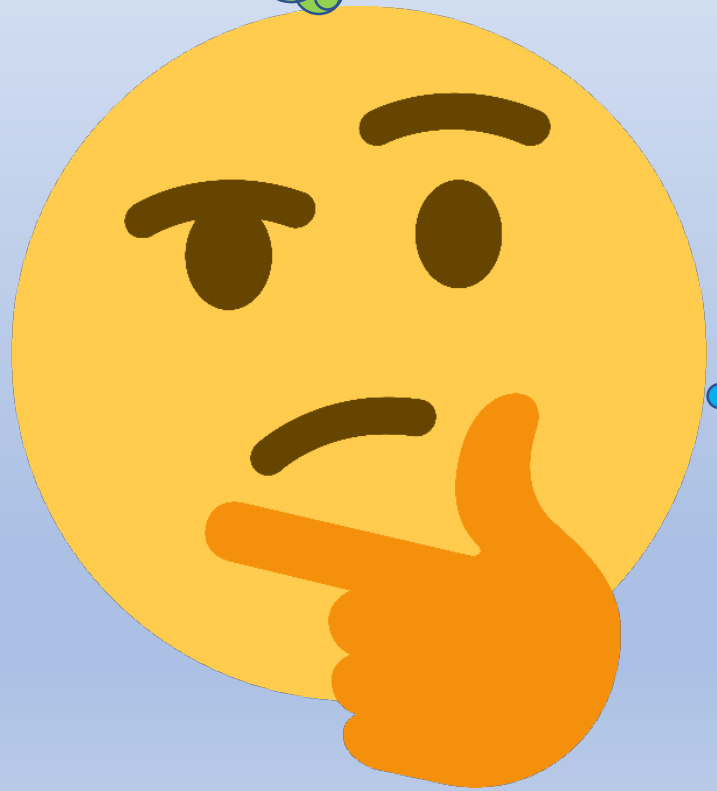
Market Samples Available in HK

Source	LDPS analysis			Blaine	Activity, %	
	-2um	-32um	-45um	m2/kg	7 days	28 days
HK-1	2.8	95.4	98.6	494	67-78	94-98
HK-2	4.9	98.1	100.0	452		
HK-3	4.0	98.4	100.0	489		
HK-4	4.4	93.6	97.5	464		
HK-5	2.5	89.5	95.8	409		

Green Island Cement
青洲英坭
Working Together to Build a Green Island

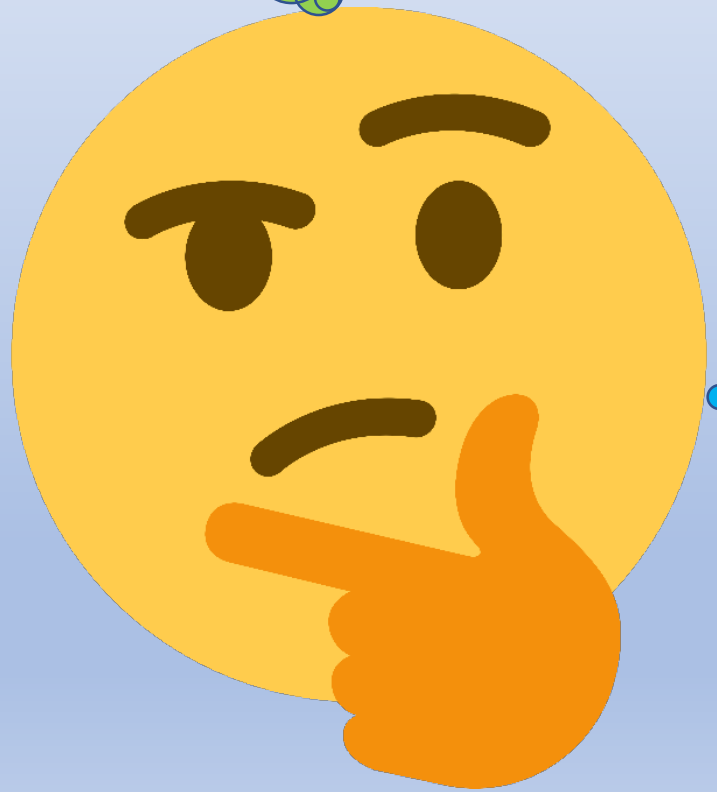
They all meet BS EN 15167-1 requirements, but with different PSD

Source	LDPS analysis			Blaine	Activity, %	
	-2um	-32um	-45um	m2/kg	7 days	28 days
廣州-1	2.9	96.2	98.1	513	63-67	93-99
廣西-1	2.8	94.2	97.4	437		
廣州-2	3.6	92.5	96.5	503		
廣州-3	2.3	96.3	97.9	453		
深圳-1	2.8	96.1	97.8	447		
HK-1	2.8	95.4	98.6	494	67-78	94-98
HK-2	4.9	98.1	100.0	452		
HK-3	4.0	98.4	100.0	489		
HK-4	4.4	93.6	97.5	464		
HK-5	2.5	89.5	95.8	409		
BS EN15167-1 requirements				> 275	> 40	> 70



Are they perform equally in my concrete ?

They all meet BS EN 15167-1 requirements, but with different PSD



No, they are performing differently in fresh concrete. Because

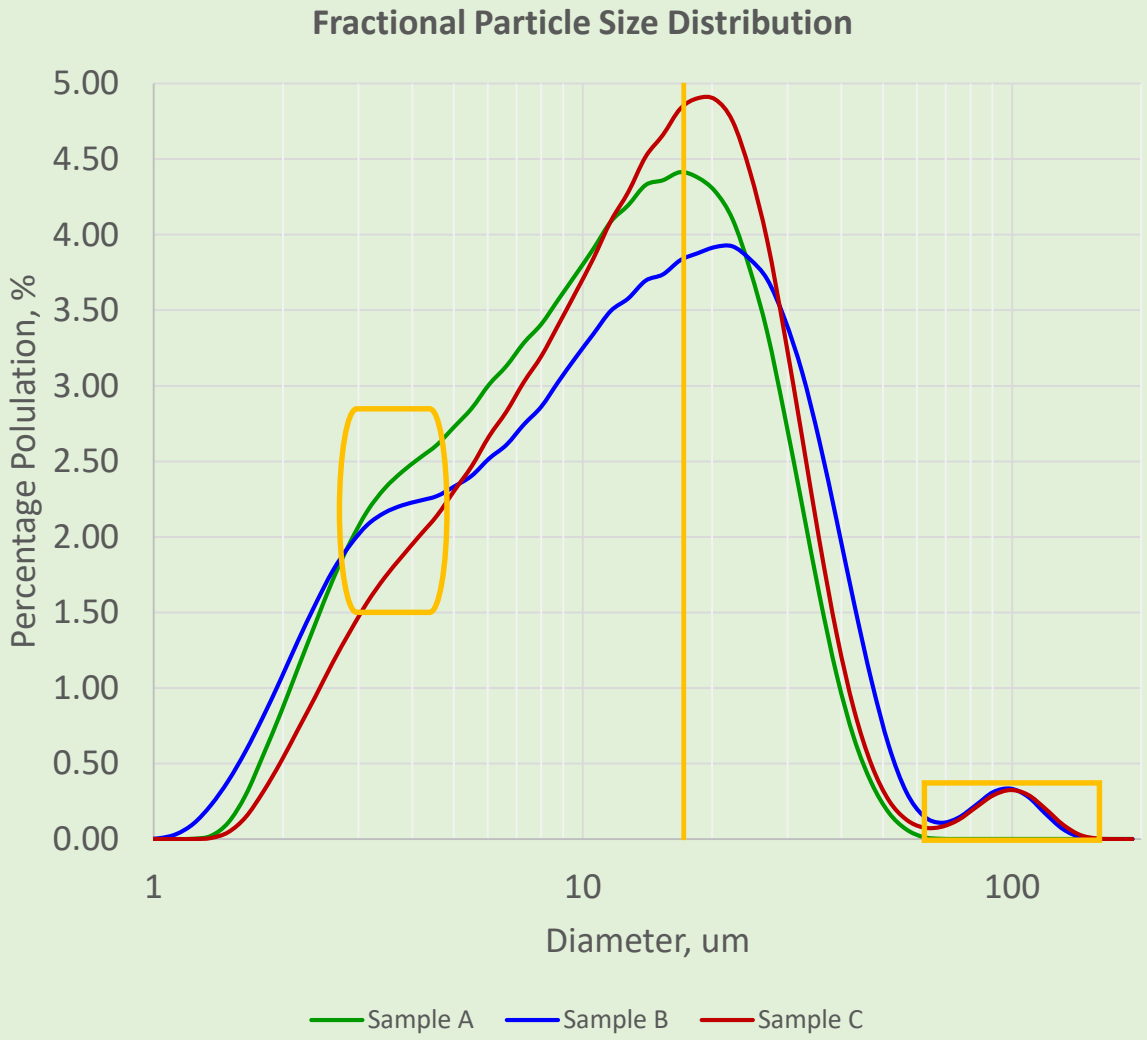
- Coarse portions act as fine aggregate, and
- Over-fines portions are reactive and affect behaviours of fresh concrete

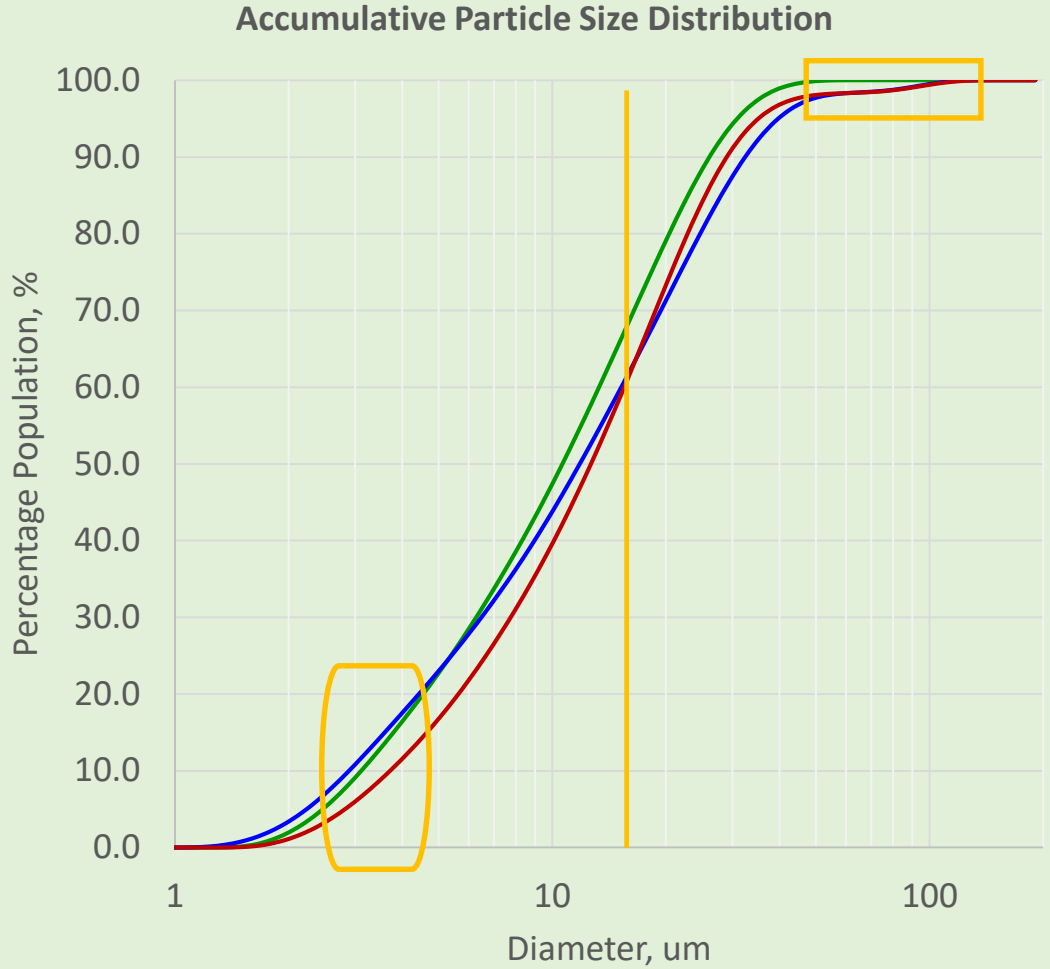
Are they perform equally in my concrete ?

Green Island Cement
青洲英坭

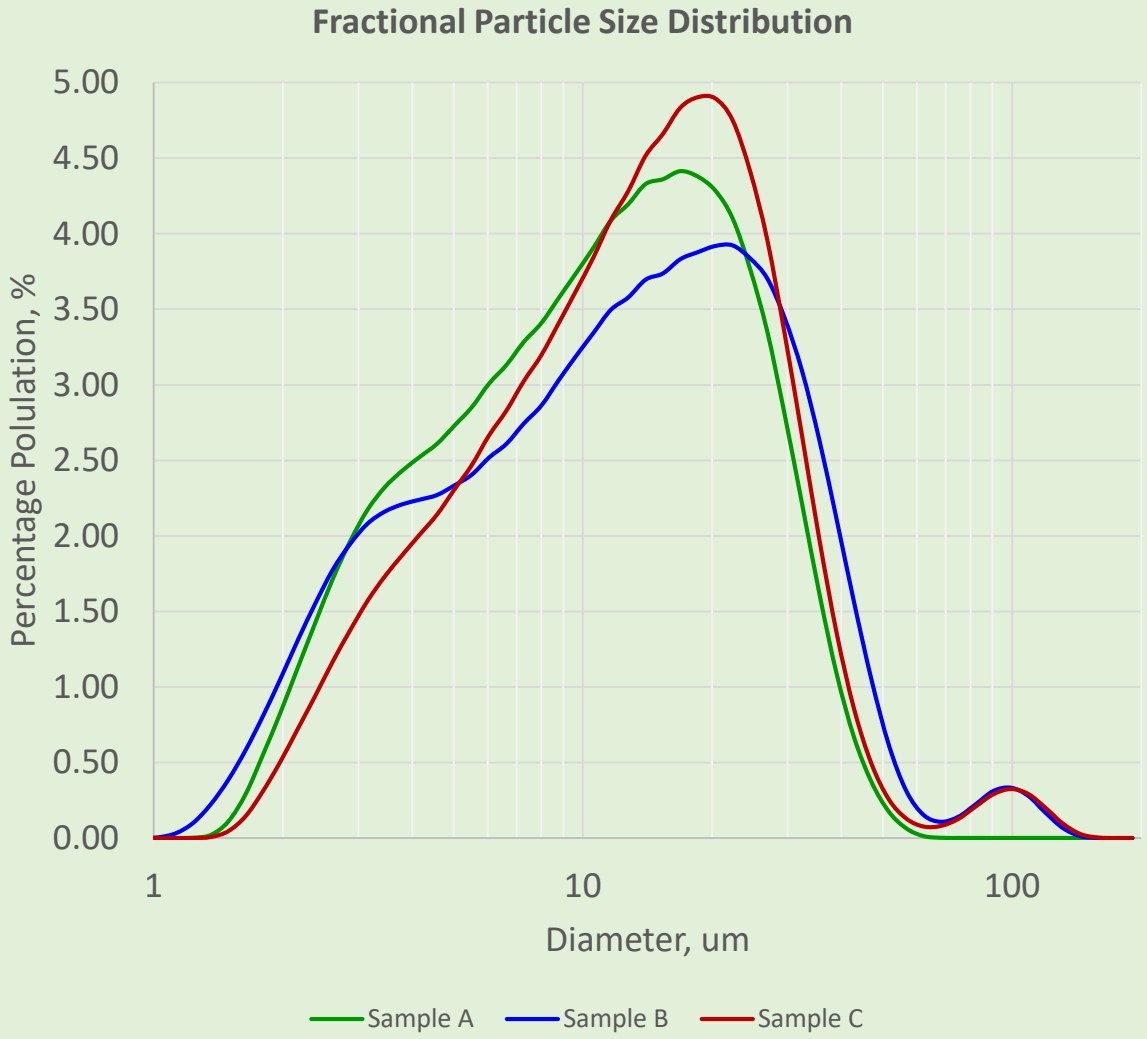
Grinding Experience in GIC's Plant

Same Blaine (~448m²/kg) with Different PSD





Green Island Cement
青洲英坭
Working Together to Build a Green Island



Green Island Cement
青洲英坭
Working Together to Build a Green Island

Green Island Cement
青洲英坭

Grinding Process Control

The Grinding Process Control

Granulated Blast-furnace Slag

Hot gas from kiln

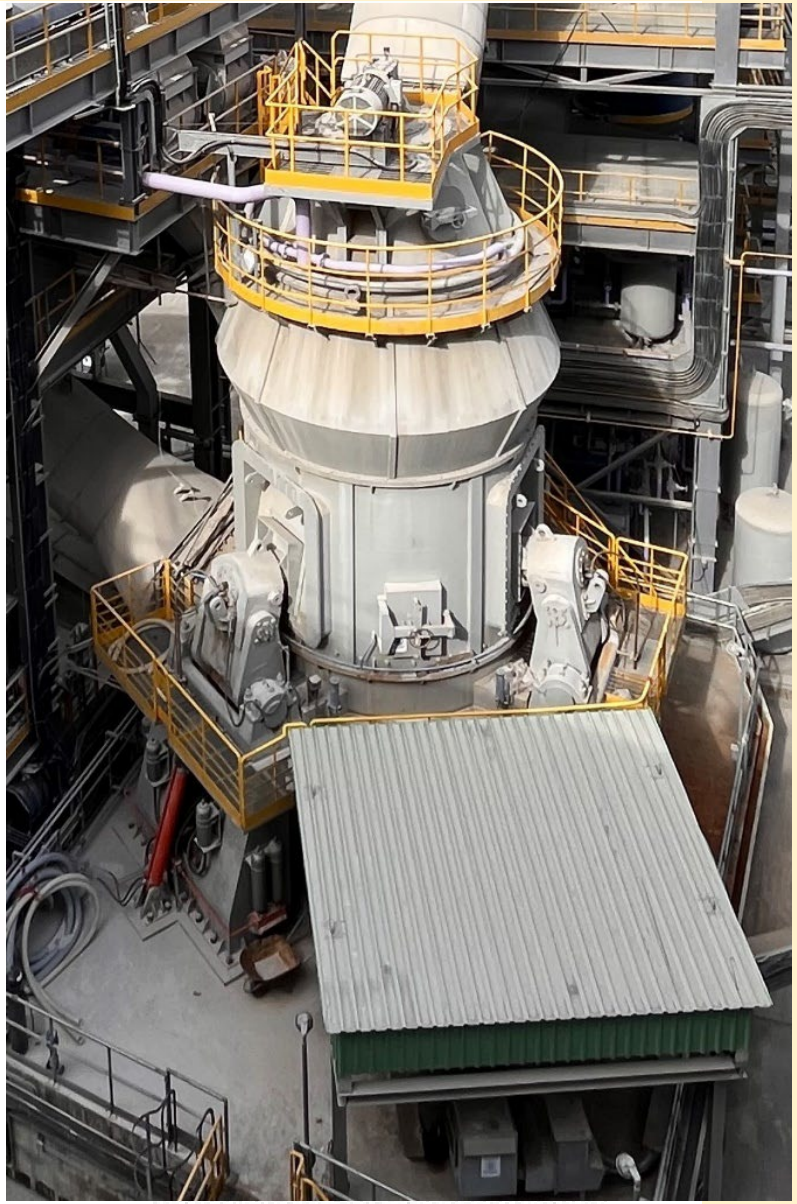
QC check by Competent Laboratory

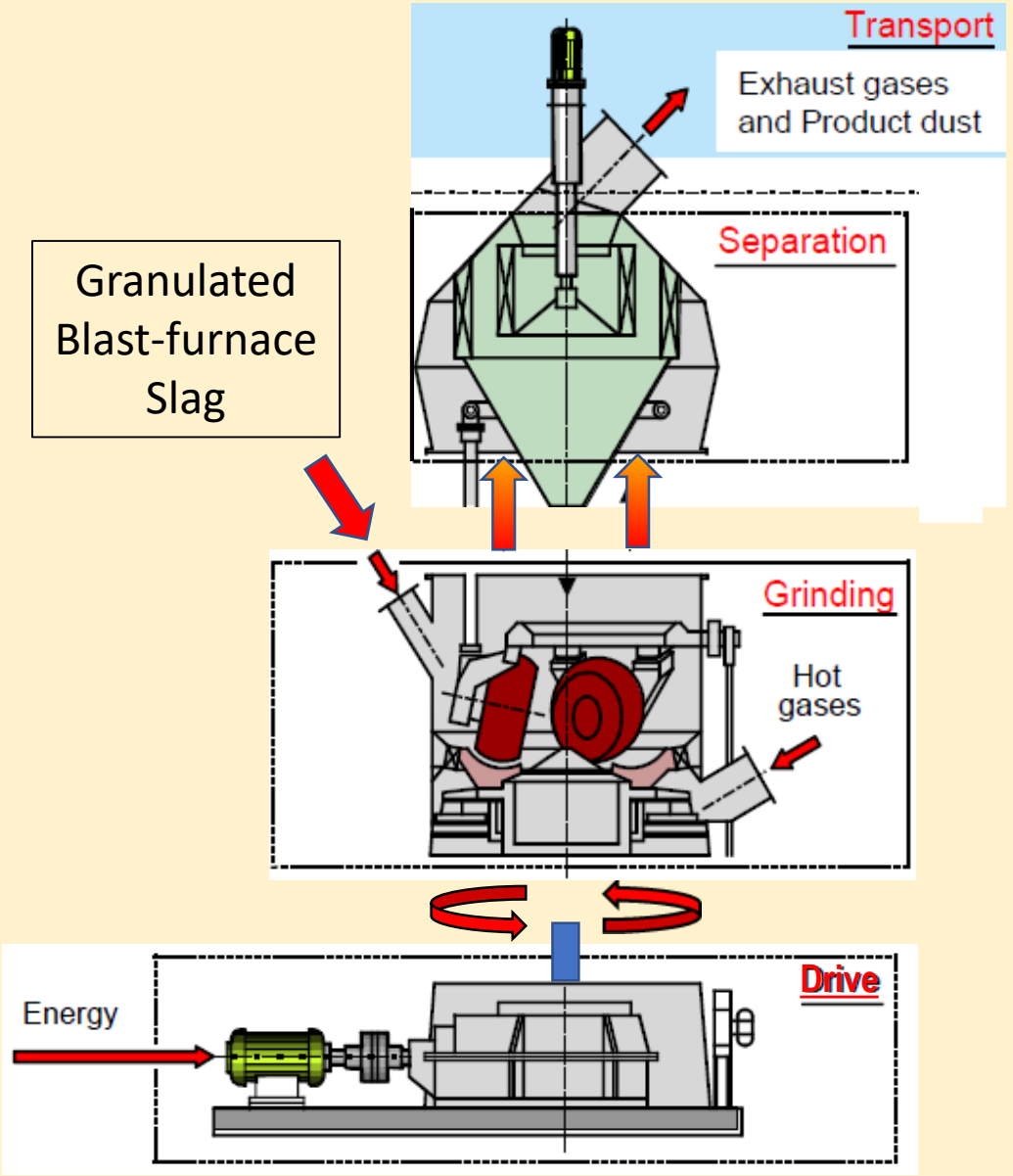
Product Storages

Barges

Compliance Check according to Product Certification

VRM – Combination of 4 Machines & 3 Processes



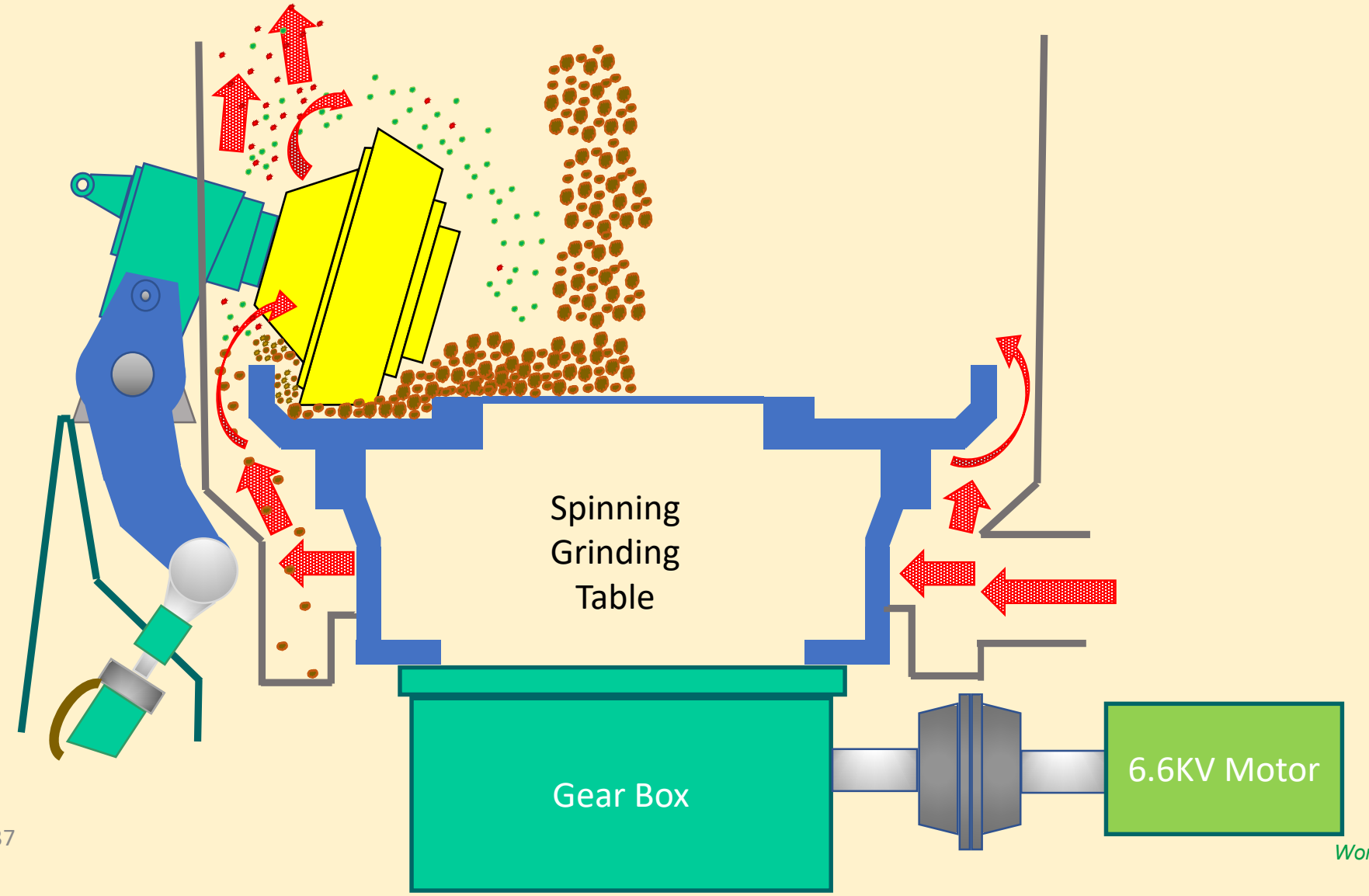


- 4 – IN – 1 Machine

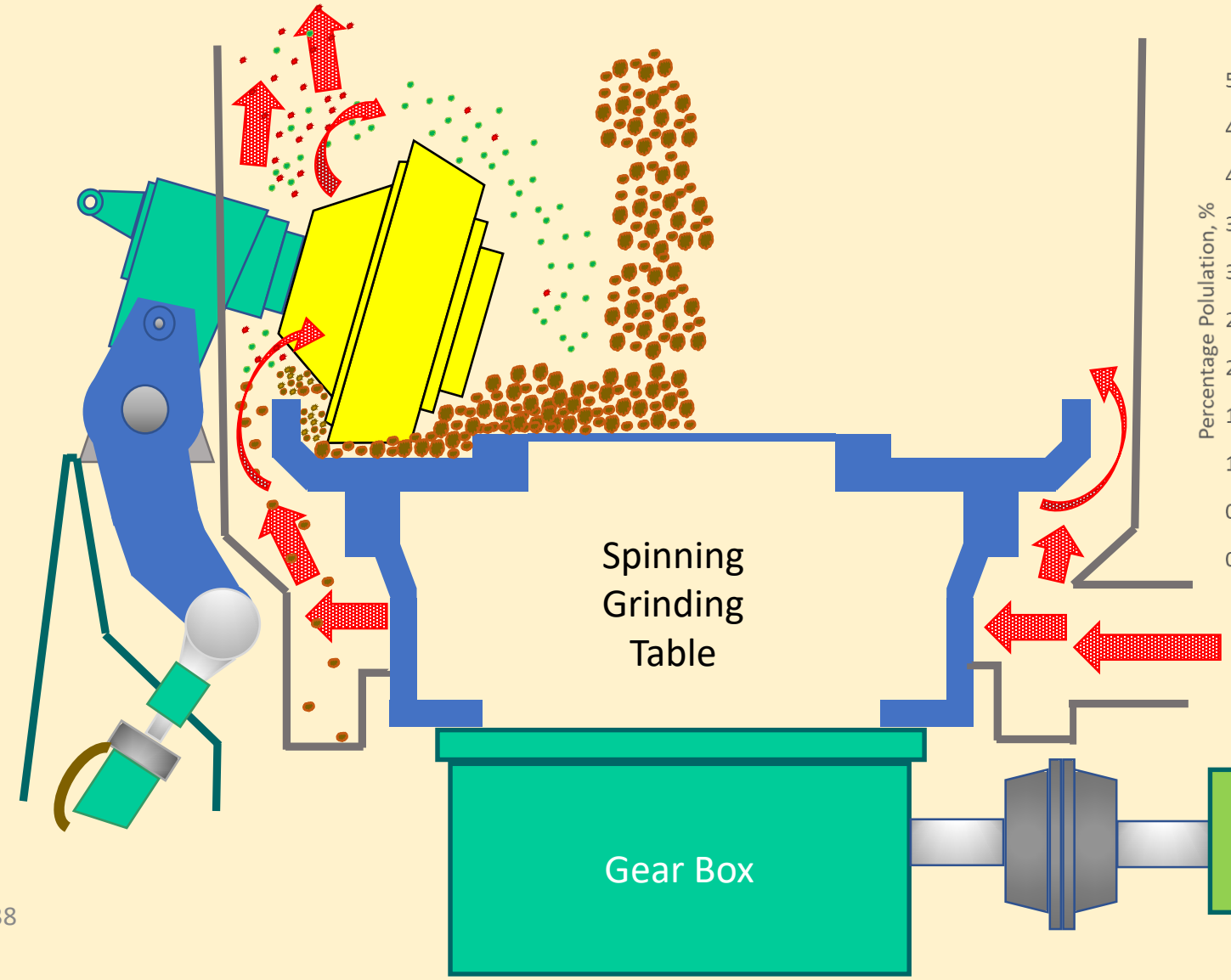
1. Main Drive
2. Grinding Machine
3. Material Conveyor (Pneumatic Conveying)
4. High Efficiency Separator

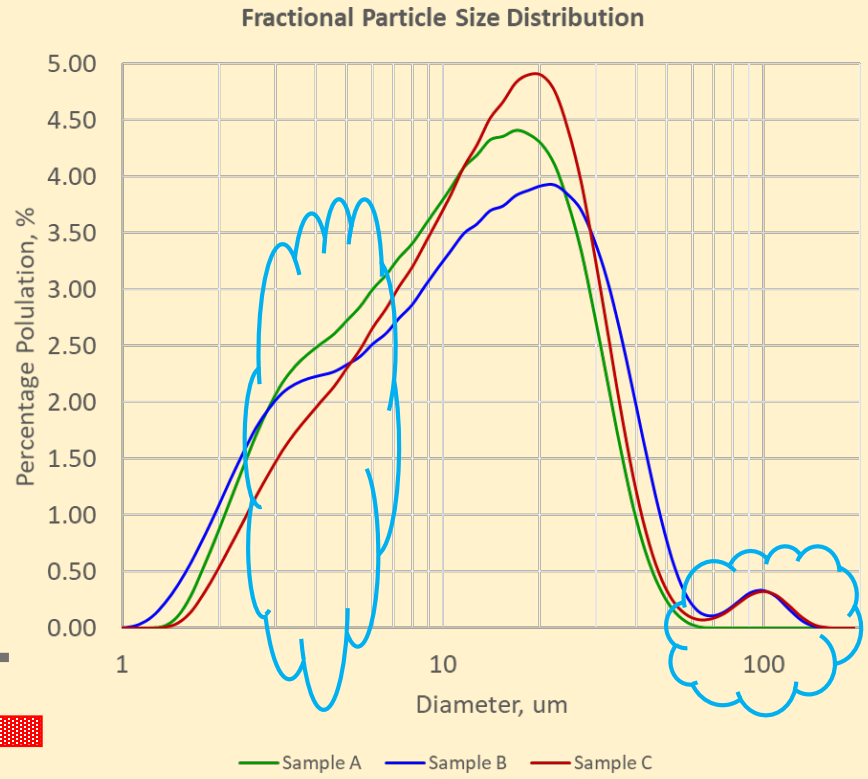
Green Island Cement
青洲英坭
Working Together to Build a Green Island

The Grinding Processes



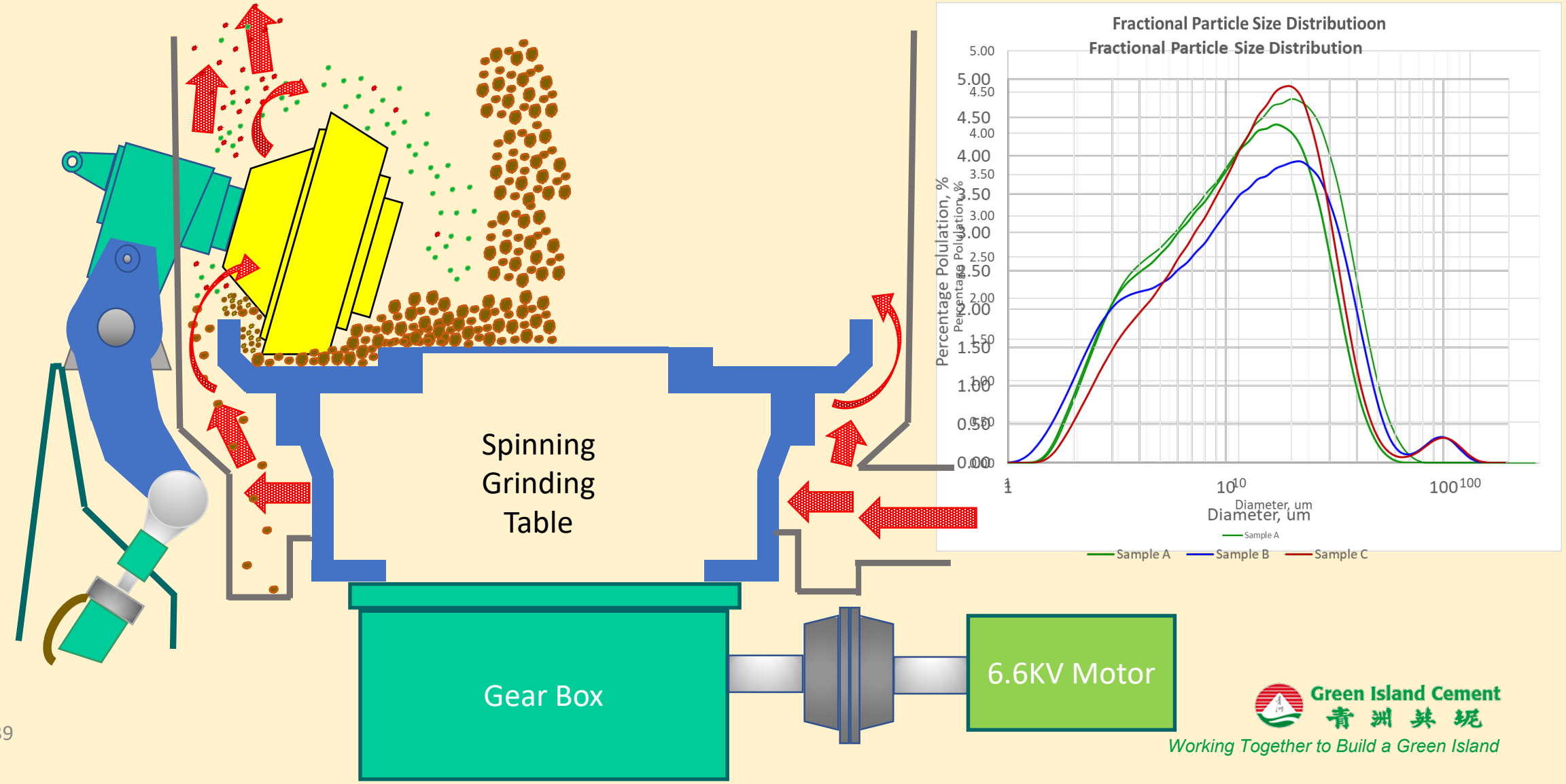
The Size Separation Processes





Green Island Cement
青洲英坭
Working Together to Build a Green Island

The PSD Optimization Process



Green Island Cement
青洲英坭
Working Together to Build a Green Island

Conclusion

Benefits of GGBS concrete:

- *Low embodied carbon*
- *Excellent protection Against Chloride*
- *Improved thermal developing profile*
- *Less sensitive to curing temperature*

- **BS EN 15161-1:2006**
- **Reliable Supply Source (Consistent Quality, Stable Supply, Strong Technical Support)**
- **Holistic Approach**
  - **Concrete / Admixture / Mill Operations / Quality Control / Technical Marketing**


WORKING TOGETHER TO BUILD A GREEN ISLAND
攜手共建 綠色香港
合力打造 低碳都會
WORKING TOGETHER TO BUILD A LOW CARBON CITY