Standing Committee on Concrete Technology
Annual Concrete Seminar 2023

HONG KONG CONSTRUCTION MATERIALS ASSOCIATION LIMITED

Opportunities and Challenges on Production and Application of Low Carbon Concrete with GGBS

Ir. Alan KL Chan

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Why GGBS for Low Carbon Concrete

- Key ingredient for carbon footprint of concrete mix – Cement
  - Burning limestone ($CaCo_3$)
  - Consumption of large amount of energy from burning fuel
- Replacement with other supplementary cementitious materials(SCM):
  - Pulverized Fuel Ash (PFA)
    - Decreasing supply due to decrease in burning coal while increase in the use of natural gas in power station
  - Silica Fume
    - High cost
    - Very low replacement content
    - Mainly for high performance concrete
  - Ground Granulated Blasted Furnace Slag (GGBS)
    - Higher replacement content
    - Sufficient supply for Hong Kong market

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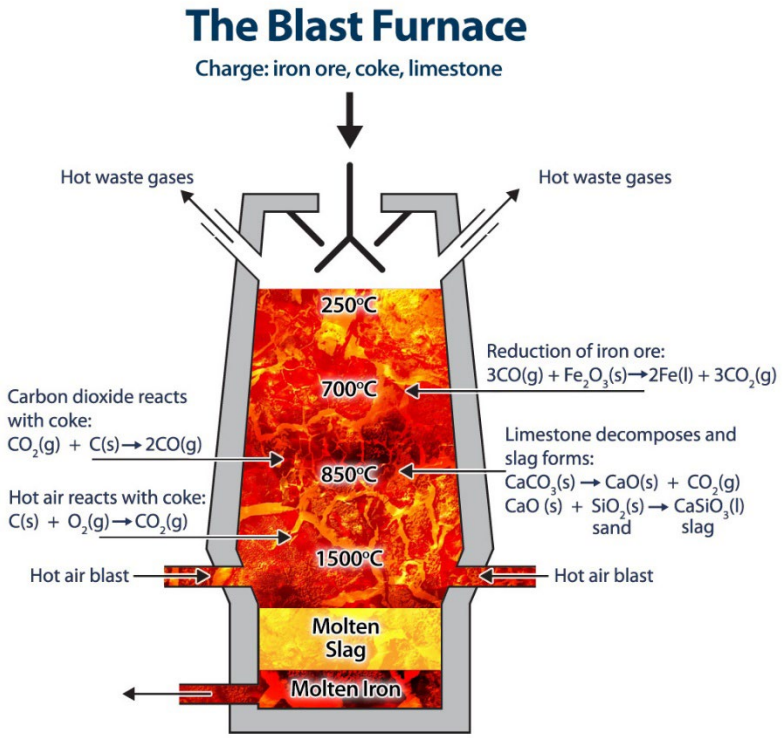
Introduction of GGBS

- By-product of iron manufacturing industry



Heating the iron ore, limestone and coke to 1500°C in Furnace

Extract molten iron slag and water quenching into glassy granulate - Granulated Blast-Furnace Slag (GBFS)

Grinding GBFS into Fine Powder (GGBS) in Grinding Mill

Stored in Silo

Reference: https://ukcsma.co.uk/

History of Using GGBS

- Used in Europe and North America for over 100 years, used in Mainland China since 1990's
- Research study being conducted by Standing Committee on Concrete Technology (SCCT) in 2008 endorsed the proposal by Public Works Central Laboratory(PWCL)
- Following BS EN 15167-1 in Hong Kong; GB/T18046 in Mainland China
- Allowable GGBS content for different specification:

Specification	ASD	CEDD	MTRC	Code of Practice	HKHA
Allowable % of GGBS to total cementitious content	Not more than 40%	35 – 75%	35 – 75%	35 – 75%	35% in precast element

- Reference of GGBS Concrete in Hong Kong
  - Tsing Ma Bridge
  - Stonecutter Island Bridge
  - Organic Resources Recovery Centre Phase 2(O-Park 2) in Sha Ling
  - Police Facilities in Kong Nga Po
  - Kowloon Central Lane
  - Tung Chung Hospital

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Benefits of GGBS

- Reduce heat of hydration from cement and risk of thermal cracking

	Grade 45		Grade 60	
Concrete Grade:	**45D/20**	**45D/20+GGBS**	**60D/20**	**60D/20+GGBS**
Slump (mm):	**150**	**150**	**200**	**200**
OPC content:	450	225	520	260
GGBS content:	0	225	0	260
GGBS % in terms of total cementitious content (OPC+GGBS):	0	50	0	50
(1) Estimated adiabatic temperature rise of concrete due to OPC/GGBS only (°C)	48.04	39.56	55.51	45.71
(2) Assumed fresh concrete placing temperature (°C):	30	30	30	30
(3) Estimated adiabatic peak temperature of concrete mix when used in reinforced concrete structure (°C) = (1)+(2)	78.04	69.56	85.51	75.71

Estimation for heat of hydration of cement with GGBS referred to CIRIA Report C660: 2007 by P.B. Bamfoth

- Improve long-term compressive strength of concrete
- Improve resistance to alkali-silica reaction, sulphate and chloride attack of concrete
- More eco-friendly

Materials	Cement	PFA	GGBS
Carbon Emission Factor (kg CO_2e/kg):	0.95	0.008	0.083
Allowable Cement Replacement %	N/A	Max. 35% only	Max. 75%

Reference for Carbon Emission Value: Bath U, ICE

Benefits of GGBS

Comparison of Carbon Emission Value

Concrete Mix	CO_2 e (kg CO_2 e/m3)
Grade 60 OPC Concrete, 200mm slump	450.792
Grade 60 PFA(25%) Concrete, 200mm slump	349.412
Grade 60 GGBS(50%) Concrete, 200mm slump	253.147
Grade 45 OPC Concrete, 150mm slump	401.290
Grade 45 PFA(25%) Concrete, 150mm slump	326.178
Grade 45 GGBS(50%) Concrete, 150mm slump	220.018

The above concrete mixes are produced with same source of cement and GGBS in same concrete batching plant
Carbon emission factor using ICE value

i.e. GGBS concrete has lower carbon emission value compared with OPC and PFA concrete (for concrete mix with the same total cementitious content)

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Supply of GGBS in Hong Kong Market

Current GGBS Source

- 1 Local brand
- Several sources in Mainland China
- Other depots in Mainland China or other regions
- Capable to meet annual market demand

Transportation Method:

- Land Transportation – Silo Truck
- Sea Transportation – Barge

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Challenges for GGBS Concrete

Concrete Production

- Complicated procedures for getting approval of construction of additional silo(s) for GGBS storage
- Logistic assurance of GGBS supply for upcoming GGBS concrete demand
- Consistency of GGBS performance
- Work out with admixture suppliers for advancement of GGBS concrete rheology
- Difficulties on proposing GGBS concrete without job reference

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Challenges for GGBS Concrete

Application on Site

- Higher designed workability is recommended
- Early strength development is sensitive to ambient and concrete temperature, subject to the GGBS content to be used
- Striking time of formwork and falsework might have to be increased compared with traditional OPC concrete

Formwork supporting cast insitu concrete in flexure may normally be struck when the strength of the concrete in the element is 10 N/mm^2 or twice the stress to which it will be subjected, whichever is the greater, provided that striking at this time will not result in unacceptable deflection, and suitable curing and protection to the concrete is provided.

In the absence of other information the recommended minimum periods before striking formwork and falsework for concrete made with Portland Cement are as follows:

(f) 12 hrs: vertical formwork for sides of beams, columns, walls and similar locations;

(g) 4 days: soffit formwork of slabs with props left in;

(h) 7 days: soffit formwork of beams with props left in;

(i) 10 days: props for slabs;

(j) 14 days: props to beams; and

(k) 14 days: props to cantilevers.

For long span or transfer structures, the specified cube strength must be achieved prior to removal of falsework and propping.

If pfa or ggbs is included in the concrete mix, or temperatures are below 15°C, an increase to these periods may be required.

Reference: Code of Practice for Structural Use of Concrete 2013

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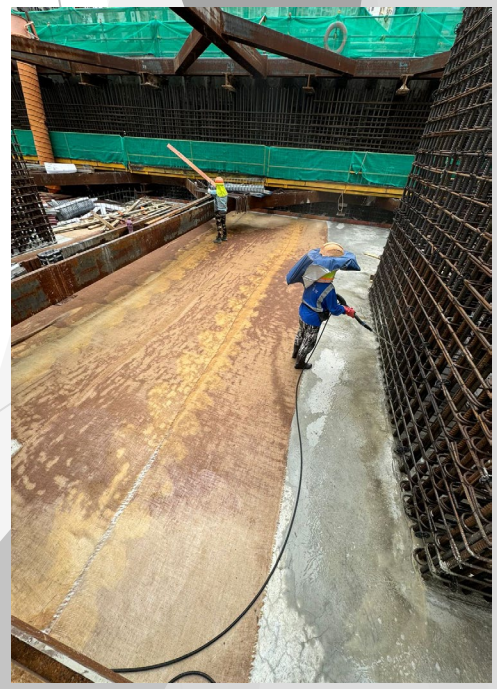
Challenges for GGBS Concrete

Application on Site

- Limitation of striking time and cycling period for superstructure prohibit the contractors' desire on the wide application of GGBS concrete
- Longer curing period for GGBS concrete is recommended compared with traditional OPC concrete
- Insufficient curing period of less than 3 days would hamper the concrete strength development
- Different GGBS content for different structural elements might be considered to reduce the possible impact



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Conclusion

- GGBS is a key ingredient to reduce the carbon footprint of concrete industry effectively
- GGBS Concrete has various benefits over traditional OPC concrete
- Regardless of the opportunities, both concrete suppliers and users have to overcome the challenges in GGBS concrete production and application respectively
- Viability for wide application of GGBS concrete in HK is a long term task that requires unwavering efforts and collaboration of different parties
- Using GGBS concrete will be a big step to achieve carbon neutrality

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Q & A Session