

“Not Just Admixtures”

Optimization of 20 MPa Concrete Using
Supplementary Cementitious Materials and PCE
Technology

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Outline

- As cement is the most expensive component of 20MPa concrete, what is the **minimum cement content** needed for adequate set?
- Cement can be replaced by **less expensive** Supplementary Cementitious Materials (SCMs) but at the cost of slower setting times.
- How much cement can be **replaced** by SCMs?
- Even in low strength concrete (20MPa) the latest admixture technology can be used to **improve** the **economics** of the concrete mix,
- And improve the plastic properties of the concrete with an added **sustainability** benefit.



Scope

- Based on materials available in New South Wales, Australia.
- Most common concrete sold in NSW is 20MPa concrete, typically for housing construction, slab-on-ground.
- Usually a lignin-based water reducer is used to give 5-10% water cut, and some extension of the setting time results.
- Using a neutral setting PCE it is possible to achieve the same level of water reduction with faster setting times.
 - This allows us to reduce the cement content



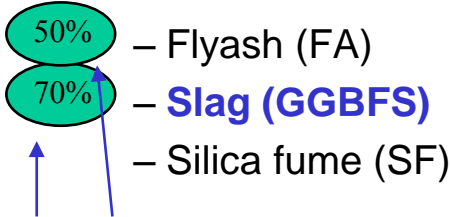
Introduction

- The project is designed to determine the minimum cement content that can be used in **everyday 20 MPa concrete**.
- The project is based on the premise that if you can resolve:
 - the loss of early stiffening
 - then the **stripping** and **finishing times** will not be changed.
- Clearly there will be a **minimum cement** content required to give an **adequate** rate of **stiffening** and then set.



Introduction

- Supplementary cementitious materials have been used for some time to replace part of the cement content in concrete



Introduction

- Blast furnace slag (GGBFS) is a waste product that can be used as recycled aggregate or ground to a similar fineness as cement to participate in hydration reactions
- GGBFS is a by-product of iron manufacture
- GGBFS is added to *improve plastic and hardened properties* in concrete
- GGBFS is a **latent hydraulic**, i.e. low exothermic heat leading to long setting times and low early strengths



Premise

- If the **set time** delay introduced by the incorporation of significant quantities of slag can be **offset** by the use of an appropriate **PCE** and set accelerating admixtures then the **stripping** times of the concrete formwork will **not** be **changed**



PCEs

- Polycarboxylates (PCEs) were developed in the 1980s for self-placing concrete in Japan.
- PCEs have since been adopted internationally, particularly in countries with high concrete quality control
- With economies of scale and further technical development the cost-performance has improved significantly.
- Additional chemical modification has given increased versatility, allowing for use with a wider range of binder materials.



GGBFS (Slag) - considerations

- Slag hydrates more slowly than OPC.
- Slag has a higher activation energy required to initiate hydration
- Binary or ternary blends containing slag are more sensitive to changes in temperature
- Slag blends produce concrete with lower early strengths
- In slab-on-ground construction the main concerns are the finishing times and stripping the formwork



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GGBFS

- Ternary blends containing slag and flyash are more sulphate resistant.
- There is an environmental benefit by using slag as it is a waste stream
- Slag blends show higher shrinkage using AS1012.13 due to early expansive reactions
- If the expansion is taken into account, the drying shrinkage is comparable to OPC concrete.



Sustainability

- 1 tonne of **GP** cement requires **7500** MJ of energy
- 1 tonne of **Slag** requires **700 – 1000** MJ of energy
- 1 tonne of **Flyash** requires **150 - 400** MJ of energy.

“A typical house slab using 130 m² of concrete can have a reduction in emissions of 41% through the use of a ternary blend of OPC, flyash and GGBFS.”¹

¹ Malhotra, Concrete International May 1999



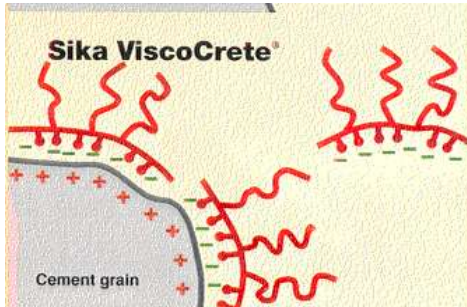
Testing procedure

- Mix Design:
 - Typical gap graded 20 MPa slab mix
 - 600 kg 20mm CRG
 - 440 kg 10mm CRG
 - 600 kg Coarse sand
 - 150 kg Fine sand
 - 230 kg binder



Admixture design

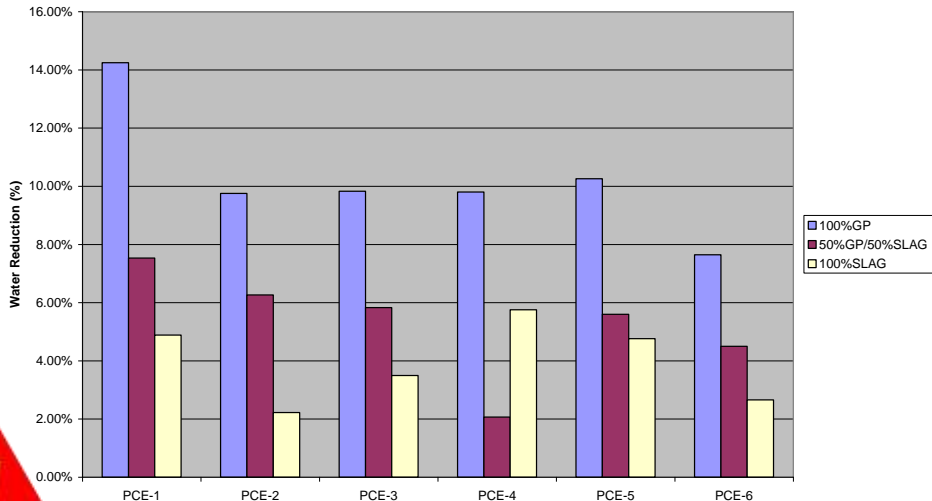
- Two step process
 - Step 1 – Determine PCE to use
 - Step 2 – Test suitable set accelerating components
- Finally blend the two – PCE + Accelerators



PCE determination

- Step 1 – Determine which PCE to use
- Some PCEs perform well with cement only
- Some PCEs perform well with slag
- Six chemically different PCEs were tested

Water Reduction of various polycarboxylates



PCE determination

- Performance of the PCE did not correlate with chemical structure
- The **best non-retarding PCE** was chosen
- This PCE has no retardation across a wide dose range compared to a control with no admixture
- Generally lignosulfonate admixtures, whilst classified neutral set, retard to some extent
- As the GP cement is replaced by slag, this retardation becomes more significant



Set Accelerators

- With the PCE chosen the next step was to identify the most efficient **set accelerating chemicals** for the ternary blend.
- Various proprietary combinations of organic amines, acids and nitrate salts.
- Setting times were determined in a mortar designed to be similar in composition to a mortar sieved from a 20MPa concrete.



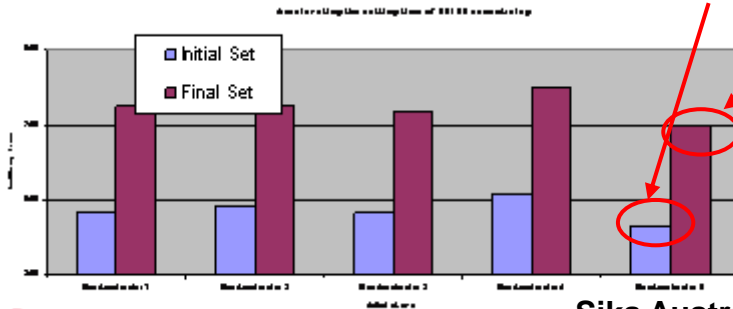
Set Accelerators

- The chemical combination with the **fastest** setting times was chosen
- New admixture is **blended** from these **accelerating chemicals** and the **best PCE**.
- This was used for subsequent tests to optimise the cementitious content of the 20MPa mix.



Set Accelerators

Mix Ref	Admixture Evaluated	Dose Rate ml/100kg	Flow @ 5 drops (mm)	water/binder ratio	Initial Set	Final Set
					hh : mm	hh : mm
1	Slag Accel. 1	600	140	0.6	4:40	7:30
2	Slag Accel. 2	600	140	0.6	4:50	7:30
3	Slag Accel. 3	600	145	0.6	4:40	7:20
4	Slag Accel. 4	600	135	0.6	5:10	8:00
6	Slag Accel. 6	600	140	0.6	4:20	7:00



Fastest set



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Concrete tests

- Summary of concrete performance with lignin and PCE admixtures.

		Control Mix	New Mix
Cement	kg	186	92
Slag	kg	0	92
Fly Ash	kg	46	46
Admixture		lignin	PCE
		BV80N	New WRAc
23°C Testing	w/b ratio	0.66	0.65
	Initial Set	hh:mm	7:20
	Final Set	hh:mm	9:50
		8:40	



Summary

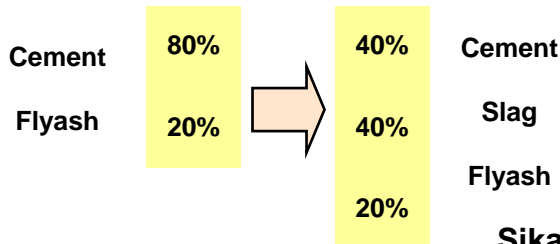
- By choosing the right admixture design it is practically possible to replace 50% of the GP in a 20MPa 80:20 mix with slag.
- This results in a more economical concrete with the same setting time characteristics
- Stripping times will not be affected and the concrete can be finished in the same time frame



Cost Savings for customer

- By reducing the GP cement content of the concrete, the economics of the mix are significantly improved:

GP replacement	50%	56%	62.50%
saving based on	3.8%	4.6%	5.5%
300,000 cubic metres	\$ 776,250	\$ 941,250	\$1,121,250



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Conclusions

- Benefits:
 - **Environmental** → replacement of GP cement
 - **Improved plastic properties**
 - increased paste volume
 - With adequate curing, hardened properties improved
 - reduced porosity
 - improved durability
 - **Concrete producer saves approximately 4% on total mix costs.**

