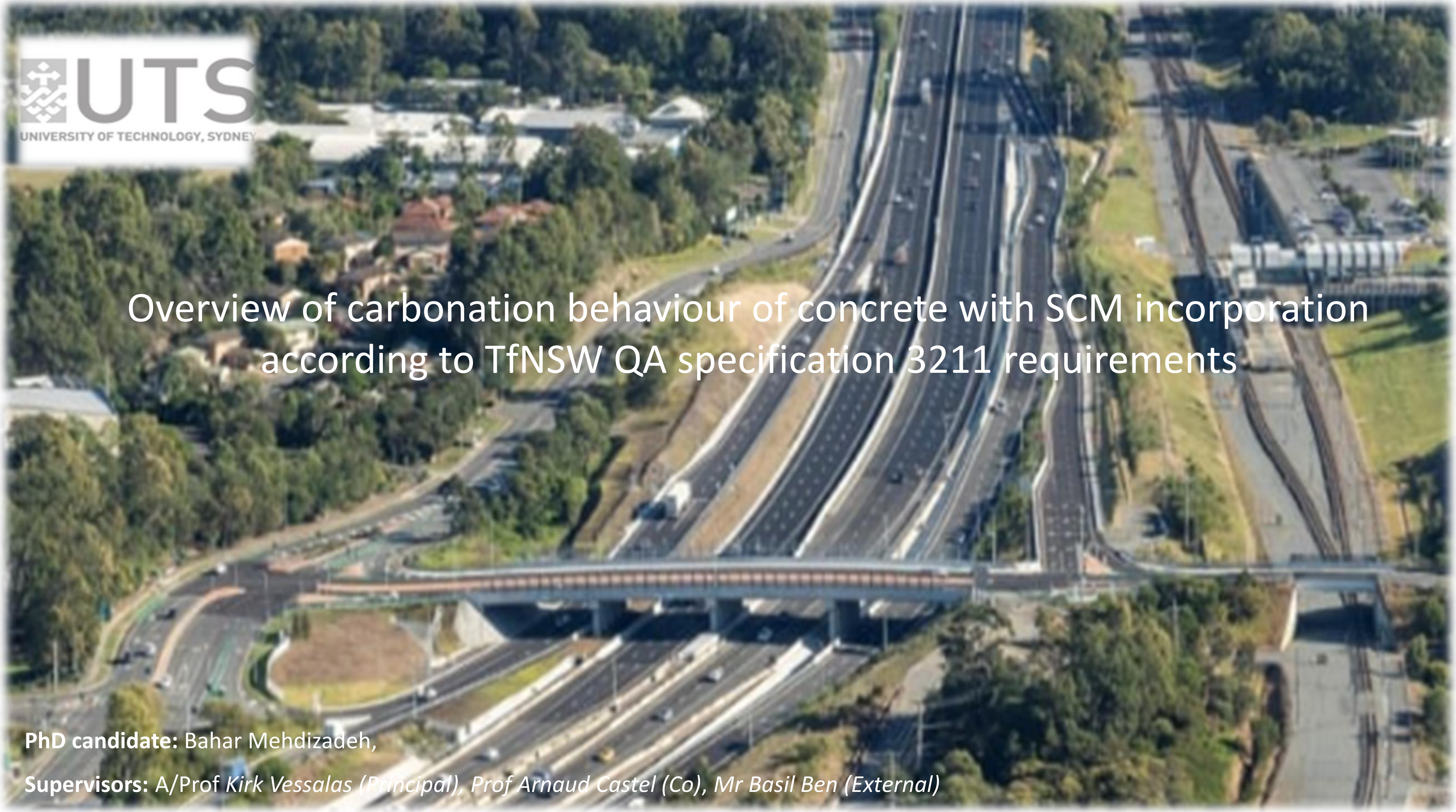

Overview of carbonation behaviour of concrete with SCM incorporation according to TfNSW QA specification 3211 requirements

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Supervisors: A/Prof *Kirk Vessalas (Principal), Prof Arnaud Castel (Co), Mr Basil Ben (External)*

Assessment of slag use in concrete for use in base mixes in rigid road pavements

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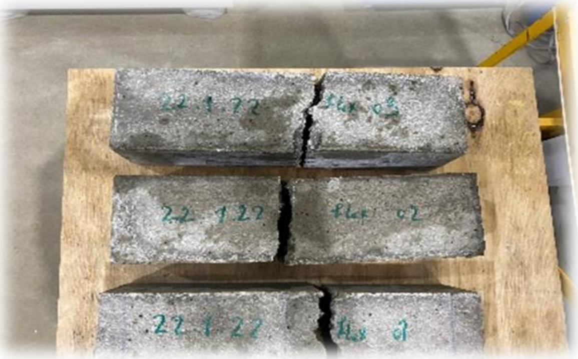

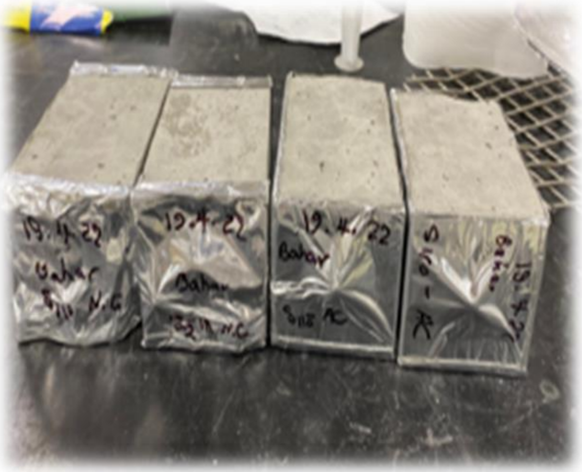

- Abstract
- Project Scopes, research objectives
- Experimental program and methods
- results
  - Compressive and Flexural strength
  - Drying shrinkage
  - Accelerated carbonation
- Accelerated Carbonation modelling

Abstract

- The carbonation of concrete in structures causes deterioration and service life reduction. When carbon dioxide (CO_2) from the surrounding atmosphere reacts with cement hydration products in concrete and imposes an environmental load, calcium carbonate forms, and the carbonation process begins.
- Validating the minimum SL cement content required for the carbonation resistance formulae in the TfNSW 3211 specification is important parts of this study.
- In this research, the carbonation behaviour of concrete mixes utilising 250, 300, and 350 kg/m^3 binder content, a fixed water-to-binder ratio of 0.45, and cement replacement levels of 40-70% GGBFS and 15-20% fly ash, will be investigated.
- Compressive strength, flexural strength, drying shrinkage and accelerated carbonation depth results will be reported. The relationship between carbonation depth and carbonation rate using GGBFS and fly ash will also be evaluated.

For carbonation resistance

The minimum proportion of cement, SL_{min}, is determined as follows:

$$SL_{min} \geq 100 - 0.55\,[FA + 0.5 \times GGBFS]$$

where:

SL_{min}	=	Minimum Type SL cement (% by mass)
FA	=	Mass of fly ash (kg/m^3)
$GGBFS$	=	Mass of GGBFS (kg/m^3)

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The overall objectives of this research study are highlighted as follows:

First
Assess carbonation behaviour, workability , strength development, and drying shrinkage limits for 350 kg/m^3(cement replacement levels by 15-20% fly ash and 40-70% GGBFS).

Second
Assess carbonation behaviour, workability , strength development, and drying shrinkage limits for 250-300 kg/m^3(cement replacement levels by 15-20% fly ash and 40-70% GGBFS).

Third
Compare natural filed samples and accelerated carbonation behaviour of slag-based to establish a correlation between natural and accelerated test conditions, according to carbonation depth.

Forth
Develop predictive carbonation models to determine the impact and ranking of carbonation factors on carbonation depth in rigid pavement.

Fifth
Introduce and correlate permeability results to carbonation results for 250, 300 and 350 kg/m^3 binder contents(cement replacement levels 40-70% GGBFS).

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? Experimental Program and methods

Materials:

Cement and Supplementary cementitious materials

shrinkage limited (SL) cement, GGBFS, FA

Aggregates

Peppertree aggregate 20mm , Peppertree aggregate 10mm, Peppertree blended man sand,

Mackas fine sand

Admixture

Plastisement10

(water-reducing)

Sika product

Australian Standards

ISO 1920-12
BS EN 14630
RILEM CPC-18

TfNSW QA specification

Description		Compressive Strength	Flexural Strength (1)
Non-SCM Mixes (2)	In the Trial Mix	45.0 MPa (F_{28Min})	5.0 MPa (F_{f28Min})
	In the Works	40.0 MPa (f_{cMin})	4.8 MPa (f_{fMin}) (3)
SCM Mixes (2)	In the Trial Mix	40.0 MPa (F_{28Min})	4.8 MPa (F_{f28Min})
	In the Works	35.0 MPa (f_{cMin})	4.5 MPa (f_{fMin}) (3)
Test specimen size		cylinder 100 mm diameter	beam 100 × 100 × 350 mm
Test methods		AS 1012.8 except: TfNSW T304 for moulding; AS 1012.9 for testing	AS 1012.8 except: TfNSW T304 for moulding; AS 1012.11 for testing

slump test for slipform paving is between 15 –50 ± 5 mm

(60% GGBFS and 40% SL Cement)

Trial mix design 40%SL, 60%GGBFS	24/08/2021
Target Slump(+/- 5mm)	50
Ambient temperature (' C)	23 +/-2
Aire content (%)	3.1
Actual Slump (mm)	45
Batch Volume m3	0.03
Actual Slump (mm)	45

Water (L)	
Water Start	4.5
Water added	0.5 + 0.2
Water contain(aggregate)	0.11
water in admixture	0.017
Total Water	5.327

Unit Weight	
Container Kg	4.55
Concrete + container Kg	24.65
Concrete Kg	20.1
Vol Container m3	0.008
Unit Weight (Kg/m3)	2577

Admixture Name	SG	solid content	Water content	Target of solid content	Target of water
Plastisement10	1.07-1.10	21.0-25,0%	79.0-75.0%	0.23	0.77
Admixture			Volume (ml)	Weight (g)	Water(ml)
Sika Plastiment 10 Specific	200ml/100kg		21	22.89	17.63

Concrete type	Total content (kg/m3)	SL Cement (kg/m3)	Eraring-Fly ash (kg/m3)	Slag-GGBFS (kg/m3)	Water (kg/m3)	Water/binder (%)	Mackas fine sand (Kg/m3)	Peppertree 20mm aggregate (Kg/m3)	Peppertree 10mm aggregate (Kg/m3)	Peppertree blended man sand (Kg/m3)	Total
Design wieght (kg/m3)	350	140	0	210	157.5	0.45	275	807	298	476	2400
Lab Batch Weight (KG)	11.65	4.66	0	6.99	4.5	0.45	9.16	26.9	9.93	15.86	78
Moisture content (%)							0	0.6	0.8	0	
Water contained(KG)							-0.08	0.21	0.12	-0.14	0.11
Total Lab Batch (KG)	11.7	4.7	0	7	5.32	0.45	9.08	27.11	10.05	15.72	78.98
Corrected weights (kg/m3)	351	141	0	210	159.60	0.45	302.67	903.67	335.00	524.00	2575.9

EX: Mix designs

Type	Total Binder (kg/m3)	SL Cement %	GGBFS %	Eraring-Fly ash %	Coarse and fine aggregates	W/C	Sika Plastiment (mL)
CO		100%	0	0			
		60-30%		0			
		85-20%	40-70%	15%			
		80-10%		20%			
		85%		15%			
Mixes	250 300 350	80%	0	20%	~ 2000	0.45	10 ±5
		60%		40%			
		20%		40%			
		20%	40%	40%			
		20%		40%			

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Results

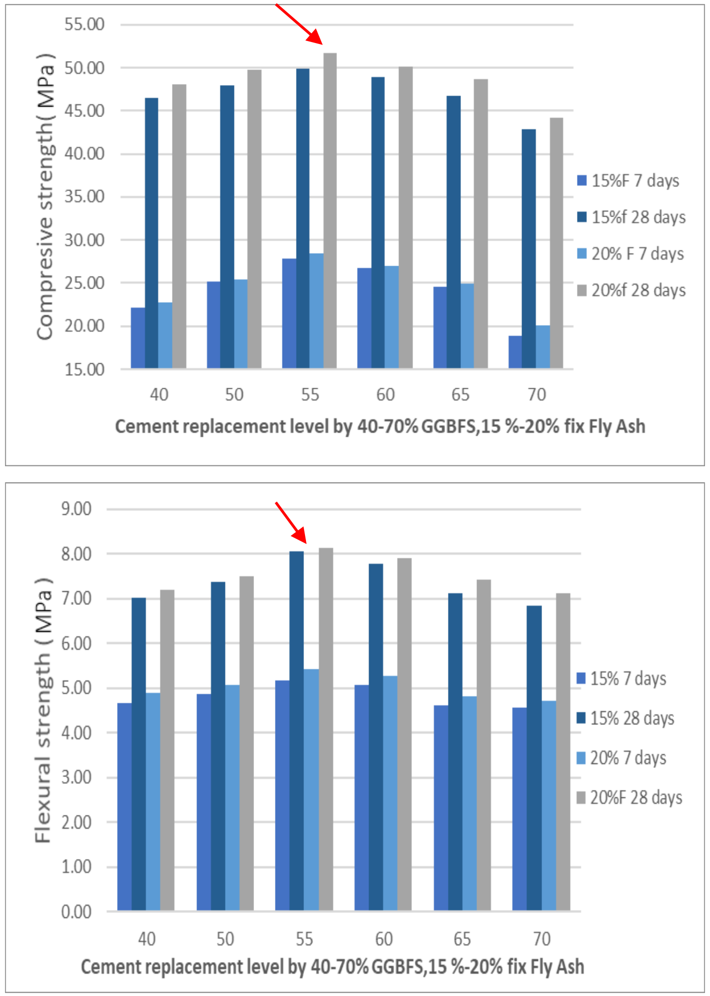

Figure 1. Compressive and flexural strength results for 40-70% GGBFS and 15% - 20% fly ash mixes

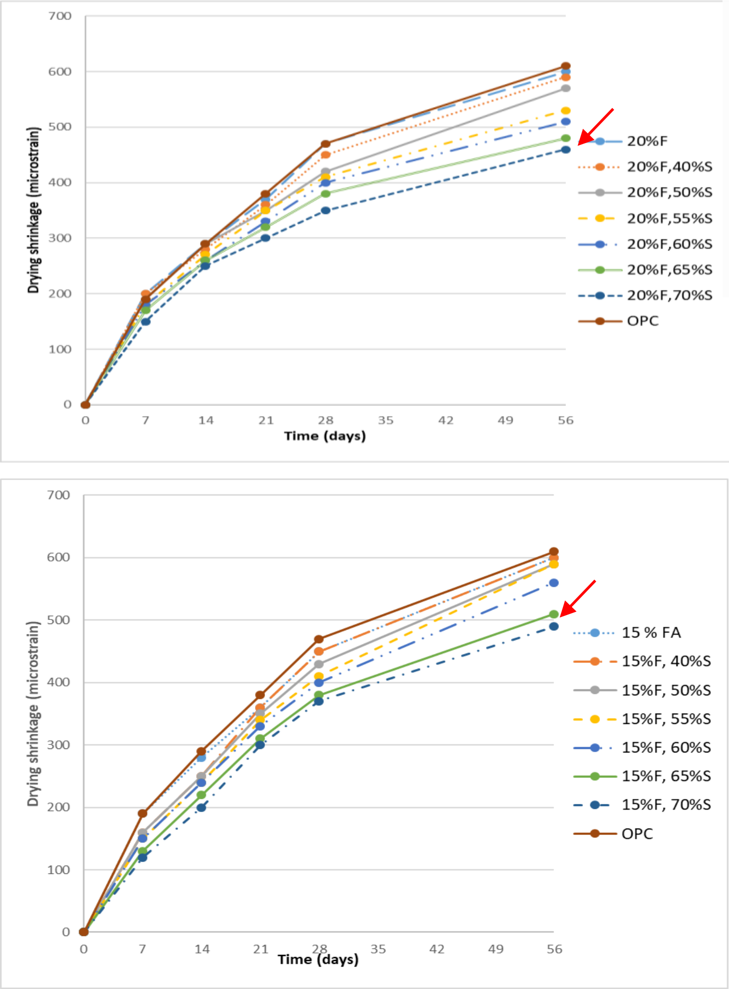

Figure2. Shrinkage results with cement replacement level by 40-70 of GGBFS(%) – 15 and 20 % Fly Ash

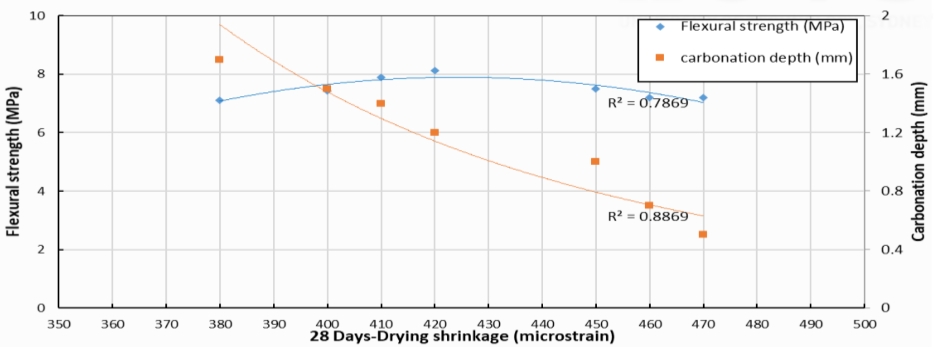

Fig 3. The relationship of drying shrinkage with flexural strength and carbonation depth for the cement replacement level by 40-70 of GGBFS (%)– 20% FA

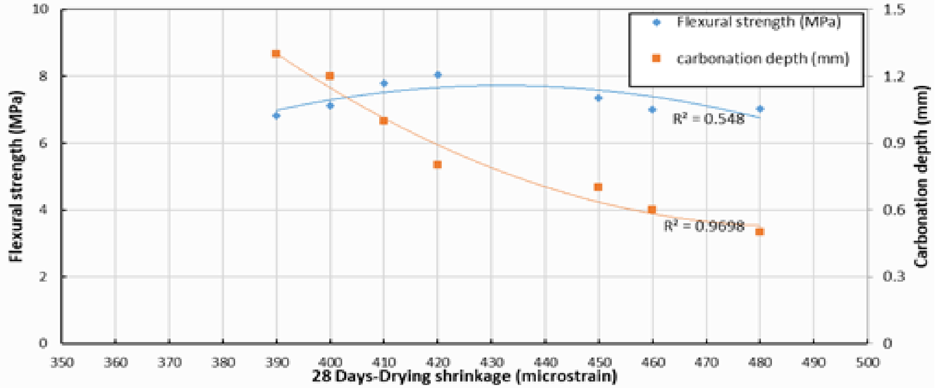

Fig4. The relationship of drying shrinkage with flexural strength and carbonation depth for the cement replacement level by 40-70 of GGBFS (%)– 15% FA

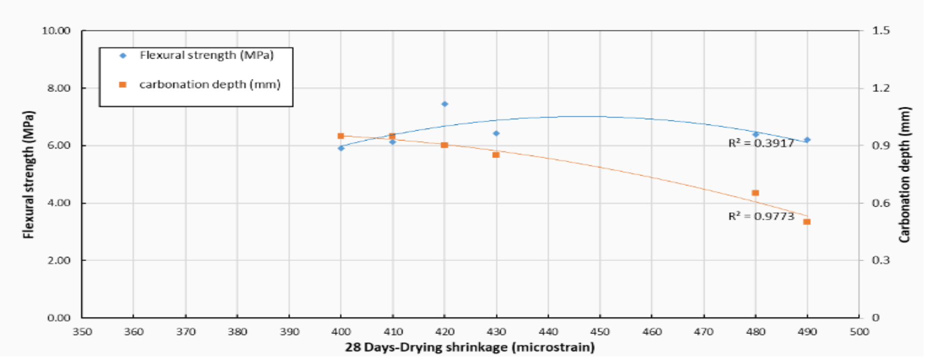

Fig 5. The relationship of drying shrinkage with flexural strength and carbonation depth for the cement replacement level by 40-70 of GGBFS (%)

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Accelerated carbonation condition and result

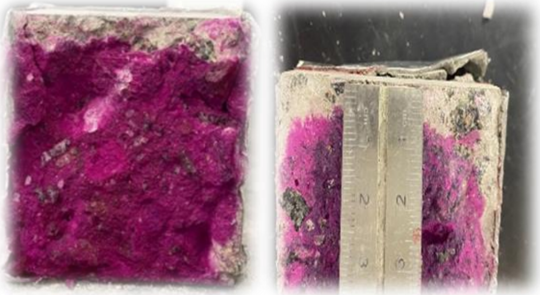
General carbonation Equation

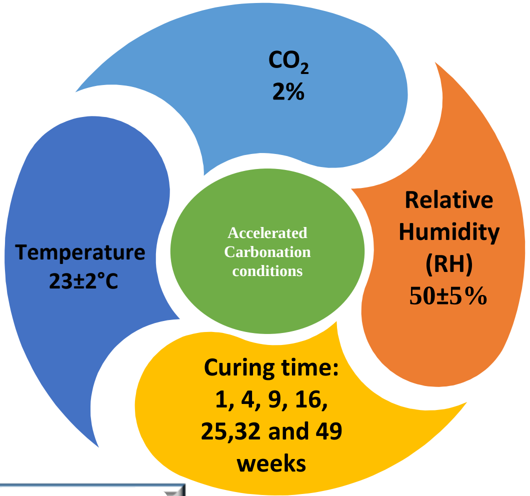
$$X = K\sqrt{t}$$

X: the carbonation depth (mm)

K: the carbonation coefficient (mm/year$^{0.5}$)

t: the exposure time to CO_2 (year)





$$b = b_1 c_1 + b_2 c_2$$

$$b_1 = 0.0019(C_3A)^2 - 0.0056(C_3A) + 0.7538$$

$$K = -4.062 + 2.568(1000/b)$$

Buffering capacity For Cement

C3A= 12.8%	b1=1
C3A = 8.6%	b1=0.85
C3A =1.6%	b1=0.75

the buffering capacity material component (b_2)

$b_{2\ slag}$ ~ 0.55 - 0.6

$b_{2\ fly\ ash}$ ~0.2

$$K_{re|RH} = -0.000508(RH)^2 + 0.0556(RH) - 0.4472$$

$$K_{cure} = 0.679 + 0.705\ p^{-0.715}$$

RH: the relative humidity of the environment in percent

P: the period of wet curing in days

K , b
the carbonation rate of Buffering capacity (pH)

K (cure) ,
the carbonation rate at curing time

K (RH)
the carbonation rate of relative humidity

Factors of carbonation rate (K value) according to concrete society, technical report no.61

$$K = K_b + K_{RH} + K_{Cure}$$

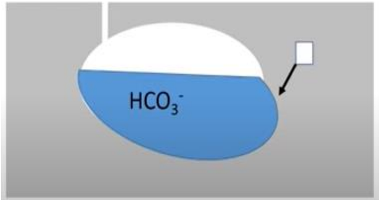
$$X = K\sqrt{t}$$

Other important factors

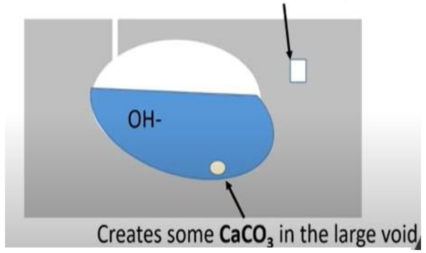
Effect of PSD (particle size distribution)

Ca/Si ratio

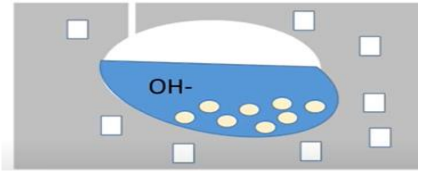
calcium hydroxide dissolves to the acids, forming carbonic acid (H_2CO_3)
This is called **buffering**.



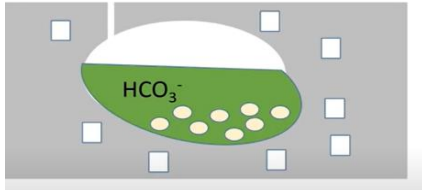
This leaves a void in the paste!



This continues until have consumed the calcium hydroxide



Now the pH ↓



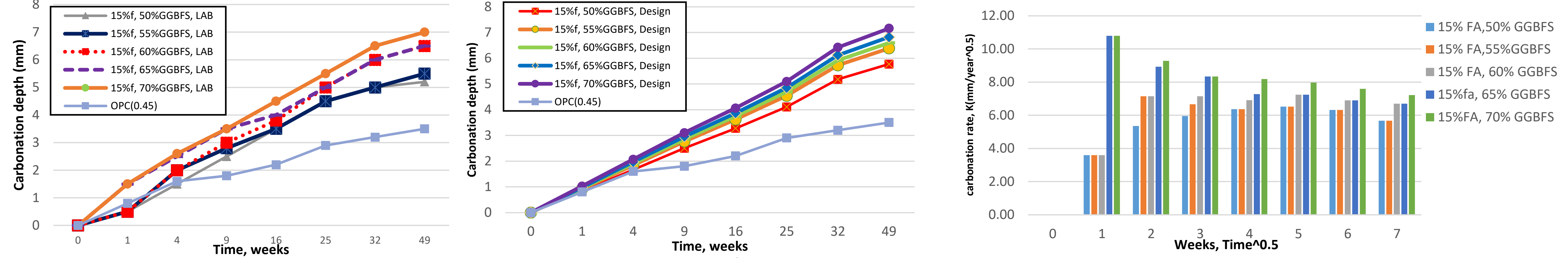


Figure 6. Carbonation depth and Carbonation rate(K (mm/year^0.5)) results for 50-70% GGBFS and 15% fly ash mixes

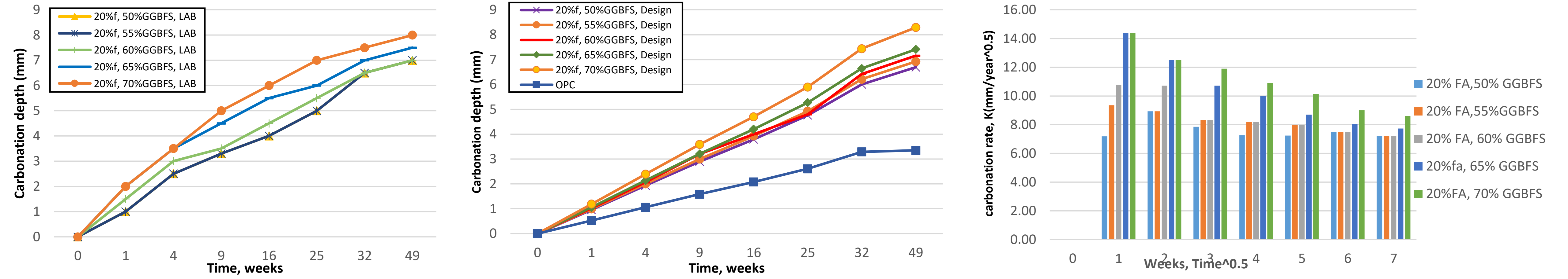


Figure 7. Carbonation depth and Carbonation rate(K (mm/year^0.5)) results for 50-70% GGBFS and 20 % fly ash mixes

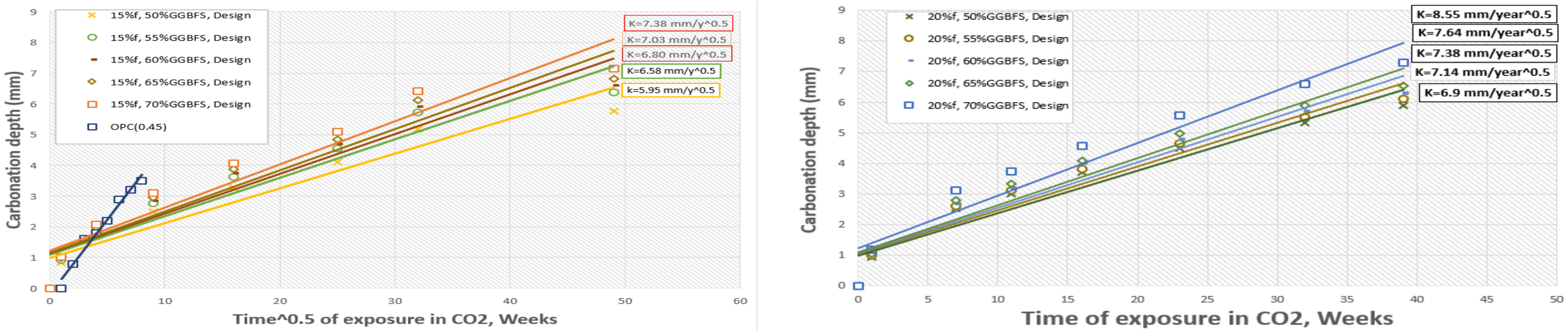


Fig 8. Calculation of carbonation depth(mm) for 40-70% GGBFS and 15-20% fly ash mixes

Thank you For your attention