Workability of Hybrid Cement with Carbonated Mixing Water.

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ABSTRACT

It is estimated that 8% of the global anthropogenic CO_2 emission is attributed to the production of Portland Cement (PC) [1]. The demand for environmentally friendly solutions has increased due the rapid urbanisation [2]. This has led to the emergence of various strategies such as electrification, replacing of PC, and carbon dioxide (CO_2) sequestration [3]. Numerous carbon sequestration and storage methods have been developed for producing low-carbon cement and concrete materials [4]. It has been reported that using carbonated mixing water could effectively sequester and store CO_2 but would reduce the workability of concrete [3].

To address the challenges of reduced workability using carbonated mixing water, the PC-GGBS (with 1:1 mass ratio) cement was doped with various hydroxides. It is hypothesised that the addition of alkaline materials could neutralise the acidity of the carbonated water, resulting in more carbonate ions and free water molecules. This would provide more lubrication between particles while promoting the development of calcium carbonate [3]. Three different alkaline materials were used including NaOH (NH), $Ca(OH)_2$ (CH) and ground cement paste (GPC) at dosages of 1%, 2% and 5% of the PC or PC-GGBS blend.

The investigation employed EN 197-1 and SS EN 15167-1-compliant CEM I PC and GGBS. The carbonated water (CW) was prepared using the SodaStream domestic soda carbonator to carbonate the potable water (PW) until a mass gain of 0.4% was achieved. For all paste mixtures, the water-to-binder ratio was 0.4. These combinations were tested for workability using modified mini slump and

flow table tests. Six 50 mm^3 cubes were cast and tested at 1, 3, and 7 days to evaluate each mixture's compress strength.

Table 1 presents the sample notation, mix composition, compressive strength and workability of the cement pastes studied in this work. It is observed that the workability of PC and GGBS pastes decreased by 66% and 42% respectively when carbonated water was used in mixing. The decrease in workability is related to the formation of $CaCO_3$ [5] or ettringite [6] as shown in the SEM image (Figure 1).

Table 1 The mix design, workability and compressive strength values of the paste samples in this study

No.	Mix	Slump (mm)	Flow (mm)	Compressive Strength (MPa)					
				1 Day		3 Day		7Day	
				Strength	Std. Dev	Strength	Std. Dev	Strength	Std. Dev
A1	PC + PW	28.0	209.3	16.3	6.2	30.8	4.7	40.4	4
A2	PC + CW	9.5	128.8	20.3	2.1	43.5	2.5	46.6	4.1
A3	PC + GGBS + PW	25.0	208.3	13.1	1.8	29.9	1.5	47.9	3.4
A4	PC + GGBS + CW	14.5	144.0	9.9	1.2	31.7	0.7	46.8	2.7
A5	PC + GGBS + CW + GPC1%	20.0	185.5	11	0.9	34.7	1.4	49.5	7.2
A6	PC + GGBS + CW + GPC5%	21.0	205.0	11.6	0.2	30.3	2.1	37.3	5.2
A7	PC + GGBS + CW + CH1%	20.0	183.7	13.5	1	35.4	2.2	46.6	3.2
A8	PC + GGBS + CW + CH2%	22.0	185.7	15.1	2.5	33.8	1.7	43.9	1.1
A9	PC + GGBS + CW + CH5%	18.5	163.3	15.9	1.9	34.8	2.9	45	2.7
A10	PC + GGBS + CW + NH1%	20.0	169.5	10.7	1.1	14.6	4.6	29	1
A11	PC + GGBS + CW + NH2%	20.0	173.5	10.2	0.4	15.7	1.7	19.8	2.3
A12	PC + GGBS + CW + NH5%	19.5	154.5	10.7	1.2	13.4	1.7	17.2	1.2

The slump value increased from 14.5mm to 20.0mm and 21.0mm respectively when 1% and 5% of ground cement paste was added. Similarly, they increased by 40% - 80% when hydrated lime or NaOH was introduced into the PC-GGBS blend. It is also observed that the workability decreased for both hydrated lime and NaOH mixes when 5% was added. This might be attributed to the formation of excessive $CaCO_3$ and $NaHCO_3$ for hydrated lime and sodium hydroxide respectively that overcome the lubrication effect.

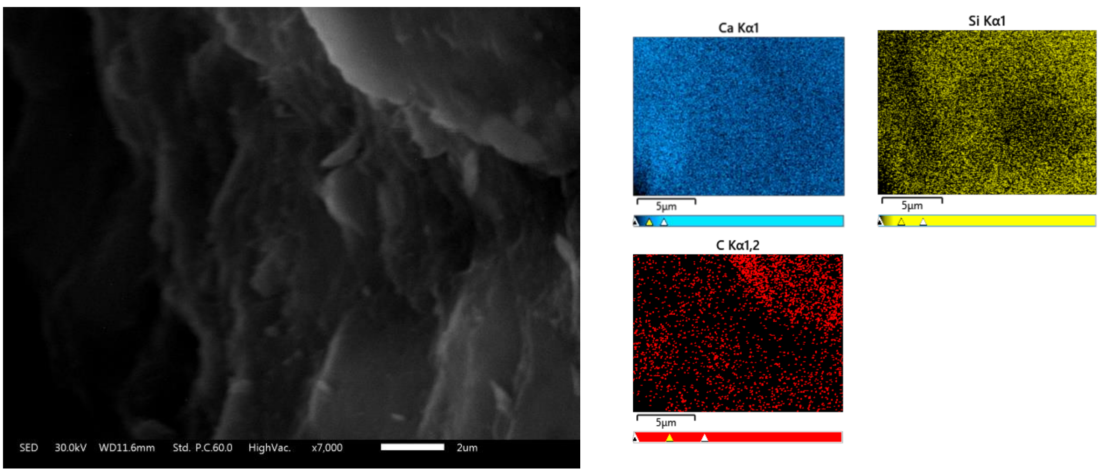

Figure 1 SEM image with EDX scan of A7

The compressive strength of PC paste increased when carbonated water was used due to the early formation and calcite and enhanced C-S-H formation [7]. However, this enhancement of early strength was not observed in the PC-GGBS blend with the carbonated water, which is likely due to the reduced alkalinity of the pore solution, leading to retarded activation of GGBS at the early age.

The hybrid cement mixes generally exhibited higher 1-d compressive strength as the percentage of alkaline materials increased. At 3 and 7 days, the mixtures with hydrated lime added showed similar strength values of 34 ± 1MPa and 45 ± 1.5 MPa respectively, regardless of the dosage. However, the NaOH mixes showed significantly lower strength, possibly due to delayed ettringite formation at high pH [8].

In conclusion, this investigation unveil the workability and compressive of cement paste can be improved with the addition of selected alkaline when CW is used as mixing water. However, more studies will have to be conducted to investigate the mechanism. Upon discovering the mechanism, this work will able to improve the quality of low-carbon ready-mix concrete and the productivity of related concrete works.

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