- The substitution of SS by WGS improved the flexural behaviors of sound ECCs for up to 50% WGS content. Improvements in the recovery rates of flexural strengths, mid-span beam deflection capacities, RCPT and ER were noticed even with total replacement of SS by WGS. However, 50% WGP content showed the optimum self-healing capacity of preloaded specimens.

- The SEM-EDS analyses showed that the healing products in the crack surface were mainly calcium carbonate with small amount of mixed C-S-H/Ca(OH)₂ for all ECC's. However, the difference in silica content suggests more volume of mixed C-S-H/Ca(OH)₂ with WGP and WGS replacements. In addition, the higher silica, sodium, potassium and aluminum in the deeper region of healed cracks of WGP- and WGS-ECCs compared to control ECCs, suggest that, the replacement of FA or SS by WGP or WGS caused the C-S-H formation to have a new composition close to C-(N-K,Al)-S-H.

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Chemical Composition, %	PC	FA	WGP					
SiO_2	19.5	57	74,07					
Al_2O_3	5.1	21	1,97					
Fe ₂ O ₃	2.92	4.2	0,44					
MgO	2.5	1.8	1,26					
CaO	61.8	9.8	13,56					
Na ₂ O	0.30	2.2	7,19					
K_2O	1.11	1.5	0,62					
Loss on Ignition	2.5	1.3	0,47					
SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃	27.52	82.2	76.48					
Physical Properties								
Specific Gravity	3.1	2.02	2,54					
Blaine Fineness (m ² /kg)	408	325	382					

Table 1- Chemical and physical characteristics of cementitious materials

Note: 1 m2/kg = 0.54 yd2/lb.

Mixture				Mixtur	e ID					
Proportions	ECC	ECP1	ECP3	ECP4	ECP6	ECC	EC	ECS5	ECS7	ECS1
(kg/m^3)	2.2	5	0	5	0	1.2	S25	0	5	00
PC	360	364	368	373	378	552	552	552	552	552
FA	791	681	567	451	333	662	662	662	662	662
WGP	0	120	243	370	500	-	-	-	-	-
WGS	-	-	-	-	-	0	110	218	328	438
Water	311	314	318	323	327	438	328	218	110	-
SS	414	420	425	430	435	328	328	328	328	328
PVA	26	26	26	26	26	26	26	26	26	26
HRWRA	8.0	9.0	9.8	10.5	12.0	8.6	10.5	11.0	11.4	12.4

Table 2-The mixture proportions of different ECCs

Notes: 1 kg/m3 = 1.685 lb/yd3; 1 MPa = 0.145 ksi.

Table 4-Crack Characteristics of Preloaded Specimens. (Note: $1 \mu m = 3.94 \times 10-5 \text{ in.}$)

Μ	lix ID	ECC	ECP 15	ECP 30	ECP 45	ECP 60	ECC	ECS 25	ECS 50	ECS 75	ECS 100
Crack	Average	~40	~40	~50	~70	~80	~50	~55	~60	~75	~80
width (µm)	Max	60	70	80	100	100	70	70	85	100	100
Numbe	er of cracks	14-17	12-14	10-12	10-12	8-10	11-13	10-12	8-10	7-9	7-9

Table 3- RCPT results of sound and pre-loaded ECC specimens

		RCP	Г (Coulom	bs)		RCPT (Coulom			mbs)
	Mixture ID	28+0 d	28+30 d	28+90 d		Mixture ID	28+0 d	28+30 d	28+90 d
	ECC2.2	2168	998	688	Pre- loaded	ECC2.2	2630	1008	659
	ECP15	2141	698	375		ECC15	2881	696	365
Sound	ECP30	2226	567	367		ECC30	3090	584	374
	ECP45	2276	646	507		ECC45	3216	706	519
	ECP60	2356	1299	634		ECC60	3448	1101	673
Sound	ECC1.2	1571	1321	704		ECC1.2	2033	1353	684
	ECS25	1596	1176	650		ECC25	2188	1250	693
	ECS50	2017	1106	664		ECC50	2937	1219	804
	ECS75	1953	1109	751		ECC75	2894	1252	919
	ECS100	1820	1012	696		ECC100	2880	1235	826

		Ele	ctrical resist	ivitv	Electrical resistivit			sistivity	
		(kΩ.cm)					(kΩ.cm)		
	Mixture	28+0	28+30	28+90		Mixture	28+0	28+30	28+90
	ID	d	d	d		ID	d	d	d
	ECC2.2	6.4	13.0	19.4	Pre- loaded	ECC2.2	5.5	11.3	18.0
	ECC15	7.5	20.7	27.2		ECC15	6.3	18.5	25.9
	ECC30	11.0	31.9	41.8		ECC30	8.9	28.2	39.1
	ECC45	13.1	32.8	37.9		ECC45	10.2	28.1	33.8
Sound	ECC60	15.3	30.2	34.1		ECC60	11.8	25.4	29.6
Sound	ECC1.2	22.0	27.9	41.1		ECC1.2	19.1	26.1	38.5
	ECC25	22.8	29.2	41.2		ECC25	19.5	27.9	35.8
	ECC50	23.7	30.8	42.9		ECC50	19.5	26.7	36.9
	ECC75	24.2	31.1	43.5		ECC75	19.4	28.0	40.0
	ECC100	24.4	39.6	48.1		ECC100	19.0	34.6	45.3

Table 4- Electrical resistivity of sound and preloaded ECC specimens



Fig. 1- Particle size distributions of different materials. (Note: $1 \mu m = 3.94 \times 10^{-5}$ in.)



Fig. 2- Electrical resistivity testing of ECC cylindrical specimens



Fig. 3-Average length change of ECC bars subjected to accelerated ASR test



Fig. 4-Compressive strength development of different ECC mixtures. (Note: 1 MPa = 0.15 ksi)



Fig. 5- Flexural strength results of sound specimens. (Note: 1 MPa = 0.15 ksi)



Fig. 6- Mid-span deflection results of sound specimens. (Note: 1 mm = 0.039 in)



Fig. 5: Typical crack pattern of ECC beams after initial preloading



Potential for Using Waste Recycled Glass in Engineered Cementitious Composites







Fig. 9: SEM micrographs and EDS data of healed cracks in the surface and core layers

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SUITABILITY OF ALKALI ACTIVATED GGBS/FLY ASH CONCRETE FOR CHLORIDE ENVIRONMENTS

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Synopsis: This study investigates chloride ingress into alkali-activated slag/fly ash (AA-S/F) concretes with various ratios of slag to fly ash (80/20, 60/40, 40/60 and 20/80). Alkaline activators were a mixture of sodium hydroxide and sodium silicate to obtain between 6-8% sodium hydroxide (NaOH) concentration by weight of cementitious material. The SiO₂/Na₂O ratios (silica modulus, Ms) of mixtures were 0.45, 1.0 and 1.25. Tests applied included typical fresh and hardened properties, air content, slump, compressive strength, bulk resistivity and non-steady state chloride migration. The results show that while attractive engineering properties can be achieved, the chloride ingress in the AA-S/F concretes studied here with \geq 20% fly ash is moderate to high and this may make them unsuitable for use in reinforced concrete in chloride environments.

Keywords: alkali activated slag/fly ash concretes, bulk resistivity, chloride migration coefficient, compressive strength, workability

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INTRODUCTION

Alkali activated materials (AAMs) have been under consideration as an alternative binder system since at least 1908 [1]. The main limitations facing the commercial adoption of these binders are the challenges in controlling engineering properties when using intrinsically variable waste-derived precursors, and the lack of field performance data, especially in extreme environments. Slag and fly ash are the major by-products used as precursors for making these types of binders. Previous investigations show that alkali-activated high calcium systems such as AAS concretes usually set rapidly, can have low workability, and sometimes also a high degree of drying shrinkage compared to portland cement (PC) based systems, and all of these are known to affect durability properties [2-6]. Low calcium alkali activated systems, on the other hand, can exhibit high workability and a lower shrinkage than PC systems [7], but need elevated temperatures for curing and hardening. Chi and Huang [8] studied the behaviour of the binder products and properties of alkali-activated slag/fly ash blended (AA-S/F) mortars and concluded that better properties, compared to PC, were obtained in terms of compressive strength, flexural strength and water absorption. Abdalqader et al. [9] found that the highest strength of AA-S/F obtained was with a paste mixture consisting of slag: fly ash in a 3:1 ratio. Gao et al. reported that samples with a higher slag/fly ash ratio exhibit a lower level of porosity [9-10].

In this investigation, blended binder systems were used as they provide control of properties such as setting time, workability, shrinkage, strength and durability compared to those based on 100% fly ash or slag. An experimental programme was developed to study the workability, strength development and resistance to chloride ingress for a range of AA-S/F concrete mixtures that do not require high temperature curing. Fresh properties, compressive strength at different ages, bulk resistivity and non-steady state chloride migration were determined and reported for various AA-S/F concretes.