The Role of Zinc (Zn) in Metakaolin-Based Geopolymer

Supplementary Information

Table S1. Chemical compositions of electroplating sludge (wt%)

MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO
0.30	7.16	6.15	1.52	6.50	1.77	0.51	2.63
Fe_2O_3	Cr_2O_3	MnO	NiO	CuO	**ZnO**	BaO	
18.48	2.82	1.49	3.10	0.13	**46.57**	0.51	

Table S2. Percentage distribution among dissolved and adsorbed species in Zn-incorporated geopolymer (simulated by Visual MINTEQ)

	pH	13.0	13.2	13.4	13.6	13.8	14.0
S/N 1.0-Z	Zn solubility (%)	0.004	0.008	0.016	0.039	0.112	0.355
	Na^+	92.47	88.70	83.44	76.45	67.71	57.43
	NaOH (aq)	7.53	11.30	16.56	23.55	32.29	42.58
	$Zn(OH)_4^{2-}$	17.36	27.88	42.68	60.02	75.76	86.67
	$Zn(OH)_2$ (aq)	2.18	1.19	0.59	0.26	0.10	0.03
	$Zn(OH)_3^-$	80.46	70.92	56.73	39.72	24.15	13.30
S/K 1.0-Z	Zn solubility (%)	0.004	0.008	0.019	0.049	0.152	0.503
	K^+	89.98	85.21	78.77	70.58	60.70	49.70
	KOH (aq)	10.02	14.79	21.23	29.42	39.31	50.30
	$Zn(OH)_4^{2-}$	18.89	30.83	47.27	65.33	80.27	89.53
	$Zn(OH)_2$ (aq)	2.12	1.13	0.54	0.22	0.08	0.03
	$Zn(OH)_3^-$	79.00	68.04	52.19	34.45	19.65	10.45

According to the mixture design in Table 1, in the Visual MINTEQ software, the initial concentrations of Na^+ and Zn^{2+} in S/N 1.0-Z sample are 196.3 g/L and 55.9 g/L, respectively, and initial concentrations of K^+ and Zn^{2+} in S/N 1.0-Z sample are 333.7 g/L and 55.9 g/L, respectively.

Table S3. Parameters obtained from spectral fitting of solid state NMR data for metakaolin and various geopolymers

		FWHM	δ_{iso}	Area IntgP (%)
Raw MK	**Q^4(4Al)**	7.28	-84.71	5.74
	Q^4(3Al)	7.28	-90.48	9.91
	Q^4(2Al)	7.28	-96.31	14.17
	Q^4(1Al)	7.72	-102.65	24.10
	Q^4(0Al)	8.84	-109.46	46.09
S/N 1.0	**Resonance**	13.96	-89.53	100
	Q^4(4Al)	7.27	-84.70	32.18
	Q^4(3Al)	7.27	-90.44	43.01
	Q^4(2Al)	7.27	-96.32	19.29
	Q^4(1Al)	7.27	-102.65	3.71
	Q^4(0Al)	7.27	-109.49	1.80
S/K 1.0	**Resonance**	14.25	-90.53	100
	Q^4(4Al)	7.27	-84.71	25.95
	Q^4(3Al)	7.27	-90.44	41.82
	Q^4(2Al)	7.27	-96.05	24.72
	Q^4(1Al)	7.27	-102.44	5.44
	Q^4(0Al)	7.27	-110.06	2.08
S/N 1.0-Z	**Resonance**	13.74	-87.03	100
	Q^4(4Al)	8.27	-84.70	54.29
	Q^4(3Al)	7.27	-90.44	29.93
	Q^4(2Al)	7.25	-96.32	10.93
	Q^4(1Al)	7.14	-102.65	1.85
	Q^4(0Al)	7.27	-110.04	3.00
S/K 1.0-Z	**Resonance**	13.75	-89.35	100
	Q^4(4Al)	8.12	-84.76	36.76
	Q^4(3Al)	7.27	-90.47	39.68
	Q^4(2Al)	7.27	-96.32	17.67
	Q^4(1Al)	7.27	-102.67	3.13
	Q^4(0Al)	7.27	-109.32	2.76

FWHM: full width at half maximum; δ_{iso}: isotropic chemical shift; Area IntgP: peak area by integrating data (%).

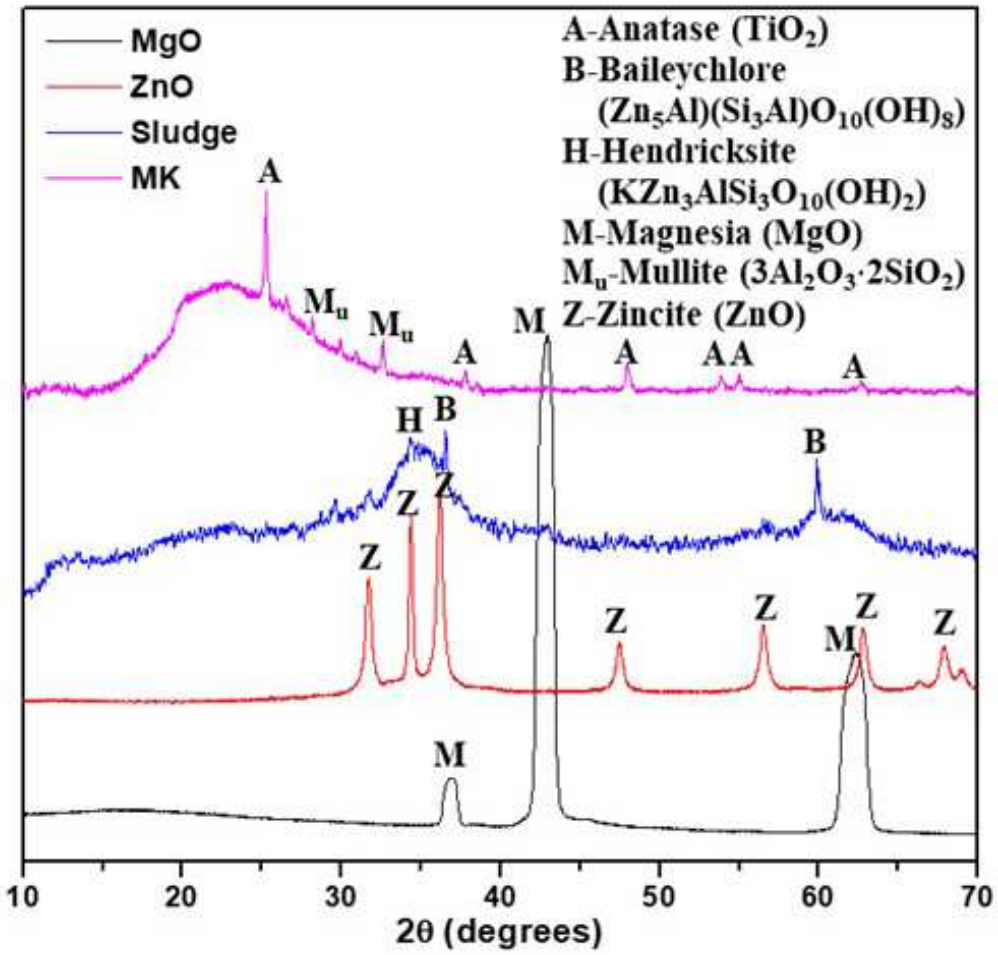

Figure S1. XRD pattern of raw materials.

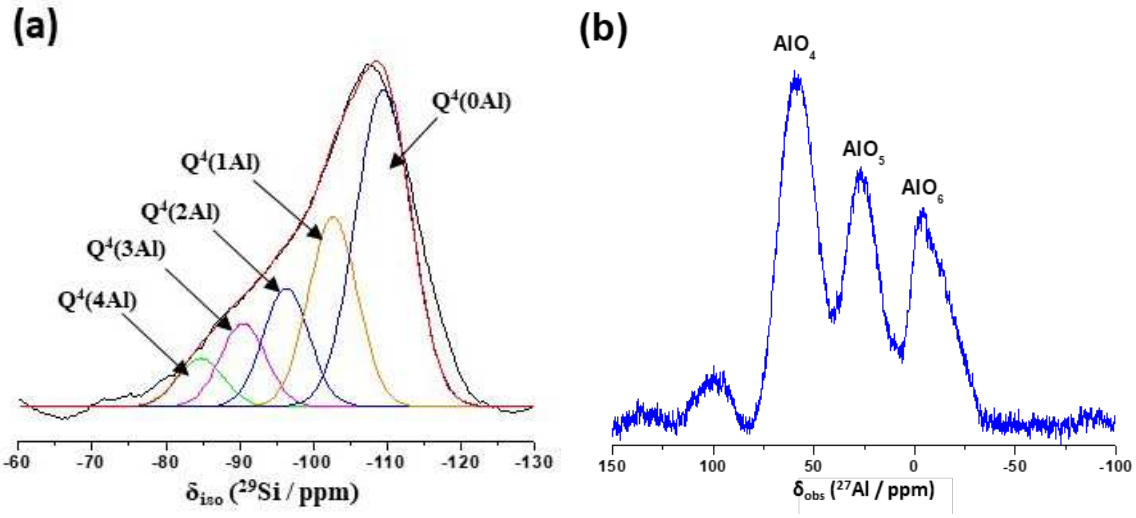

Figure S2. ^{29}Si (a) and ^{27}Al (b) MAS NMR spectra of raw metakaolin.

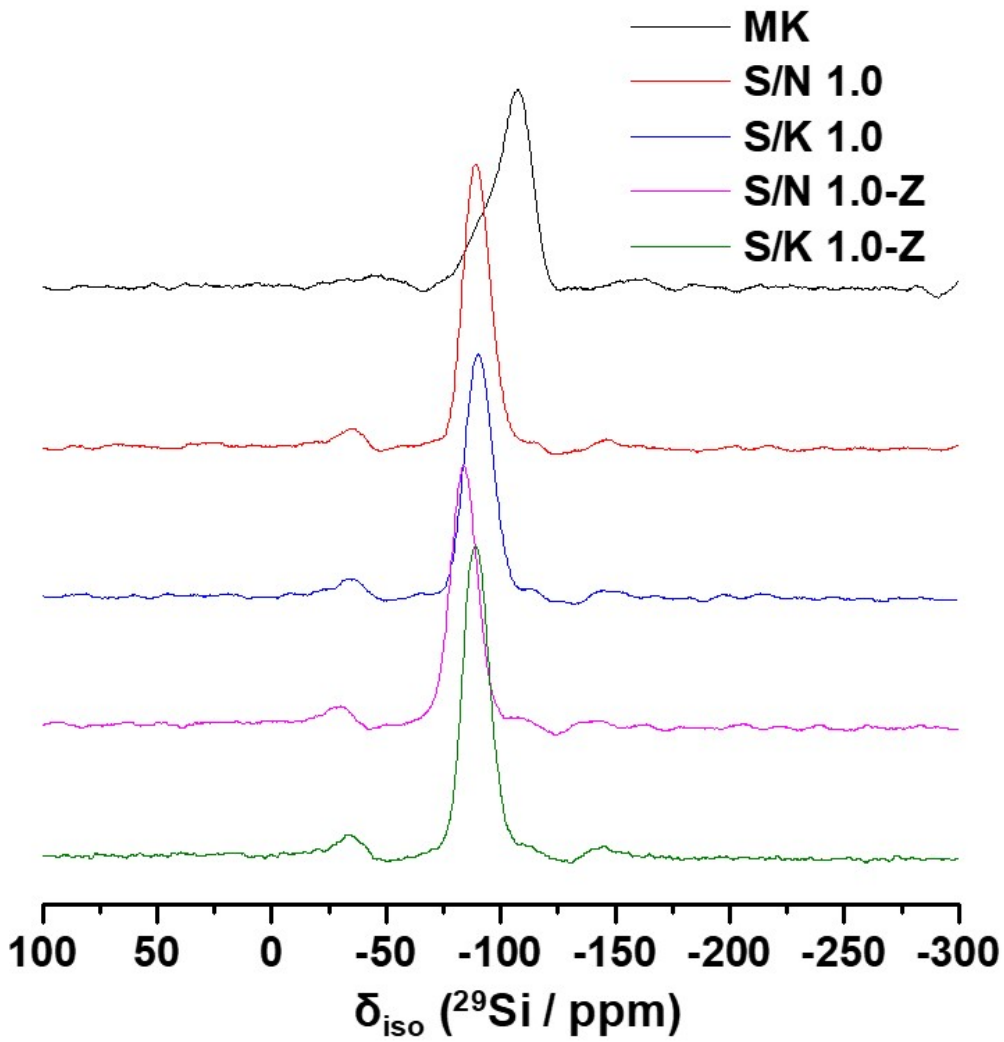

Figure S3. ^{29}Si MAS NMR spectra of MK and geopolymers showing the full spectral width.

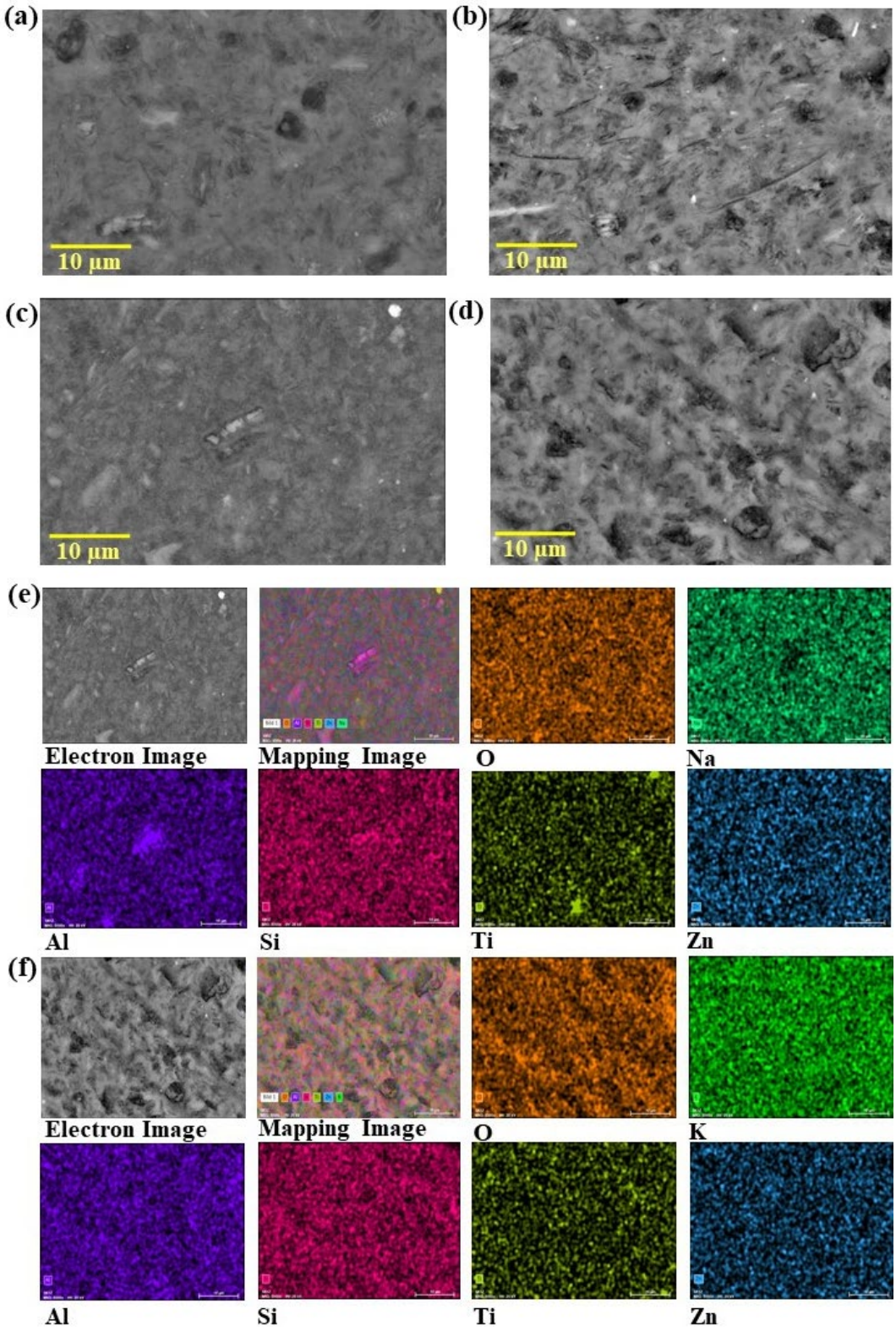

Figure S4. BSE images with elemental mapping of polished geopolymer pastes: (a) BSE image of S/N 1.0; (b) BSE image of S/K 1.0; (c) BSE image of S/N 1.0-Z; (d) BSE image of S/K 1.0-Z; (e) element mapping of S/N 1.0-Z; (f) element mapping of S/K 1.0-Z.

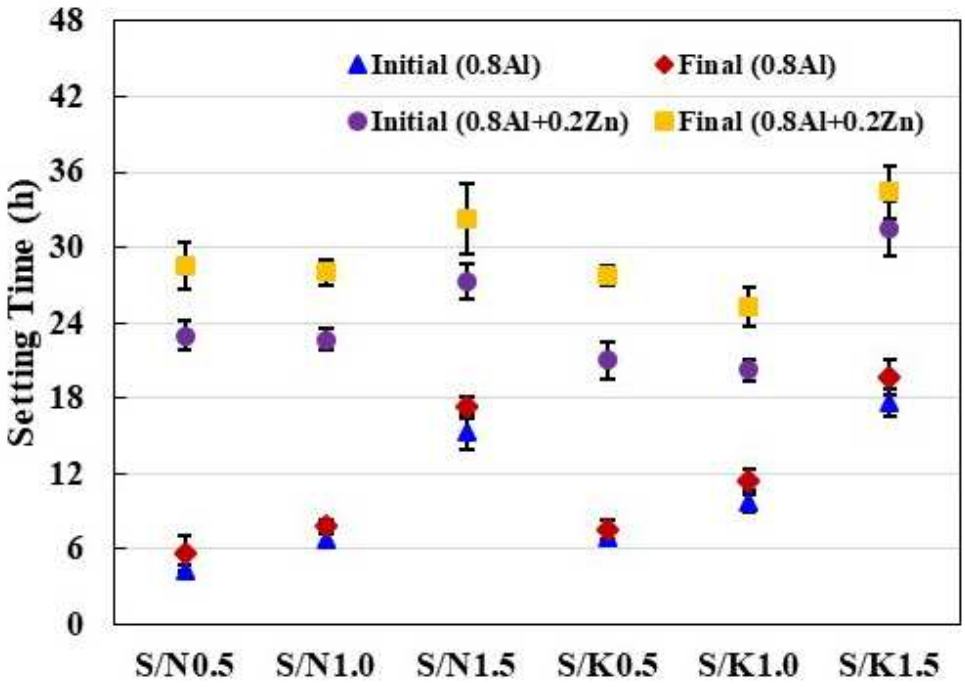

Figure S5. Setting time of geopolymer pastes and ZnO-added geopolymer pastes (dosage: Zn to Al molar ratio at 2: 8).

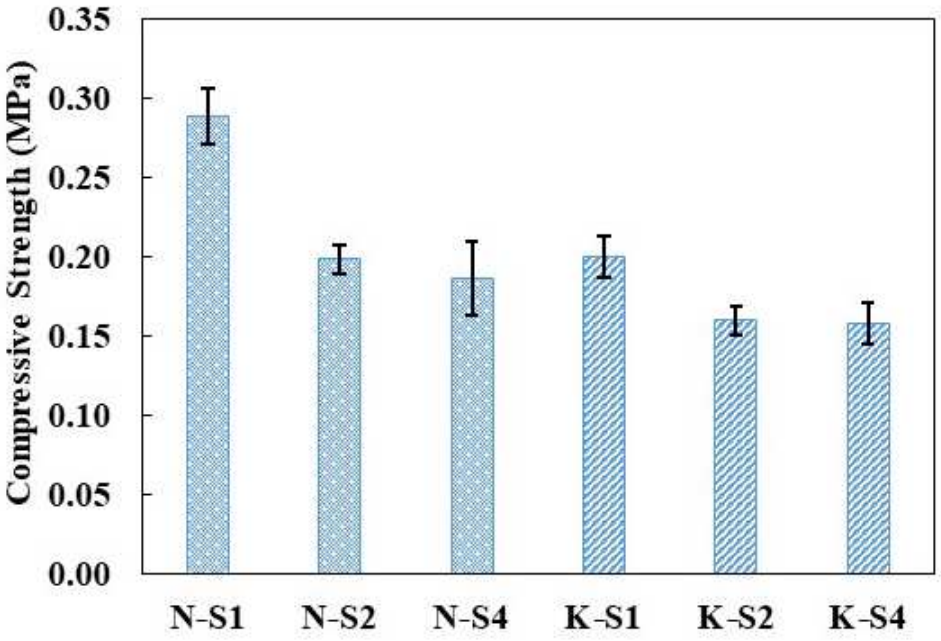

Figure S6. Compressive strength of Zn-rich sludge incorporated geopolymer blocks after 28-day curing. (N/K-Sn: sodium/potassium silicate-activated geopolymer/sludge mass ratio of 1/n).