

Metakaolin-Reinforced Sulfoaluminate-Cement-Solidified Wasteforms of Spent Radioactive Resins—Optimization by a Mixture Design

Jiaqian Xu, Mengzhou Wang, Cong Li, Mengxing Han, Qi Wang and Qina Sun *,

Hebei Key Laboratory of Heavy Metal Deep-Remediation in Water and Resource Reuse,
School of Environmental and Chemical Engineering, Yanshan University, Qinhuangdao 066004, China
* Correspondence: sunqn@ysu.edu.cn

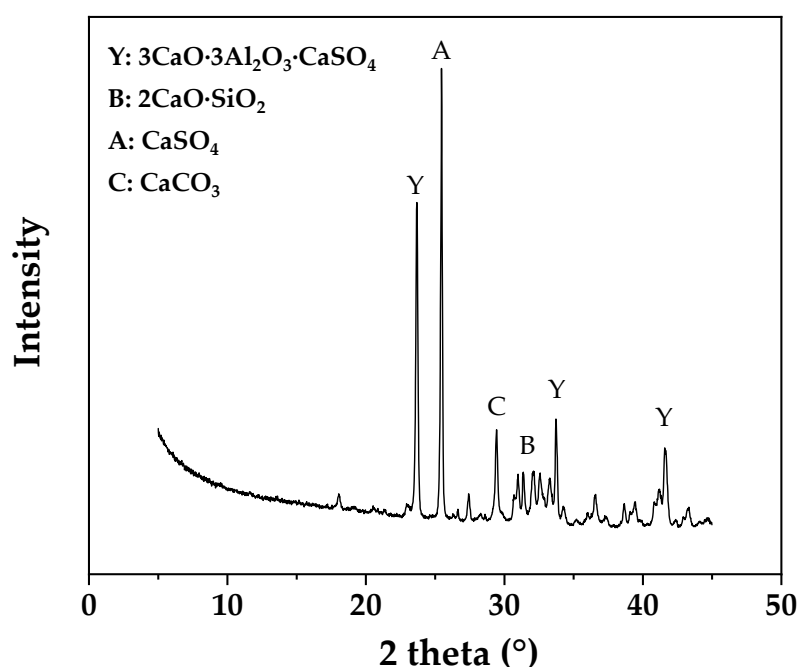


Figure S1. Main mineral components of the sulfoaluminate cement used in the solidification experiment.

Table S1. Main composition and property of the ion exchange resin used in the solidification experiment.

Ion exchange resin	Matrix	Functional group	Total exchange capacity (mmol/g)
Zhengguang	Polystyrene-divinylbenzene	Sulfonate	4.35

Table S2. Mixture design and experimental data.

Runs	Mixture composition (wt.%)				Responses			
	X ₁	X ₂	X ₃	X ₄	Y ₁ (MPa)	Y ₂ (min)	Y ₃ (mm)	Y ₄ (%)
1	39.8	51.8	5.9	2.5	8.23	64	222	67.6
2	48	47.3	2.2	2.5	-	65	-	86.5
3	45.1	47	5.9	2	-	61	295	78.9
4*	35	57.6	5.3	2.2	14.63	46	177	59.5
5*	42.9	52.7	2.2	2.2	-	61	285	75.0
6	48	47.8	2.2	2	-	65	-	92.1
7*	41.5	52.4	4.1	2	10.46	44	263	72.6
8	39.7	55.1	3.1	2.1	8.53	60	243	71.5
9	45.9	47	4.8	2.3	-	67	261	78.0
10	36.2	57.8	4.3	2.5	13.66	52	183	63.3
11	38.2	53.4	5.9	2.5	8.2	54	210	66.8
12*	35	57.6	5.3	2.2	10.92	42	163	61.2
13*	41.5	52.4	4.1	2	7.93	52	240	74.8
14	43.1	49.7	4.9	2.2	7.23	60	265	80.1
15*	42.9	52.7	2.2	2.2	8.26	60	265	79.7
16	37	57.8	3.2	2	11.81	56	180	66.7
17	45.9	47	4.8	2.3	4.08	67	275	82.7
18	36.2	57.8	3.4	2.5	11.77	49	180	65.2
19	44.7	49.7	3.5	2.1	7.16	61	296	83.0
20	41.4	50.2	5.9	2.5	7.06	71	258	74.6

* Repeated runs.

Table S3. Regression model coefficients.

Responses	β_1	β_2	β_3	β_4	β_{12}	β_{13}	β_{14}	β_{23}	β_{24}	β_{34}
Y ₁	3.12	13.81	11.12	-11.36	-	-	-	-	-	-
Y ₂	65.59	75.29	2.34×10^2	-4.47×10^3	-24.35	-2.57×10^2	4.68×10^2	-4.09×10^2	4.29×10^3	6.64×10^3
Y ₃	3.02×10^2	1.34×10^2	0.62×10^2	-1.04×10^4	1.64×10^2	-4.89×10^2	1.10×10^4	-4.39×10^2	1.18×10^4	6.99×10^3
Y ₄	90.42	63.45	52.57	36.04	-	-	-	-	-	-

Table S4. ANOVA results of the regression model.

Responses	Source of variance	Degree of freedom	Sum of squares	Mean square	F value	P > F	Significance
Y ₁	Model	3	1.8779×10^2	62.60	32.44	<0.0001	Significant
	residual	16	30.88	1.93	-	-	-
	Lack of fit	11	11.85	1.08	0.28	0.9622	Not significant
	Pure error	5	19.02	3.80	-	-	-
	Total	9	2.1867×10^2	-	-	-	-
Y ₂	Model	9	1.1578×10^3	1.2866×10^2	11.23	<0.0004	Significant
	residual	10	1.1461×10^2	11.46	-	-	-
	Lack of fit	5	69.91	13.92	1.55	0.3219	Not significant
	Pure error	5	45	9.00	-	-	-
	Total	19	1.2725×10^3	-	-	-	-
Y ₃	Model	9	3.9137×10^4	4.3485×10^3	30.79	<0.0001	Significant
	residual	10	1.4124×10^3	1.4124×10^2	-	-	-
	Lack of fit	5	7.4735×10^2	1.4947×10^2	43.47	0.4506	Not significant
	Pure error	5	665.00	133.00	-	-	-
	Total	19	4.0561×10^4	-	-	-	-

	Total	19	4.0549×10^4	-	-	-	-
	Model	3	1.3949×10^3	4.6497×10^2	96.76	<0.0001	Significant
	residual	16	76.89	4.81	-	-	-
Y ₄	Lack of fit	11	48.97	4.45	0.80	0.6509	Not significant
	Pure error	5	27.91	5.58	-	-	-
	Total	19	1.4718×10^3	-	-	-	-