Electronic Supplementary Material (ESI) for Reaction Chemistry & Engineering.

Supplementary Information

Integrated leaching-carbonation kinetic model on CO_2 mineralization of alkaline solid wastes in a high-gravity rotating packed bed

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The number of tables: 5

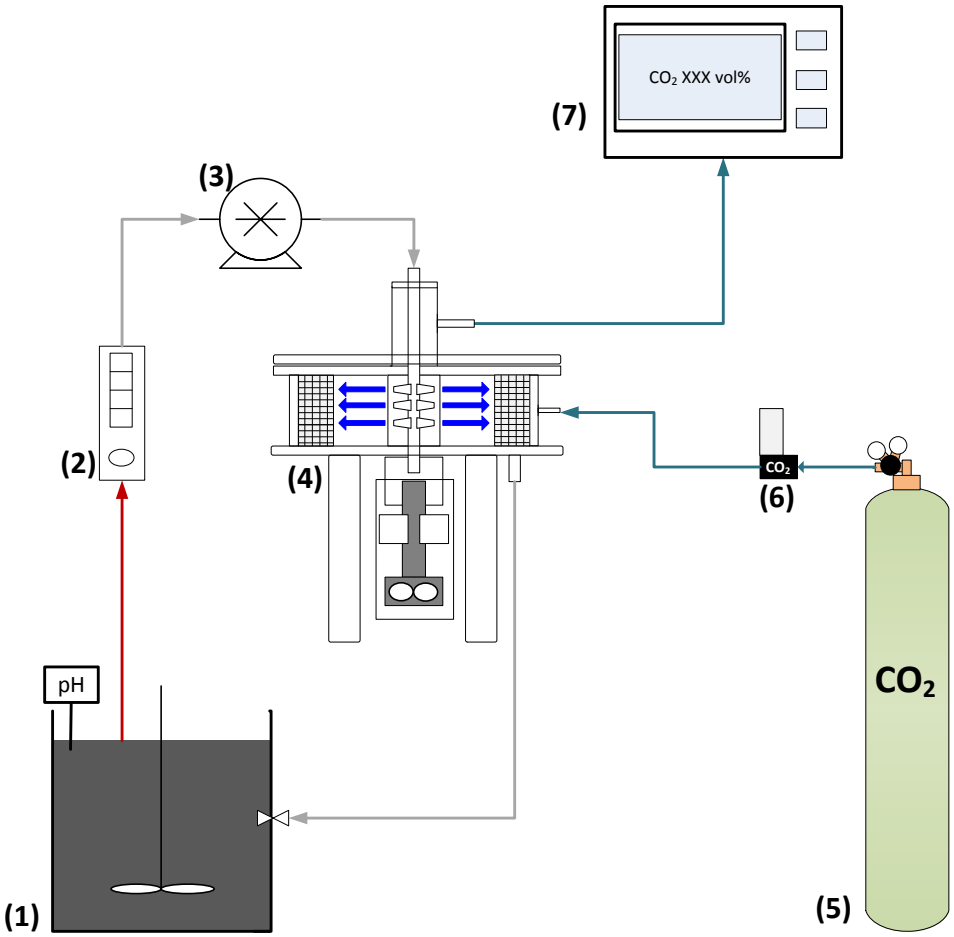


Figure S1 Schematic of batch mode CO_2 mineralization using alkaline solid wastes in the lab-scale high-gravity rotating packed bed. (1) Slurry tank, (2) flowmeter, (3) peristaltic pump, (4) rotating packed bed reactor, (5) gas cylinders, (6) gas flowmeters, (7) gas analyzer.

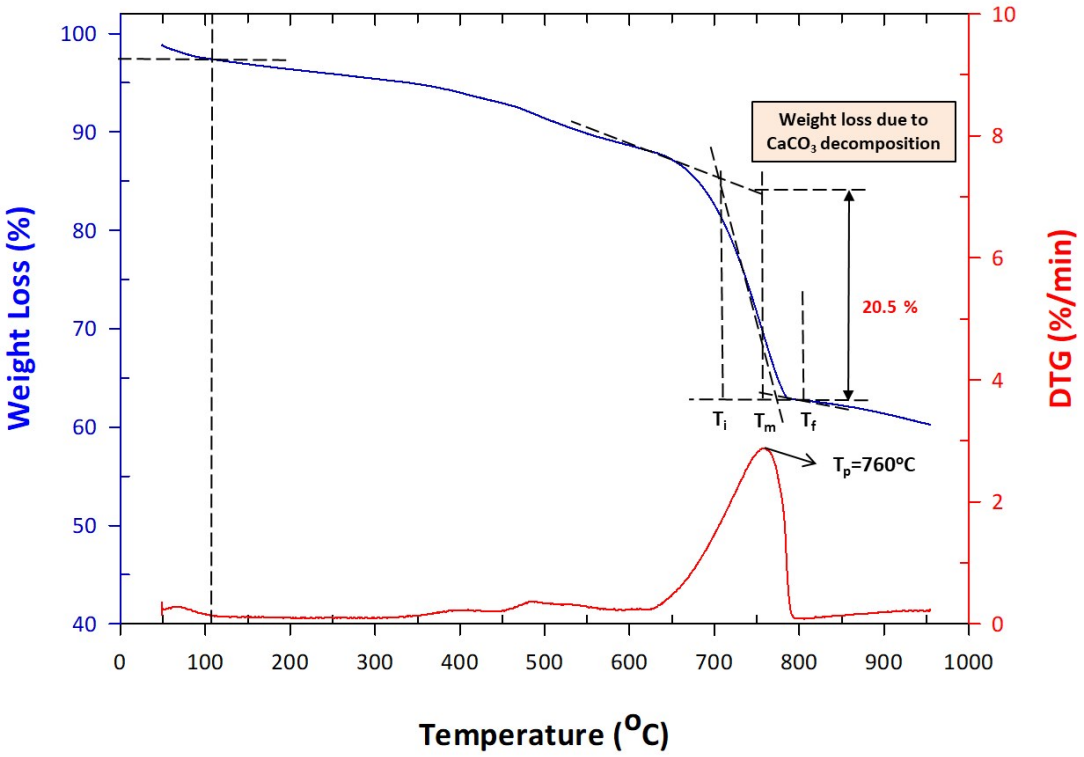
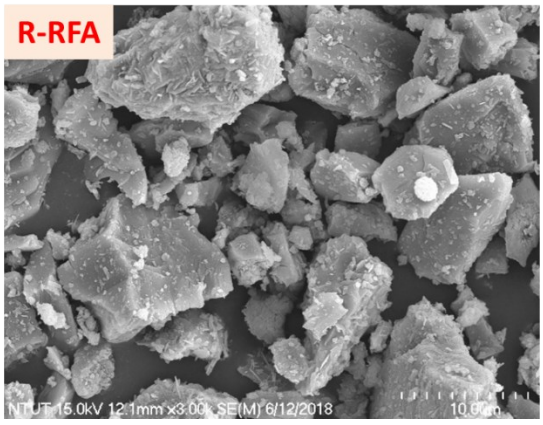


Figure S2 TG-DTG plot for determining the conversion of carbonated ASW sample in this study.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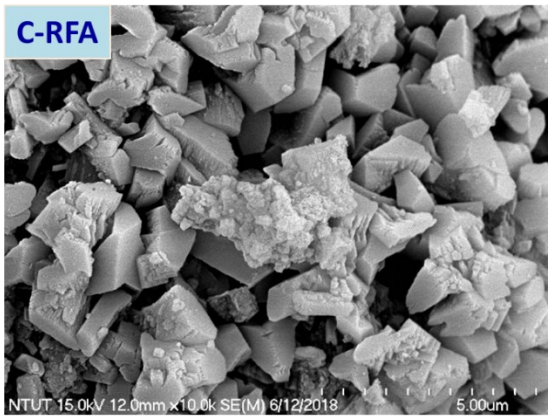
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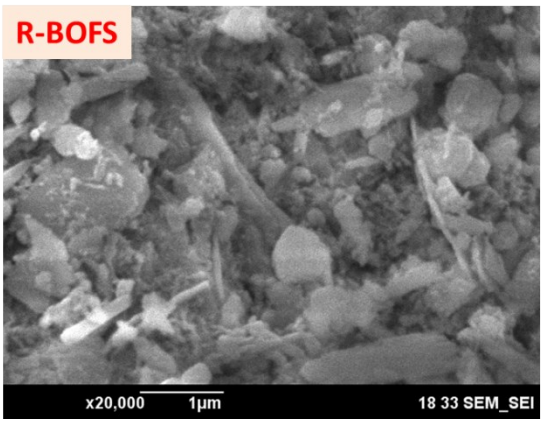
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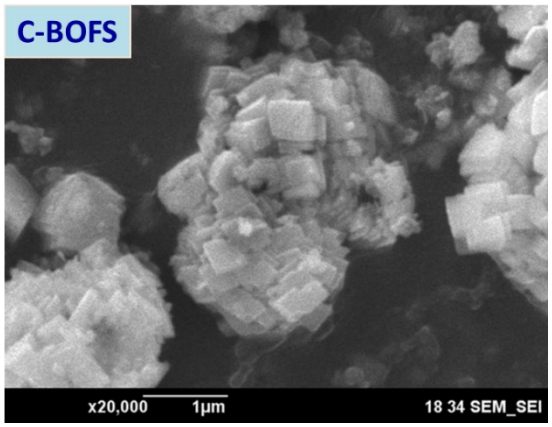
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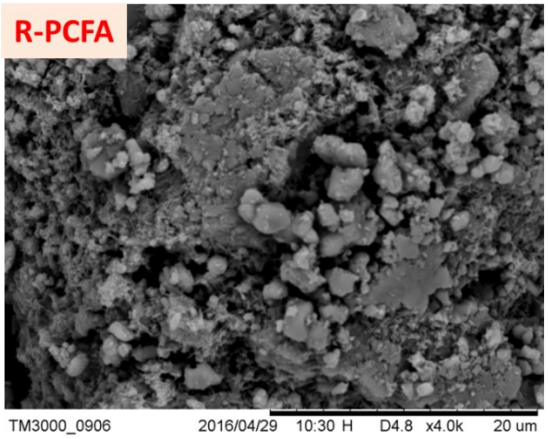
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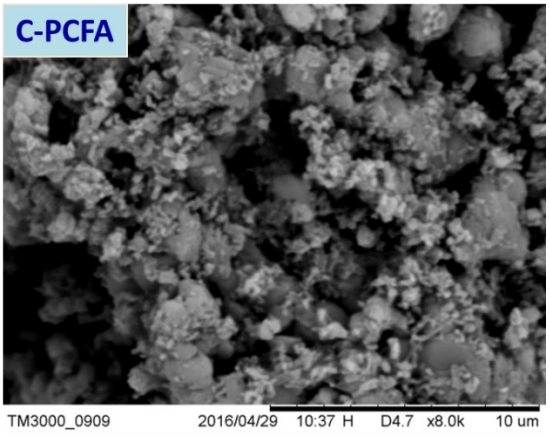
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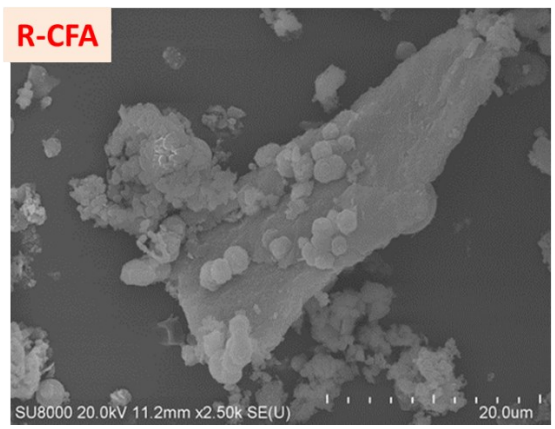
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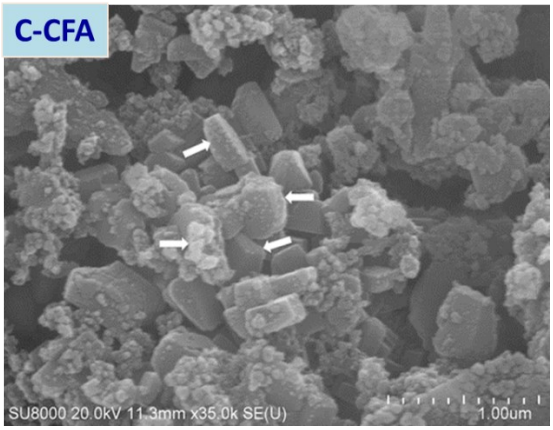
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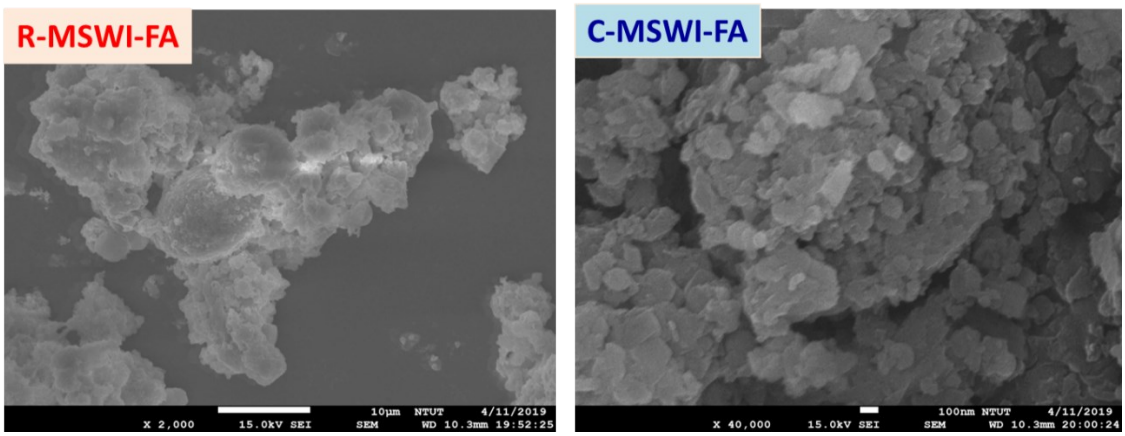

Figure S-3 SEM images of raw (R-) and carbonated (C-) alkaline solid wastes used in this study.

Table S1 Fixed parameters used for estimation of liquid mass transfer coefficient.

Parameters	Symbol	Unit	Values
Rotating Speed	-	RPM	300, 600, 750, 900, 1200
High-gravity factor	β	-	15, 59, 92, 132, 235
Specific surface area of packing materials	a_p	m^2/m^3	0.08
spherical equivalent diameter of the packing	D_p	m	0.0075
Average liquid density	ρ_l	kg/m^3	1023
Average gas density	ρ_g	kg/m^3	0.92
Liquid surface tension	σL	N/m	0.08
Schmidt number	*Sc*	-	437.41
Reynolds number	*Re*	-	17.47

Table S2 Calculated parameters used for estimation of liquid mass transfer coefficient (All parameters were changed with the rotating speed increased).

Parameters	Symbol	Unit	Values
Rotating Speed	-	RPM	300, 600, 750, 900, 1200
High-gravity factor	β	-	15, 59, 92, 132, 235
Grashof number	*Gr*	-	1.2×10^5, 4.81×10^5, 7.52×10^5, 1.08×10^6, 1.93×10^6
Liquid holdup	ε_L	cm	0.042, 0.021, 0.017, 0.014, 0.01
Thickness of liquid film	δ	mm	0.289, 0.072, 0.046, 0.032, 0.018
Droplet specific surface area	a_d	-	463.51, 463.64, 463.67, 463.69, 463.71
Average droplet diameter	d_d	mm	0.54, 0.27, 0.21, 0.18, 0.13
Ratio of Specific surface area between packing materials and droplet	a_p/a_d	-	1.72×10^{-4}

Table S3. Physical-chemical properties, conversion, theoretical and experimental CO_2 capture capacity of various ASW.

Items[a]		R-RFS	C-RFS	R-BOFS	C-BOFS	R-PCFA	C-PCFA	R-CFA	C-CFA	R-MSWI-FA	C-MSWI-FA
Chemical Composition (%)	SiO_2	23.76	22.11	10.7	9.89	5.54	3.35	18.36	19.03	5.81	8.76
	Al_2O_3	17.23	15.76	4.27	3.78	2.12	0.95	14.92	16.79	1.99	2.36
	Fe_2O_3	11.54	12.47	37.36	34.07	0.53	0.65	2.53	3.19	1.74	2.55
	CaO	35.18	33.94	37.05	37.38	45.39	46.14	51.46	50.79	40.02	53.61
	MgO	6.62	5.72	5.06	4.18	1.49	1	2.45	2.08	0.94	1.57
	SO_3	1.1	0.82	0.27	0.4	44.12	47.23	7.5	5.87	6.7	6.17
	K_2O	N.D.[b]	N.D.	N.D.	N.D.	0.27	0.16	0.31	0.1	4.67	1.98
	Na_2O	N.D.	N.D.	N.D.	N.D.	N.D.	0.02	0.38	0.34	7.47	N.D
	TiO_2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.78	1.1
	P_2O_5	N.D.	N.D.	2.62	2.76	N.D.	N.D.	N.D.	N.D.	N.D	N.D
	MnO	1.47	1.53	2.53	2.37	N.D.	N.D.	N.D.	N.D.	N.D	N.D
	Total	96.9	92.35	99.86	94.83	99.46	99.5	97.91	98.19	69.34	78.1
	F-CaO	1.37	0.3	1.26	0.58	3.24	0.21	4.72	0.13	21.66	N.D
Physical Properties	Specific Surface (m^2/g)	1.34	3.58	10.31	8.35	1.91	3.58	4.27	5.35	14.14	10.78
	Density (g/cm^3)	3.06	2.8	3.39	2.65	2.8	N.A.	2.01	N.A.	2.27	2.34
	Mean diameter (μm)	N.A.[c]	N.A.	N.A.	10.91	N.A.	N.A.	31.49	N.A.	15.03	14.08
Theoretical C_{cap}	$kgCO_2/kg$-ASW	0.253		0.277		0.091		0.350		0.356	
Max. δ_{Ca}	%	66.1		60.9		65.35		69.35		89.66	
Experimental	$kgCO_2/kg$-ASW	0.183		0.177		0.233		0.280		0.282	

C_{cap}

[a] the acronyms R and C represent the raw and carbonated ASW. [b] N.D. is non-detected. c N.A. is the sample was not analyzed.

Table S4. Effect of operating conditions on the carbonation kinetics parameters for various.

ASW types	S_g (m^2/g)[a]	M (g/mole)[b]	Operating conditions			Model parameters			
			β	L/S ratio	Max. δ_{Ca} (%)	k_p ($\times 10^3$) (m^2/mole)	k_s ($\times 10^{-4}$) (mole/min/m^2)	$k_s k_p$ (min^{-1})	r^2
RFS	1.335	159.18	15	20	43.86	0.483	2.04	0.098	0.709
			59	20	53.91	0.393	2.32	0.091	0.994
			92	20	63.01	0.337	5.79	0.195	0.973
			132	20	65.83	0.323	3.29	0.106	0.670
			235	20	66.11	0.321	9.12	0.293	0.978
			235	10	63.49	0.333	2.61	0.087	0.936
			235	20	63.01	0.337	5.79	0.195	0.973
			235	30	57.13	0.36	1.60	0.058	0.974
			235	40	60.23	0.346	1.90	0.066	0.982
			235	50	54.29	0.385	1.79	0.069	0.956
BOF	10.31	151.15	15	20	58.65	2.657	0.66	0.176	0.947
			59	20	58.58	2.660	0.76	0.201	0.898
			92	20	58.21	2.677	0.86	0.229	0.911
			132	20	51.35	3.035	0.40	0.123	0.962
			235	20	47.35	3.291	0.69	0.228	0.836
			235	10	51.35	3.035	0.43	0.131	0.948
			235	20	58.54	2.662	0.66	0.176	0.943
			235	30	55.32	2.817	0.39	0.109	0.862
			235	40	50.35	3.095	0.74	0.230	0.910
			235	50	52.23	2.984	0.44	0.131	0.932

			15	20	58.32	0.404	4.43	0.179	0.975
			59	20	60.32	0.391	3.41	0.133	0.986
			92	20	65.35	0.361	6.32	0.228	0.979
			132	20	54.32	0.434	1.68	0.073	0.773
PCFA	1.91	123.38	235	20	56.55	0.417	2.26	0.094	0.847
			235	10	61.24	0.385	2.42	0.093	0.810
			235	15	58.23	0.405	3.65	0.148	0.857
			235	20	57.57	0.409	1.61	0.066	0.762
			235	25	57.58	0.409	2.99	0.122	0.890
			15	20	54.5	0.853	2.66	0.227	0.988
			59	20	55.8	0.833	1.81	0.151	0.841
			92	20	62.33	0.746	2.70	0.201	0.939
			132	20	63.25	0.735	2.61	0.192	0.938
CFA	4.27	108.52	235	20	63.85	0.728	2.05	0.149	0.880
			235	20	63.5	0.732	1.77	0.130	0.818
			235	30	67.38	0.690	2.34	0.162	0.888
			235	40	69.35	0.670	2.19	0.147	0.838
			235	50	63.65	0.730	2.28	0.167	0.861
			15	20	58.35	3.391	0.47	0.161	0.900
			59	20	73.58	2.689	0.61	0.164	0.906
			92	20	82.32	2.404	0.61	0.146	0.907
			132	20	88.32	2.240	0.84	0.188	0.953
MSWI-FA	14.14	139.93	235	20	89.66	2.207	1.03	0.227	0.980
			235	10	79.8	2.479	0.73	0.181	0.931
			235	20	85.5	2.314	0.62	0.143	0.801
			235	30	89.66	2.207	1.03	0.227	0.980

	235	40	75.33	2.627	0.55	0.146	0.901
	235	50	72.25	2.739	0.64	0.175	0.956

[a]Sg was referred to the specific surface area of the ASW particle. [b]M was calculated the molecular weight of CaO divided by weigh percentage of CaO in the ASW.

Table S5. Influence of operating parameters on kinetics parameters of Ca^{2+} leaching behavior for various ASW.

ASW types	Operating conditions		Max. $C_{Ca^{2+}}$ (mg/L)	Model parameters		
	β	L/S ratio		S_{max} (mg/L)	k_a (min^{-1})	k_d (min^{-1})
RFS	15	20	1453	252	0.0814	0.3335
	59	20	1518	565	0.0249	0.2228
	92	20	1703	995	0.0149	0.1865
	132	20	1812	1329	0.0133	0.2849
	235	20	1805	1400	0.0119	0.4516
	235	10	1805	1400	0.0109	0.3167
	235	20	1635	1217	0.0112	0.1035
	235	30	1224	809	0.0155	0.2809
	235	40	832	519	0.0258	0.2467
	235	50	708	410	0.0363	0.2055
BOFS	15	20	1385	550	0.0536	0.7801
	59	20	1213	410	0.0734	0.9791
	92	20	1157	501	0.0463	1.3251
	132	20	1124	519	0.0522	0.5327
	235	20	1193	591	0.0355	0.2093
	235	10	1433	798	0.0187	0.5621
	235	20	1285	640	0.0303	0.9705
	235	30	1232	629	0.0225	0.1465
	235	40	1192	567	0.0206	0.1909
	235	50	1101	566	0.0262	0.9410
PCFA	15	20	1297	481	0.0429	0.3417

	59	20	1048	272	0.0596	0.2247
	92	20	1136	390	0.0256	0.5354
	132	20	1114	381	0.0246	0.8603
	235	20	1198	391	0.0236	0.1490
	367	20	1124	318	0.0333	0.2564
	235	10	1153	371	0.0613	0.4618
	235	15	1121	317	0.0603	0.1467
	235	20	1088	354	0.0520	0.1264
	235	25	953	355	0.0647	0.1021
	235	30	829	136	0.0802	0.0767
	15	20	2564	2285	0.0102	0.5732
	59	20	2543	2272	0.0095	0.6994
	92	20	2571	2399	0.0091	0.1505
	132	20	2523	2364	0.0108	0.7163
CFA	235	20	2533	2398	0.0111	0.6769
	235	20	2533	2398	0.0111	0.7752
	235	30	2322	2124	0.0135	0.6753
	235	40	2059	1694	0.0155	0.6365
	235	50	2006	1619	0.0193	0.6081
	15	20	6821	2395	0.0205	0.1705
	59	20	6928	2680	0.0190	0.8590
	92	20	7058	3033	0.0182	0.9166
MSWI-FA	132	20	7358	3406	0.0155	0.7437
	235	20	6895	3183	0.0152	0.6612
	235	10	13058	4057	0.0311	0.4348
	235	20	7125	2511	0.0284	0.6844

235	30	6895	3183	0.0152	0.6612
235	40	4458	2235	0.0151	0.5753
235	50	4005	2219	0.0116	0.6868