Monitoring pH in BCSA Cement

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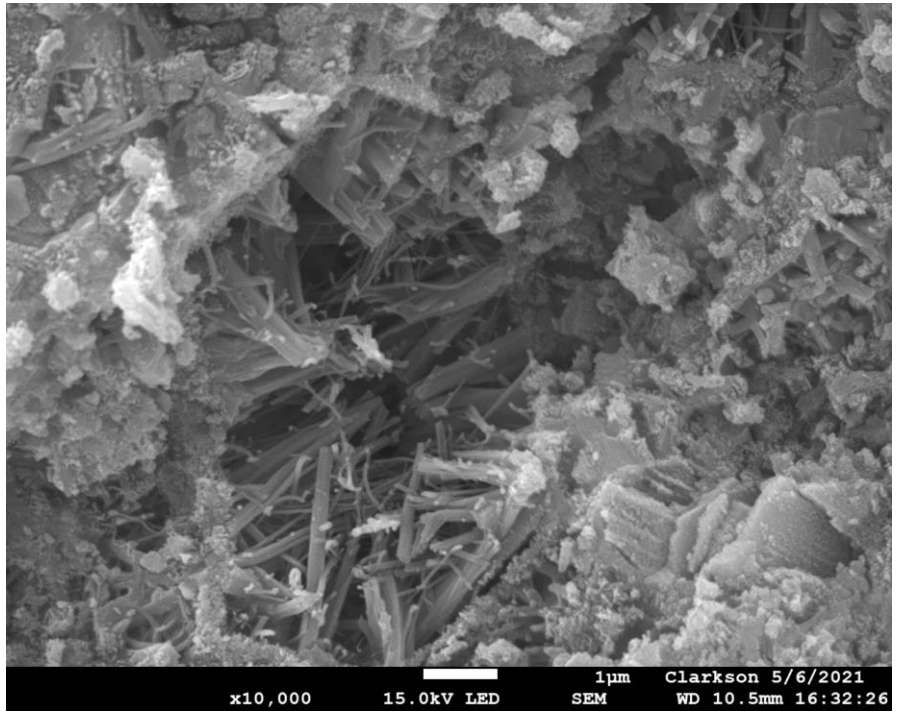
Belitic Calcium Sulfoaluminate (BCSA) Cement



Scanning electron micrograph of BCSA showing ettringite formation after 4 hours of hydration

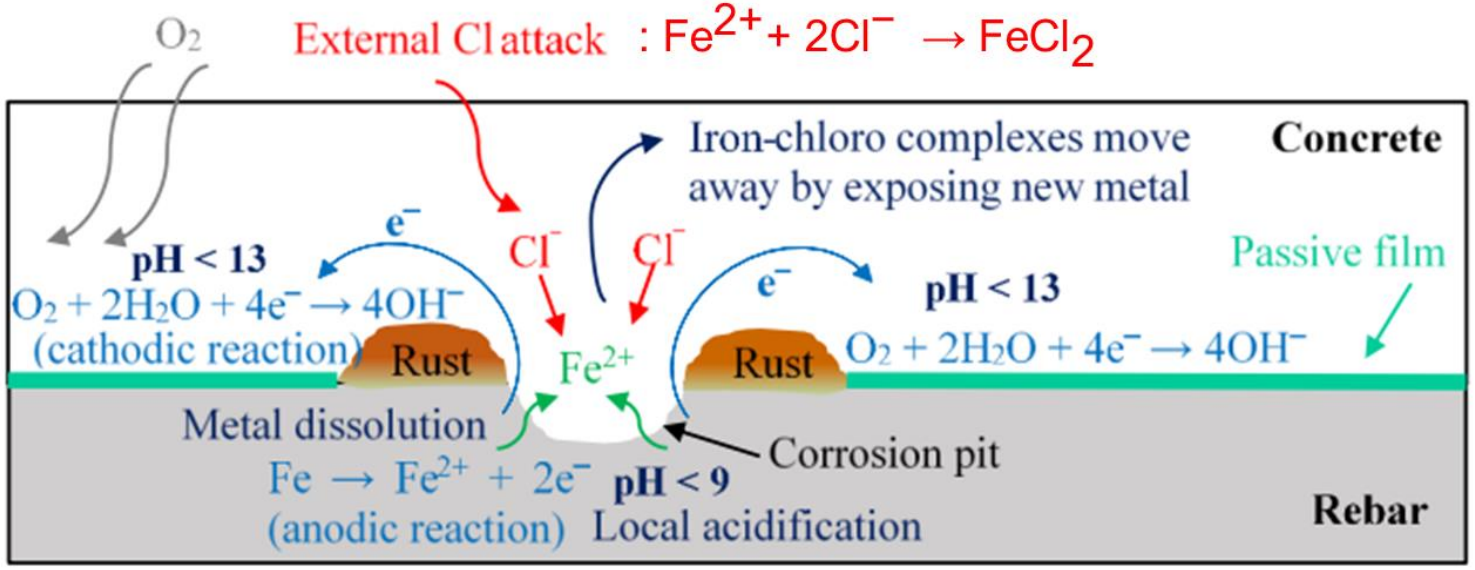
	BCSA	Portland cement
	(% by mass)	
Belite (C_2S)	30-60	15-30
Calcium sulfoaluminate ($C_4A_3\bar{S}$)	20-30	-
Calcium sulfate ($C\bar{S}$)	5-25	2-8
Ferrite (C_4AF)	<10	5-15
Alite (C_3S)	-	50-70
Aluminate (C_3A)	-	5-10

Benefits of BCSA

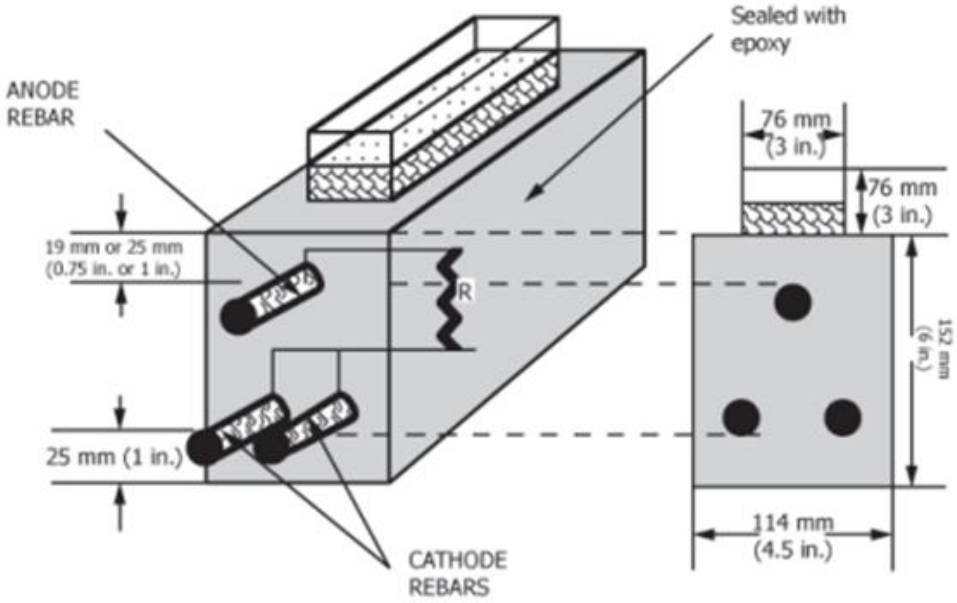
- Environmental benefits
- Low-carbon cement for use in construction
- Accelerated construction for repairs, general applications, and 3D printing

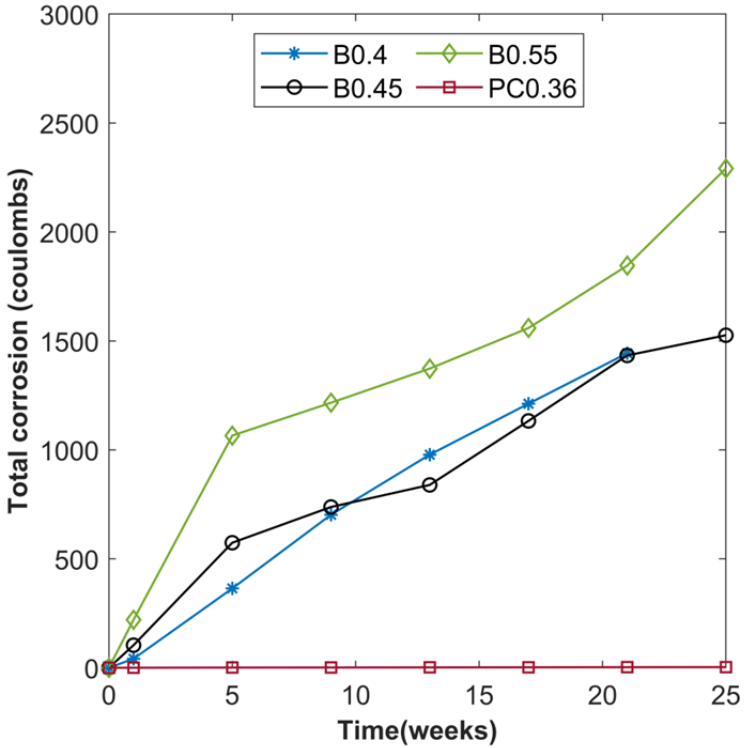
Steel Passivation

- Formation of a protective layer at high alkalinity
- In presence of chloride ions, depassivation occurs at high pH near 12.0
- Prefer a pH of 12-12.5 for steel doubly protected by passive oxide film and low-permeability concrete cover

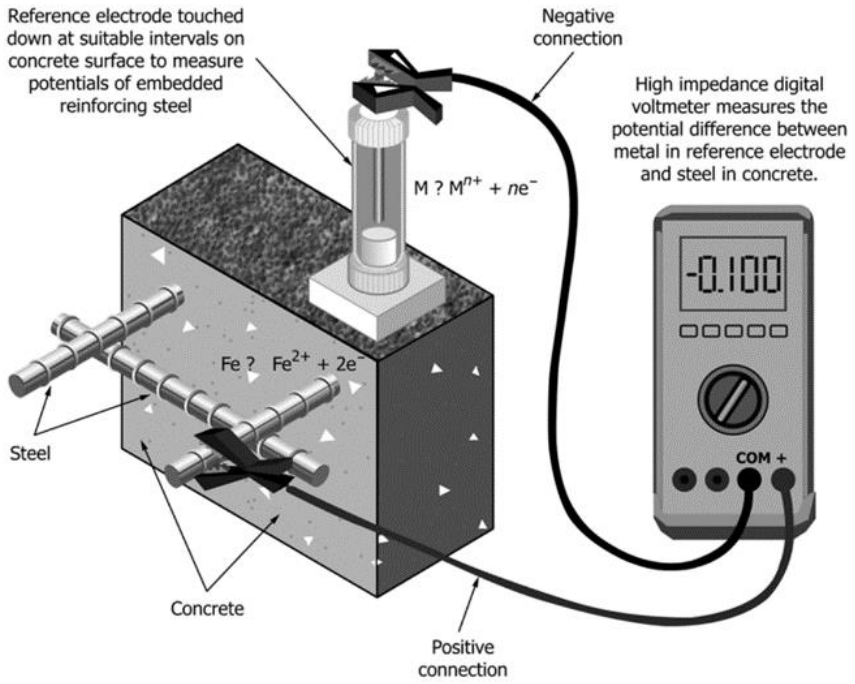


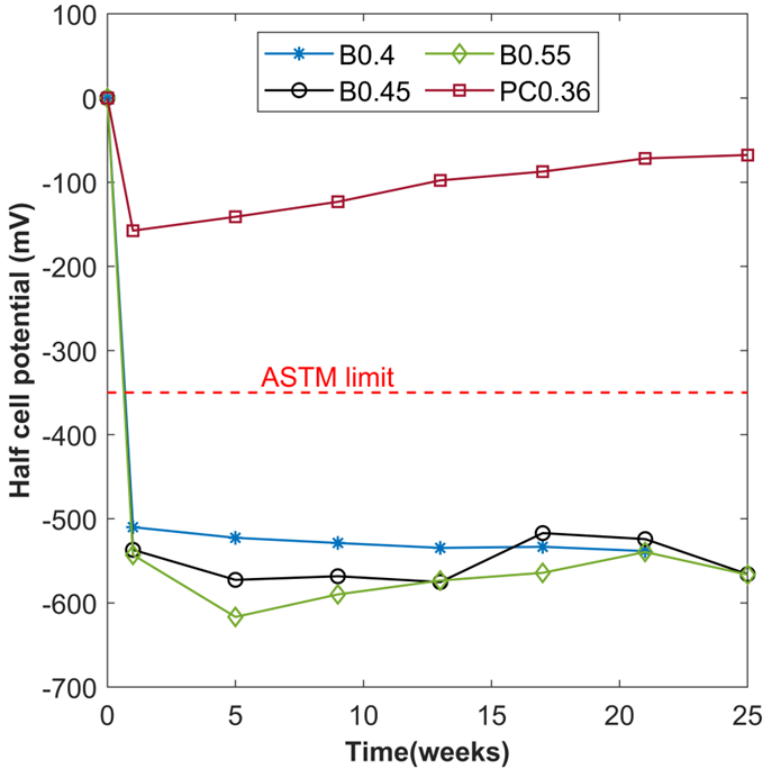
Corrosion in BCSA concrete (ASTM G109)





Corrosion in BCSA concrete (ASTM C876)





Objectives

- Understand pH through hydration to determine when steel passivates in BCSA cement
- Use dilute slurry monitoring to characterize pH changes during the first few days of cement hydration
- Use ex-situ leaching tests to monitor pH development from several hours after batching through later age

Methodology

Dilute Slurry Monitoring

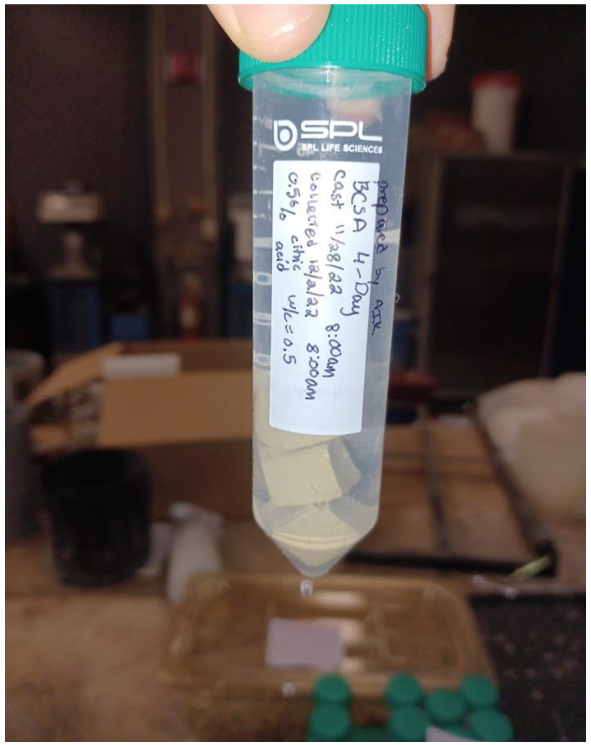
- Continuous pH probe data logging over several days
- BCSA cement, citric acid solution, and deionized water slurry
- Measurements taken every minute

Position	Date	Time	Ch1_Value	Ch1_Unit
1	3/21/2023	7:40:51	11.53	ph
2	3/21/2023	7:41:51	11.66	ph
3	3/21/2023	7:42:51	11.69	ph
4	3/21/2023	7:43:51	11.87	ph
5	3/21/2023	7:44:51	11.94	ph
6	3/21/2023	7:45:51	11.99	ph

Methodology

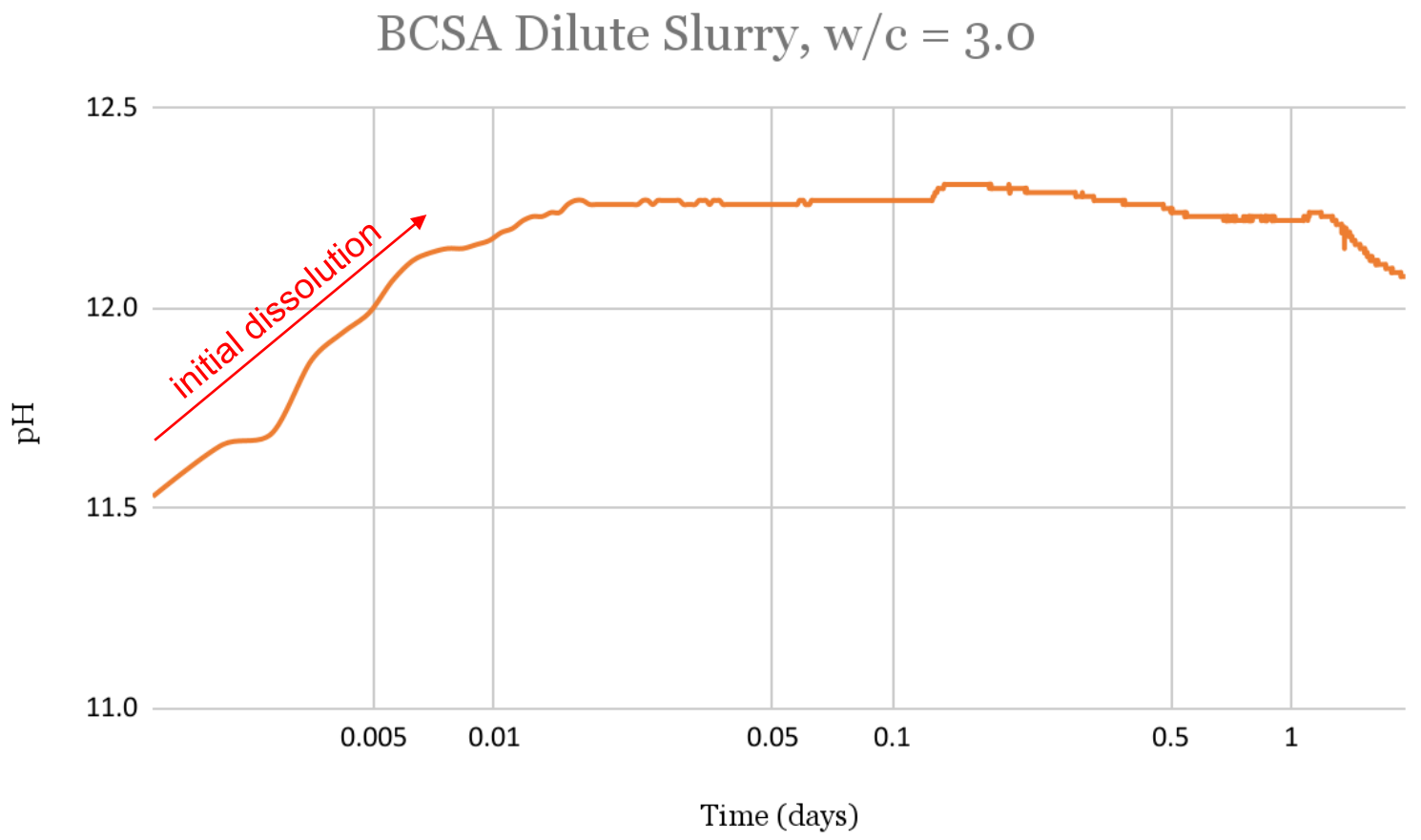
Ex-Situ Leaching Tests

- Samples cast and cured in controlled tank
- Collected at regular intervals for solvent exchange
- Ground to fine powder; 10g combined with 10 mL deionized water
- Readings with pH probe every 5 minutes until stabilization

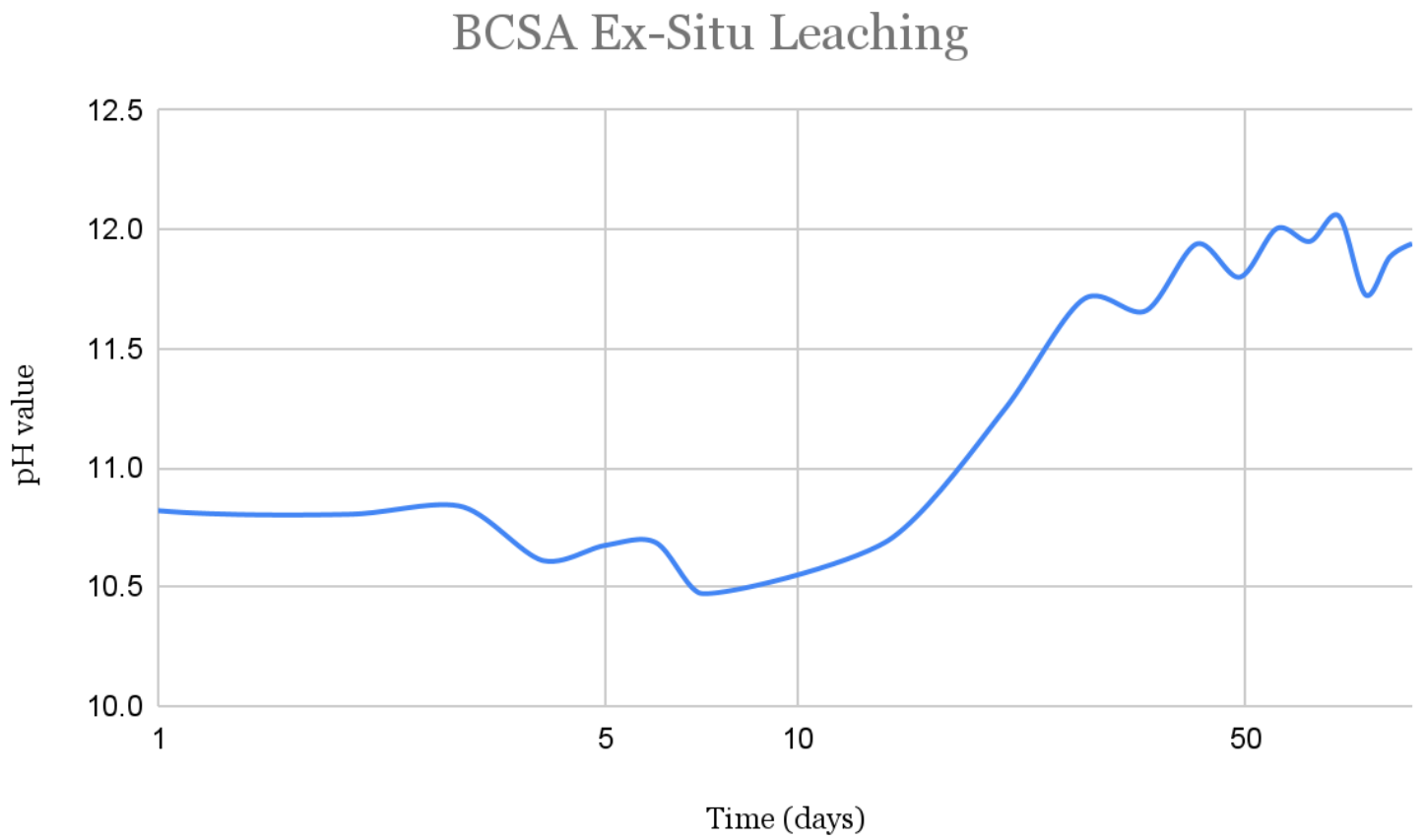


Elapsed Time/Time Collected	pH @ 5 mins	pH @ 10 mins	pH @ 15 mins	pH @ 20 mins	pH @ 25 mins	Avg Last 2
2-Hours	10.79	10.78	10.80			10.79
4-Hours	10.87	11.07	11.05	11.08		11.07
8- Hours	10.76	10.92	11.11	11.06		11.09
12-Hours	10.65	10.80	10.83	10.93	10.96	10.95
24-Hours	10.38	10.39	10.64	10.80	10.84	10.82

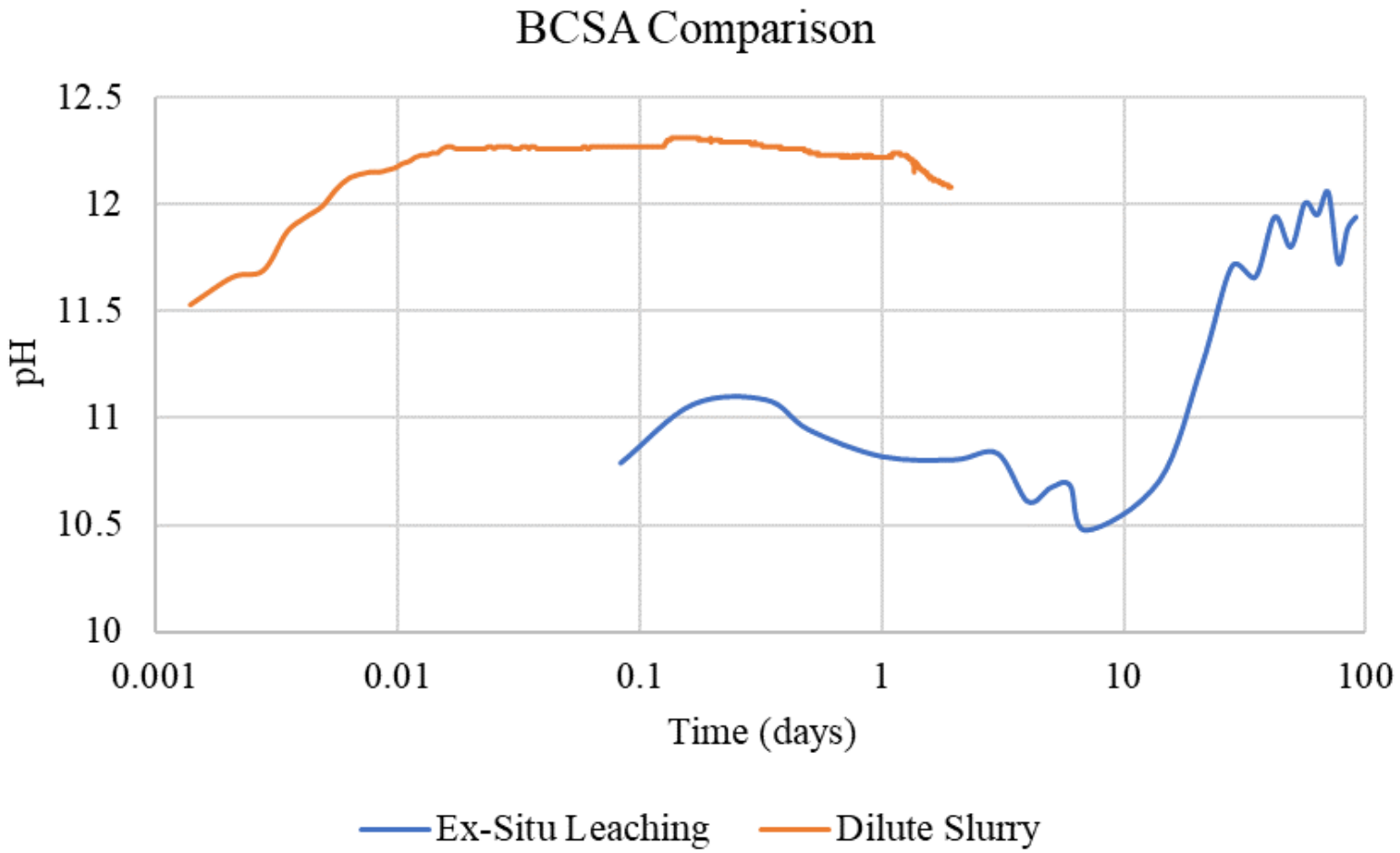
Dilute Slurry



Ex-Situ Leaching



Comparison


BCSA Comparison
12.5
12
11.5
11
10.5
10
pH
0.001
0.01
0.1
1
10
100
Time (days)
Ex-Situ Leaching
Dilute Slurry

Conclusions

- Corrosion performance testing periods do not account for belite hydration or stratlingite formation
- Steel may not have passivated at time of corrosion performance tests
- BCSA pH increases during its lifespan
- Results suggest that it is able to reach passivation, but later than testing periods account for

Discussion

- Extend corrosion performance testing period to account for belite hydration
- Additional testing will supplement and verify these results

Future Steps

- Continue control testing with portland cement
- Additional BCSA testing to verify trends
- Pore solution tests for most accurate information
- Extend testing period for ASTM G109 and C876 tests to allow for the late formation of belite and higher alkalinity from stratlingite

Thank You

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