Measurement and characterization of chloride transport properties for belitic calcium sulfoaluminate (BCSA) cement concrete

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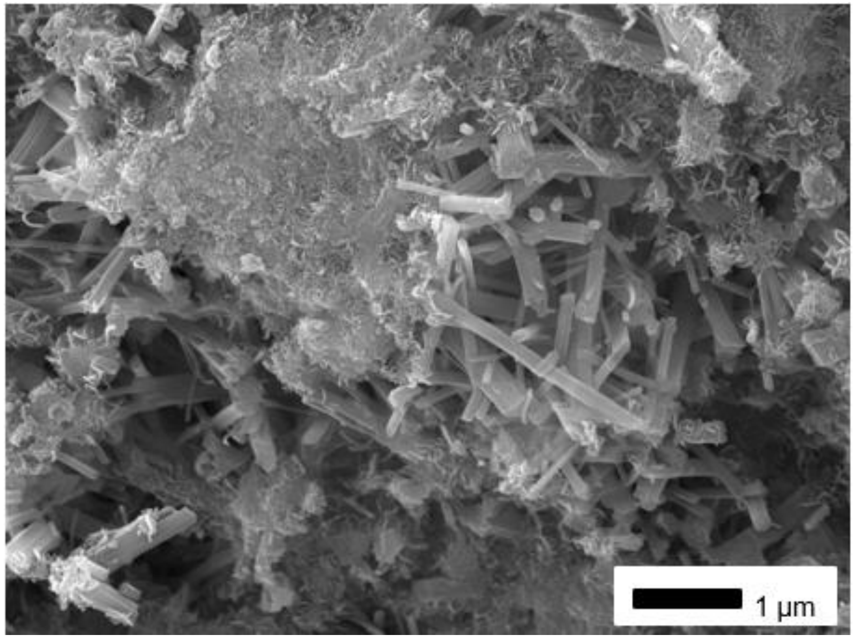
Introduction

Belitic calcium sulfoaluminate (BCSA) cement

- Eco-friendly cement
- Rapid-strength gaining properties – Repair material
- **Use in structural concrete?**
  - Strength and durability of the concrete
- Durability properties??
  - Chloride-induced corrosion
    - Limited literature
    - Contradictory results



Extensive formation of ettringite after four hours of hydration

Objectives

- Evaluate chloride penetrability and corrosion tests for application to BCSA concrete
- Quantify the chloride penetrability of BCSA concrete
- Quantify the corrosion performance of BCSA concrete
- Identify the factors contributing to the observed performance

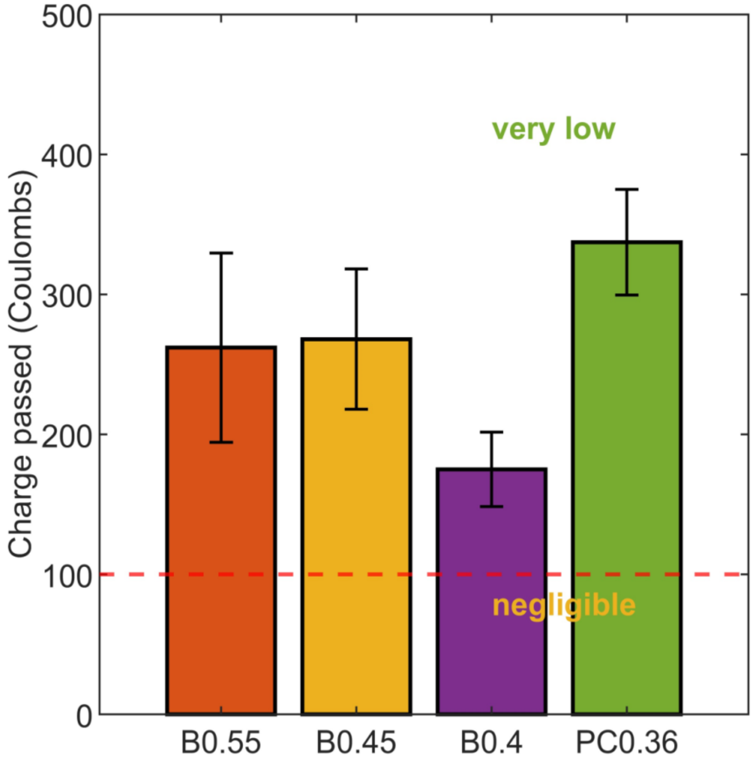
Methodology

Cement type	w/cm	Cement kg/m³	Water kg/m³	Citric acid % cm	Sand kg/m³	#67 stone kg/m³
PC	0.36	360	130	nil	900	1100
BCSA	0.40	340	136	1.00		
	0.45	320	144	1.00		
	0.55	280	154	1.00		

Test methods to assess chloride penetrability		Test methods for corrosion assessment
Qualitative test methods	**Quantitative test methods**	
Rapid chloride permeability *(ASTM C1202)*	Migration test *(NT492)*	Corrosion potential *(ASTM C876)*
Surface resistivity *(AASHTO T358)*	Bulk diffusion *(ASTM C1556)*	Macrocell current *(ASTM G109)*
Bulk resistivity *(ASTM C1876)*	Ponding *(ASTM C1543)*	

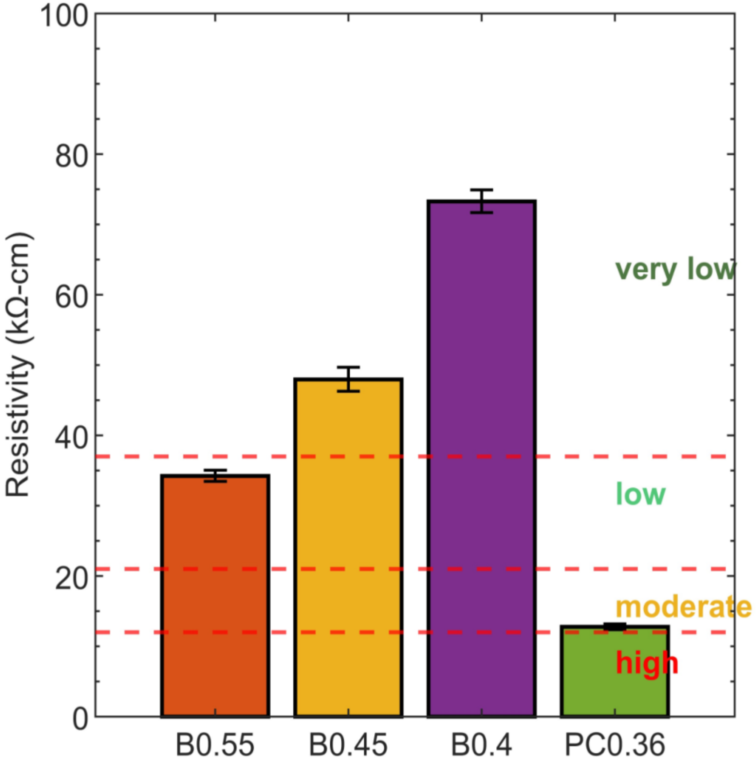
Qualitative test methods

Rapid chloride permeability test (ASTM C1202)



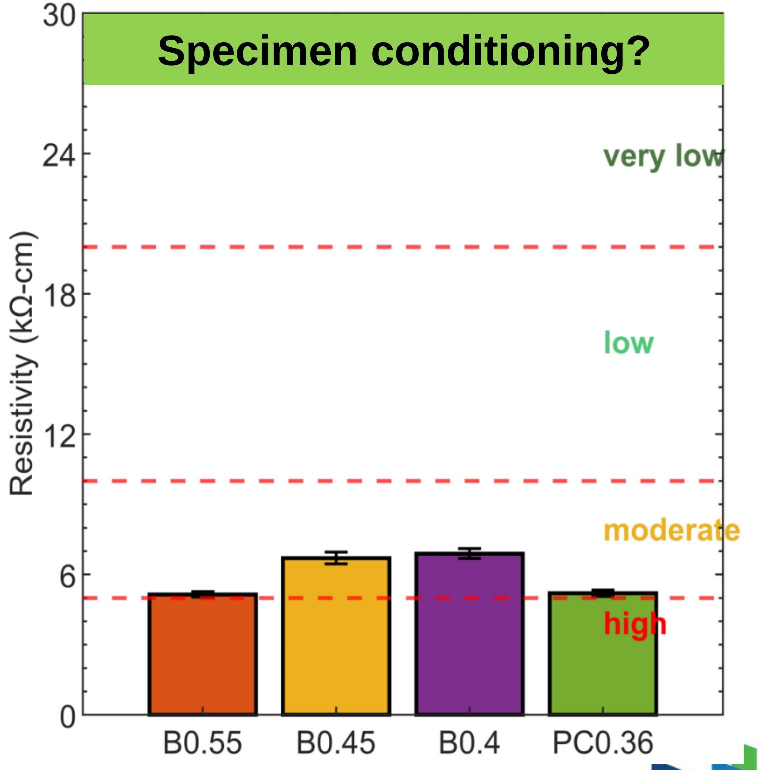
Age – 28 days (Lime cured)

Surface resistivity (AASHTO T358)



Age – 28 days (Lime cured)

Bulk resistivity (ASTM C1876)



Age – 28 days (Lime cured)

Qualitative test methods

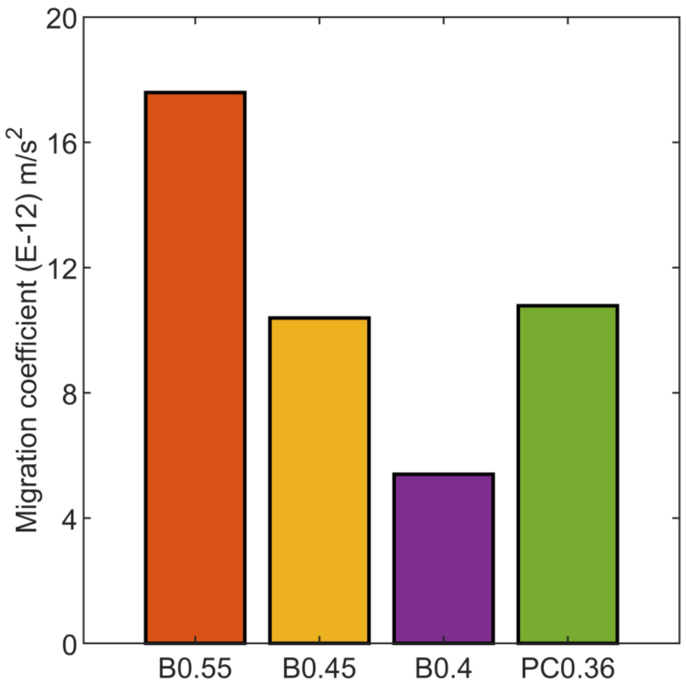
Bulk resistivity test

Even standard curing in water saturated with calcium hydroxide can influence the resistivity of the solution inside the pores of the concrete as potassium and sodium hydroxides are leached out. As such, concrete cylinders and cores are immersed in simulated pore solution for at least 6 days prior to testing.

Oxide	BCSA	PC
CaO	51	63
SiO_2	14	19
Al_2O_3	14	4.6
Fe_2O_3	0.87	3.3
MgO	0.76	2.0
SO_3	17	4.4
Na_2O	-	0.17
K_2O	0.61	1.1
Na_2O_{eq}	0.4	0.89
LOI	1.6	2.5

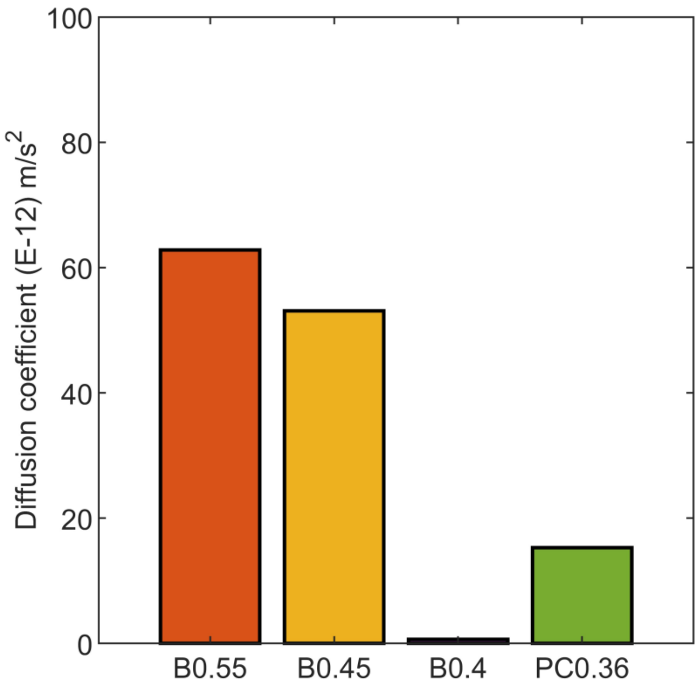
Quantitative test methods

Migration test (NORD NT 492)



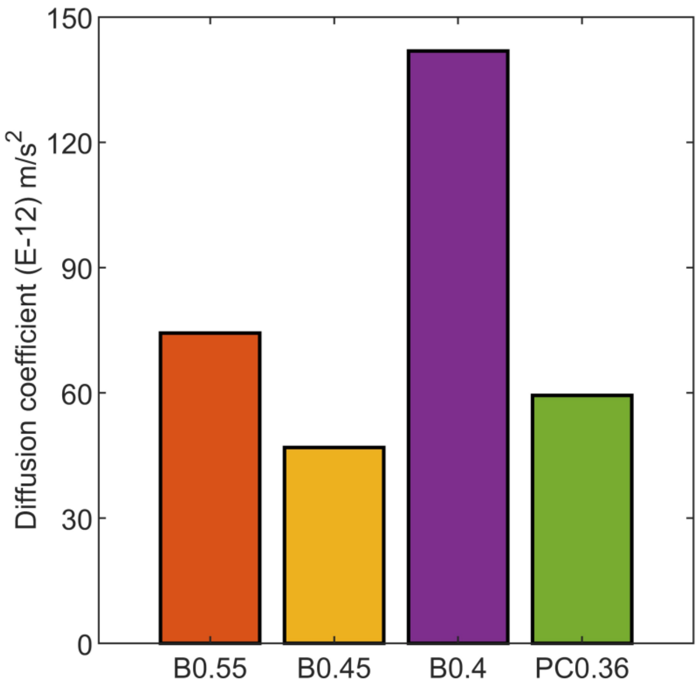
Age – 28 days (Lime cured)
Duration – 1 to 3 days

Bulk diffusion (ASTM C1556)



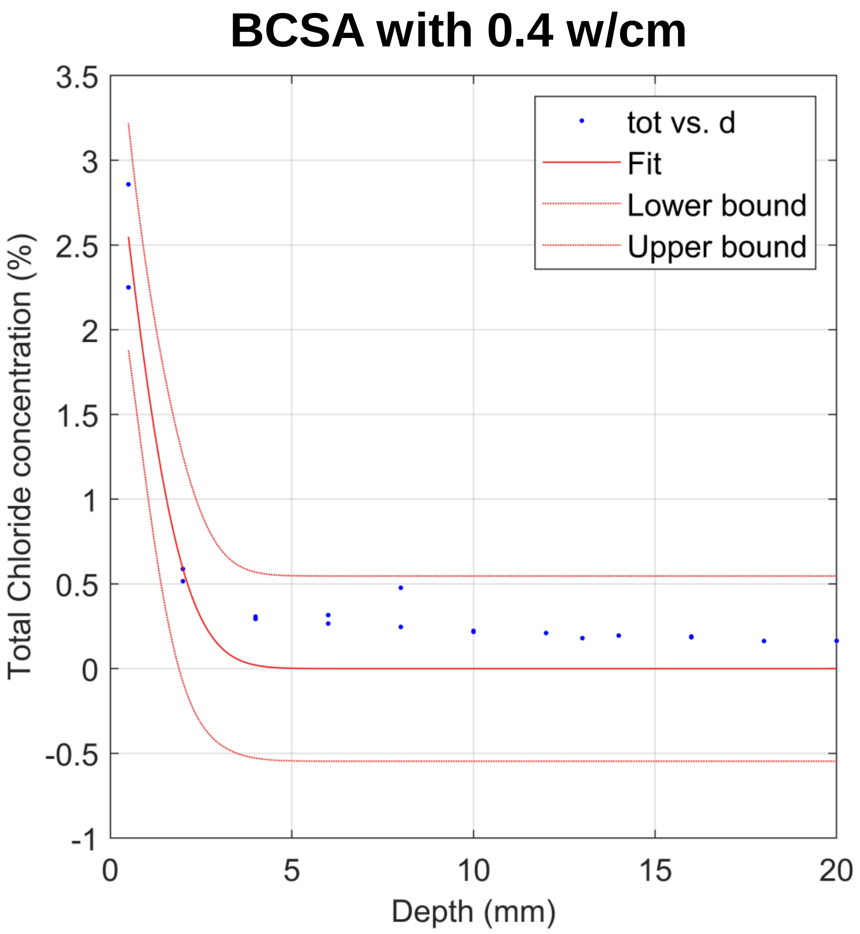
Age – 28 days (Lime cured)
Duration – 60 days

Ponding test (ASTM C1543)



Age – 28 days (Lime cured)
Duration – 90 days

Diffusion coefficient – Bulk diffusion test



ASTM C1556:

$$C(x,t) = C_s - (C_s - C_i) \cdot \mathrm{erf}\left(\frac{x}{\sqrt{4D_a t}}\right)$$

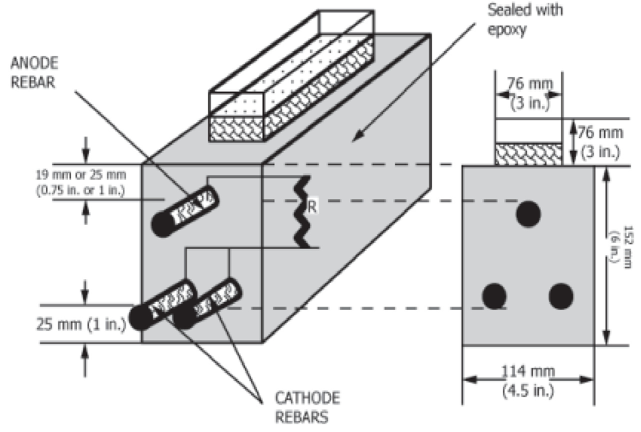
Coefficients (with 95% confidence bounds):

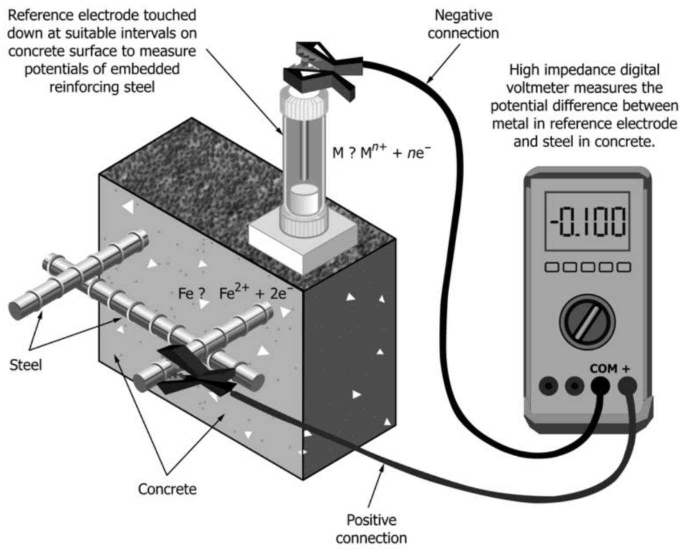
C_s = 3.485 % (2.895 4.076)

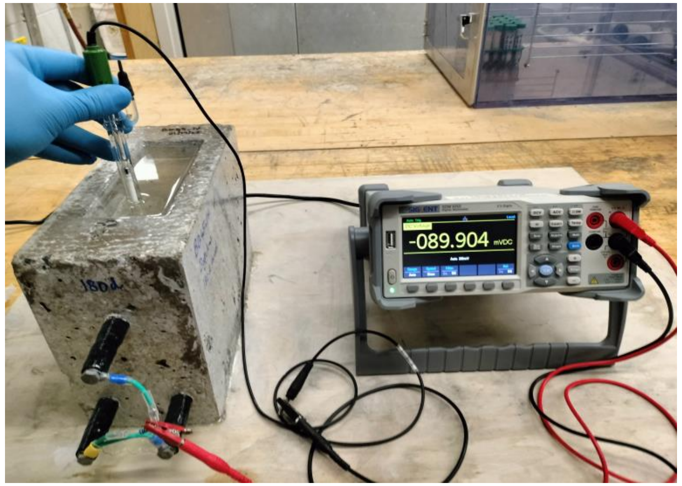
D_a = 6.432 E-13 (m^2/s) (3.167 9.697)

Are tests developed for portland cement (concrete) applicable to alternative cements ??

Corrosion assessment *(ASTM G109 and C876)*



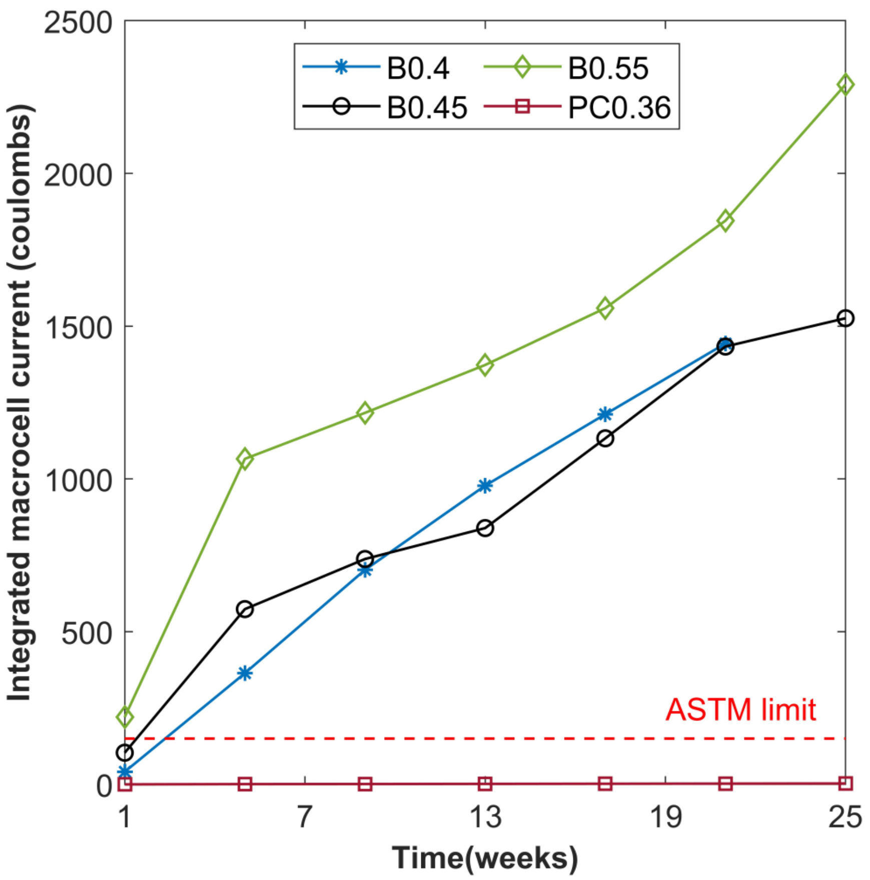




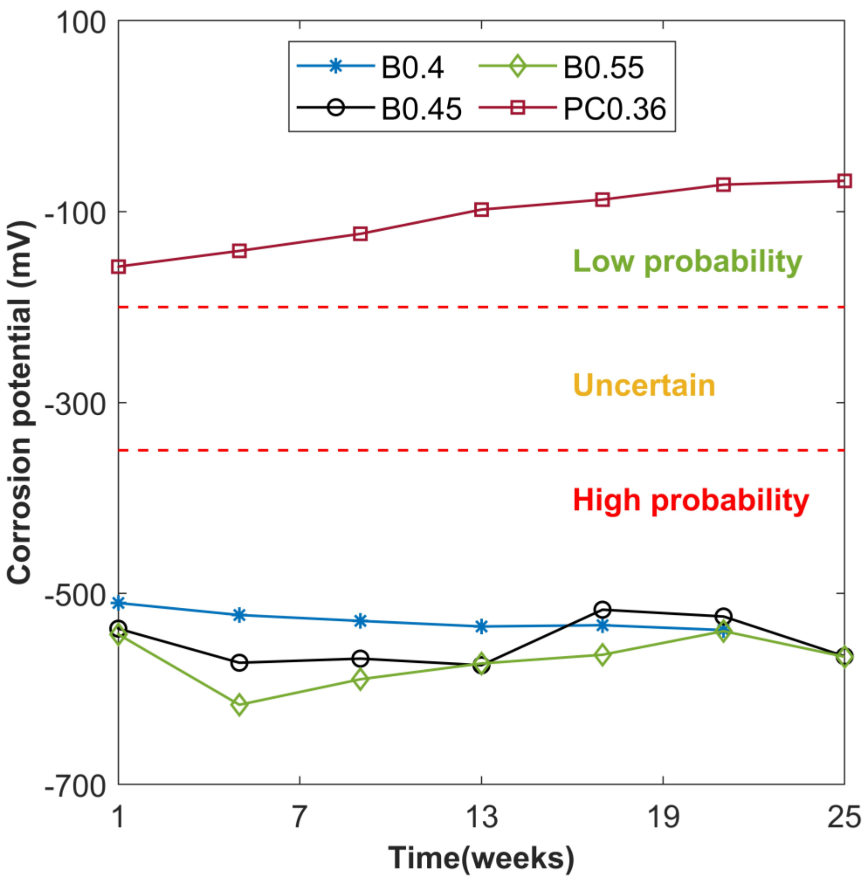
Batches	BCSA mixtures
Batch 1	B0.4, B0.45, B0.55, and PC0.36 (28 days cured)
Batch 2	B0.45 (56, 90, and 180 days cured)

Corrosion assessment– Batch 1

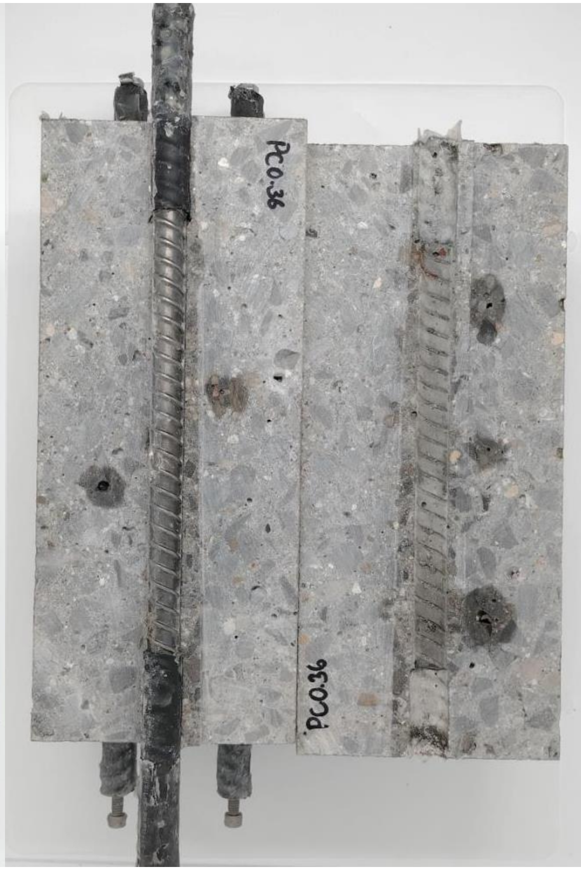
Macrocell current (ASTM G109)



Corrosion potential (ASTM C876)



G109 specimens after Cl^- exposure – Batch 1



B0.55
(1 cycle)

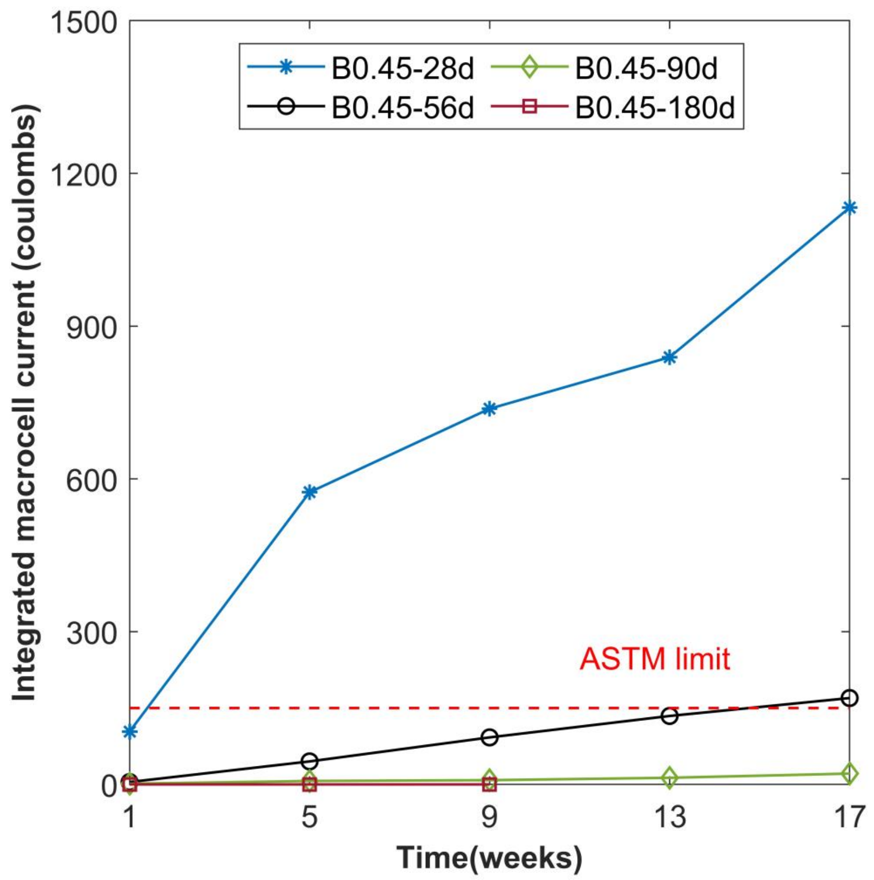
B0.45
(1 cycle)

B0.4
(1 cycle)

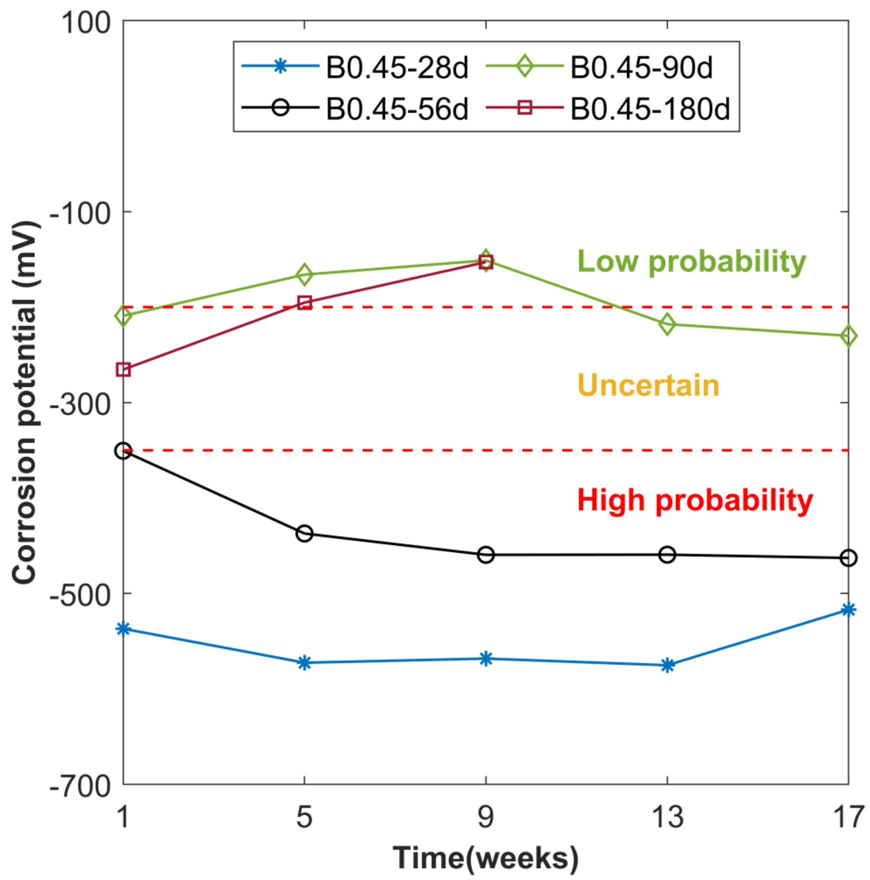
PC0.36
(7 cycles)

Corrosion assessment – Batch 2

Macrocell current (ASTM G109)



Corrosion potential (ASTM C876)



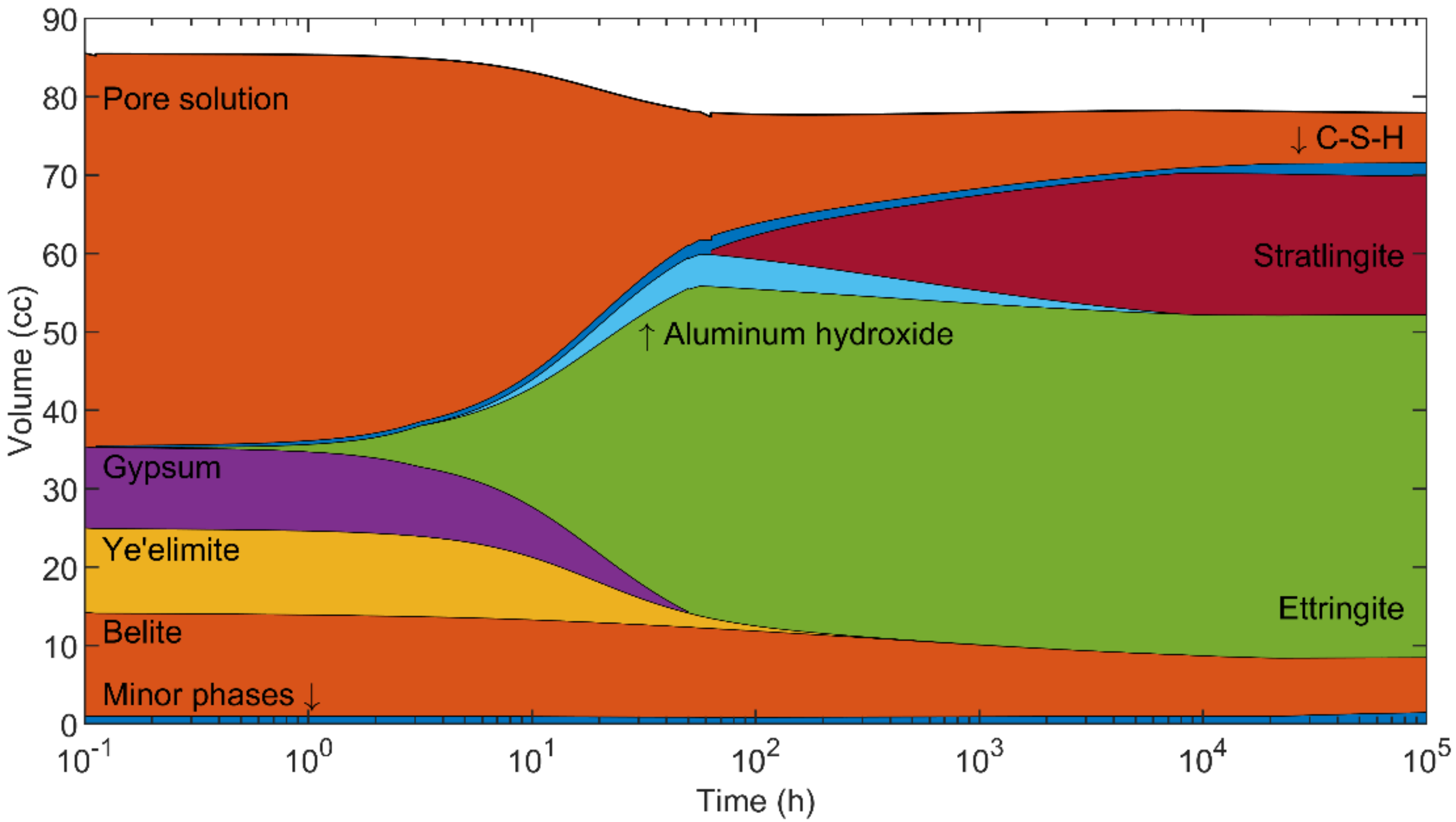
G109 specimens – Different curing periods

B0.45-28 days
(1 cycle)

B0.45-56 days
(5 cycles)

B0.45-90 days
(5 cycles)

CEMGEMS hydration simulation



<u>Later-age hydration products</u>

1. Strätlingite
2. C-S-H

- ➢ Significant later-age microstructure refinement
- ➢ Increase in later-age pH

Conclusion

1. Electrical tests: Low chloride penetrability
    - Specimen conditioning may cause erroneous readings
2. Migration and diffusion test show contradictory results for chloride penetrability of BCSA cement
3. Corrosion resistance improves with curing age
4. Future work:
    - Time dependence of chloride penetrability
    - Time dependence of passivation
    - Corrosion service life model

Thank You!

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