Rechargeable Cement-Based Concrete Batteries

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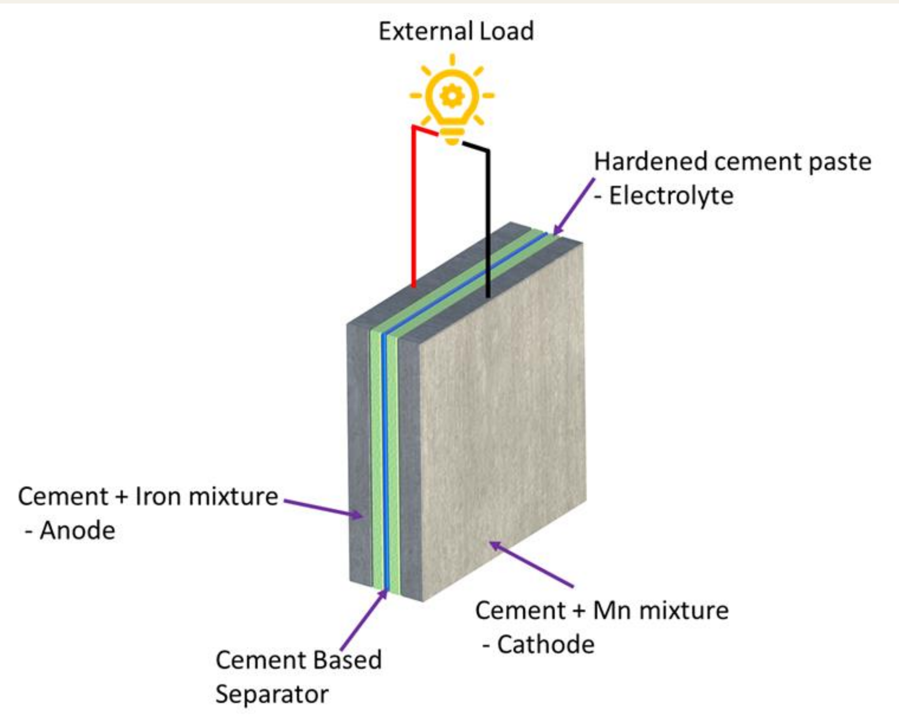
Introduction

Aim:

Develop rechargeable cement-based batteries that can be integrated into buildings and used for storage of energy from solar cells

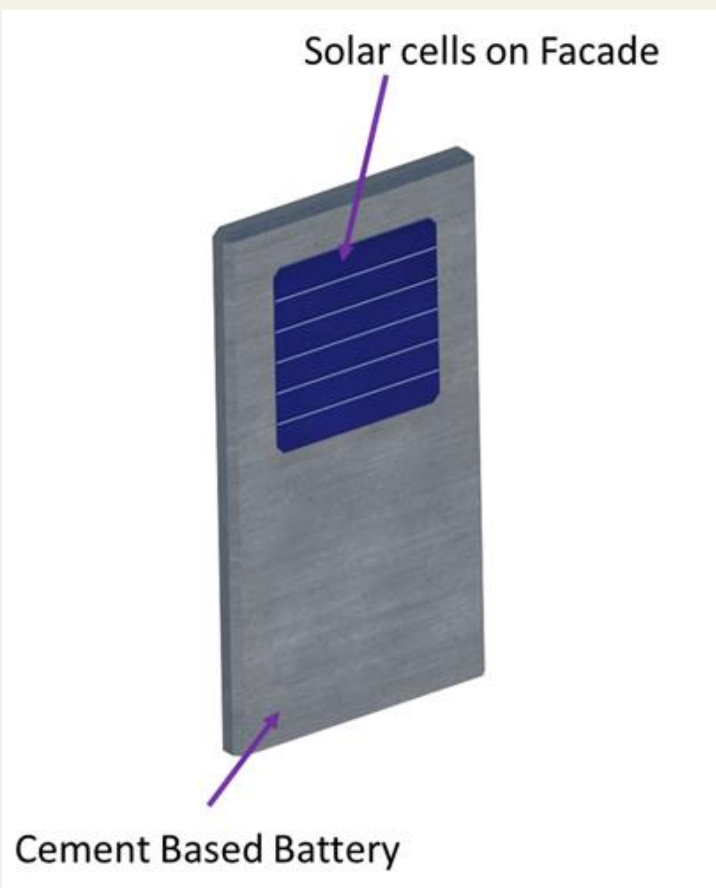


Main Components:

- Cement, iron particles and chopped carbon fiber are mixed and cast to form anode
- Cement, manganese dioxide/nickel particles and chopped carbon fiber are mixed and cast to form cathode
- The alkaline pore water in hardened cement paste acts as an electrolyte
- Separator helps to electrically insulate the electrodes to avoid short circuiting and works as a conduit for ions
- Cement based separator with anionic exchange resin/fibers are used to enhance ion transport
- In some configurations, cement paste (electrolyte) and separator could be a single component

Advantages:

- Large volume available in building spaces can compensate for the low energy density of concrete batteries
- Low cost materials – No expensive nano material
- Concrete batteries integrated with solar cells can act as distributed energy storage to balance the grids
- Integration of concrete batteries on pavement can provide power to sensors for monitoring traffic, drainage and pollution level



Challenges:

- Low energy and power density of the batteries
- High electrical resistivity of electrodes leading to low battery performance
- Poor ionic conductivity and low electrical resistivity of separators leading to dissipation of stored energy
- Interface between separators/electrolyte/electrodes to improve mechanical and electrochemical performance
- Making the batteries rechargeable

Experiments

The study focuses mainly on the electrochemical performance of separators

Materials:

- Superplasticizer/water reducer, cement, sand, water
- Ionic conductive additive – one of the following
  - Anion exchange resin (AER) – in the form of beads
  - Anion exchange resin (AER) – in the form of fibres

Manufacturing:

To ensure homogeneous dispersion of particles in separator, we tried two different mixing methods – pre-mixing and post-mixing method

In pre-mixing method all the dry components are mixed and later water, water reducing agents are added to the mixture

In post-mixing method, cement and sand are mixed first in a separate container, then fibre/resin, water and water reducing agent are mixed in another container and finally all of them are mixed.

Experimental Factors:

The following 5 factors affect separator performance. We chose 4 levels for all of them except curing medium which has 3 levels.

Factors	Levels	Values at Levels
Sand	4	2, 4, 6 and 8 g
Superplasticizer/Water Reducing agent	4	0, 0.16, 0.3 and 0.16g
Water	4	4, 5, 6, 8g
Ionic Conductive Additive (Either AER fiber or AER resin)	4	0, 0.2, 0.3 and 0.5g
Curing medium	3	Water, $CaCl_2/Ca(OH)_2$ and Humid room

Considering the manufacturing methods and other ionic conductive additive, we need a total of 3072 experiments

To minimize the experiments and maximize the information out of them, we used Greco-Latin square design

	Sand (g)	Superplasticizer (g)	Water (g)	AER resin or fibers (g)	Curing Medium	Cement (g)
E01	2	0	4	0	Water	10
E02	2	0,16	5	0,2	$CaCl_2/Ca(OH)_2$	10
E03	2	0,3	6	0,3	humide room	10
E04	2	0,6	8	0,5	Water	10
E05	4	0	5	0,3	Water	10
E06	4	0,16	4	0,5	humide room	10
E07	4	0,3	8	0	$CaCl_2/Ca(OH)_2$	10
E08	4	0,6	6	0,2	Water	10
E09	6	0	6	0,5	$CaCl_2/Ca(OH)_2$	10
E10	6	0,16	8	0,3	Water	10
E11	6	0,3	4	0,2	Water	10
E12	6	0,6	5	0	humide room	10
E13	8	0	8	0,2	humide room	10
E14	8	0,16	6	0	Water	10
E15	8	0,3	5	0,5	Water	10
E16	8	0,6	4	0,3	$CaCl_2/Ca(OH)_2$	10

16 experiments are repeated for each of AER resin and AER fiber, using two manufacturing methods for a total of 64 trials

Separator Performance:

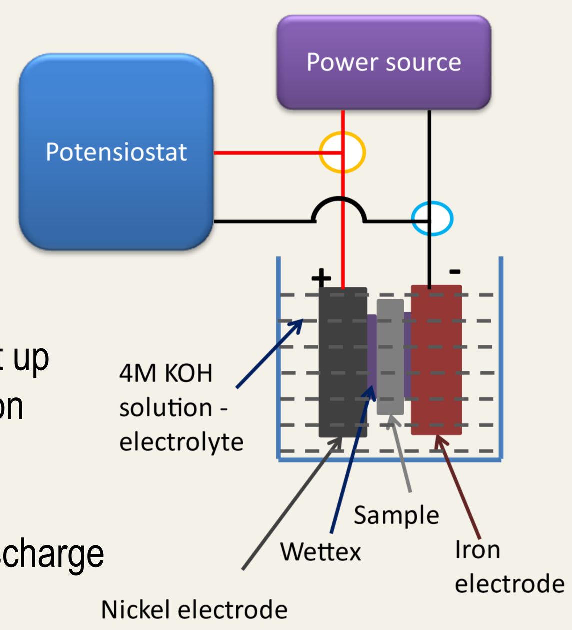
Resistance measurement – Ohmic resistance was measured using LCR meter at 1kHz frequency, higher resistance helps in avoiding short circuits

Open circuit voltage potential –

The separator sample is sandwiched between two wettex fabric to maximize contact with electrodes.

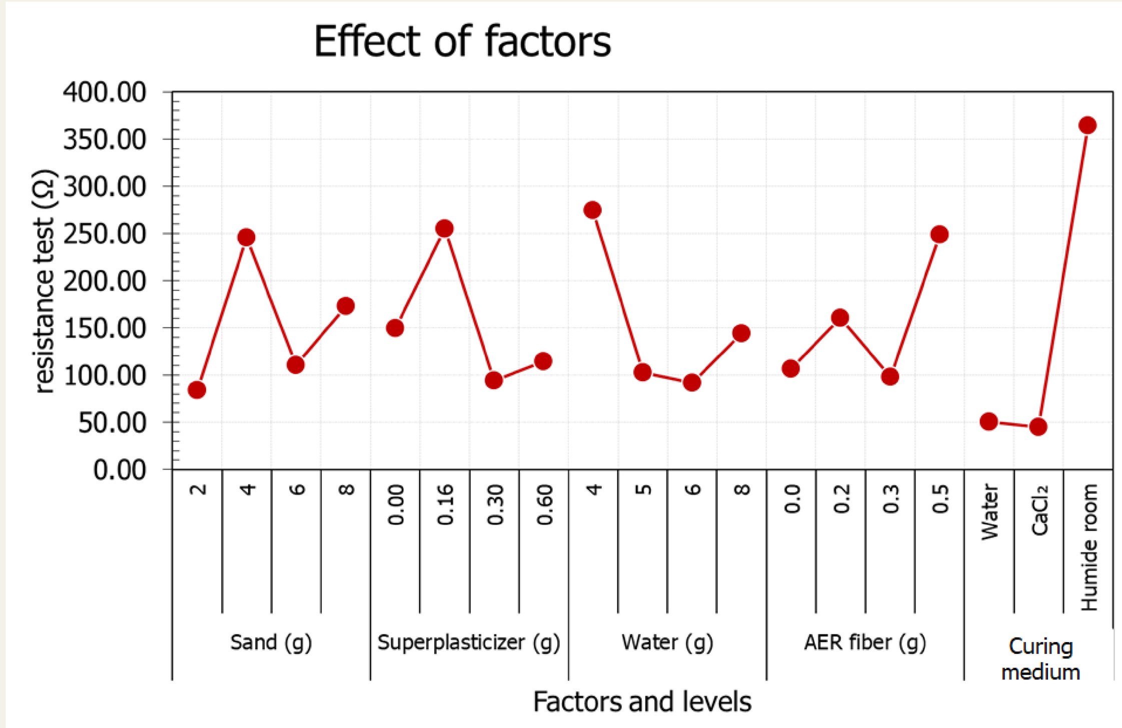
Nickel electrode is used as cathode and Iron electrode is used as anode. The set up is immersed in a bath of 4M KOH solution

2V at 0.1A is used to charge the system for 24 hours and discharged. Rate of discharge is used as performance indicator.



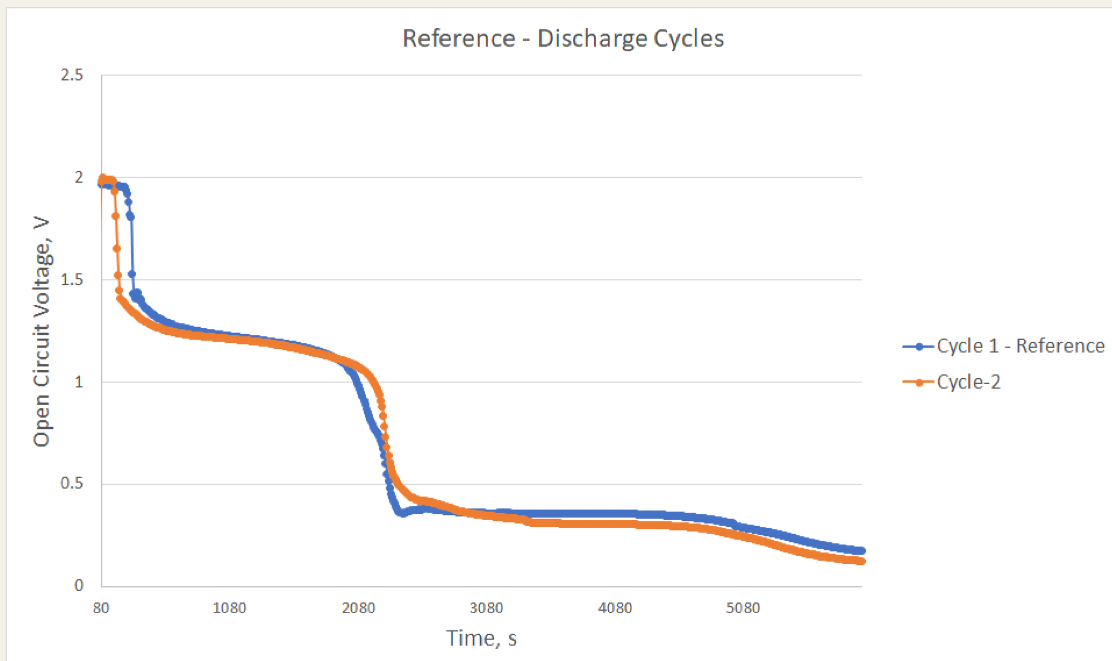
Results

Effect of factors, charge discharge cycle



Observations of effect of factors:

- Homogenous distribution of AER are dependent on low levels of superplasticizer < 1.6 w%
- Porosity: homogenous in the series approx. 36%
- Resistivity: curing media have largest impact: Humid room > water > $CaCl_2/Ca(OH)_2$
- Low mechanical strength with high cement/sand and/or water/cement ratio (i.e. 80 respective 0.8)



Observations of charge-discharge cycle:

- Open circuit voltage testing results demonstrate the ion conducting ability of cement-based separators without AER fibers and it could improve with the addition of AER fibers/resin
- After an initial drop in voltage from 2 to 1.25 V, the voltage is maintained for 30 minutes before it drops below 1V
- Tests are ongoing to optimize the fiber/resin content to improve ion conduction

Conclusion

- Initial tests demonstrate huge potential of cement-based batteries in infrastructure applications, especially for storing solar energy
- Major experimental factor affecting the separator performance is superplasticizer content, which influences the homogeneous distribution of AER fiber/resin
- Water content of the curing media has the largest impact on the resistance of separator which affects its performance
- Further investigation of cement-based anode and cathode are ongoing to optimize these batteries at system level

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