

Research progress with the ASTM C1202 chloride test

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http://www.concrete.org/committees/committeehome.asp?committee_code=0000123-00

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ACI Chicago

Research in Progress

Proposed Presentation

Presentation Title:

Research Progress with the ASTM C1202 Chloride Test

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Abstract:

The aim of this research is to overcome problems with the ASTM C1202 test which make it give misleading readings if pozzolans or some types of accelerating admixtures are used. These materials deplete or increase the numbers of charge carriers in concrete and thus affect the observed charge passing without necessarily affecting the true chloride diffusion.

Recent work has provided experimental validation of a multi-species model for the test. The experiments use an electrode which is drilled into the centre of the sample and shows that the voltage drop across it is not linear. By modelling the experiment the observations of this centre voltage have been used to calculate the intrinsic diffusion coefficient for chlorides in samples.

Further analysis of the model showed that it is also applicable to diffusion tests in which no voltage is applied and indicated that the traditional interpretation of these experiments using Fick's law may be improved.

The presentation will:

Outline the experimental methods and the modelling used.

Discuss some laboratory results and their applications.

Discuss future research which will be intended to develop experimental methods which achieve the same results but are more practical for general use in testing laboratories.

Give details of references for delegates who wish to see greater detail of the work.

Problems associated with the measurement of chloride diffusion in concrete

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CV1 5FB, UK

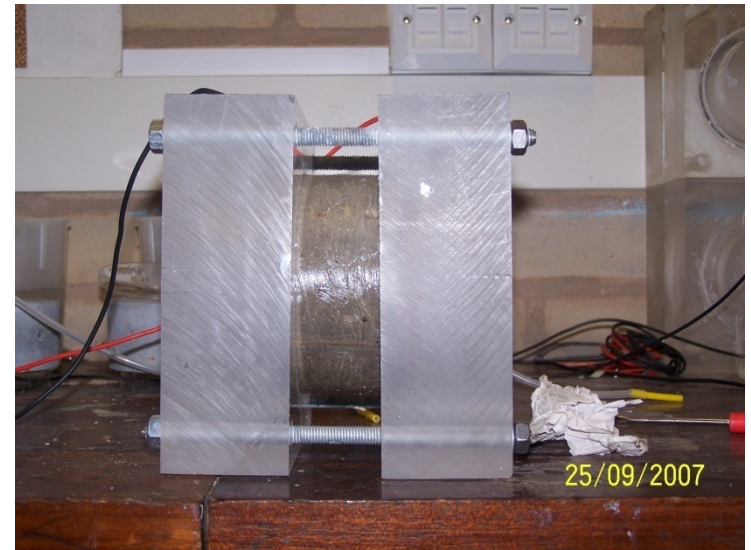
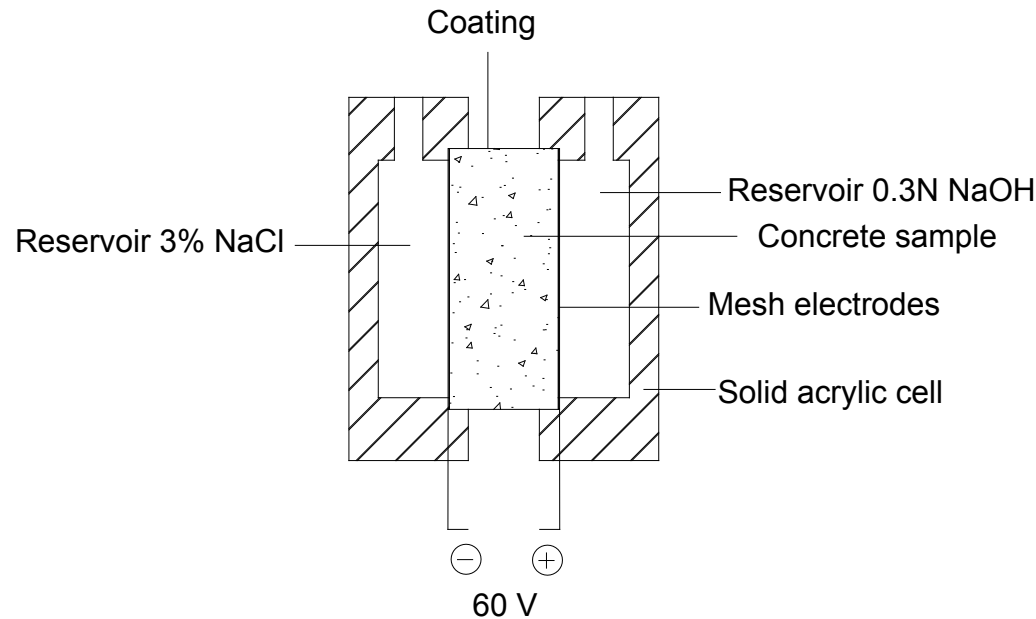
Presentation contents

1. Electromigration tests
2. “Traditional” diffusion tests

ASTM C1202 – Names for the Test

- Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration (in the ASTM).
- The Rapid Chloride Permeability Test (after Whiting – who invented the test)
- The Coulomb Test (it measures Coulombs)

ASTM C1202: Rapid Chloride Penetration Test (RCPT)

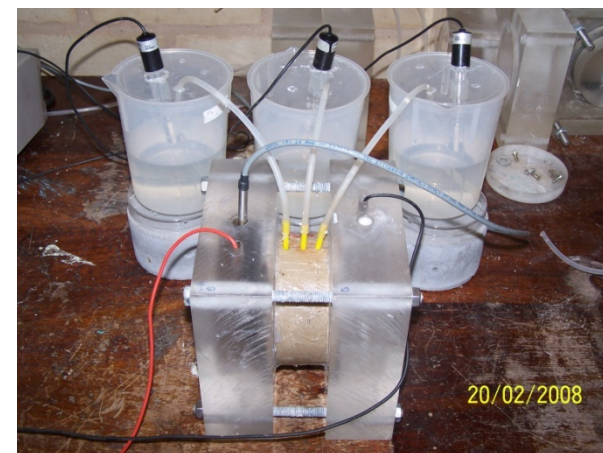
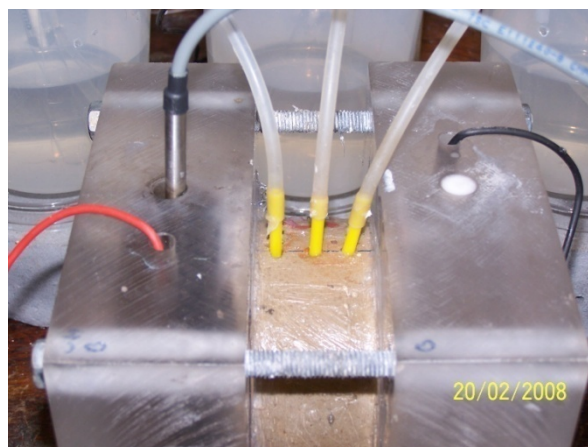
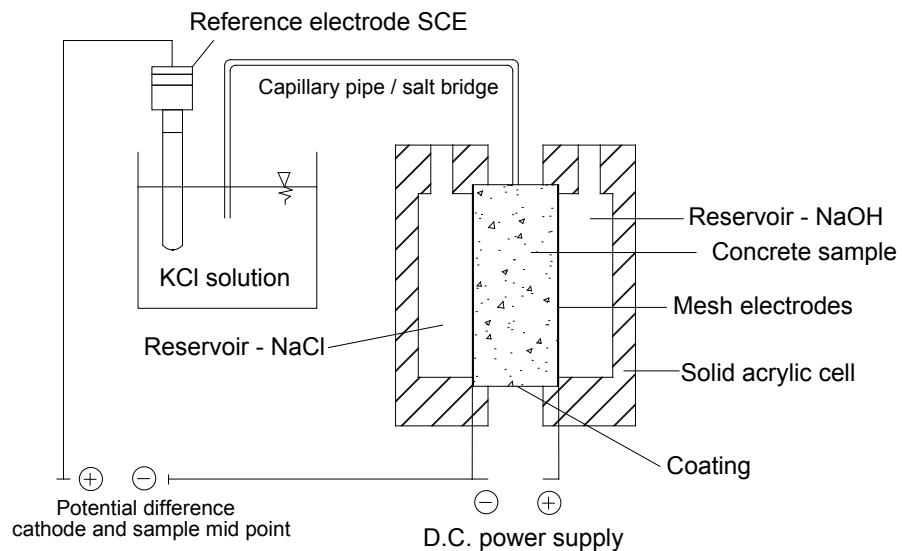


Charge Passed (coulombs)	Chloride Ion Penetrability
>4,000	High
2,000 - 4,000	Moderate
1,000 – 2,000	Low
100 – 1,000	Very low
<100	Negligible

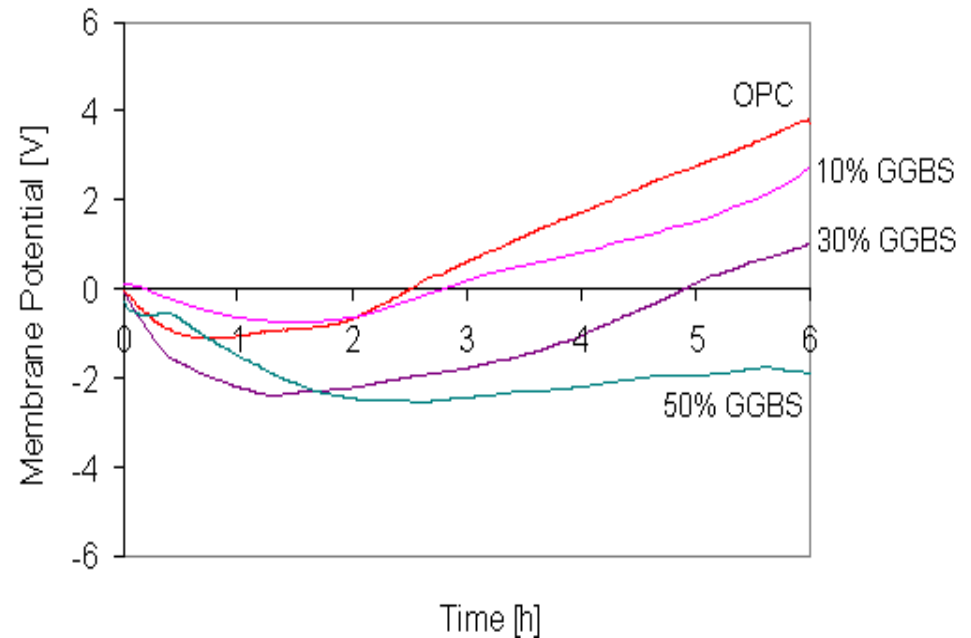
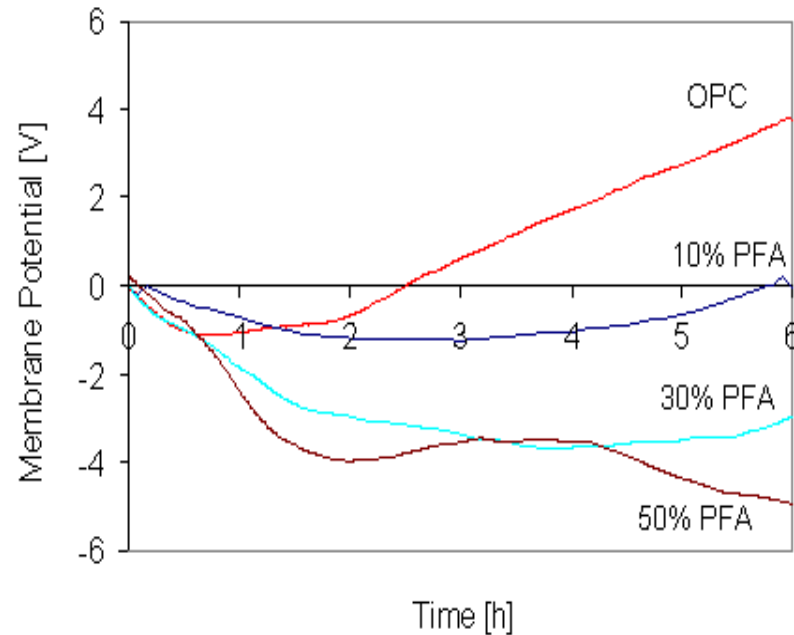
The Problem

- At the start of the test there is no chloride in the sample so the current depends on other charge carriers (primarily OH⁻)
- Adding pozzolans to concrete depletes the OH⁻ and can give misleading low results.
- Adding some accelerators with nitrates or other conducting ions can give misleading high results.

The new test



Using the mid-point voltage to identify cement replacements



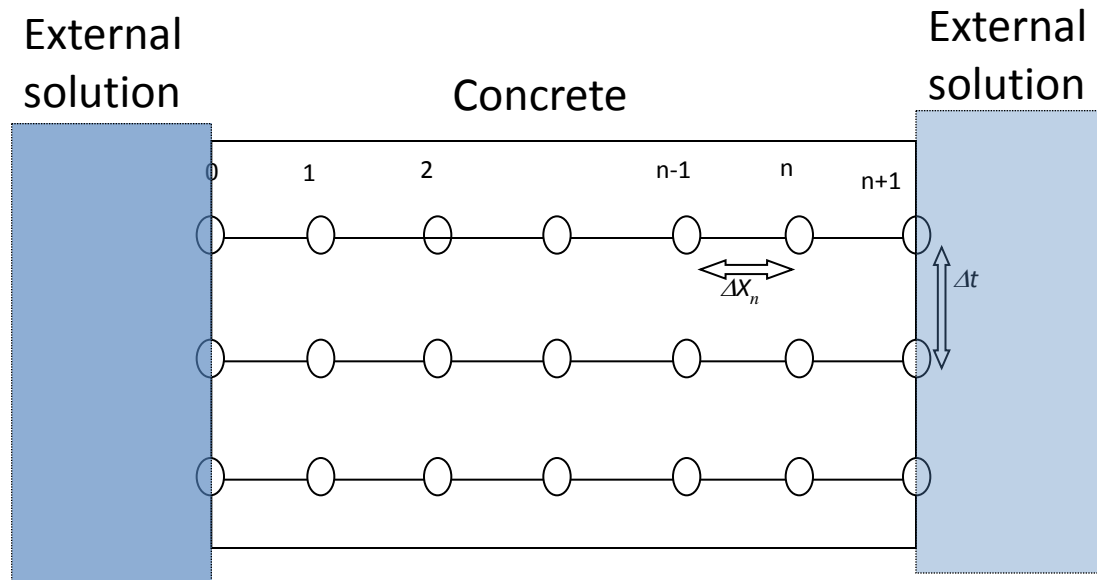
Electro-diffusion model for chlorides in concrete

- **Nernst-Planck equation:**

$$J_i = \underbrace{D_i \frac{\partial c_i}{\partial x}}_{\text{Diffusion}} + \underbrace{\frac{z_i F}{RT} D_i c_i \frac{\partial E}{\partial x}}_{\text{Migration}}$$

- **Charge electroneutrality (Kirchoff's law):**

$$0 = F \sum_i z_i J_i$$



Solving the hard way –

assuming E is constant

$$I = FADc_o a \left[\frac{2}{\beta \sqrt{\pi}} e^{\left(\frac{\alpha}{2} - \frac{\alpha^2}{\beta^2} - \frac{\beta^2}{16} \right)} + \frac{1}{2} \operatorname{erfc} \left(\frac{\alpha}{\beta} - \frac{\beta}{4} \right) \right]$$

where

$$a = \frac{zFE}{RT}$$

$$\alpha = ax$$

$$\beta = 2a\sqrt{Dt}$$

Section through sample during test

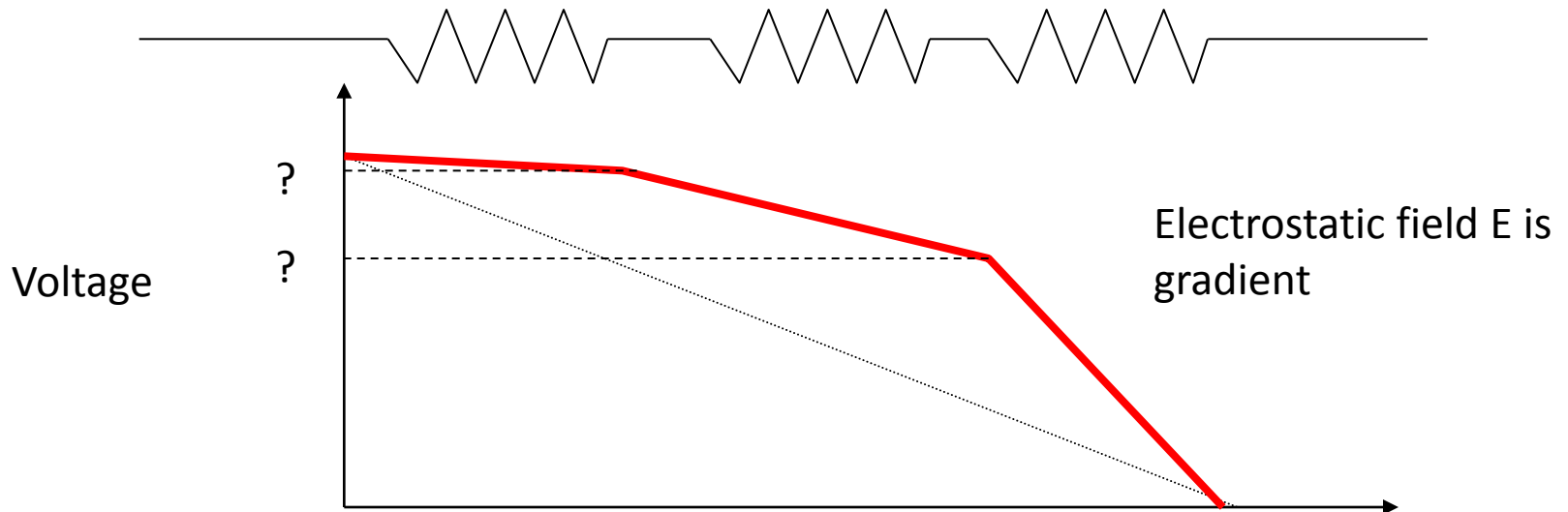


Chloride zone

Sodium zone

Low resistance (high D)

High resistance (low D)



The Progress of a Chloride Ion



A Chloride ion enters the sample...
what happens next?

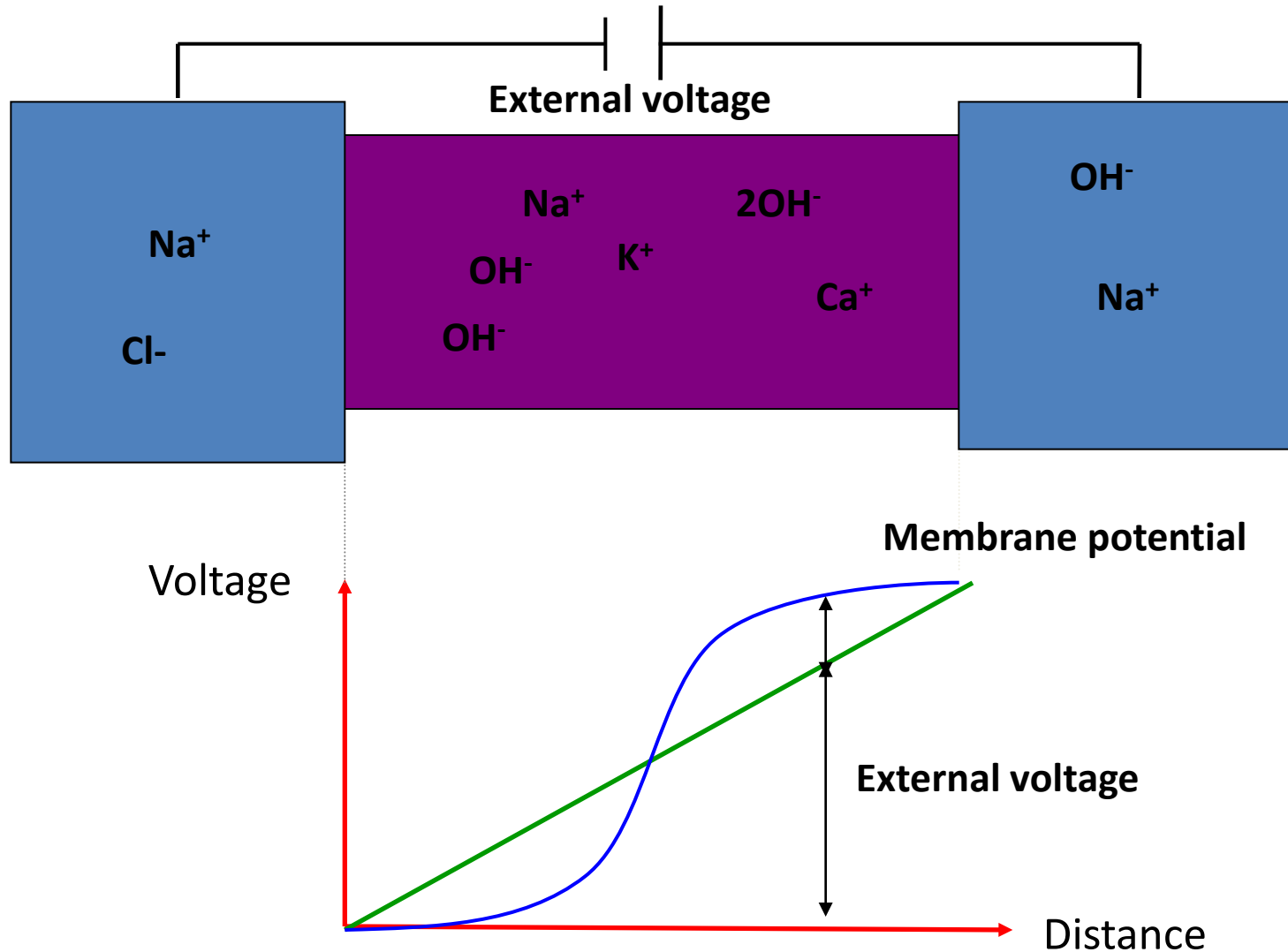


Either it finds another negative ion that can
move away in front of it



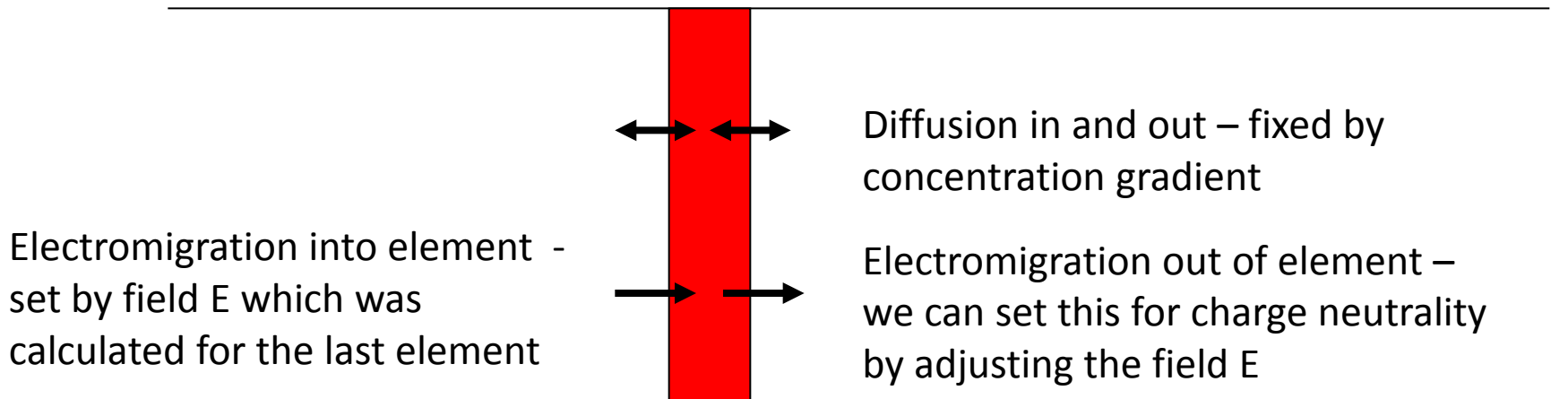
+ Or it has to bring a positive sodium ion with it

Membrane Potential



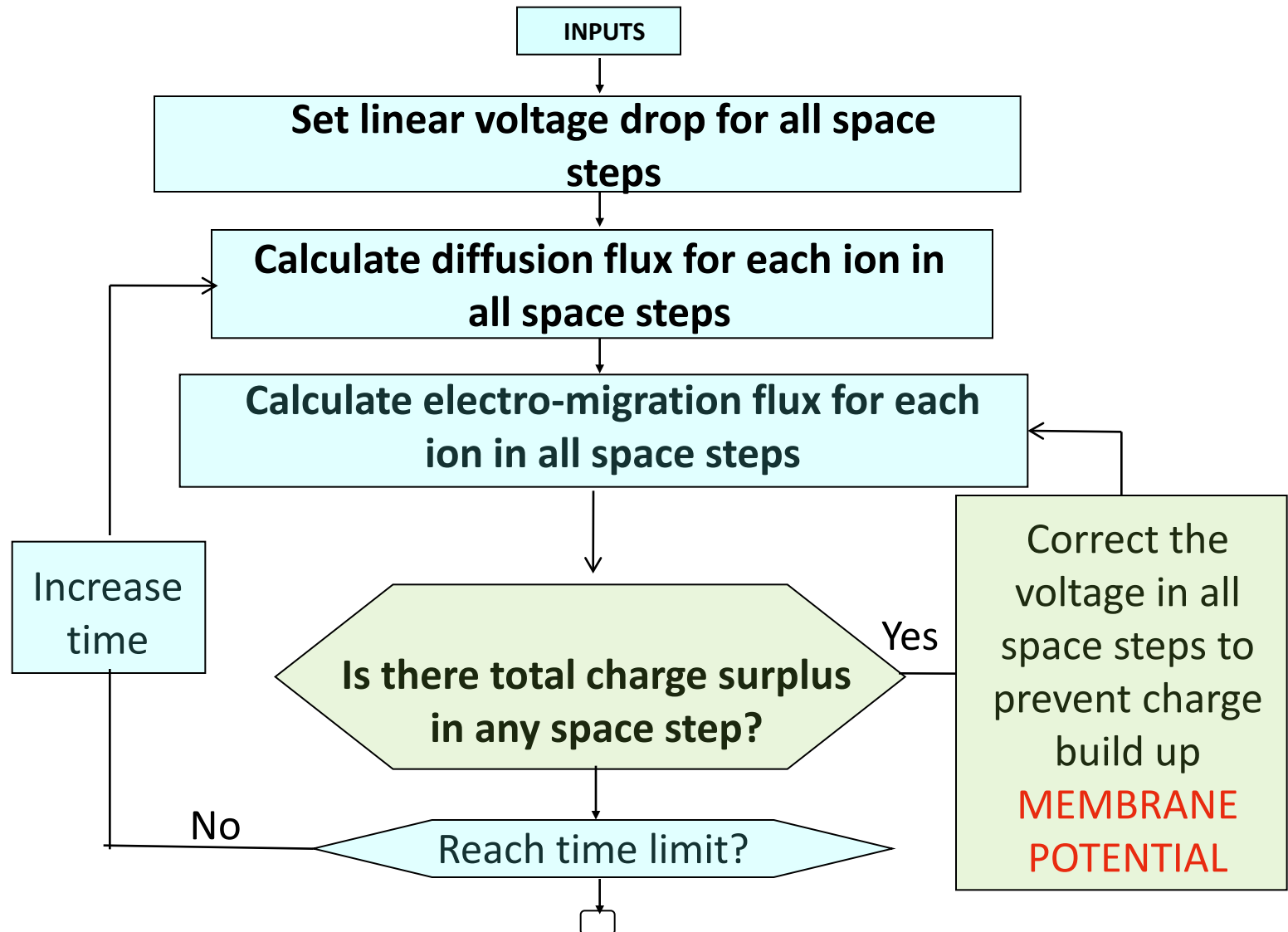
Modelling a thin slice of the sample for a short time step

Apply Kirchoff's law : current in = current out

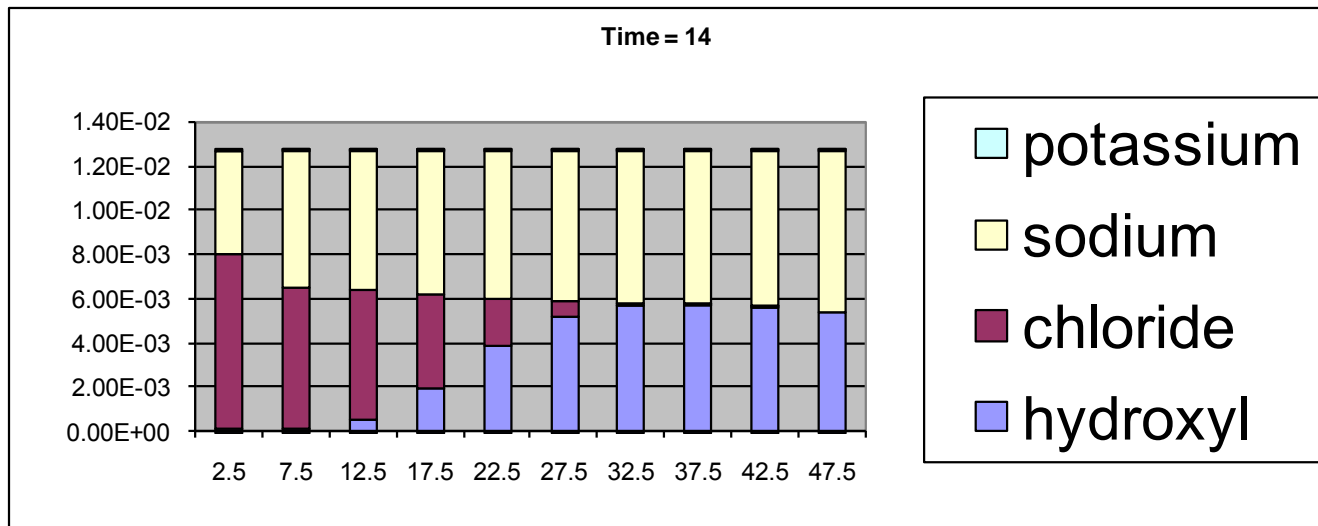
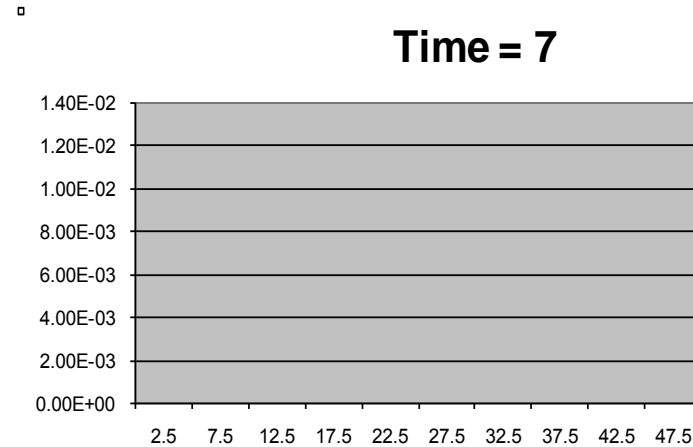
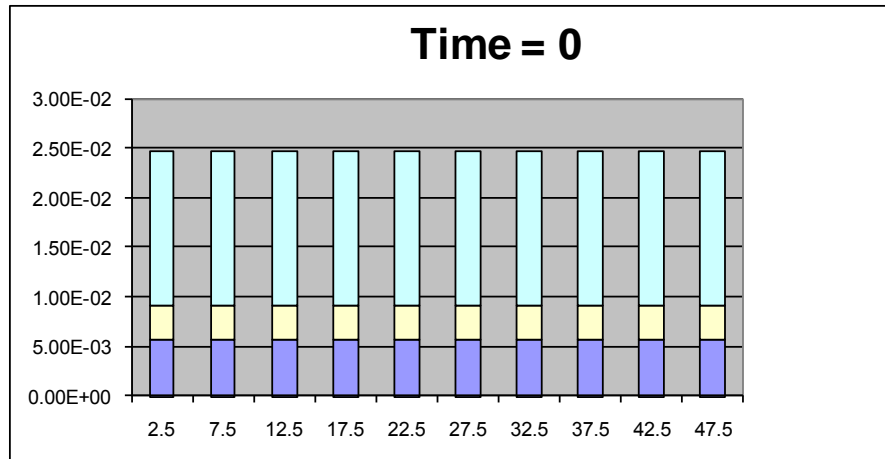


Final adjustments are needed to get the correct total voltage across the sample.

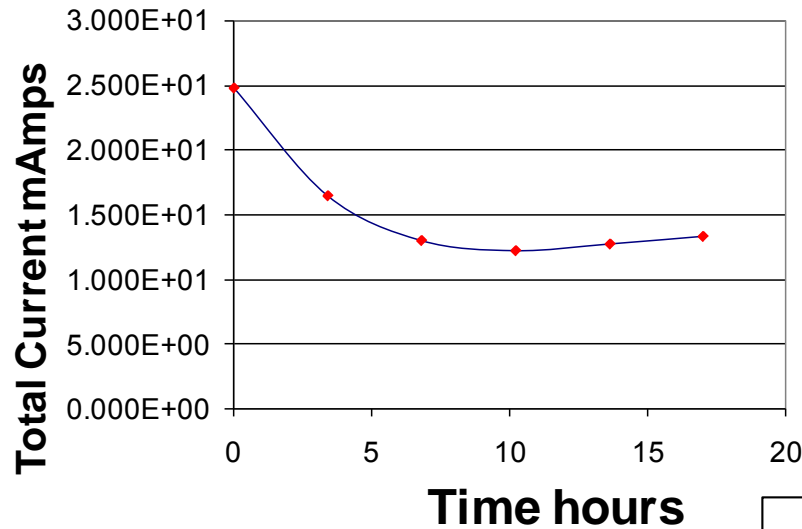
Key innovation in the computer code



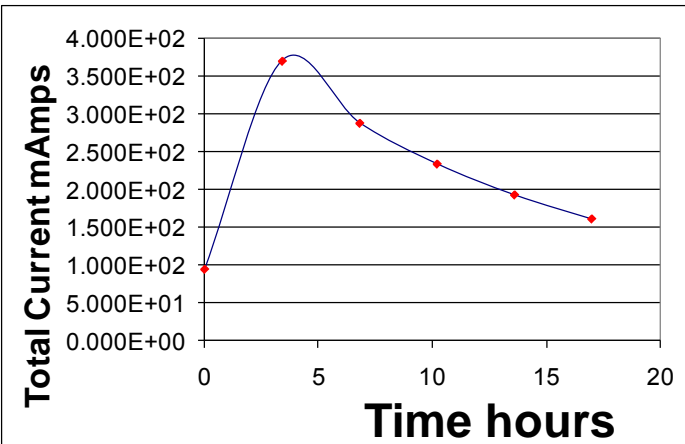
Current in amps at different times in hours vs position in mm from the negative side



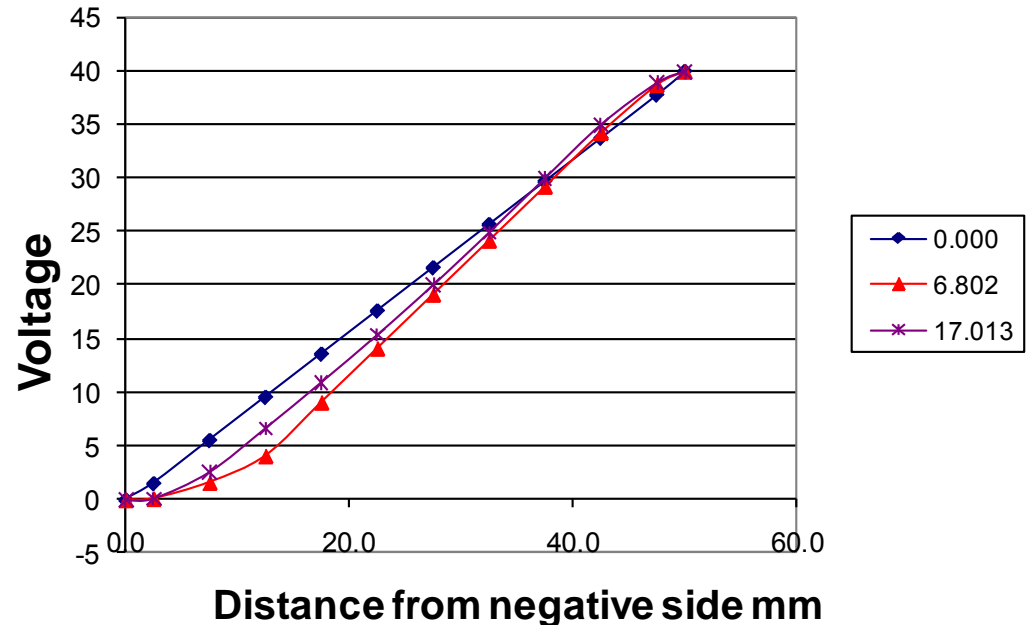
Model output for current and voltage



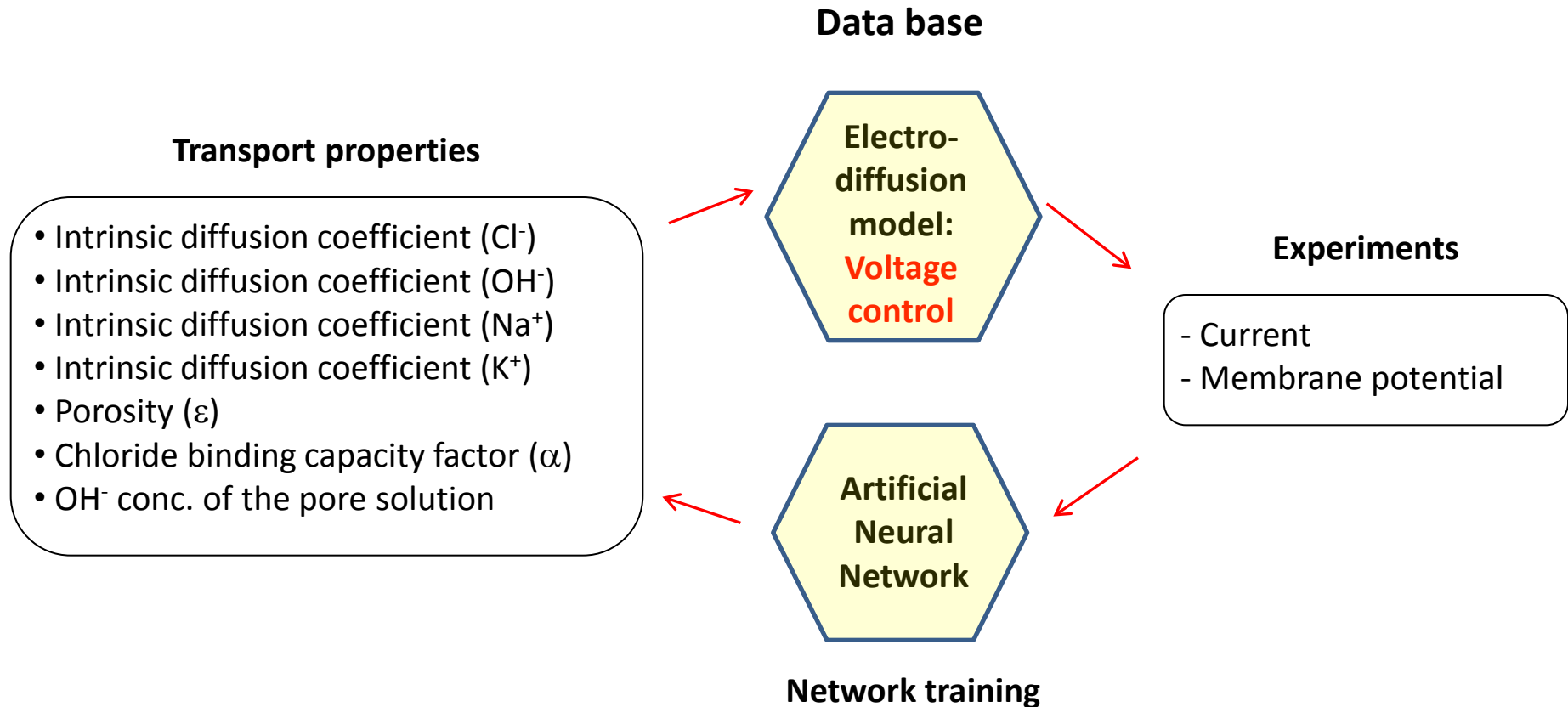
Current vs time with no voltage correction (average)



Voltage adjustments at different times

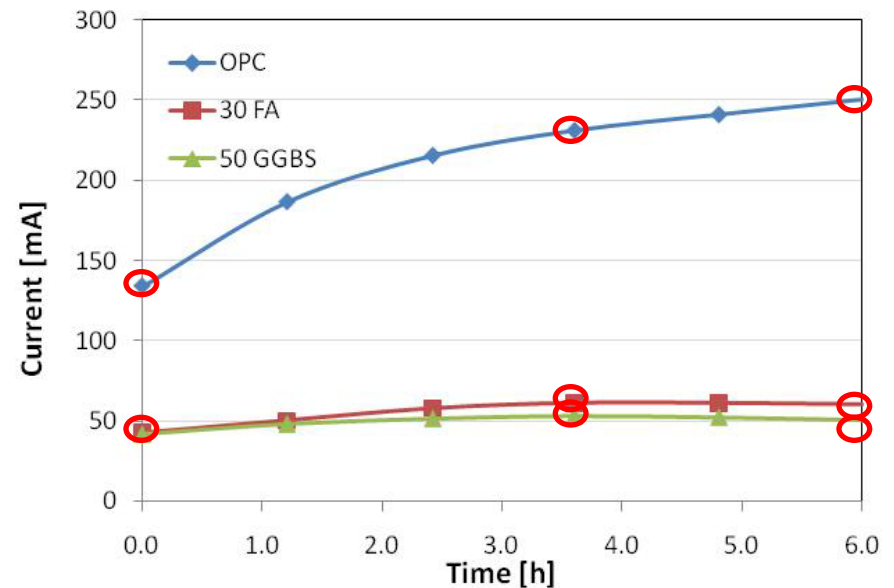
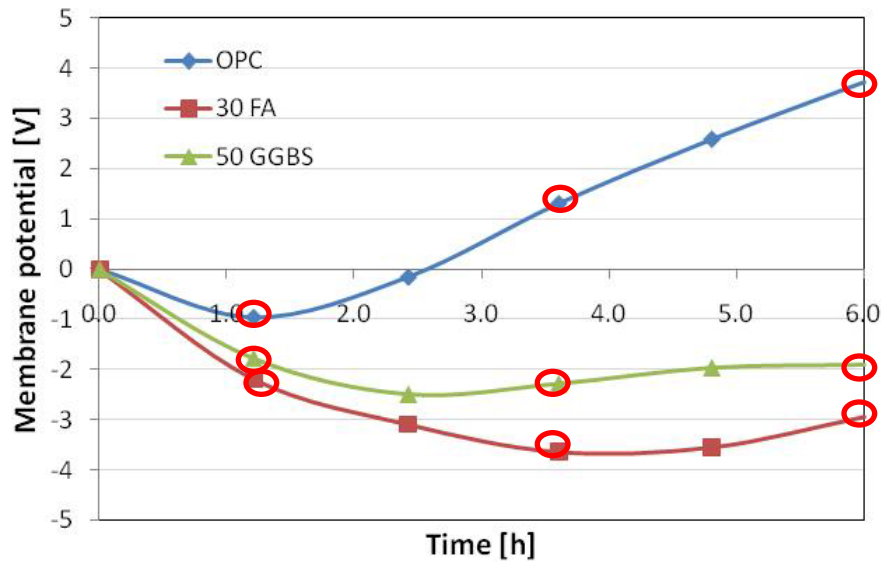


Optimization Model



Experimental programme

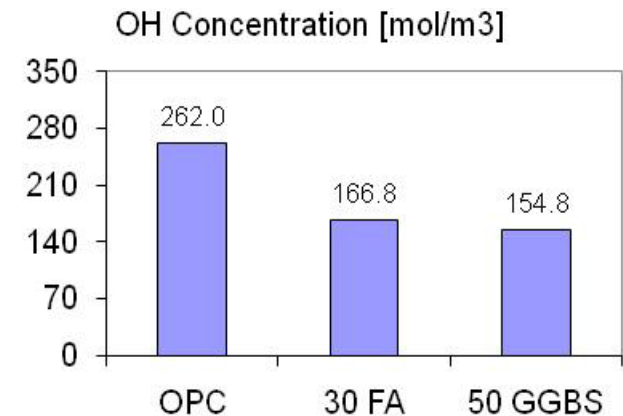
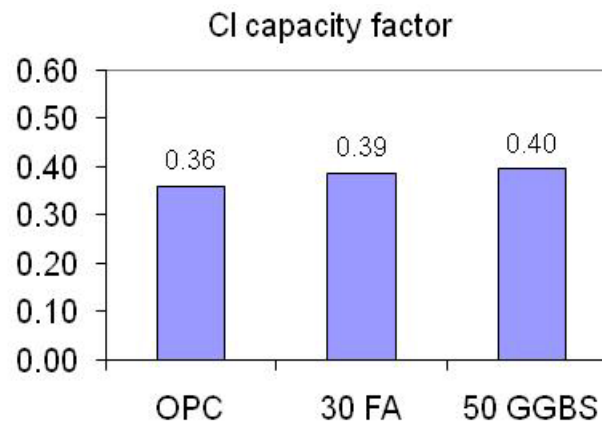
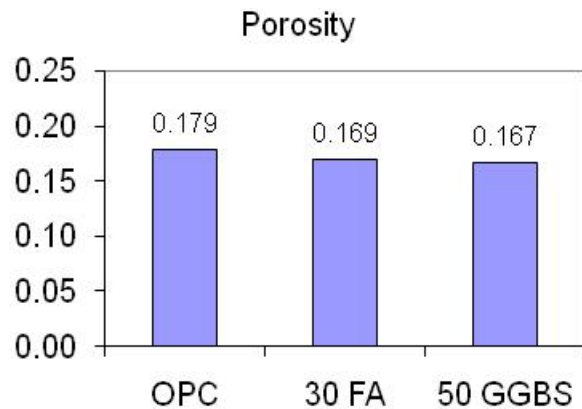
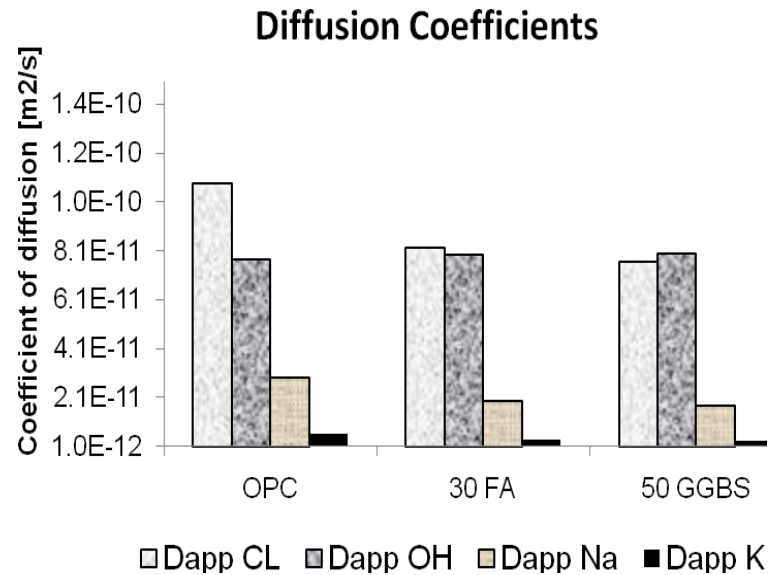
Mix	w/b	%		
		OPC %	PFA %	GGBS %
OPC	0.49	100	0	0
30%PFA	0.49	70	30	0
50%GGBS	0.49	50	0	50



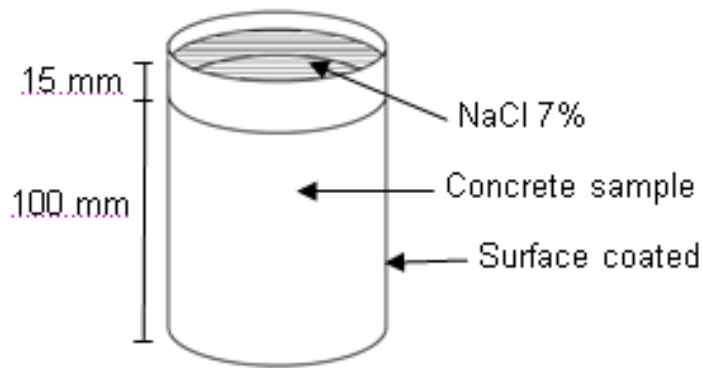
○ Inputs of the neural network

Chloride related properties from voltage control model

You can't get these with a 5 minute test!



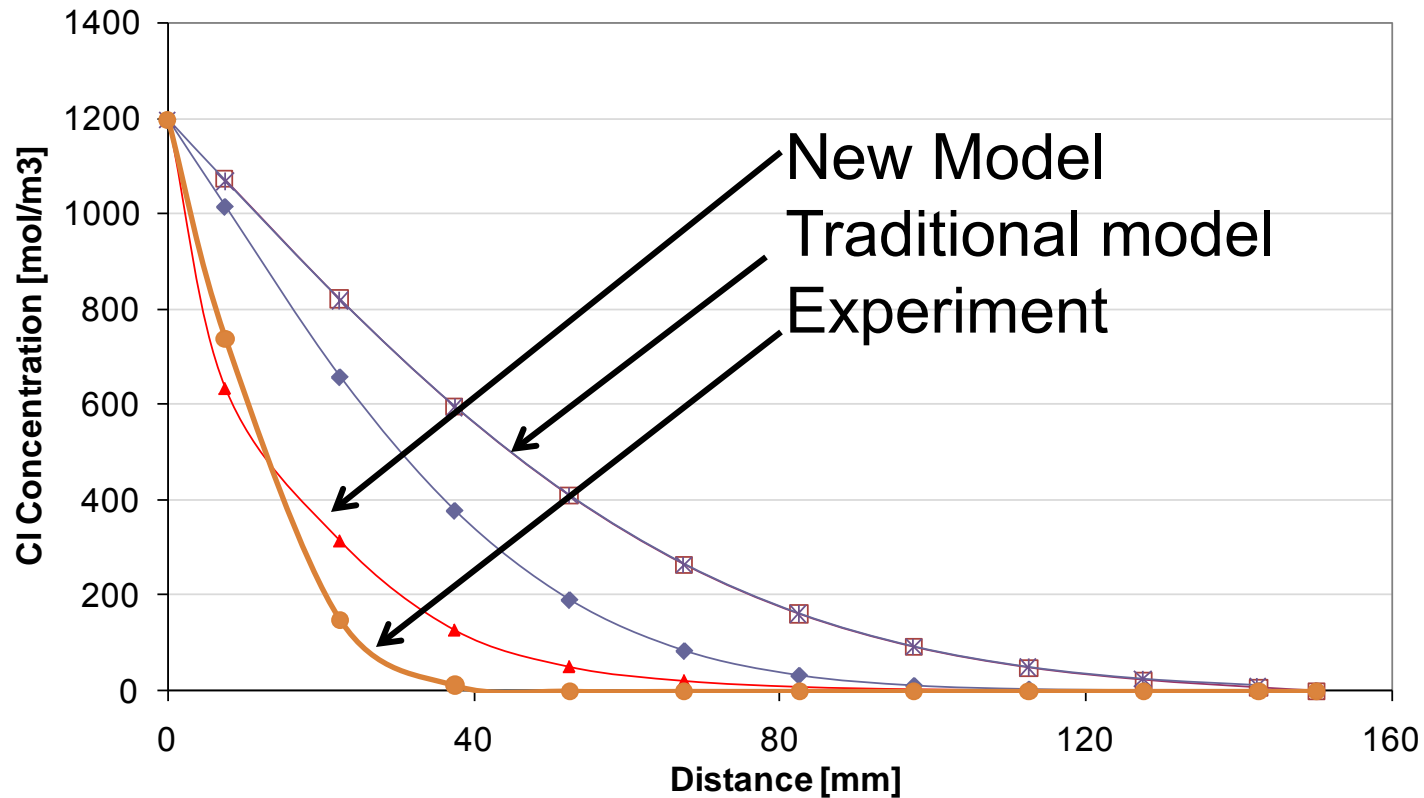
“Traditional” diffusion test



For modelling:

- The boundary condition is not zero voltage because the ends of the sample are not short-circuited.
- A voltage can be measured.
- The voltage in the model is set to give zero current.

Traditional diffusion test (no applied voltage)



- ▲— (1) Current control model - zero current (properties calculated)
- ◆— (2) Model with non-zero current, no voltage correction (properties calculated)
- (3) Model with no binding, no voltage correction and just diffusion of Cl (Dint-cl calculated)
- *— (4) Equation 7 (Dint-cl calculated)
- (5) Equation 7 (Dint-Fick)

Equation (7) is the integral of Fick's law. D_{int} = Intrinsic diffusion coefficient
 (3) and (4) coincide – showing that the computer model gives the same results as integrating Fick's law if the ion-ion interactions are switched off.
 (5) Is based on experimental data

Future work on the Voltage Driven Test

- Controlled power tests to avoid overheating.
- Voltage steps (or similar technique) to get the same results but avoid the need for a salt bridge.

Conclusions

- The electrical model can be used with an artificial neural network (ANN) to give good values for transport properties.
- Even when no voltage is applied, an electrical model is needed to simulate a diffusion test because of ion-ion interactions.

Thank you

www.claisse.info

References:

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Effect of non-linear membrane potential on the migration of ionic species in concrete
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Coventry University and The University of Wisconsin Milwaukee Centre for By-products Utilization

Second International Conference on Sustainable Construction Materials and Technologies

June 28 - June 30, 2010, Università Politecnica delle Marche, Ancona, Italy.

<http://www4.uwm.edu/cbu/ancona.html>