Professorial Lecture

Peter Claisse

What Can We Do About Concrete?
Pete Claisse

1. What can be done with concrete – past, present and future
2. Environmental problems and solutions
3. Durability problems – trying to predict them

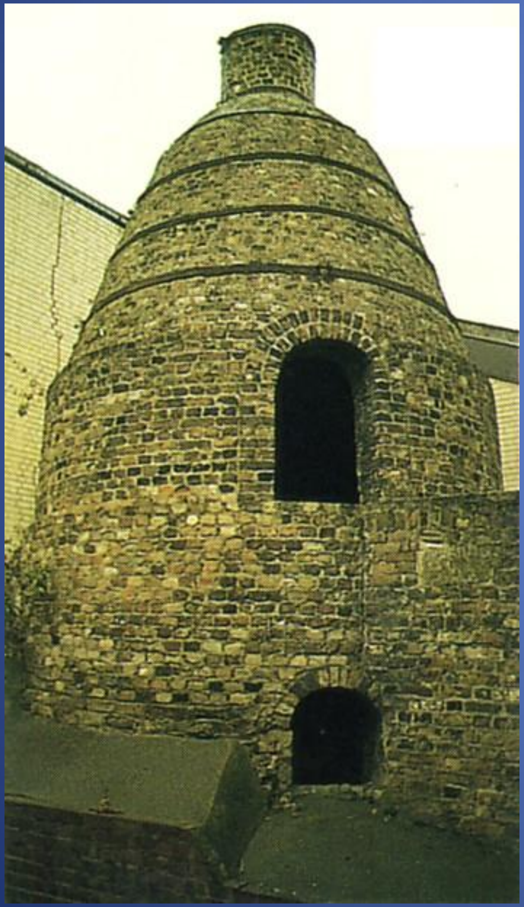
2500 BC. Egyptian pyramids.

burnt limestone + ash + stones = concrete

The Incas in central America made the same discovery

127 AD. The Pantheon in Rome.
The largest dome in the world until the 20[th] century

Rediscovery in the 18th century.
1759 Eddystone lighthouse
1824 Cement is patented by John Aspdin



Cement Production 1828

20th century concrete
Slender columns in the cathedral

Ferrocement

The cheapest way to build a boat

Versatile concrete:

Precast concrete room units for the Formule 1 hotel

Stairs for the sports centre

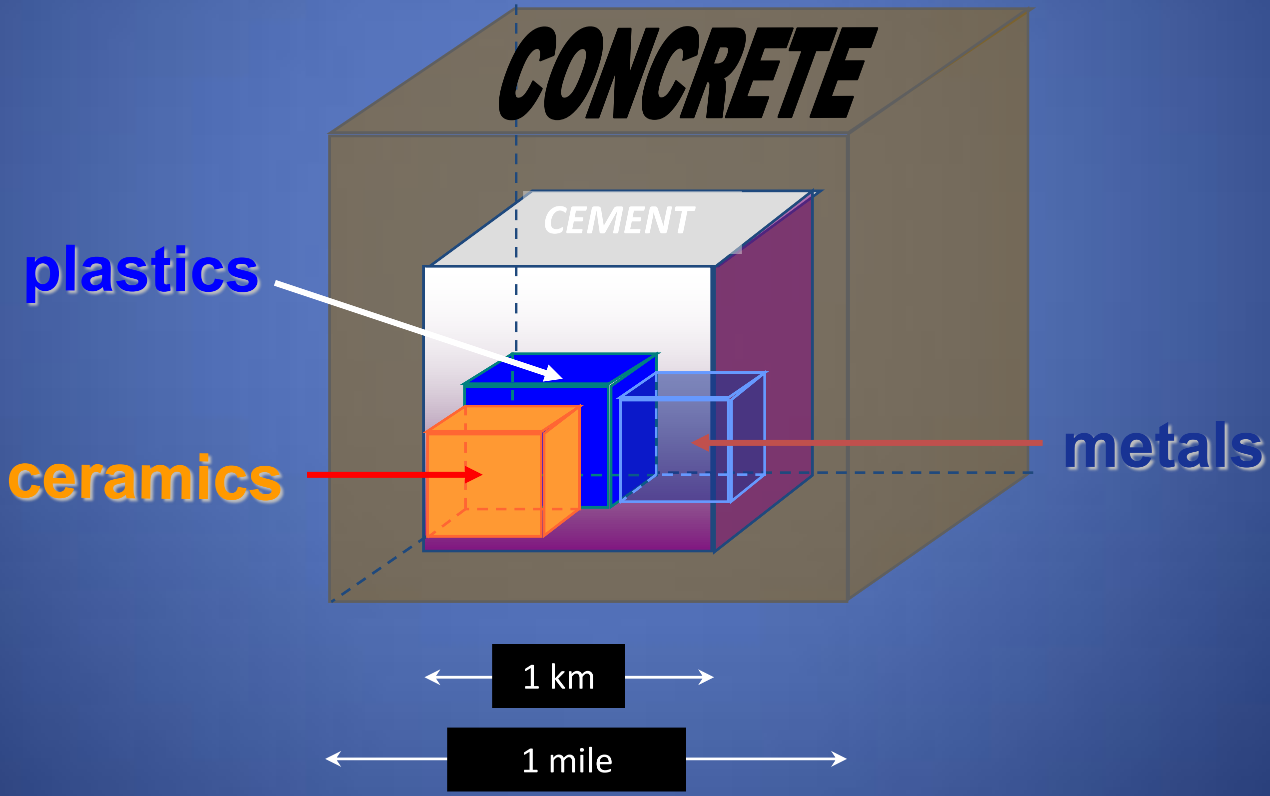
Oresund link between Denmark and Sweden.

Floating concrete
Proposed “floating ecopolis”

Where it comes from:
Northfleet works. Each of the 6 kilns of this plant produces a million tonnes a year (2 tonnes/min)

Cement Works and quarry

We use a lot of concrete !



Its influence is enormous…

	United Kingdom	World
Cement	12 MTpa	1,800 MTpa
Sales	£600 M	£50,000 M
Concrete	50 Mm^3	6,000 Mm^3
Sales	£3,800 M	£450,000 M
Construction	10% GDP	11 % GDP
Employment	1.5 M people	111 M people

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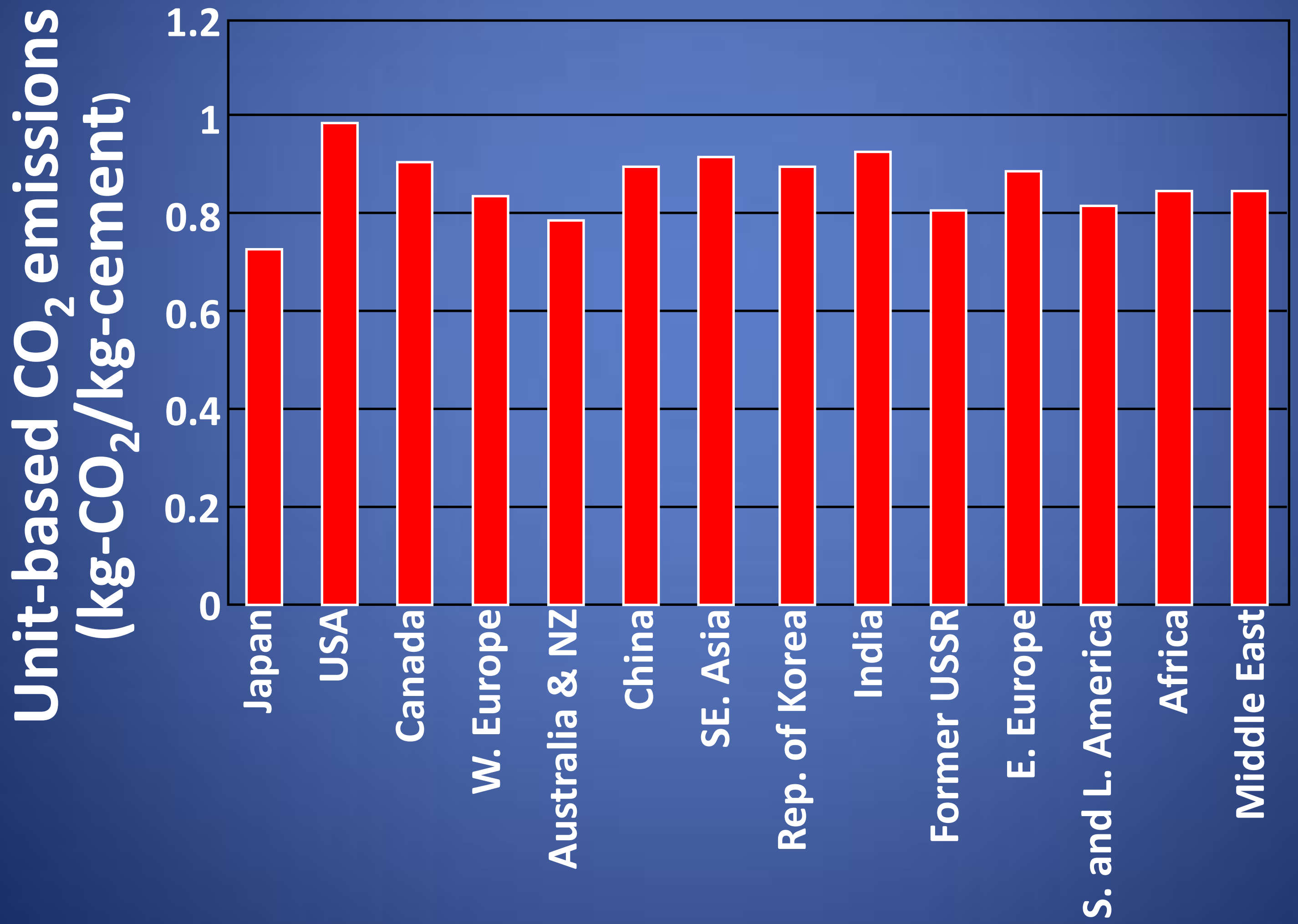
Cement Production

Limestone + Clay + Energy → Cement + Carbon dioxide

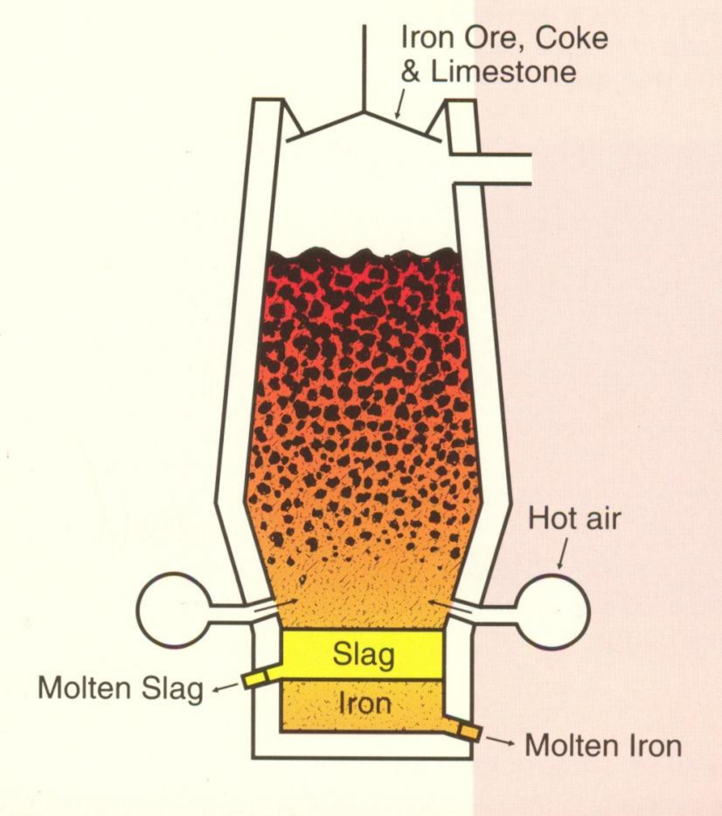
5% of world CO2 production (more than air travel)

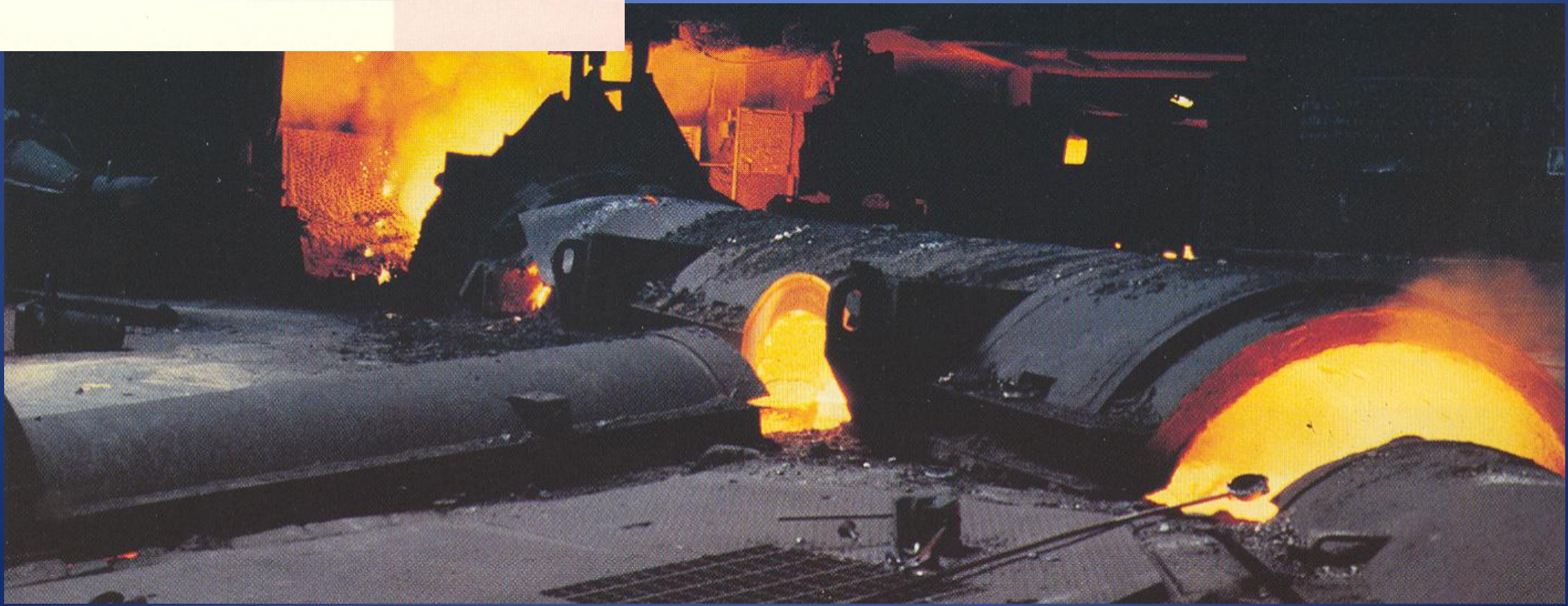


Solutions

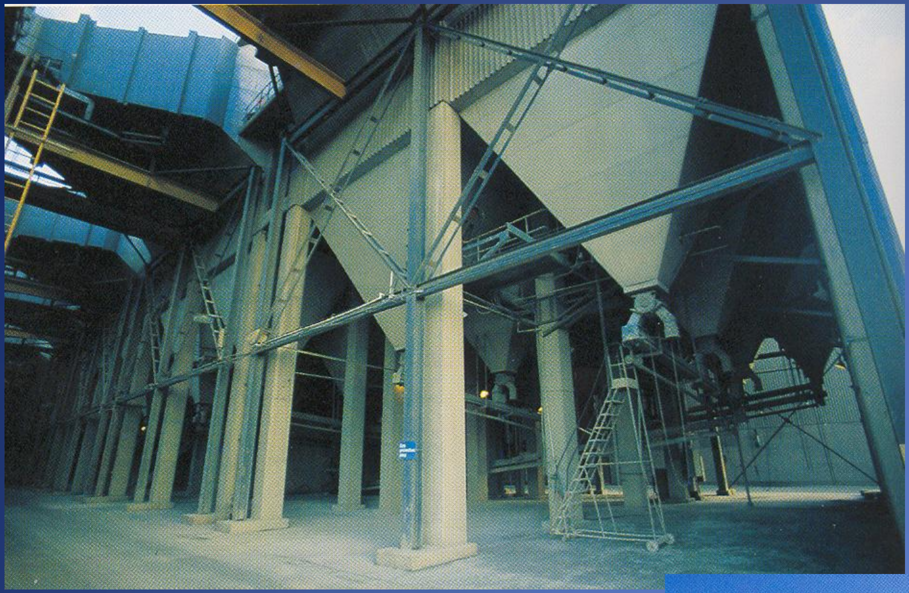
- Alternative fuel to replace coal and oil in the kilns
  - Shredded tyres
  - Domestic waste
- Waste minerals to replace the cement in the concrete
  - Ashes
  - Slags from metal production
- Different cements
  - Supersulphated cement
  - Magnesia Cements

Blastfurnace Slag





Projects using blastfurnace slag



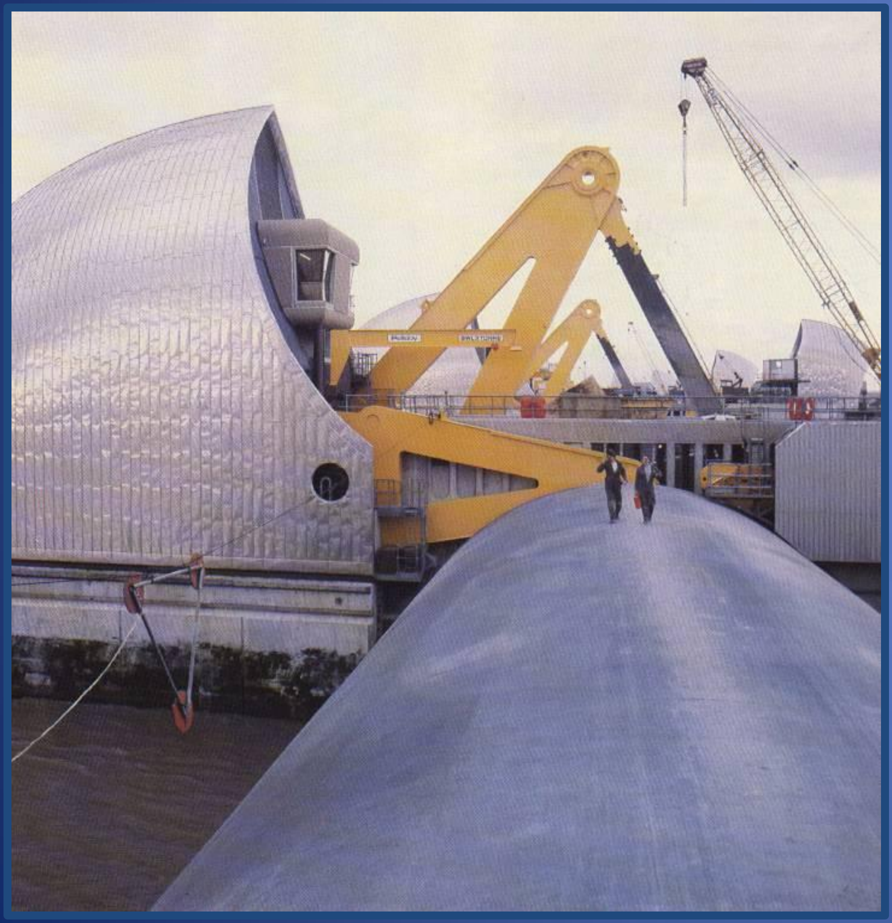
Ash from coal burning power station

Ash Dumping

Existing Dump

Limestone quarry that will be filled

Projects that used ash in the concrete



Applications for fly ash

The Channel Tunnel Rail Link.

Barriers to the use of cement replacements

- Fly ash is classified as a waste under environmental legislation.
- Constantly changing sources of coal.
- Mercury control on emissions from power stations makes unsuitable ash.
- Limited supplies of ash and slag.
- Can only replace part of the cement.

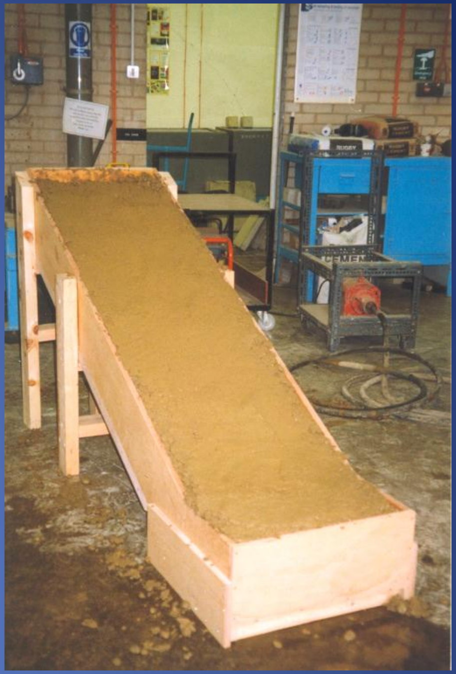
Work at Coventry

- Replacing all the cement with waste materials.
- Using waste gypsum and slag to make supersulphated mixes.

The Six Trials

- Trials 1-3
  - concrete barriers for landfills.
  - 70 m^3 of concrete.
- Trial 4
  - trench trial for mine or trench backfill.
  - 7 m^3 of concrete.
- Trial 5
  - slab in a car park
  - 16 m^3 of semi-dry concrete
- Trial 6
  - access road
  - stabilised 72 m^3 of soil and placed 6m^3 of a semi-dry paste (grout) as a road base

Lab testing for Trials 1-3

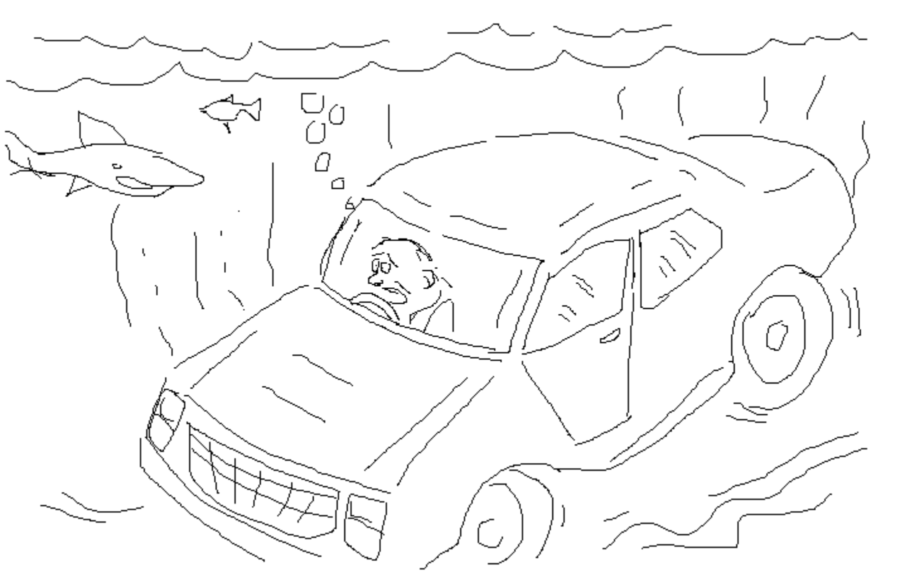


Secondary materials in the mixes

Constructing Trials 1-3

Leachate Monitoring

Site conditions at Risley



Trial 4 – Gypsum/slag Trench Trial

Placing Trial 4. Waste gypsum and steel slag (no cement)

Where we want to put the gypsum/slag blend (10 M m^3)

The "Coventry Blend"

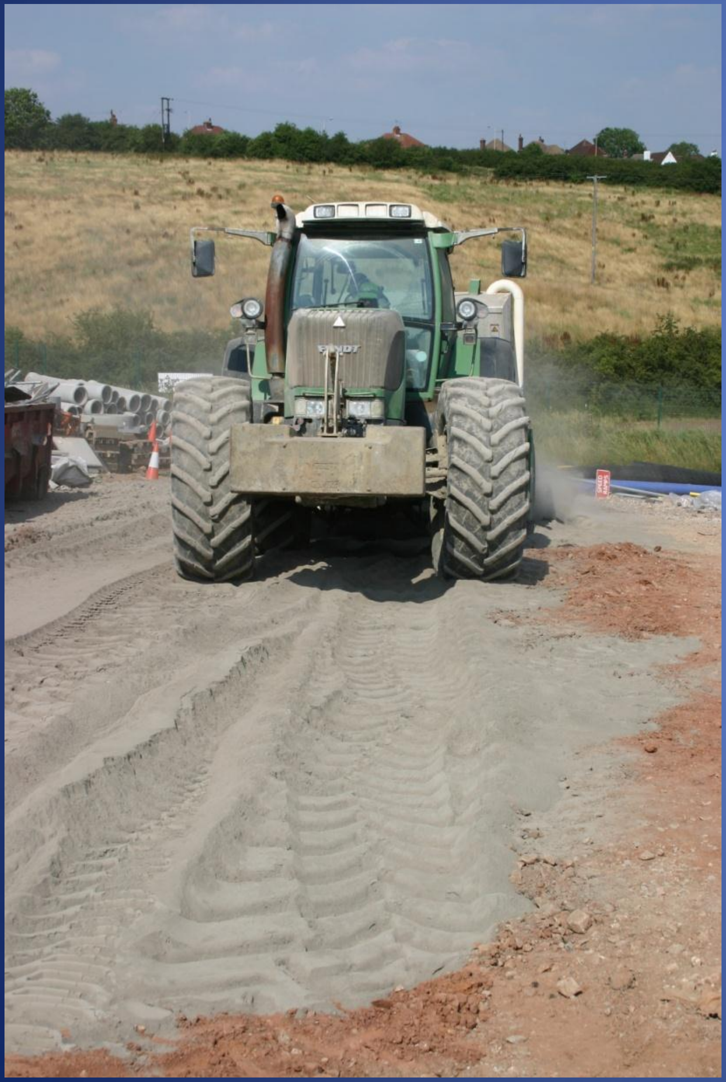
- Basic oxygen slag from steel manufacture (80%)
- Waste plasterboard (15%)
- Kiln by-pass dust from cement manufacture.(5%)

100 Tonnes of this blend were made for trials 5 and 6

This blend is not recommended for partial replacement of cement – it is for use without cement

Trial 5
Car Park

Trial 6 Haul Road – Soil Stabilisation



Trial 6
Semi-Dry
Paste/grout

Conclusions From The Site Trials

- While it is possible to demonstrate the viability of cementitious mixtures which are sustainable there are many difficulties which may prevent their industrial use. These include:
  - Environmental concerns which may or may not have any scientific basis
  - Insurance problems
  - Lack of capital investment

The environmental questions

- Is it worth accepting a minor risk of pollution in order to save significant amounts of CO_2 by using as much ash as possible?
- Should CO_2 savings be a given a high priority by the regulators?

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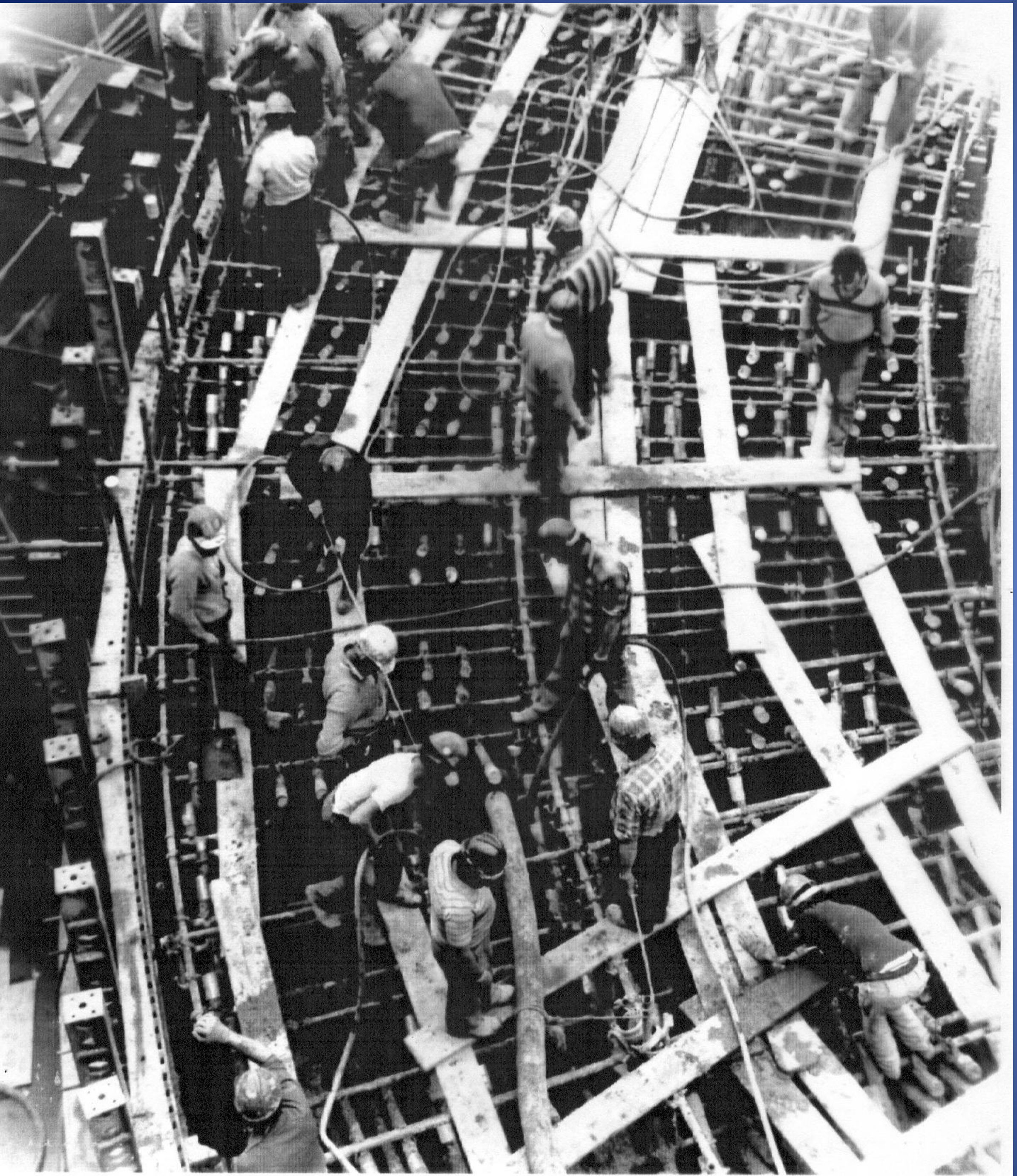
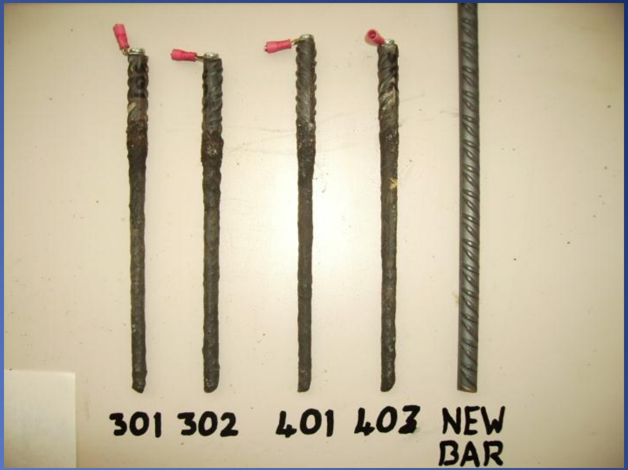


Structural concrete has steel reinforcement in it

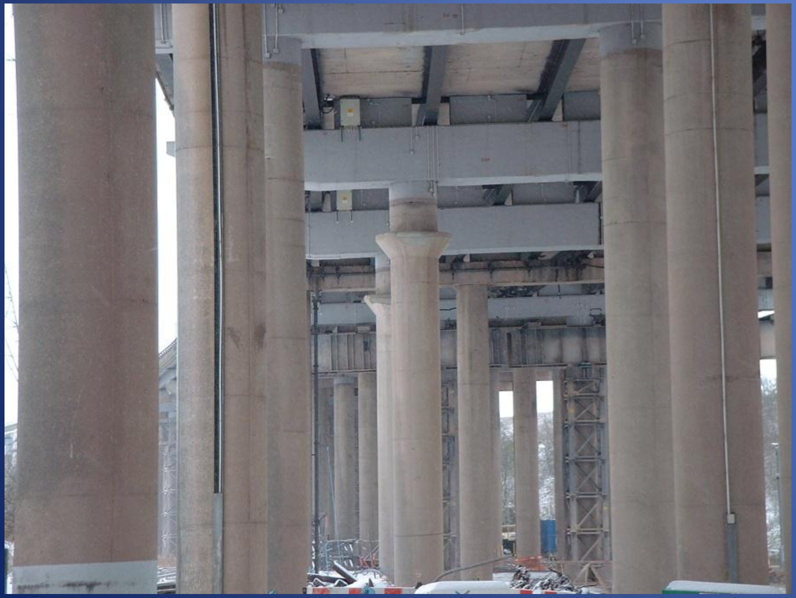
Reactor 1 lift 4 15/9/81

Salt causes corrosion

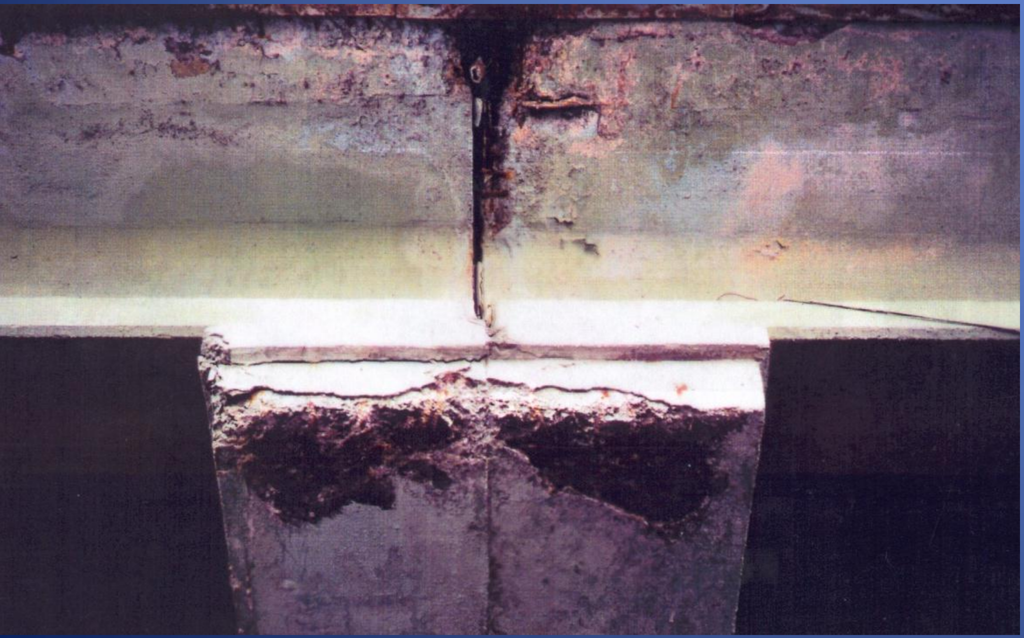


John Laing building Richard Crossman building

M6 Viaducts



Moscow



Egypt

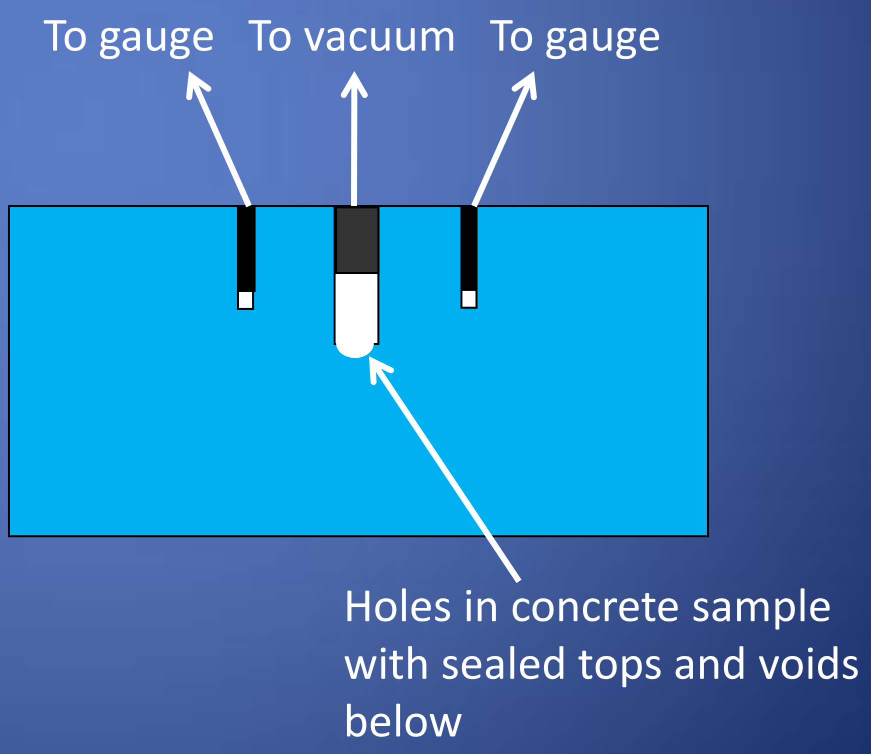
The Problem –
How to make sure concrete is durable

- It is possible to make durable concrete.
- It is also very easy to make non-durable concrete e.g. by adding too much water.
- The problem is that there is no reliable test to find out if it is durable.
- For the last 100 years concrete on most sites has only been tested for strength.

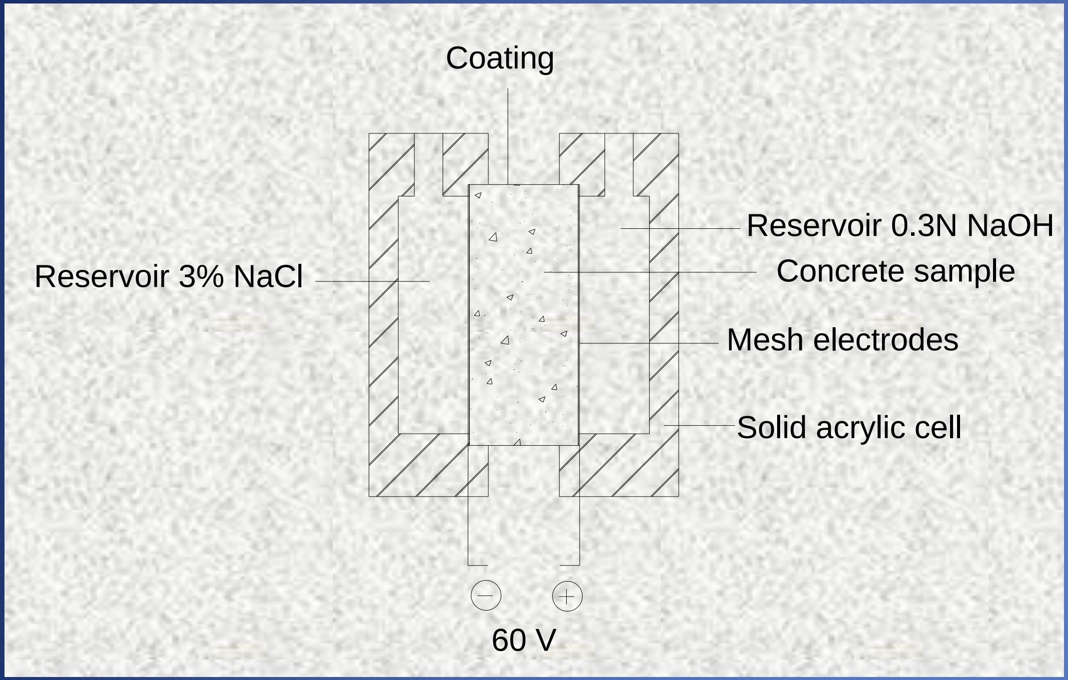
Two types of test to measure durability

- To reach the steel the salt must move through the concrete.
- Most durability tests measure how easily salt (and other compounds) can move through it.

- Gas/water permeability tests
  - Apply a vacuum to the centre hole and monitor the pressure in the side holes
- Electrical tests

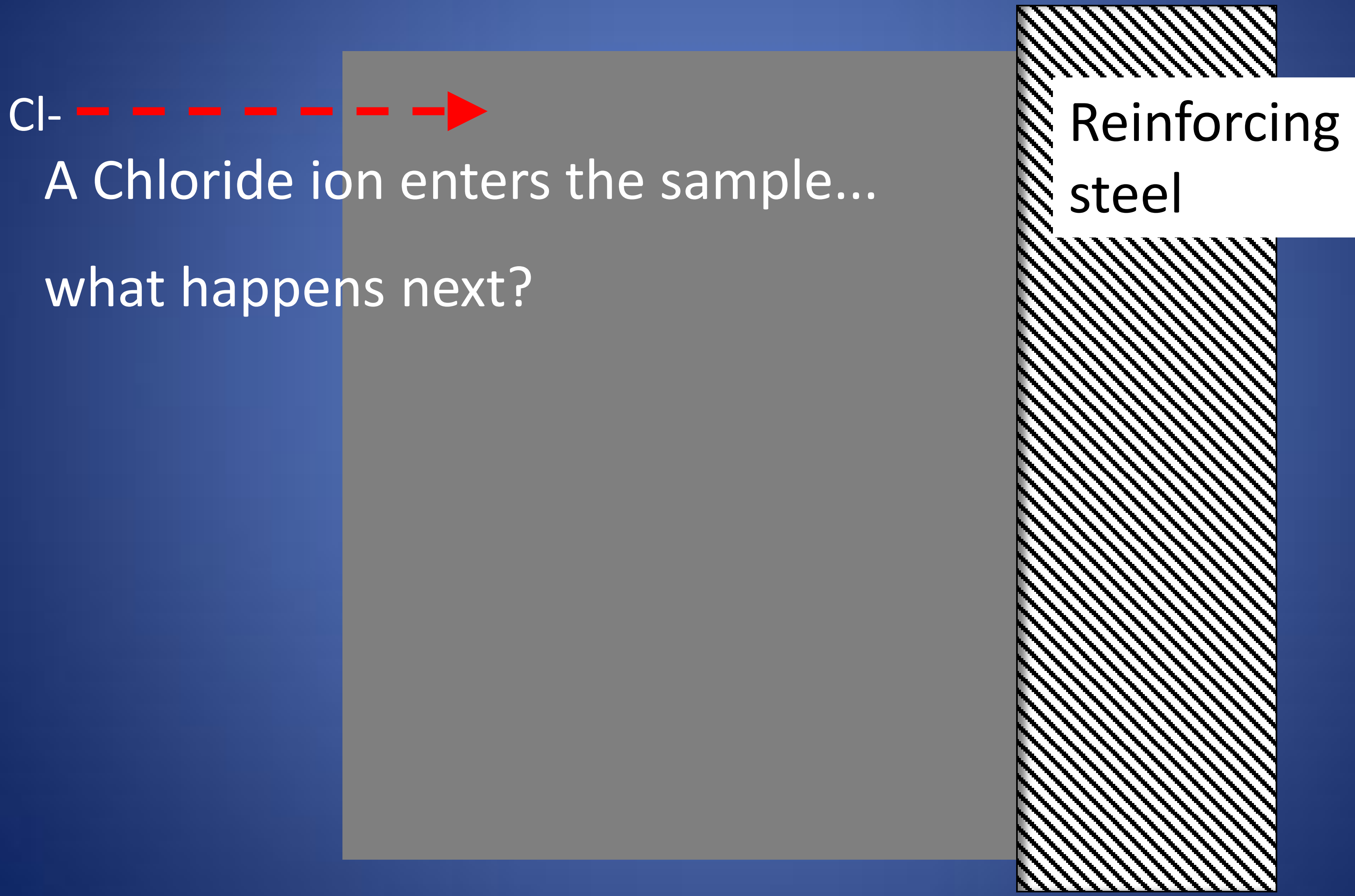


ASTM C1202: Rapid Chloride Penetration Test
The most popular durability test in current use



- The test works by measuring the current through the sample
- Can be fooled by reducing the current with highly resistive mixes which are not particularly resistant to salt penetration

The Progress of a Chloride Ion



A Chloride ion enters the sample...

what happens next?

Does it carry on moving?
To find out…
Apply the Nernst-Plank equation

(Derived in the late 19th century)

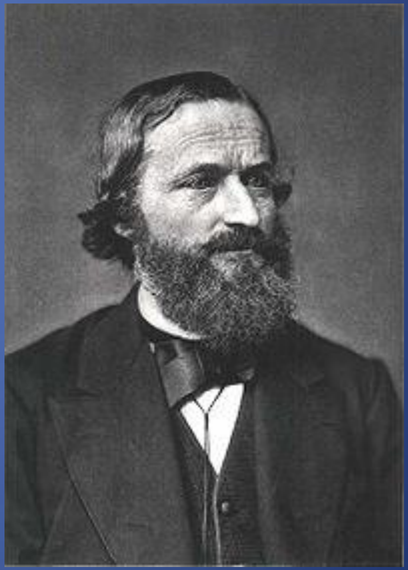
$$J_i = D_i \frac{\partial c_i}{\partial x} + \frac{z_i F}{RT} D_i c_i \frac{\partial E}{\partial x}$$

The integrated version
(we use it to check the computer model)

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

Kirchoff’s law
(current in = current out)
Can stop it moving

Kirchhoff formulated his circuit laws, which are now ubiquitous in electrical engineering, in 1845, while still a student.



The Progress of a Chloride Ion

Cl^-

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

Cl^- OH^-

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

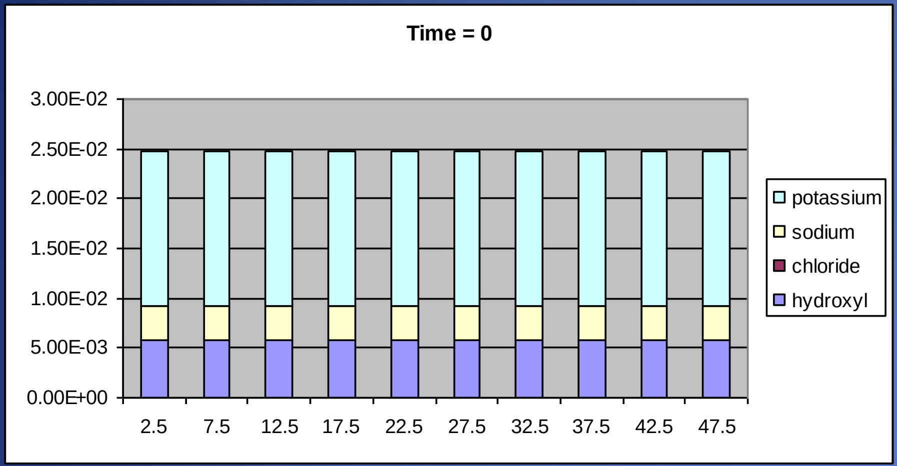
Cl^-

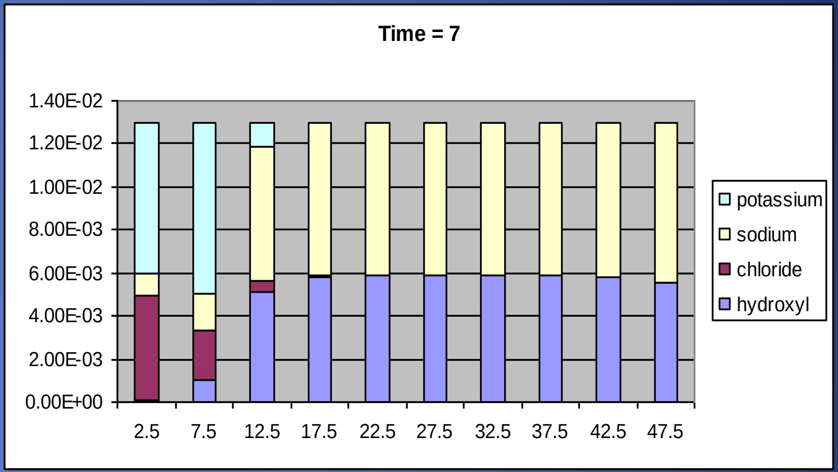
Na^+

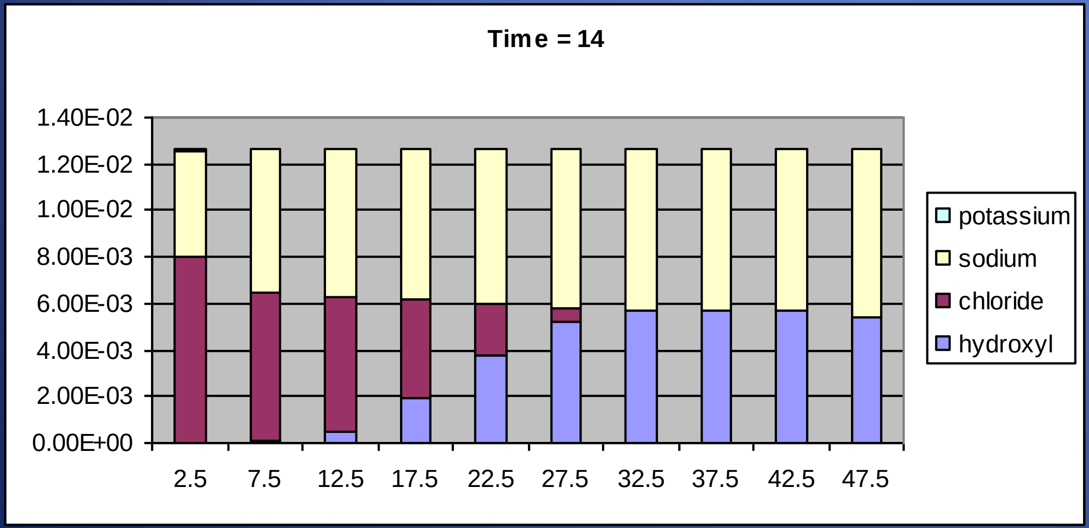
Or it has to bring a positive sodium ion with it

Reinforcing steel

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

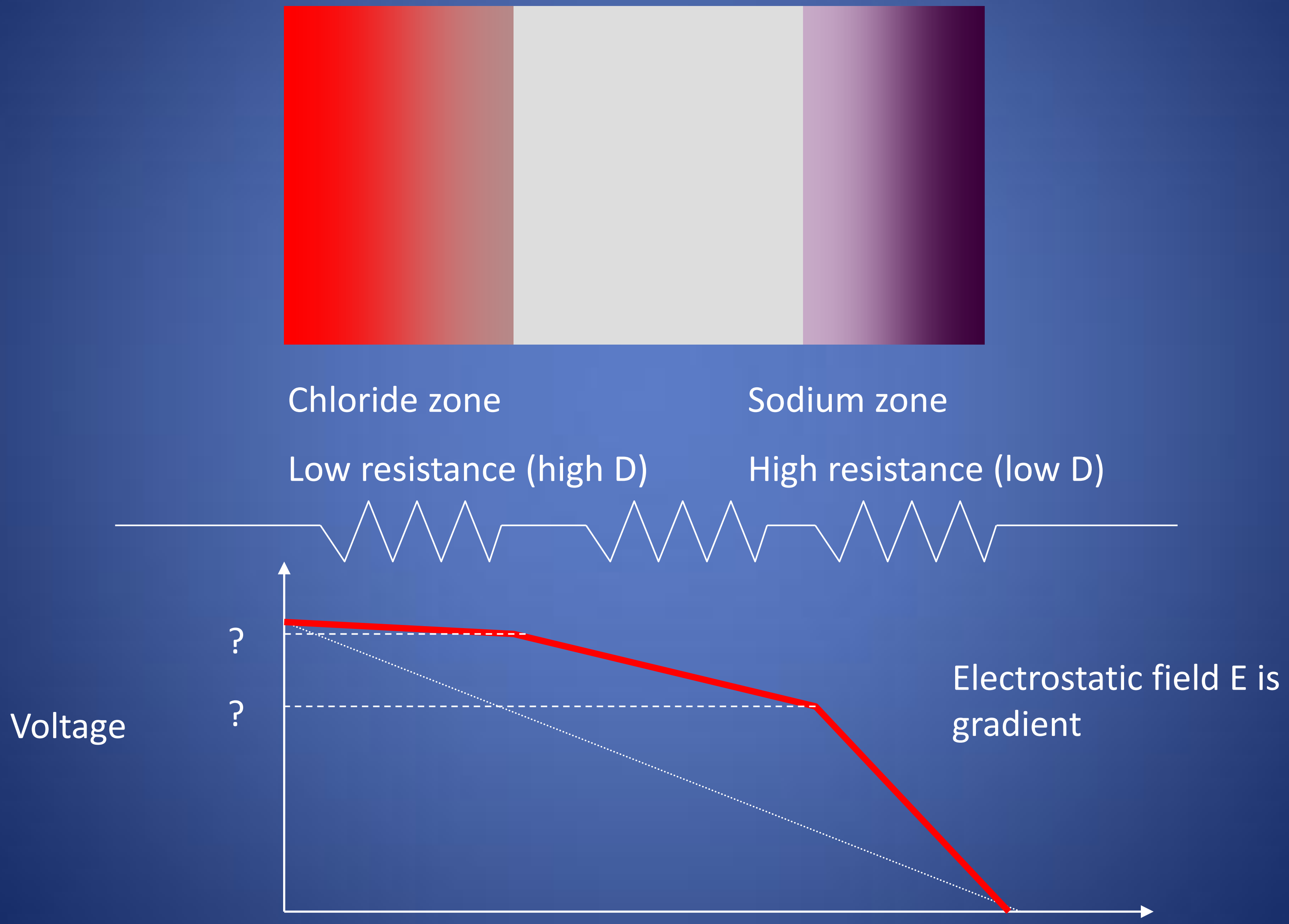




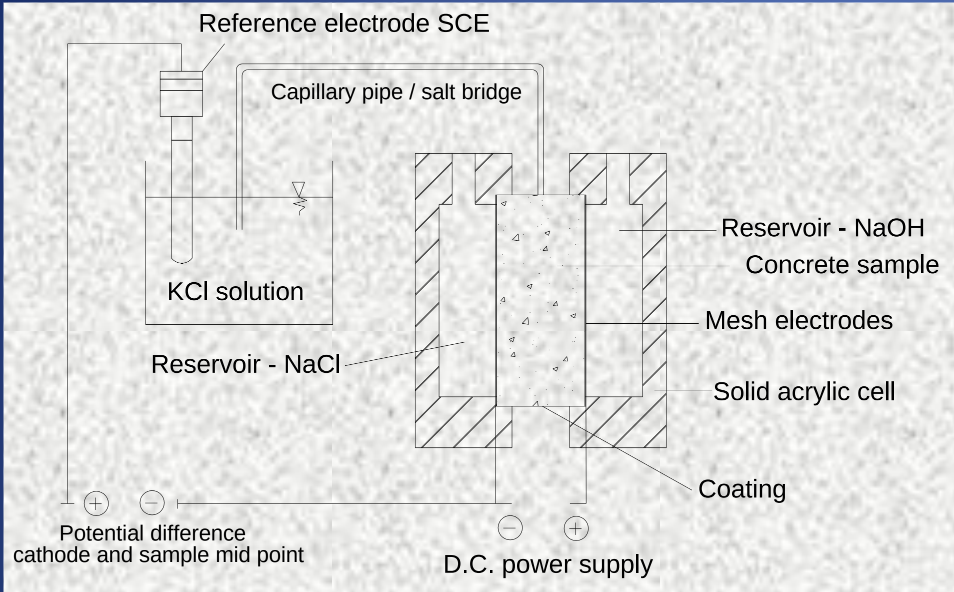


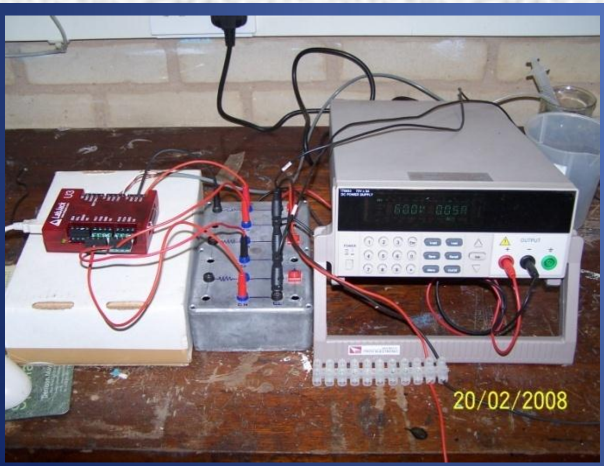
Graphs obtained with model written in Visual Basic

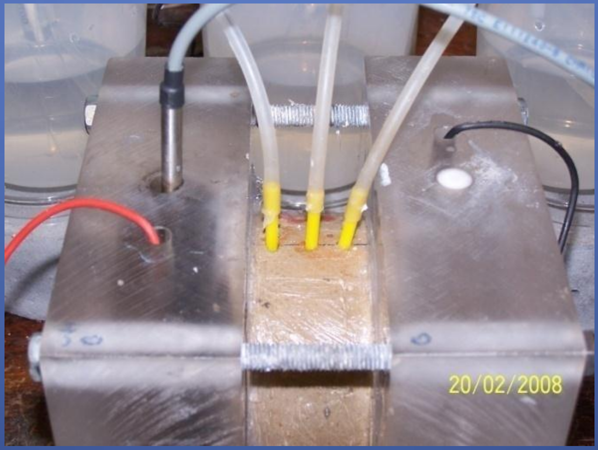
Section through sample during test

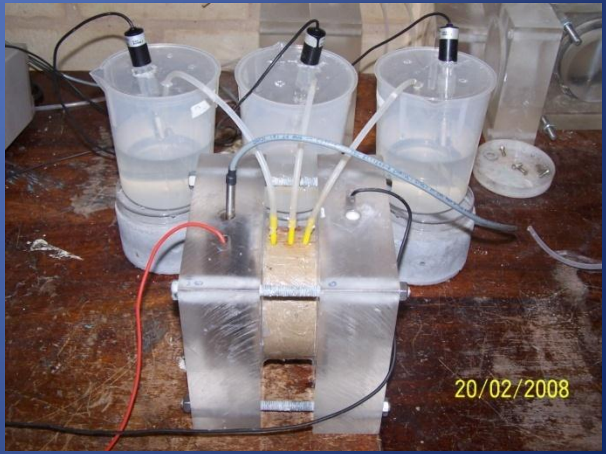


The new test – our computer model is needed to get an answer from it.

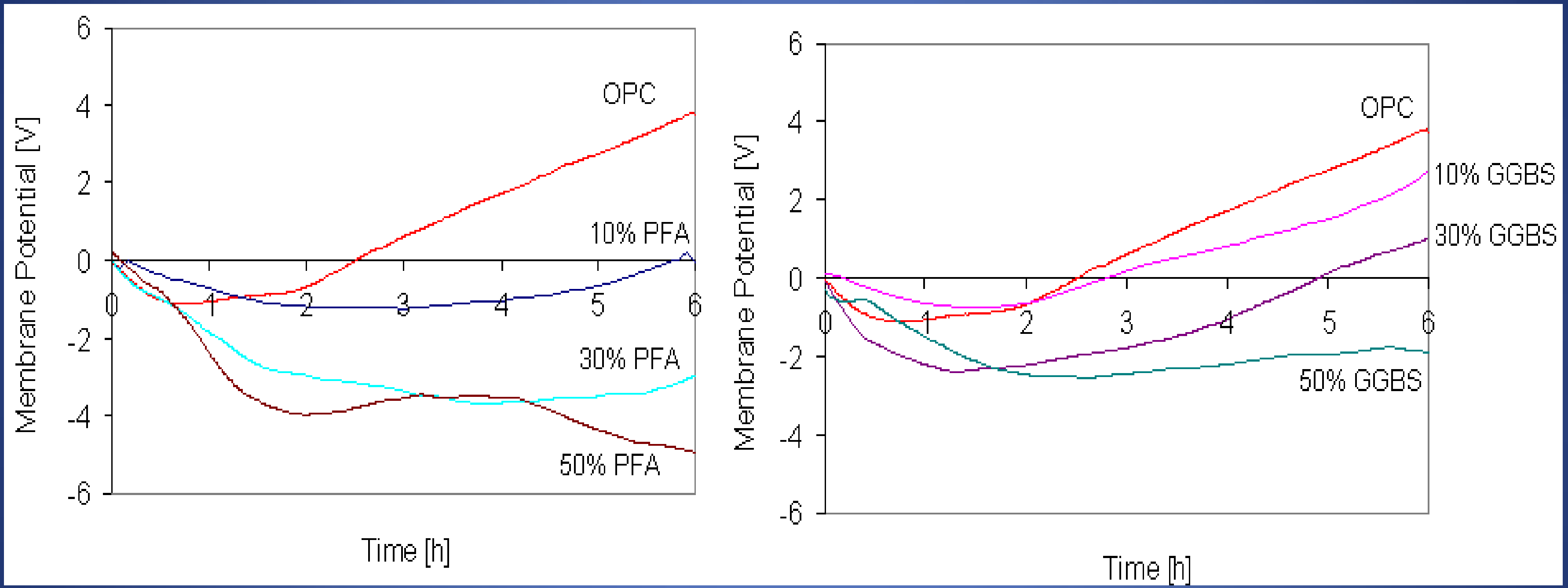








Using the mid-point voltage to identify cement replacements



The requirements of a new test

- Easy to use to predict the service life of structures.
- Difficult to confuse.
- Reliable for all types of concrete.

Conclusions

- If we are going to solve the environmental problems the regulators must focus on the real issues.
- If we are going to solve the durability problem we need a reliable and simple test to measure it.

Thank you

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Coventry University and The University of Wisconsin Milwaukee

Second International Conference on

Sustainable Construction Materials and Technologies

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