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McFarland Associates Limited

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duratiNET
The Queen's University of Belfast
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Carbonation, Chlorides & Electrochemical Repair

- Carbonation
- Chloride Attack
- Inspection & Testing
- Traditional Repair
- Electrochemical Repair
- Case Histories

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Millions of pounds are spent every year dealing with the symptoms of corrosion

Expense

Disruption

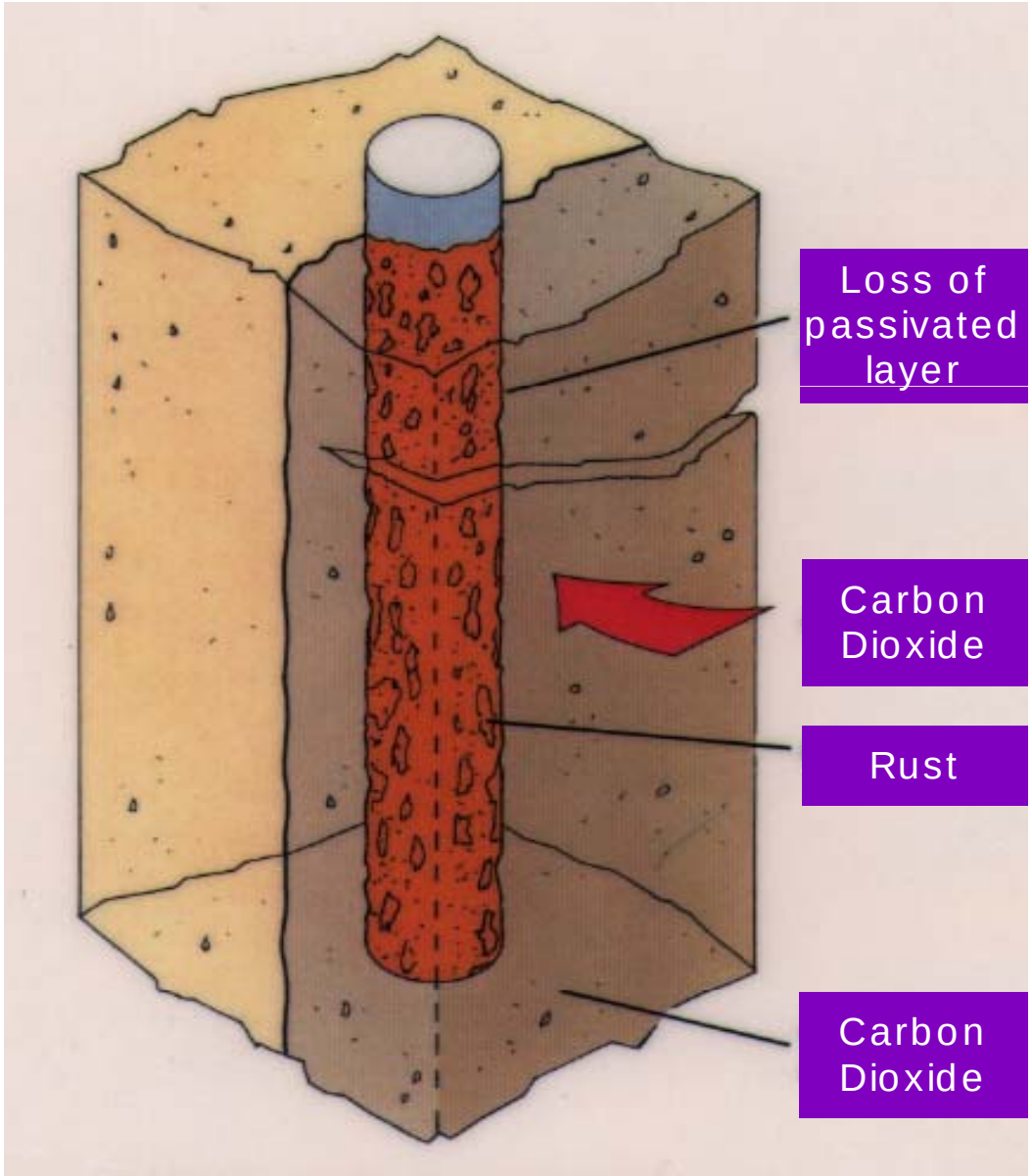
Danger

The Cause of the Problem

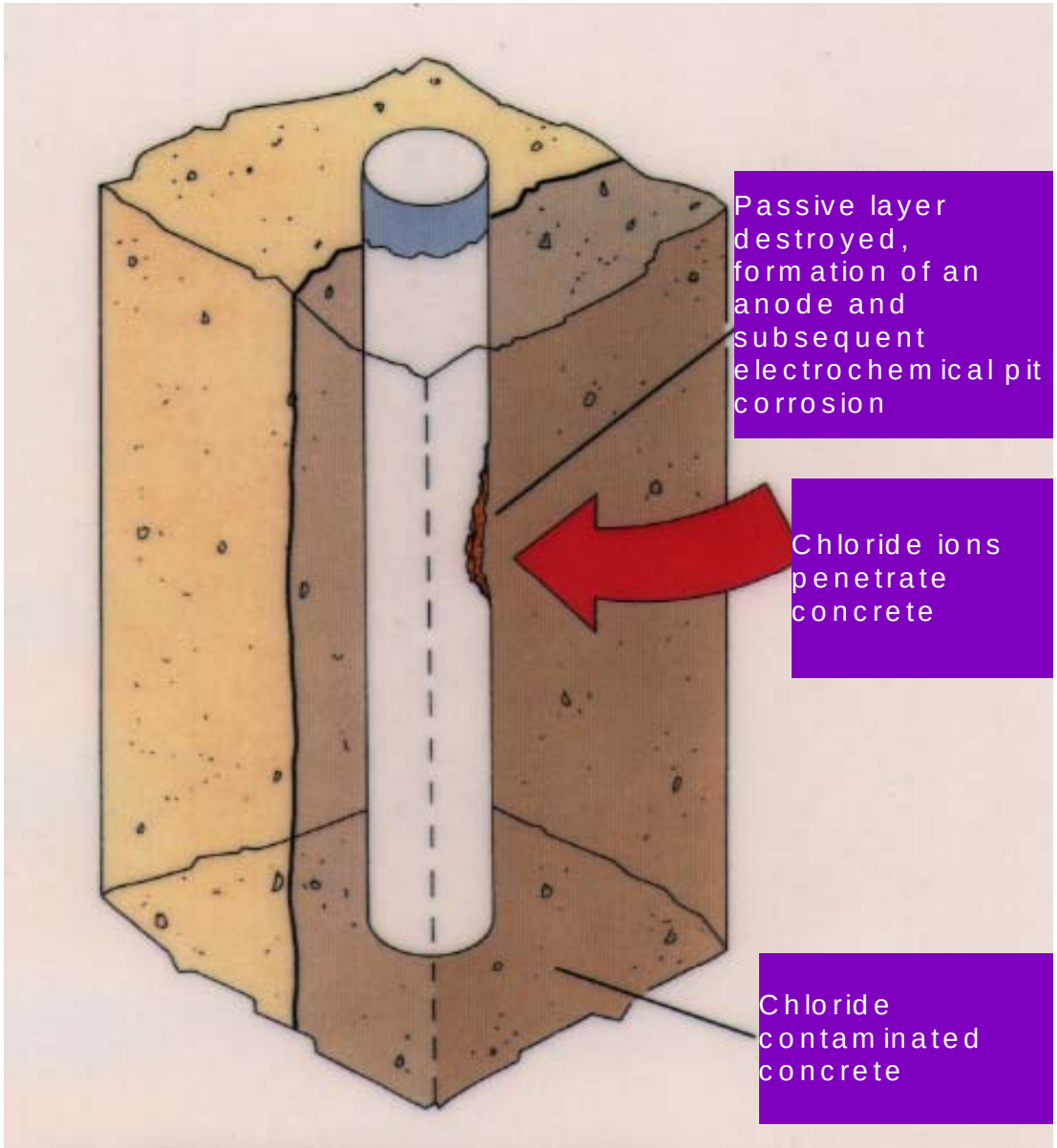
Poor design
Carbonation
ASR
Sulphate attack
Impact damage
Chemical attack

Chloride attack
Freeze thaw
Low cover
Poor site practice
Erosion

Carbonation



Chloride attack



Chloride induced corrosion pits

Inspection & Testing

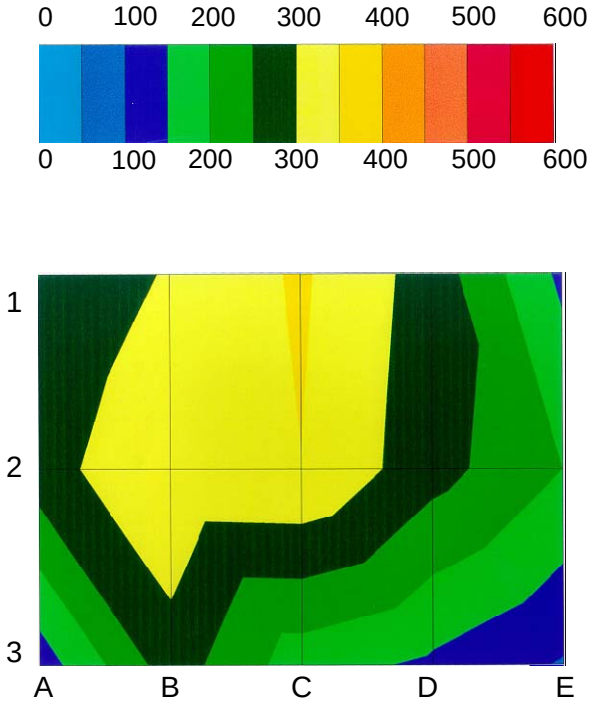
Chloride threshold values

Chloride content (% cement)	Risk of corrosion
< 0.4	Negligible
0.4 – 1.0	Possible
1.0 – 2.0	Probable
> 2.0	Certain

Ref: Browne (1982)

Half cell potential threshold values

CSE	Corrosion Condition
> -200 mV	Low – 10% risk of corrosion
-200 to –350 mV	Intermediate corrosion risk
< -350 mV	High - <90% risk of corrosion
< -500 mV	Severe corrosion



Traditional repair methods

BUT traditional patch repair alone does not . . . . .

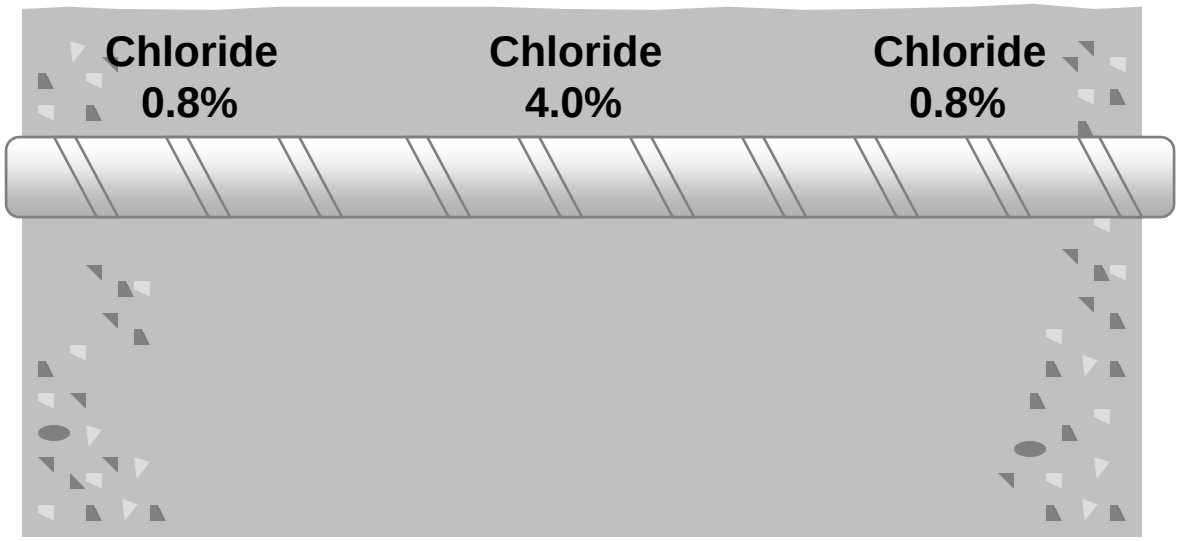
- Stop ongoing corrosion
- Prevent further spalling
- Break the repair cycle

Chasing the corrosion

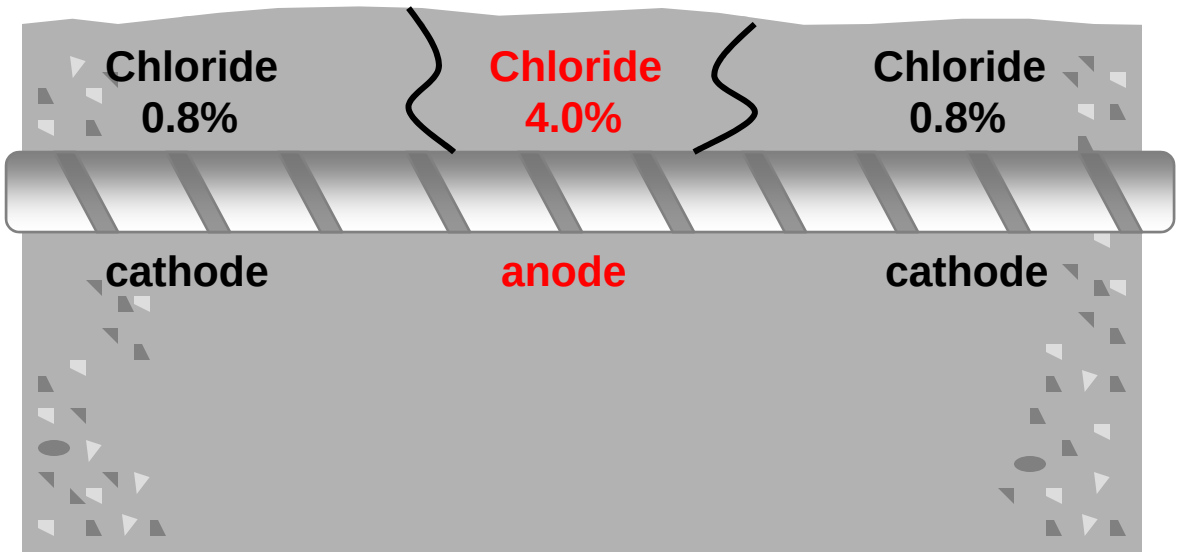
The problem … “the newly established cathodic area within the repair will drive the new anode site in the contaminated region”

How does this mechanism work? ……

Chloride contaminated concrete prior to patch repair



Chloride contaminated concrete prior to patch repair



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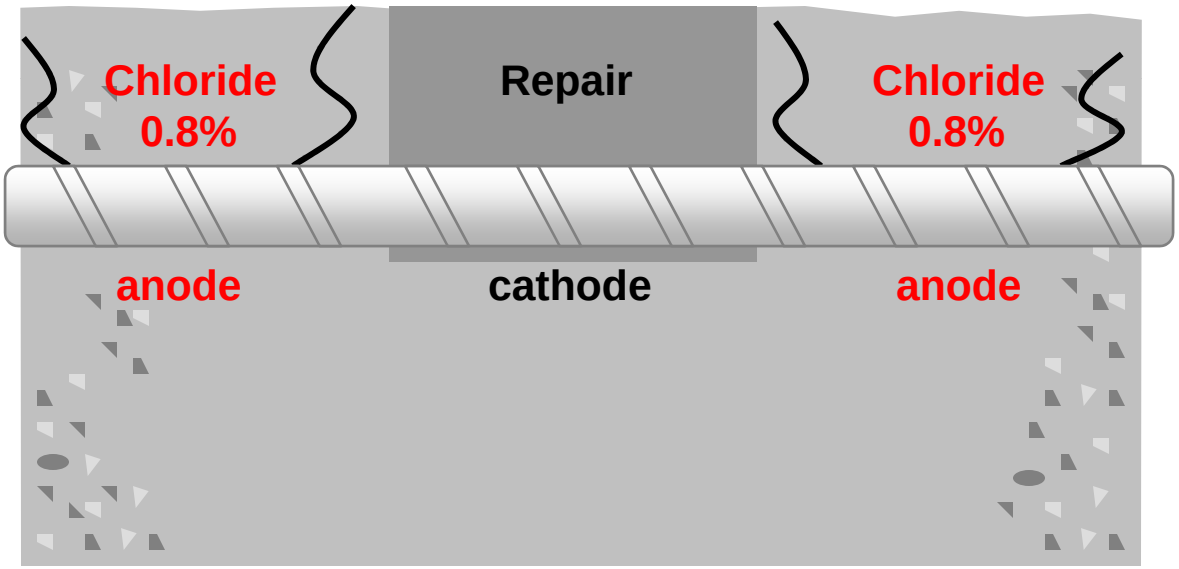
incipient anode effect



Downsides of Traditional Repair

Break out all contaminated concrete

Noisy

Expensive

Dusty

Disruptive

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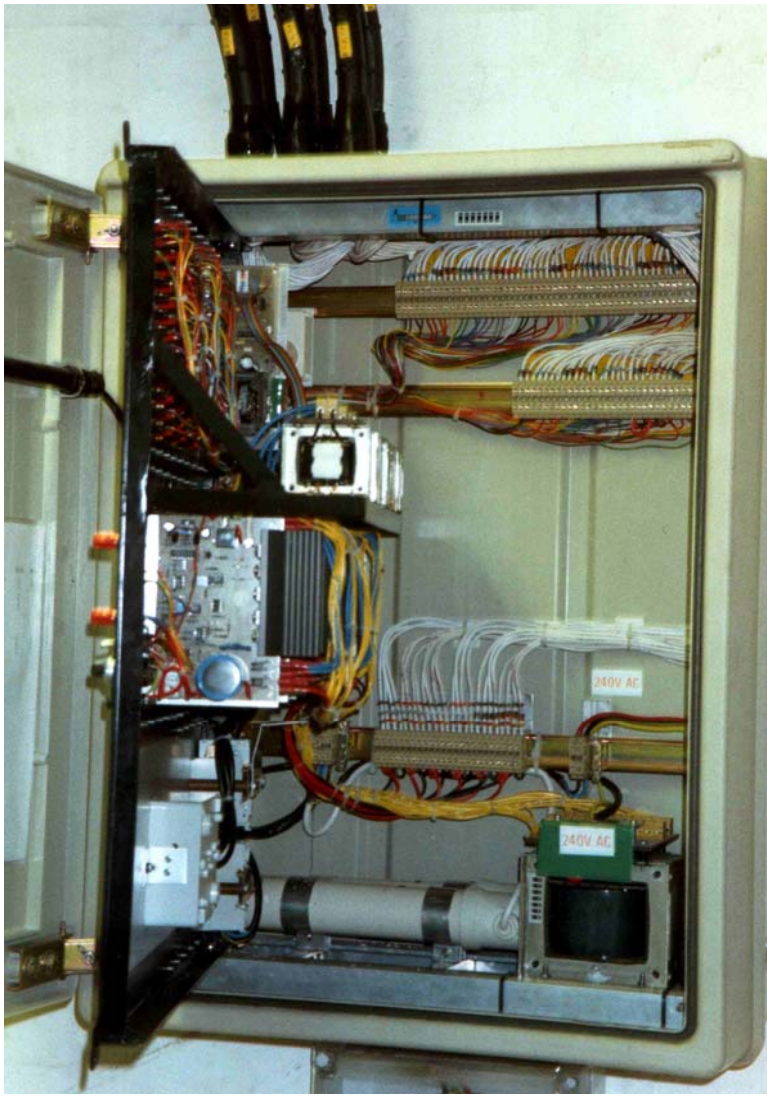
Electrochemical Repair

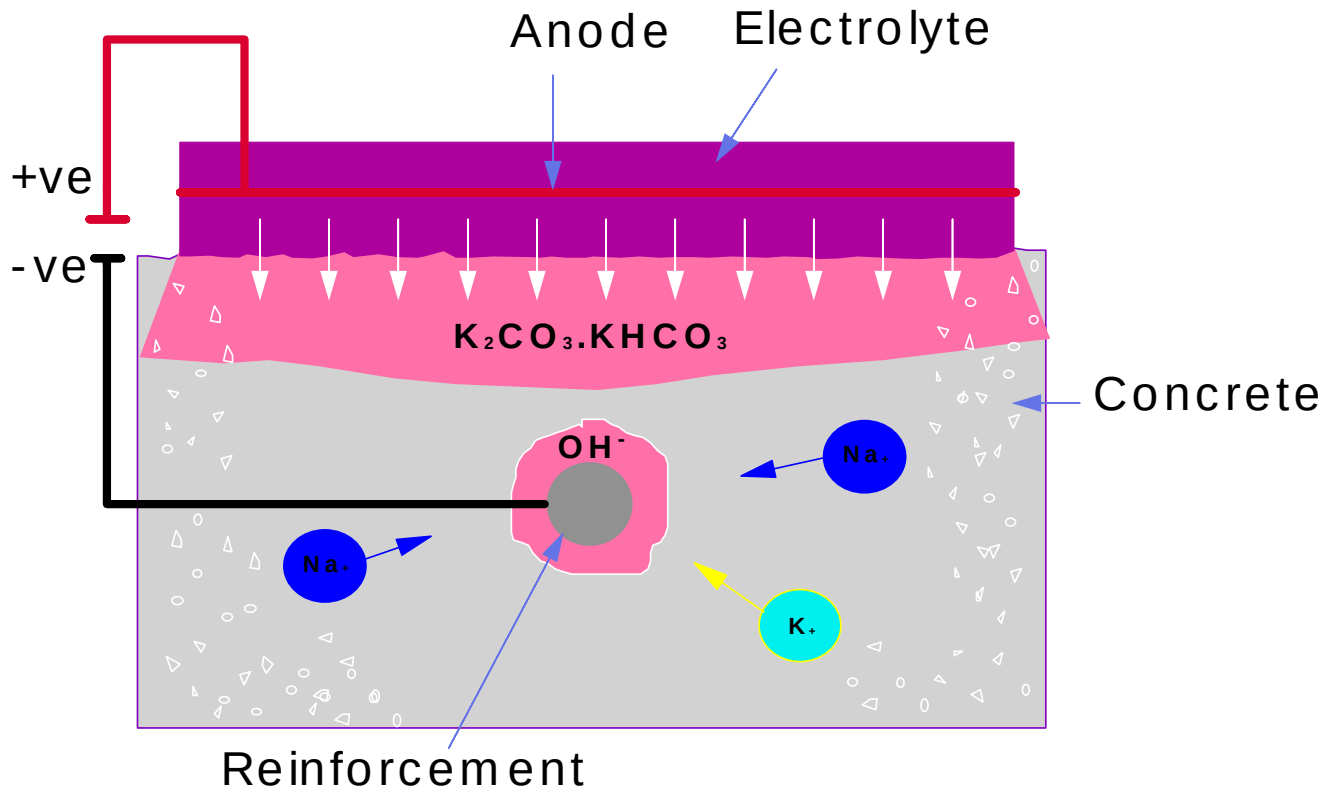
“Fighting Fire with Fire”

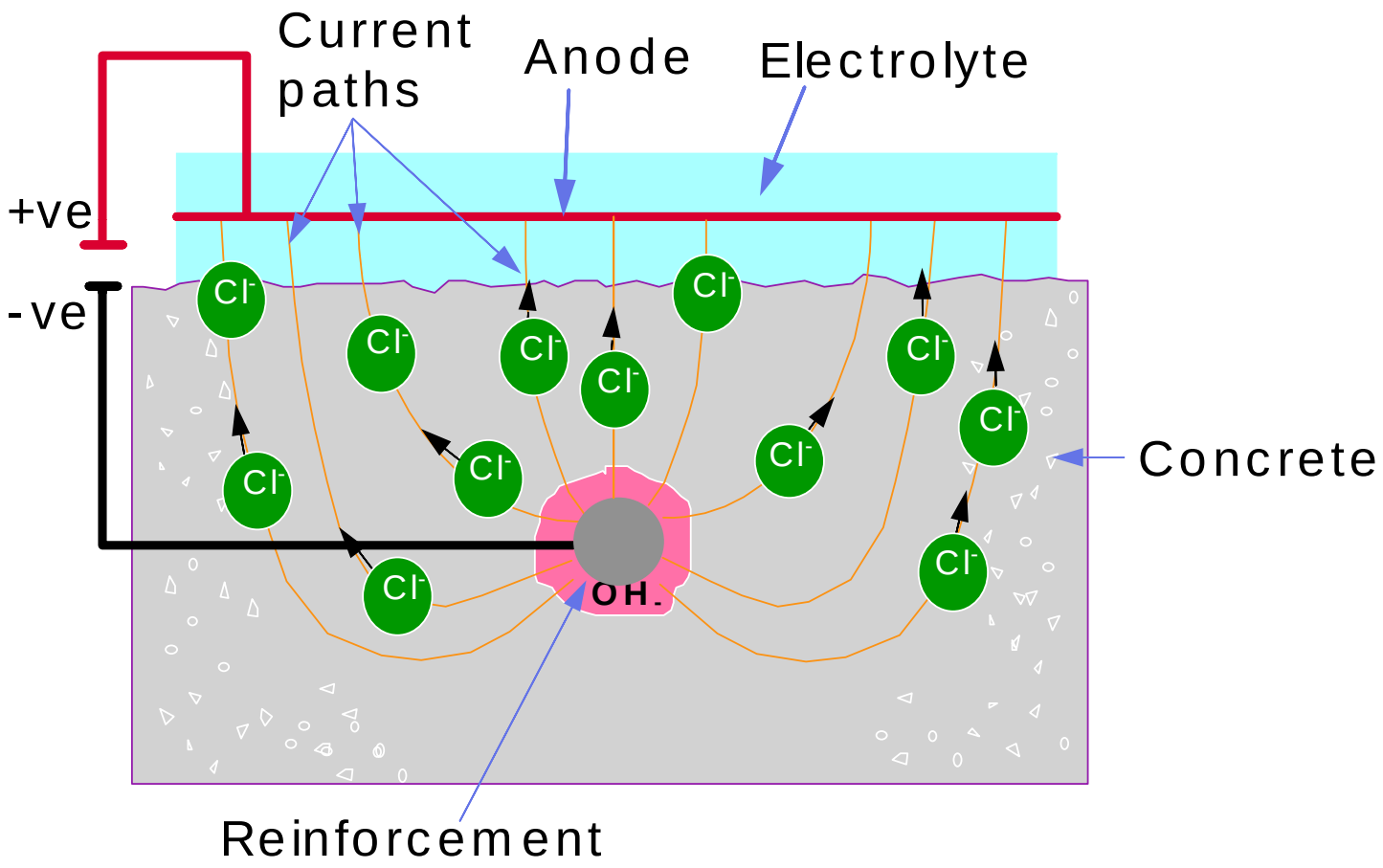
- **Cathodic Protection**
- **Realkalisation**
- **Chloride Extraction**
- **Sacrificial Anodes**
- **Next Generation Hybrid Systems**

Cathodic Protection



Realkalisation




Current paths
Anode
Electrolyte
+ve
-ve
Cl-
Concrete
OH-
Reinforcement

Hydroxide Precipitation

Proc. 7th Int. Conf. Concrete in Hot and Aggressive Environments, Vol. 2, p.477, 2003

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XP

for patch repairs

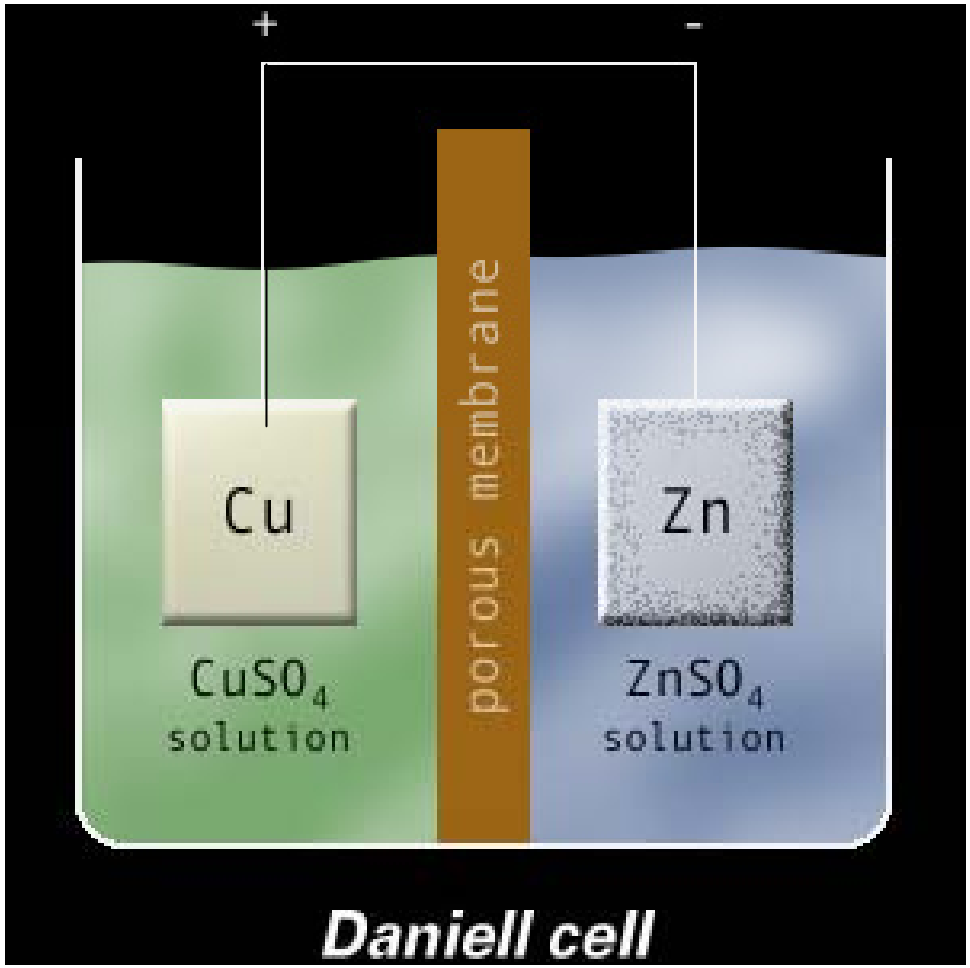
CC

for blanket protection

LJ

for jetty piles

All the Galvashield systems work on the same principle ...



Oil Rig Example

Hybrid Systems

- Chloride extraction type process
- Cathodic prevention type process (low maintenance)
- Single electrode system

Hybrid Application

- Install discrete alloy electrodes
- Apply specialised electrochemical treatment for 1 week
- Connect activated sacrificial anode to steel

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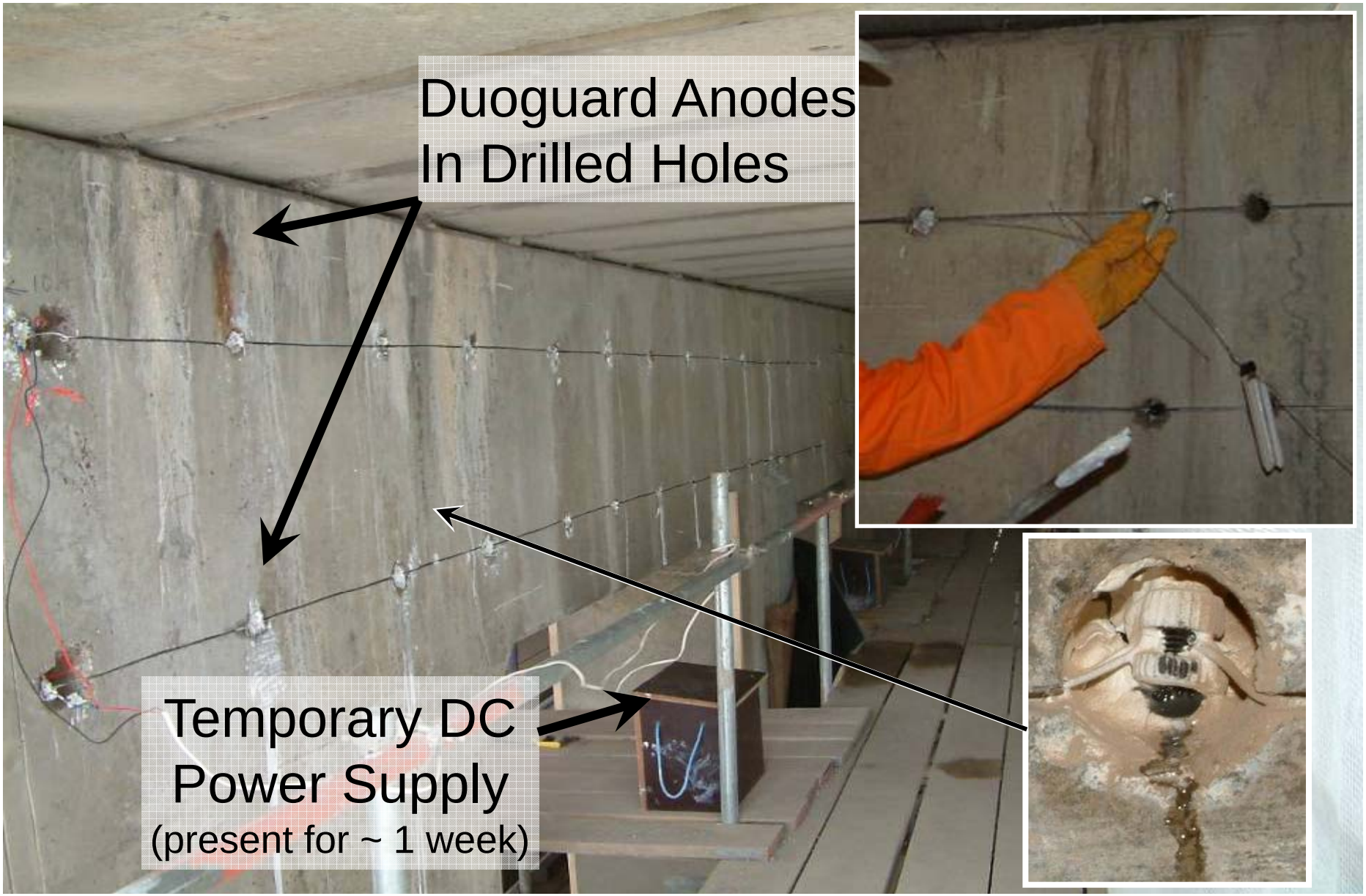
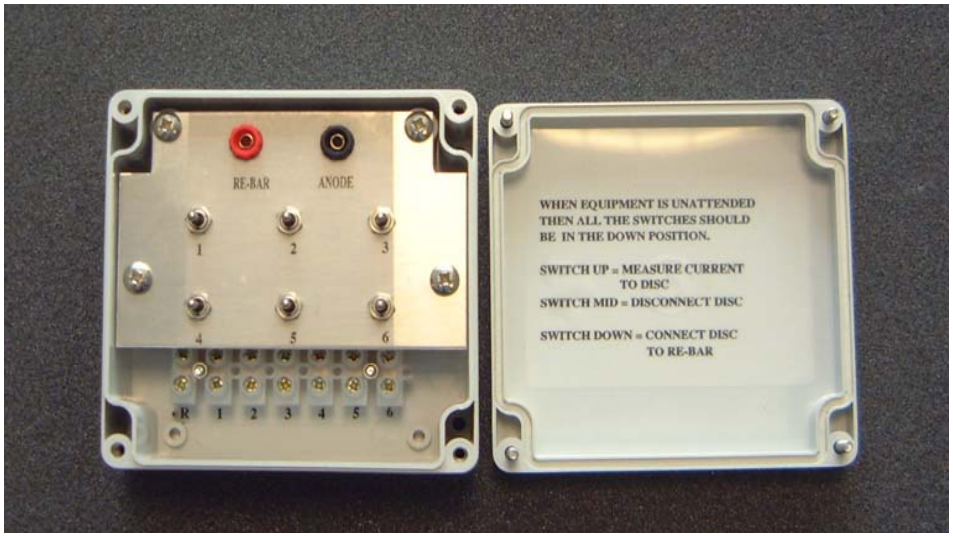


Monitoring options



Manual monitoring box

Measure …….

Current ↙

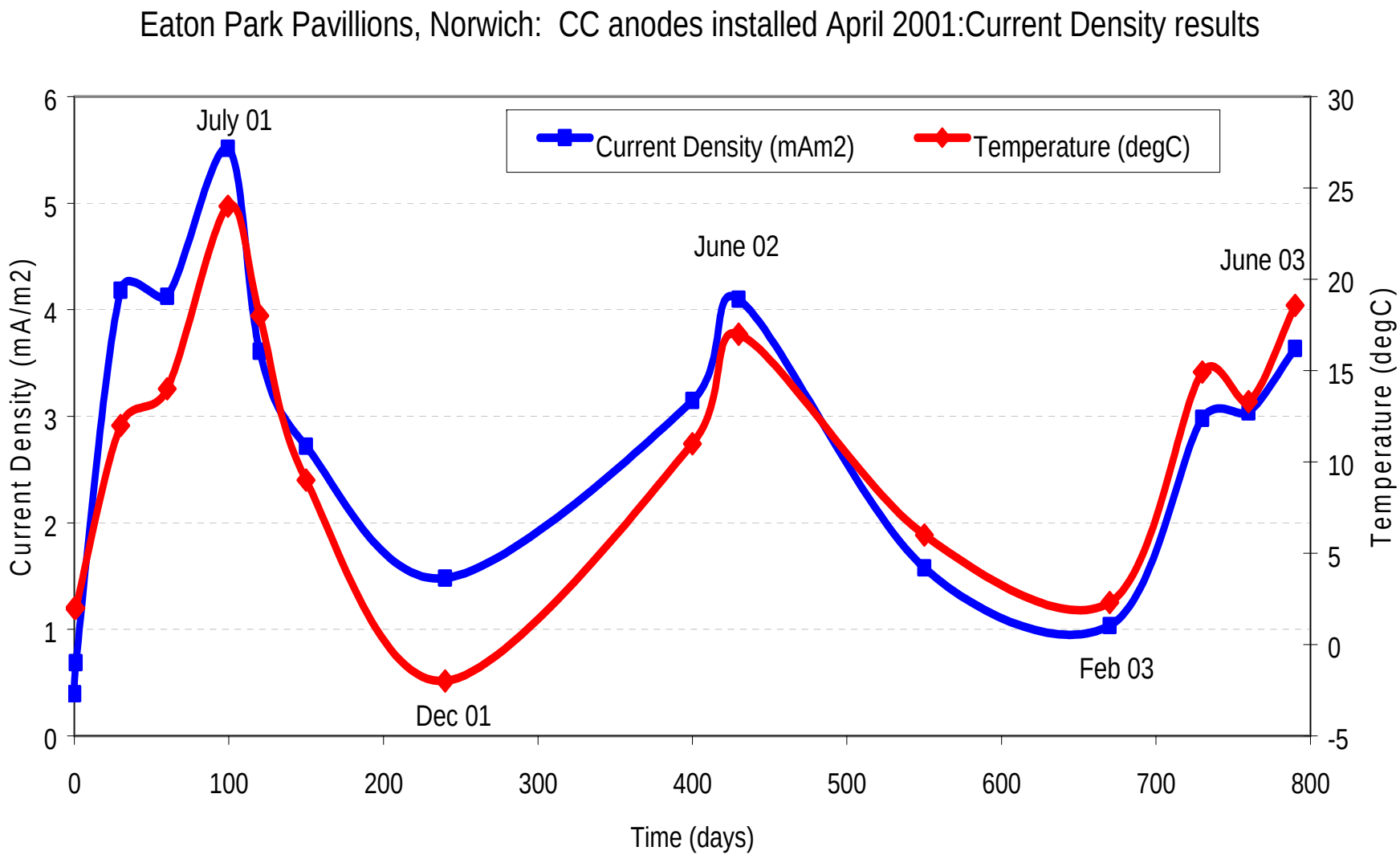
Temperature ↙

Steel potential ↙

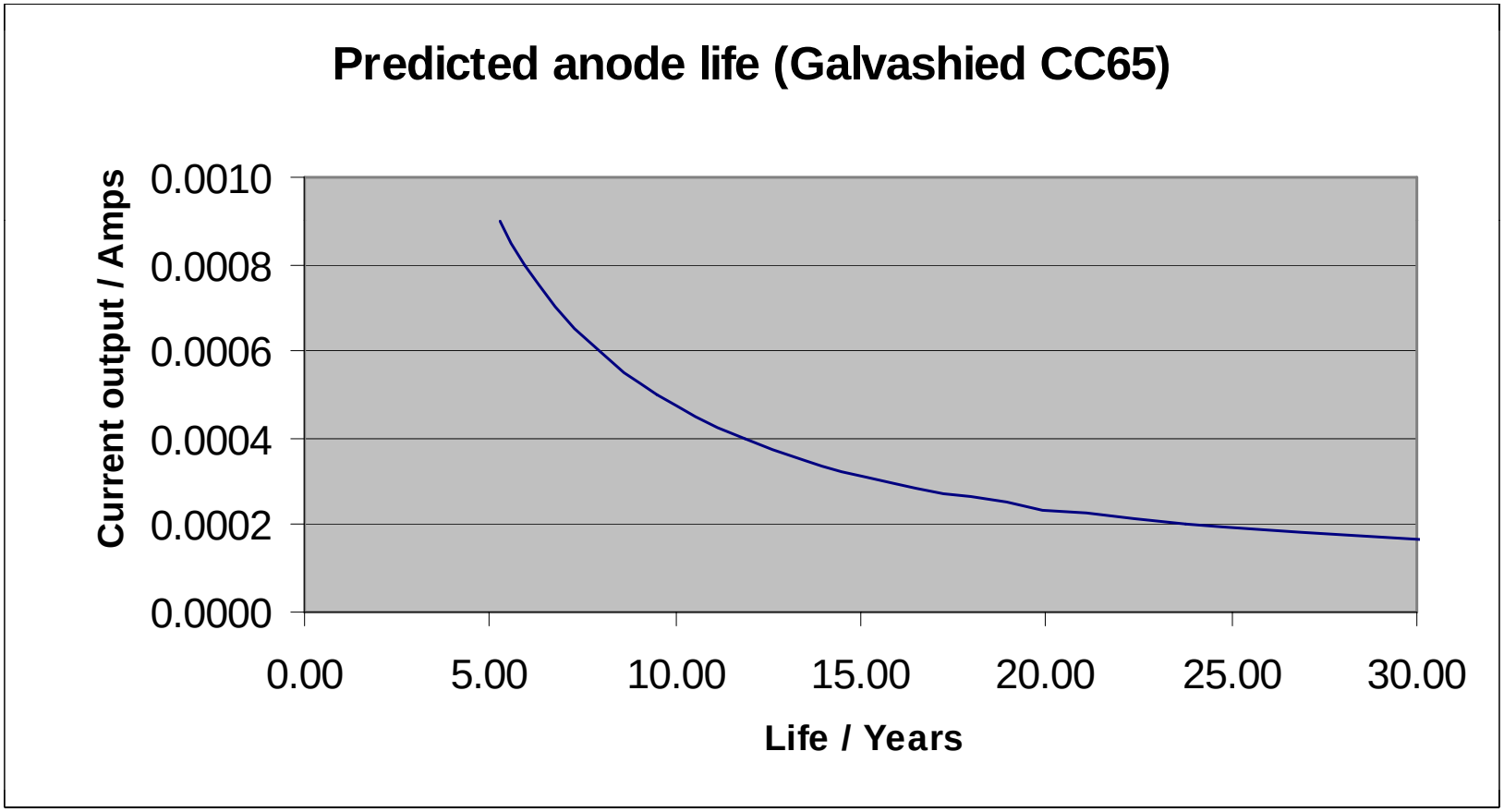
Residual life ↙

Automated monitoring box

Current output can be easily monitored



Residual life can be calculated



Comber Bridge

Comber Bridge

Comber Bridge


McDAID


WIN

Eglinton Church

Red Arch Bridge

Red Arch Bridge

Red Arch Bridge

Ballylumford Jetty

Beatties Bridge

Conclusions

- **Carbonation & Chloride Attack are the main problems encountered**
- **Traditional Repair alone rarely deals with the source of the problem**
- **Electrochemical Repair treats “Fire with Fire” and deals with the source of the problem – reinforcement corrosion**
- **Realkalisation & Chloride Extraction are time consuming and costly**
- **Cathodic Protection requires a power source and monitoring and is prone to breaking down, vandalism and failure of the anodes**
- **Sacrificial Anodes are passive**
- **Hybrid Solutions maximise the benefits of CP, CE and SAs without the downsides**