Sustainable Asset Management and Maintenance of Infrastructure

An Innovative Approach

Marine & Civil Maintenance

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ASSOCIATION OF PACIFIC PORTS

Presentation Outline:

- About MCM and Sustainable Remediation
- MCM GreenTech Shield Technology Profile
    - Background on Electrochemical Protection and Chloride Extraction
    - System Performance/Results
    - Sustainable Designs
    - Towards Net Zero

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MCM Marine & Civil Maintenance

Services

- Condition Assessments
- Design & Construct
- Concrete/Steel/Timber Repairs
- Cathodic Protection
- Structural Strengthening
- Fender & Wharf Furniture
- Underwater/dive works
- Revetment Remediation
- Protective Coatings
- Stonework
- Piling/Pile Splicing

Sustainable Remediation

Sustainability is at the heart of our business.

We aim to recycle and re-use wherever possible, and our dedication to sustainable practices extends beyond our natural alignment with the environment.

Through MCM GreenTech, we deliver sustainable initiatives and innovative products to our clients and the broader community.

MCM GreenTech

Technology profile

MCM GreenTech Shield (GTS)

Australian Patent

Australian Government

IP Australia

CERTIFICATE OF GRANT

STANDARD PATENT

Patent number: 2020277139

The Commissioner of Patents has granted the above patent on 17 March 2022, and certifies that the below particulars have been registered in the Register of Patents.

Name and address of patentee(s):

Marine & Civil Maintenance Pty Ltd of Unit 9, 41-43 Higginbotham Road Gladesville NSW 2111 Australia

Title of invention:

Reusable system for cathodic protection of a steel-reinforced concrete structure

Name of inventor(s):

McGuiness, Blane Patrick; Critchley, Nicholas Edward and Goncalves, Henrique Sica

Term of Patent:

Twenty years from 24 November 2020

Background

Previous research undertaken by our MCM Engineering Manager, Blane McGuiness (as co-author) across several Electrochemical Systems in PNG has demonstrated the ability for systems to operate intermittently with ongoing performance and residual protection of the steel reinforcement when the systems are switched off.

ACA Corrosion & Prevention Conference 2013

"THE EFFECT OF POWER SHORTAGES ON ICCP OF STEEL IN MARINE CONCRETE"

Electrochemical Protection

The simplest electrochemical method of preventing corrosion of a metal component, is to attach another more reactive metal with, for example, a conducting wire. The more susceptible metal, referred to as an anode, will corrode in preference to the component (Galvanic Anode Protection).

Another method involves current being applied to the component to be protected. As you may recall, corrosion requires a flow of electrons from the anode to the cathode. If an external current is applied in the other direction, then the component will be protected (Impressed Current Cathodic Protection, Hybrid CP, Chloride Extraction).

Current State of Play

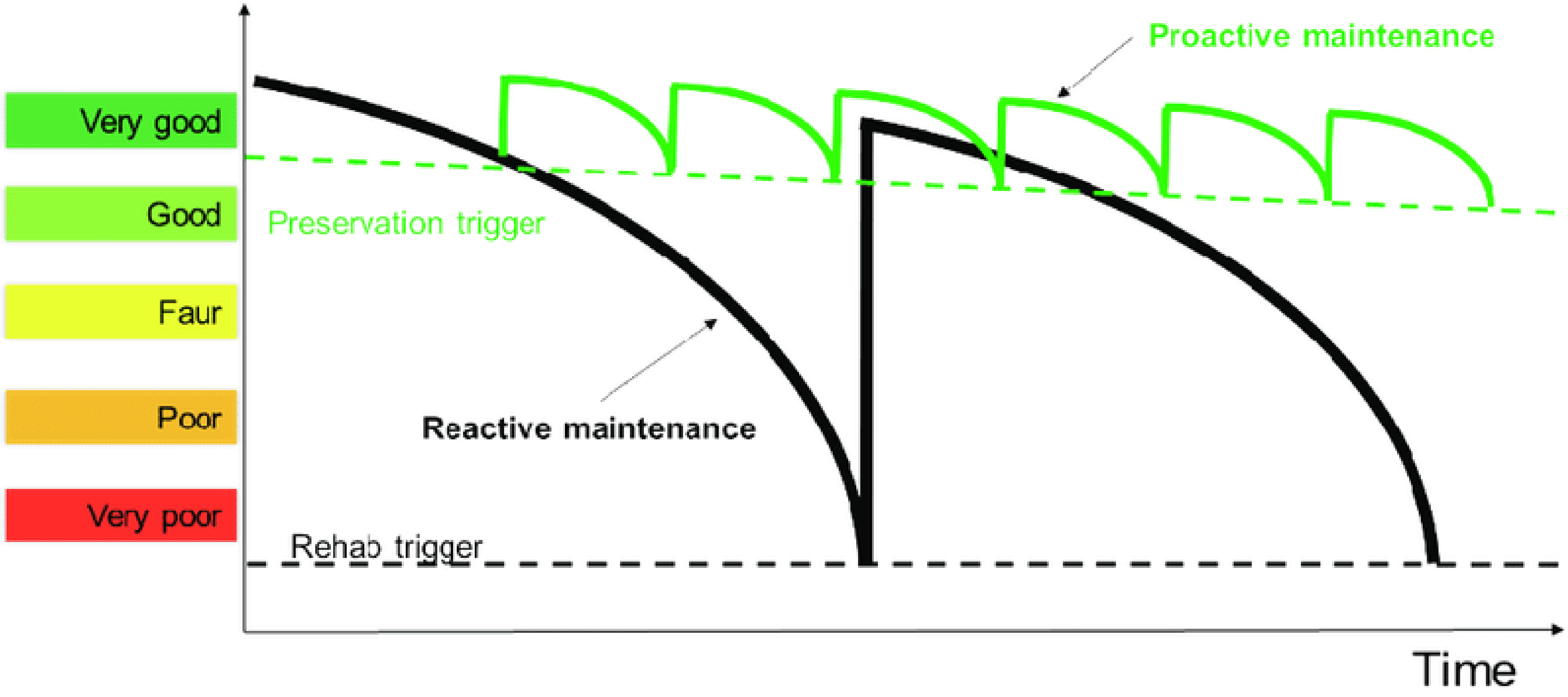
Traditional Remediation Options, following inspections and assessments:

- Cathodic Protection (Impressed, Galvanic, Hybrid)
- Conventional Concrete Repairs
- Protective Coatings
- Continual monitoring and assessment (do nothing approach)

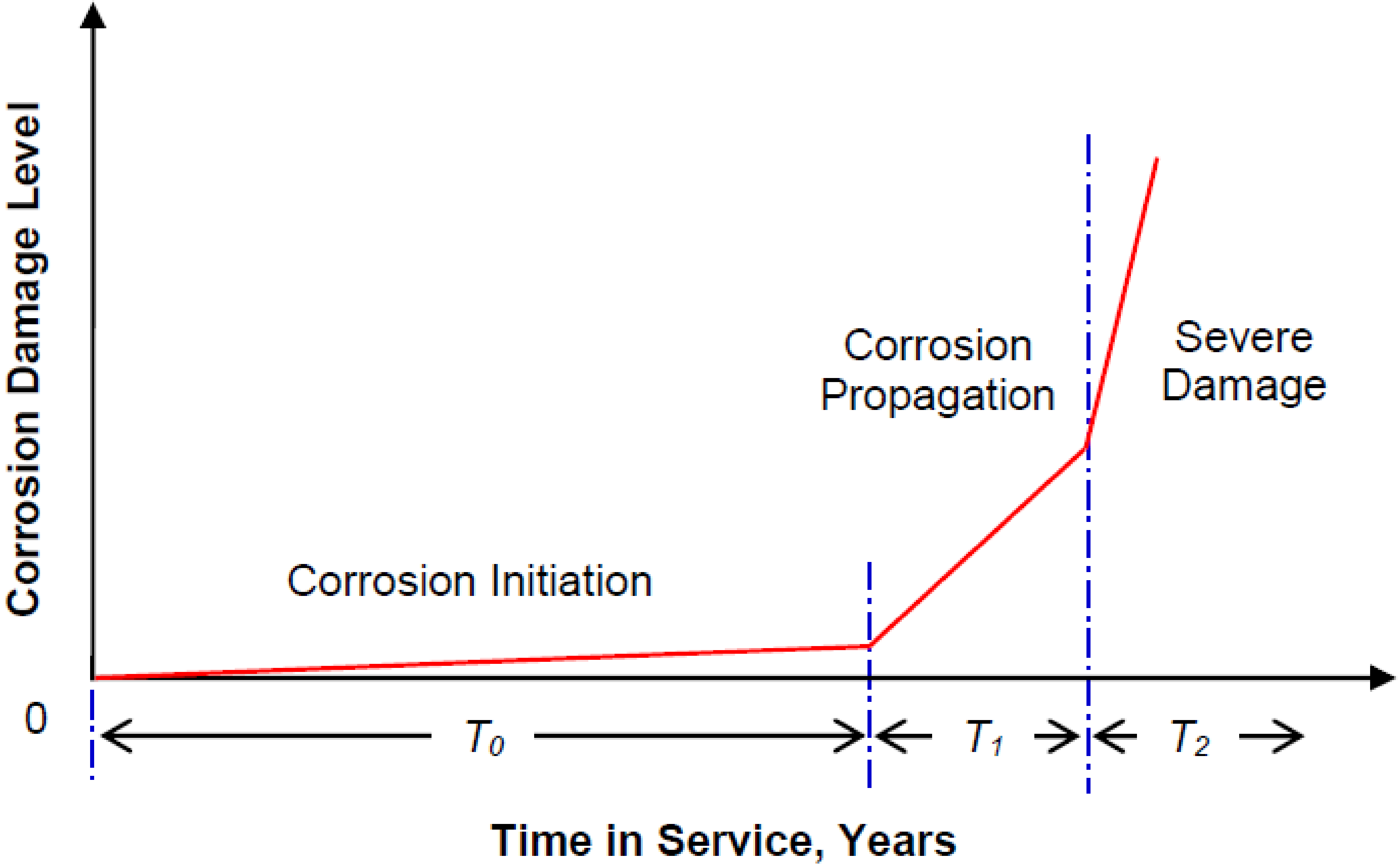
A "renewed" approach

- Electrochemical Chloride Extraction

Principles of Environmental Sustainability and Proactive Maintenance



Principles of Environmental Sustainability and Proactive Maintenance



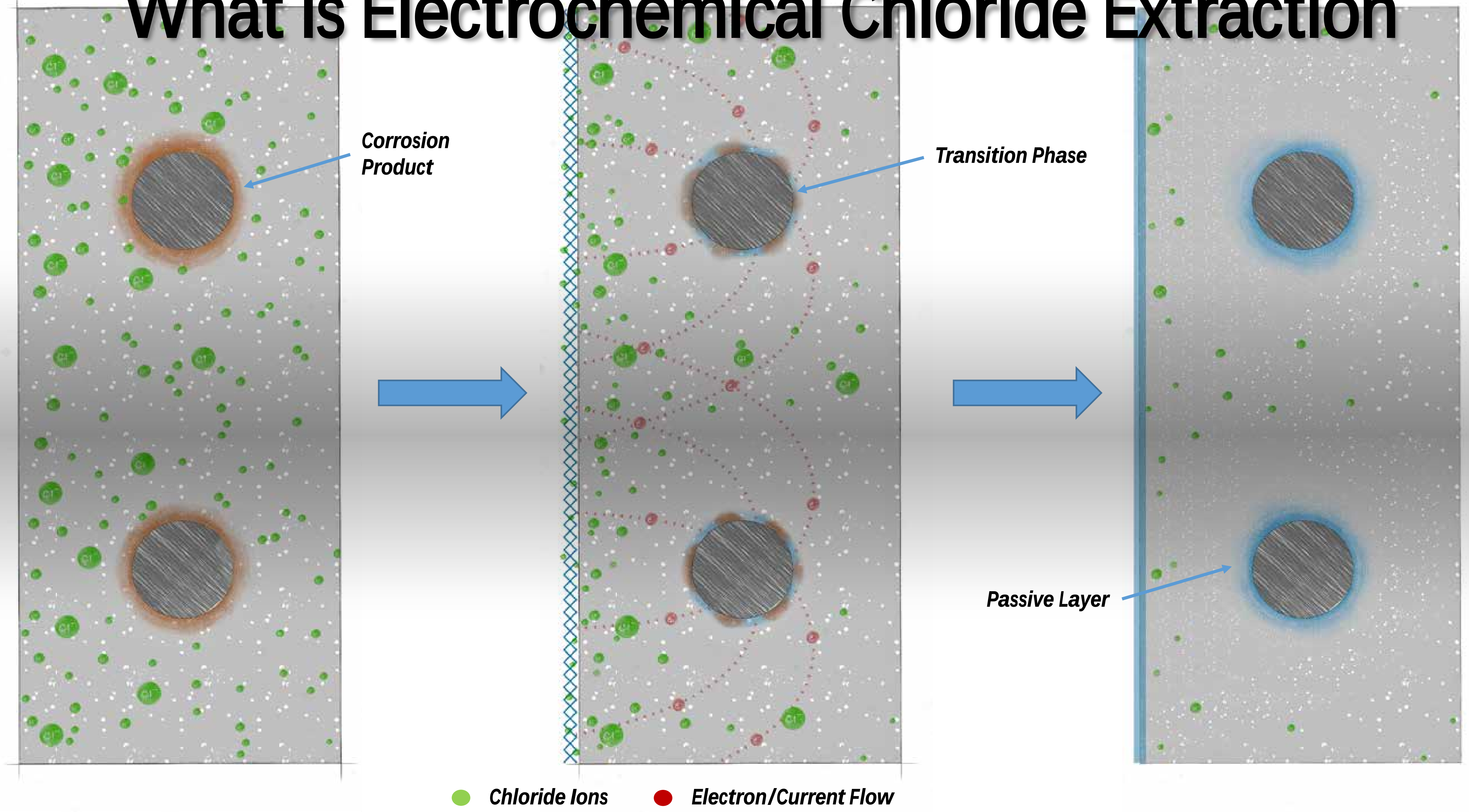
Basis of Design

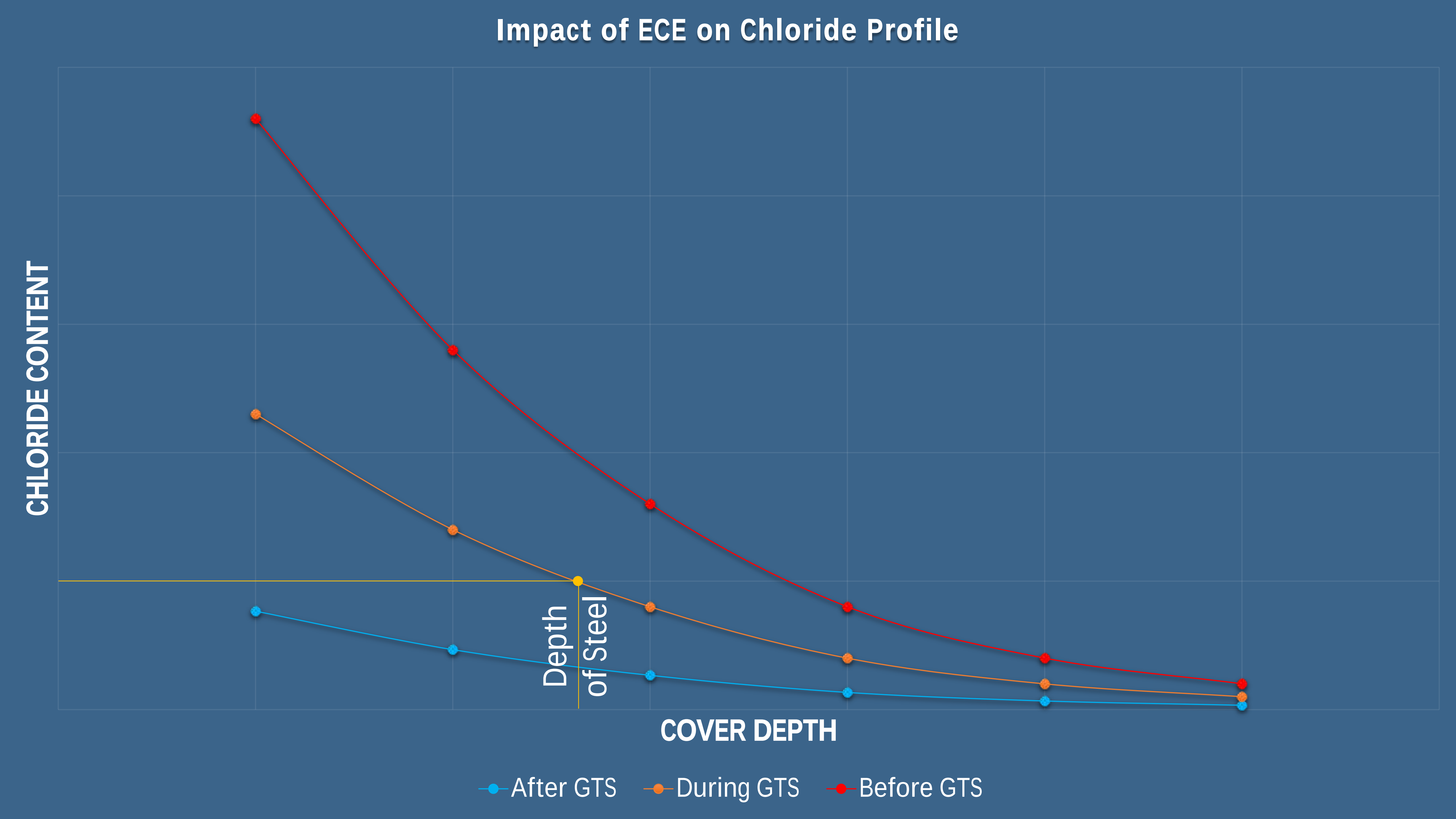
The system is designed to re-passivate the steel whilst enticing chlorides away from the steel reinforcement via the application of the DC current.

As the system is temporary, certain control limitations no longer exist and it can be easily reapplied to targeted areas as the need presents itself across the service life of the structure.

The system is best positioned as a preventative maintenance regime and provides greater system performance real time **data**, **transparency**, and **assurance**.

What is Electrochemical Chloride Extraction





Impact of ECE on Chloride Profile
CHLORIDE CONTENT
Depth of Steel
COVER DEPTH
After GTS
During GTS
Before GTS

Traditional Electrochemical Chloride Extraction

Electrochemical treatments for reinforced concrete include cathodic protection (CP), electrochemical chloride extraction (ECE), and electrochemical realkalization (ER). ECE and ER are short-term treatments with a temporary installation that is removed after treatment. Treatment is intended to remove the cause of corrosion.

Advantages:

- Low maintenance: No requirements for permanent system for monitoring.
- Long term global protection: Provides effective treatment for the entire area of application.
- Proven technology: Long history and an excellent track record.

Disadvantages:

- Requires application of chemicals
- Cumbersome installation (sprayed fibers, chemical dosing, temporary formwork
- Not suitable in tidal and splash areas due to chemical leeching and washout

MCM GTS Electrochemical Chloride Extraction

The MCM GTS is based on the proven technology of chloride extraction, however, is constructed with MCM’s patented self-contained matting (consisting of water retaining matting, conductive foam isolation strips, conductive adhesive, and encapsulated high efficiency ribbon anodes)

Advantages:

- Ease and speed of application
- Reduced Access requirements
- Elimination of chemicals (no leeching or washout)
- Reusable
- Self-contained

NACE/AMPP STANDARD SP0107-2021

2.3.3 Electrochemical Chloride Extraction Criteria—At least one of criterion A, B, or C below (Paragraphs 2.3.3.1, 2.3.3.2, and 2.3.3.3) shall be used:

2.3.3.1 Criterion A—Chloride content within the concrete: Treatment shall be continued until the chloride content within the concrete in the vicinity of the reinforcing steel is reduced to a predetermined level. A suitable test method for chloride determination is ASTM C1152/C1152M-04e1.[13] Treatment is halted when the target chloride value is reached. Samples are collected carefully to prevent contamination and are located relative to the location of the rebar. Because of the inhomogeneous nature of embedded concrete, samples are statistically analyzed to account for natural variations in chloride content.

NOTE: Typical target values used for these measurements are acid-soluble chloride content of less than 0.4% by weight of cement (when corrected for background levels of chloride permanently bound in aggregates, if appropriate) within 25 mm (1.0 in) or one diameter of the reinforcing steel.

NACE/AMPP STANDARD SP0107-2021

2.3.3.2 Criterion B—Ampere-hours (A-h) per square meter (per square foot) of steel surface area: This criterion ensures a minimum treatment of charge density per unit area of steel to be treated.

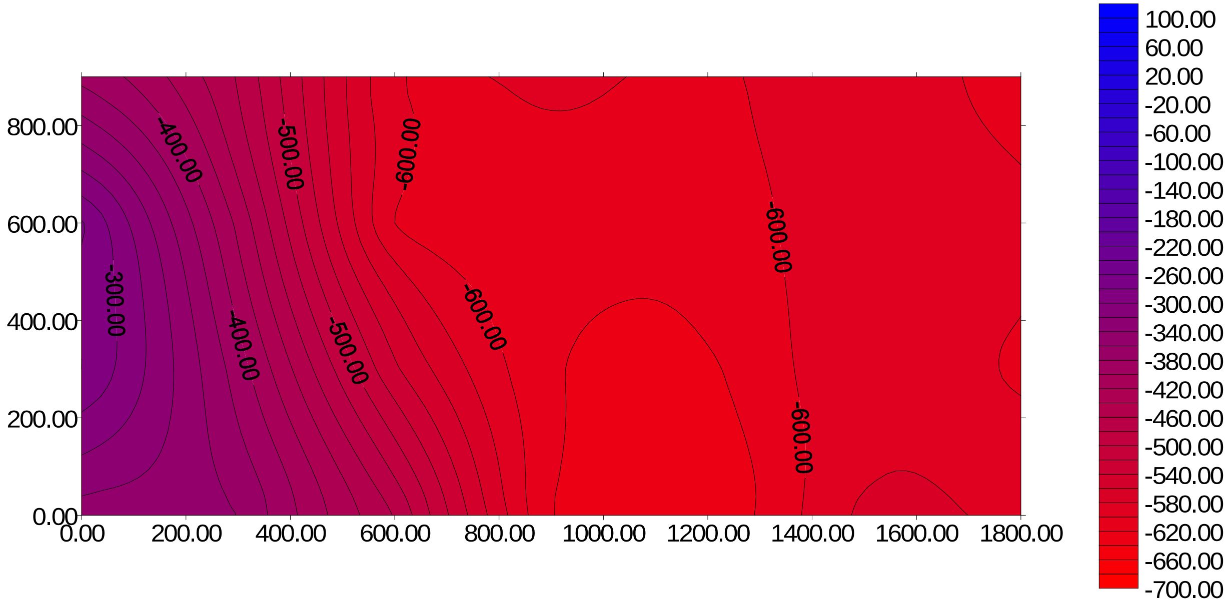
NOTE: The allowance for current discharge to other reinforcing steel may be by calculation of all reinforcement surface area within a particular depth of concrete, typically 200 mm, which should all receive the required number of A-h/m^2. Alternatively, the allowance may be of the reinforcing steel surface area of deeper layers and the assumption that second and subsequent reinforcement layers will receive a lower percentage of the current density received by the reinforcement layer above it. See Hassanein et al. for information on distribution of current to lower layers of reinforcement.[14]

NOTE: 600 A-h/m^2 (56 A-h/ft^2) is a typical minimum target. 1,500 A-h/m^2 (140 A-h/ft^2) is a very conservative value and should not be exceeded for most applications. There are some structures for which it might not be practical to achieve a given accumulated charge. In such cases, Criterion A or C should be used.

Stages of Development

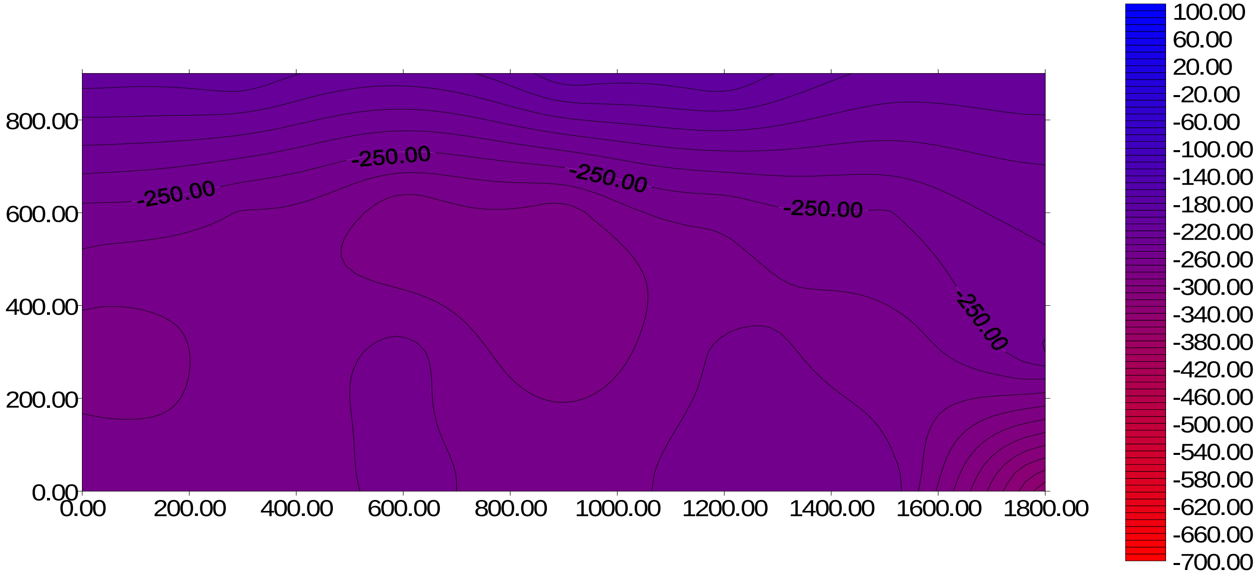
- Office based trials and proof of concept
- Port of Melbourne (South Wharf Installation)
- Development Victoria (Docklands Installation)
- Port of Hastings Installation (Stony Point Jetty, Crib Point, and Long Island Point)
- Connect Sydney/TfNSW Asset Maintenance Program
- University of New South Wales Research Hub

System Performance – Half Cell Potentials



Port of Melbourne – South Wharf

Soffit A – Prior to Application



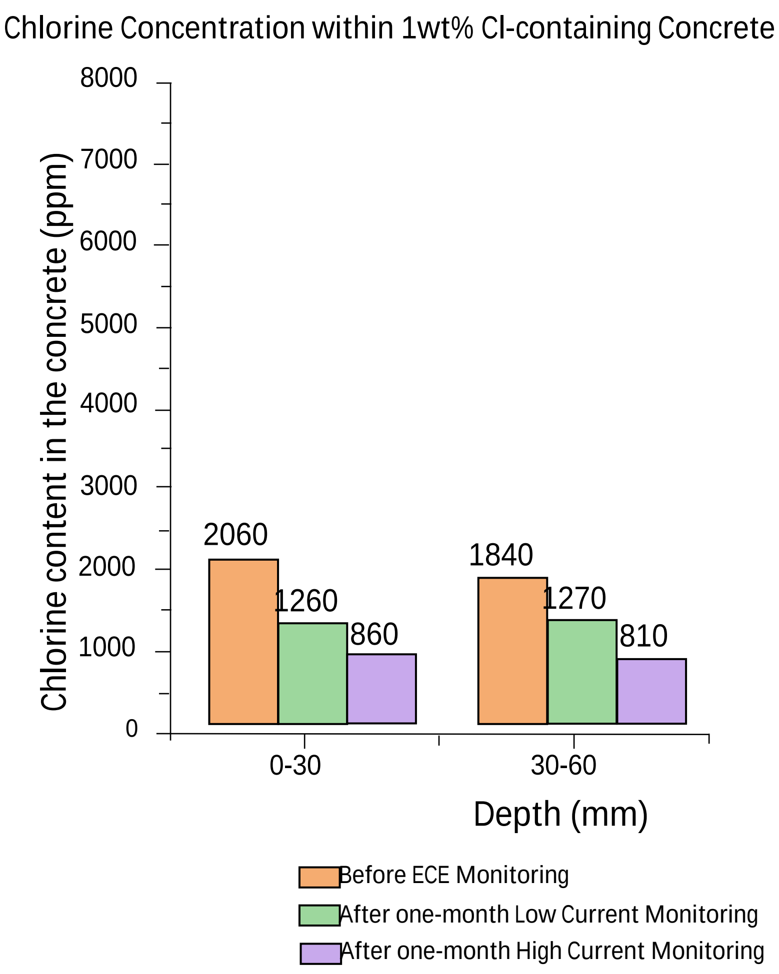
Port of Melbourne – South Wharf

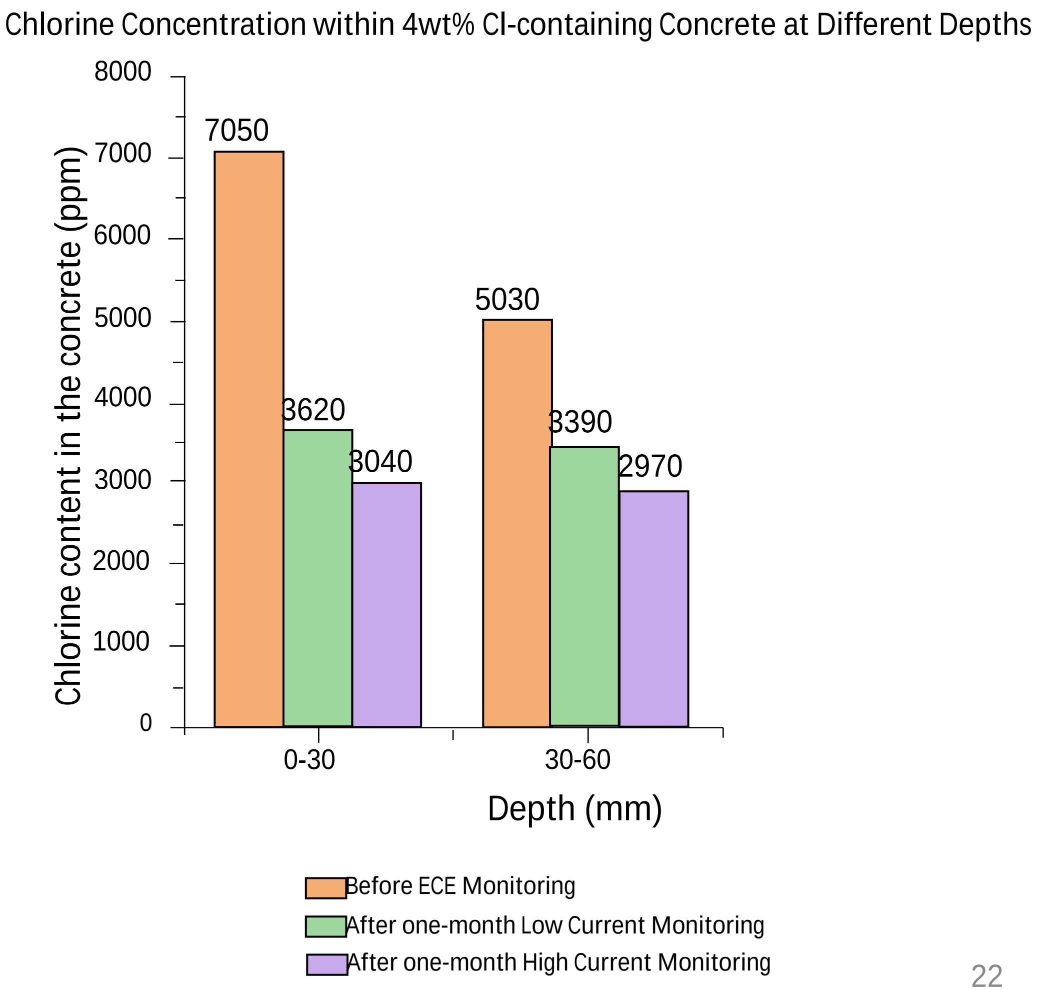
Soffit A – Post Application

System Performance – Chloride Profiling

LOCATION	DEPTH (MM)	CL (%W/W CONCRETE) PRIOR TO ECE APPLICATION	CL (%W/W CONCRETE) POST ECE APPLICATION
AREA A	0-20	0.158	0.254
	20-40	0.123	0.091
	40-60	0.094	0.023
AREA B	0-20	0.100	0.104
	20-40	0.016	0.026
	40-60	0.015	0.010
AREA C	0-20	0.120	0.138
	20-40	0.020	0.023
	40-60	0.017	0.015

UNSW Research – Chloride Profiling





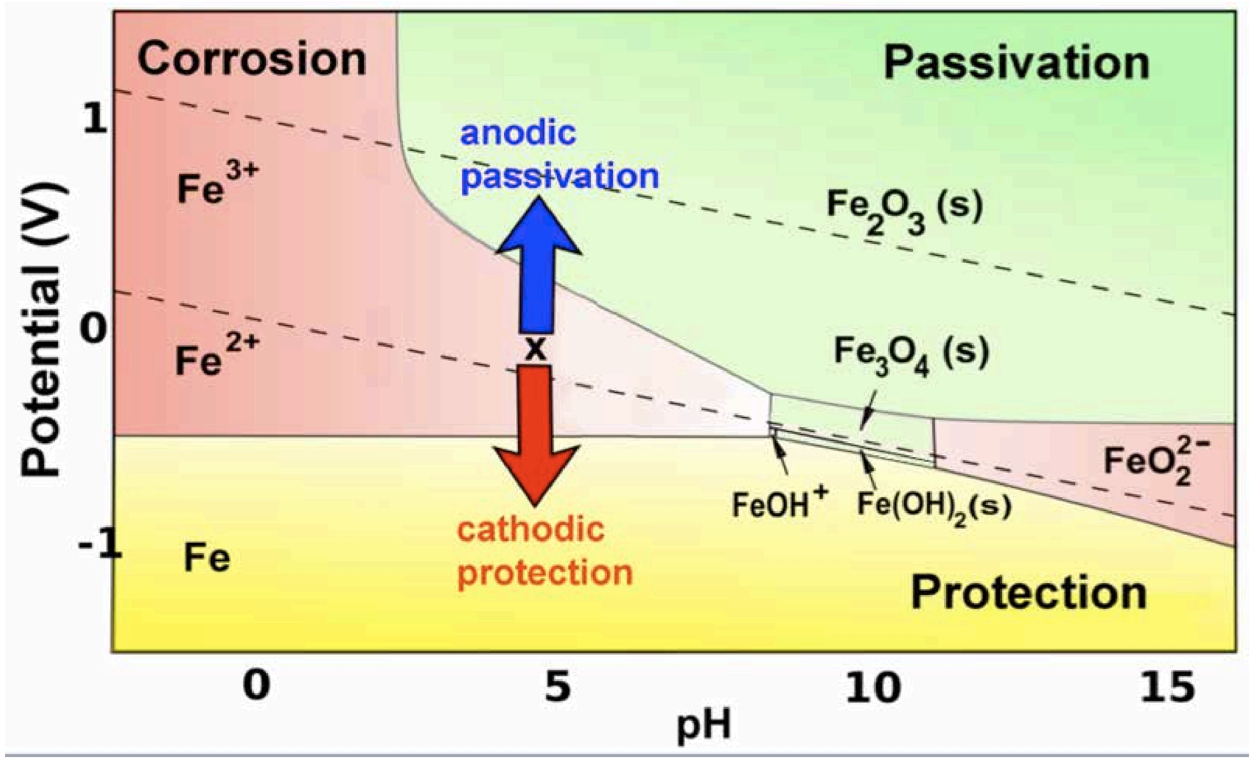
UNSW Research – Energy Dispersive Spectrograph (EDS) Analysis

Before ECE

ELEMENT	STEEL [WT%]	INTERFACE [WT%]
IRON (FE)	52.04	46.15
OXYGEN (O)	27.55	33.24
CHLORIDE (CL)	0.38	0.20
CALCIUM (CA)	0.68	3.15
SODIUM (NA)	2.77	2.01
CARBON (C)	14.49	4.37
SILICON (SI)	2.08	10.89

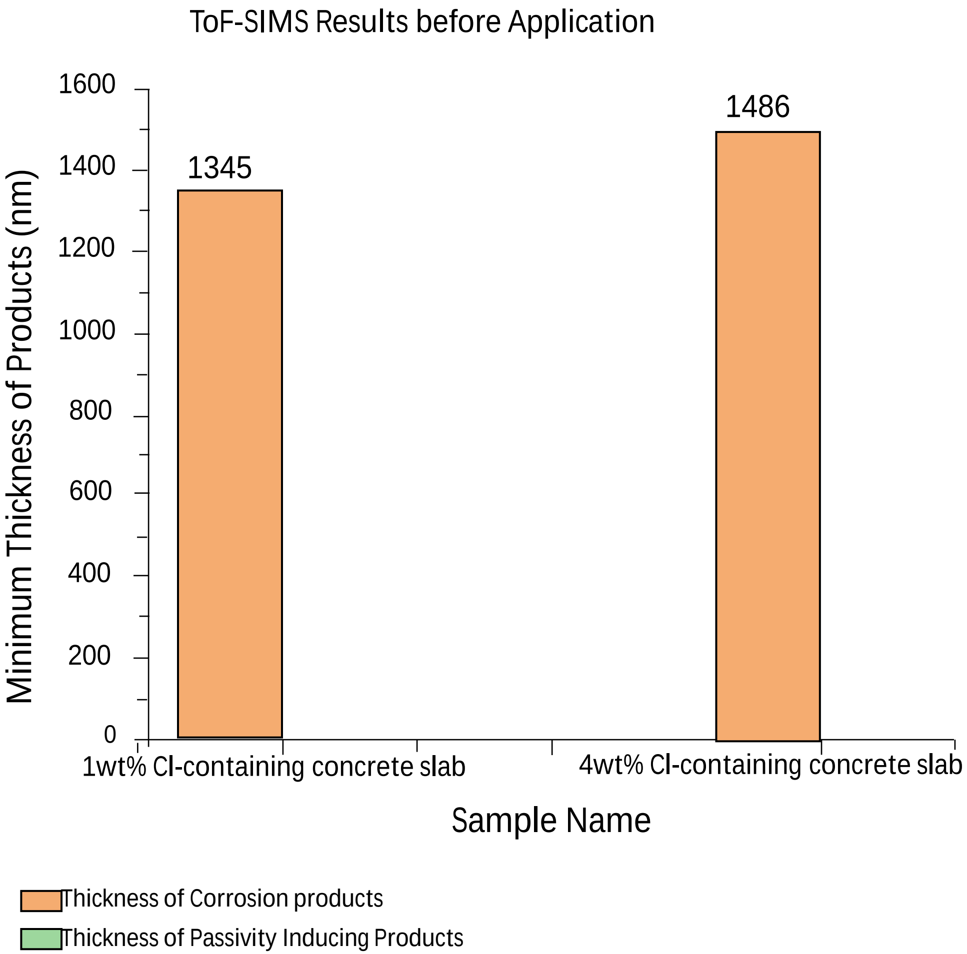
After ECE

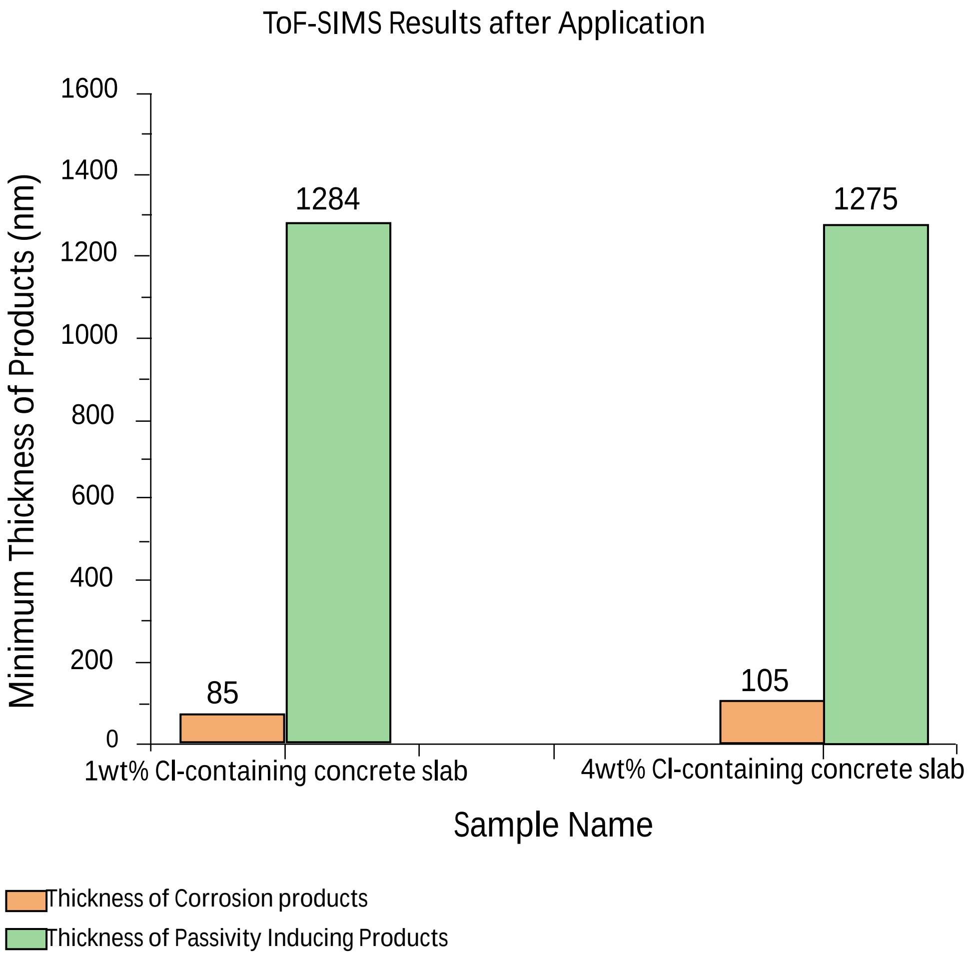
ELEMENT	STEEL [WT%]	INTERFACE [WT%]
IRON (FE)	83.59	44.64
OXYGEN (O)	1.37	5.49
CHLORIDE (CL)	0.04	0.04
CALCIUM (CA)	0.00	0.52
SODIUM (NA)	0.00	0.15
CARBON (C)	14.53	48.69
SILICON (SI)	0.47	0.48



UNSW Research

Effect of ECE system on Corrosion and Protective Layer Formation





Removal of chlorides, depletion of oxygen, generation of Hydroxyl ions, and the increased alkalinity à Re-passivation

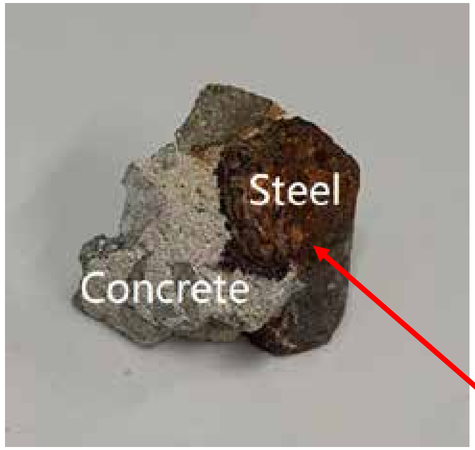
Multilayer Passive layer consisting of Fe3O4, FeO, Fe, and Hydroxides

ToF-SIMS – Time of Flight Secondary Ion Mass Spectrometry

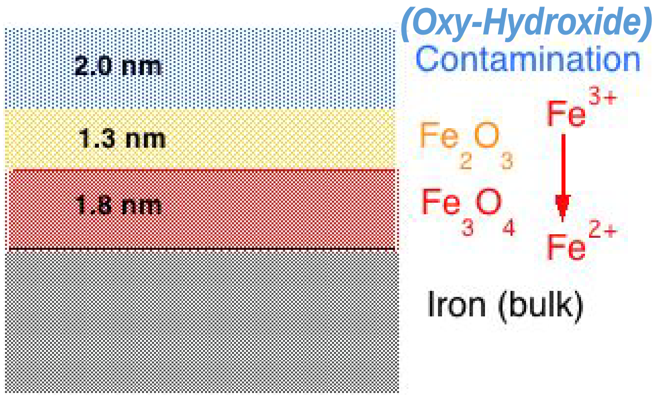
System Performance - Visual Analysis

1wt% Cl-contained concrete sample

4wt% Cl-contained concrete sample



After ECE system



Increasing negative potential favours formation of Fe3O4 and reduces Fe2O3

Fe_2O_3 (Hematite)

Fe_3O_4 (Magnetite)

ECE Design Calculations ©

ELECTROCHEMICAL PROTECTION DESIGN CALCULATIONS
CHLORIDE EXTRACTION

Structural Element: Stony Point - Tug Berth

Drawings: DWG 1964/2

Element: **Tug Berth Piles**

Assumptions:

1. *Steel Surface within* 1000 mm length of Pile
2. *Steel Surface area =* m_s^2 = Rebar diameter x Pi x (bar length x no. bars) x percentage of layer
3. *Concrete Surface Area =* m_c^2 = Surface area of 1m section of pile
4. *Current requirement as follows:*
   600A.h per m^2 steel in accordance with NACE SP0107-2007 Item: 21113
5. *Total protected length of each pile* 1500 mm length (from +3.2m to +4.7m)

TUG BERTH PILE

Bar description	Bar diameter (mm)	Bar Length (mm)	No. Bars	Distance from concrete surface (mm)	Percentage assumed	Steel Surface/Concrete Surface (m_s^2/m_c)
Main Horizontal	30	1000	4	65	100%	0.38
Ligatures	12	840	14	65	100%	0.44

		Subtotal	**0.82**	m_s^2/m_c
Assume & Add	10%	**of Subtotal**	**0.08**	m_s^2/m_c
		Total	0.90	m_s^2/m_c

Assumed Protected length of Concrete Piles	66	m			
Assumed Amp Hours for Dolphin Soffit	35734	A.h			
TOTAL AMP HOURS REQUIRED	35734	A.h	***Steel Protected***	59.56	m_s^2
Hours per week	168	Hours	***Current Density***	0.74	A/m_s^2
Max Output Amps	44	Amps			
Calculated Duration	5	Weeks			

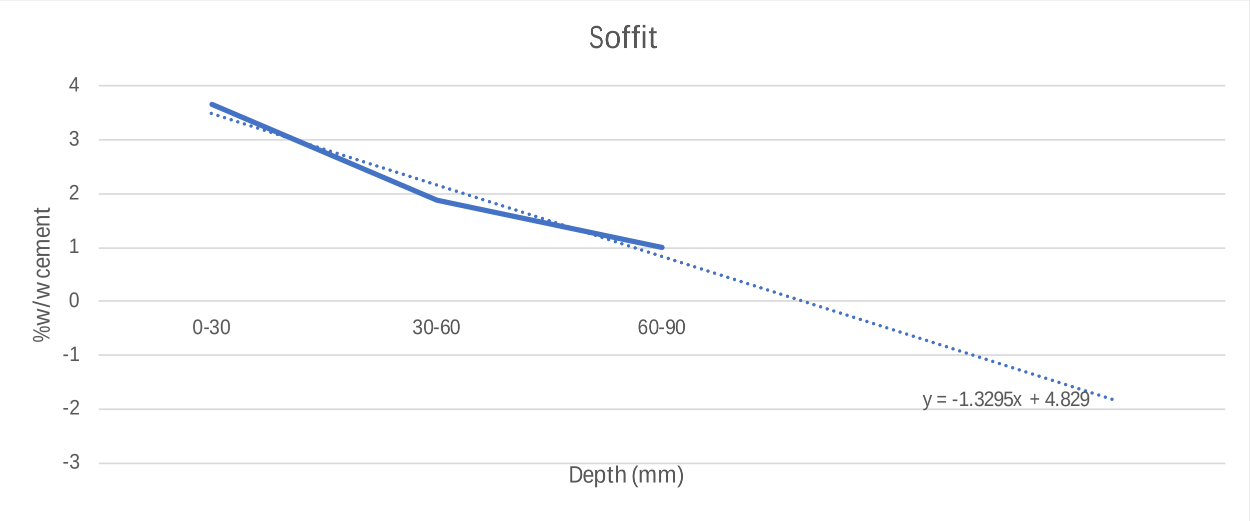
ASSUME THE USE OF THE DR50 - 50AMP UNIT OPERATING @ 44A for 5 weeks

MCM Design Life Prediction Model©

Crib Point Dolphin 4A - Design Life Assessment

Year of Construction	1980	
Age of structure	42	

Depth	Cl (%w/w cement)
0-30	3.649
30-60	1.871
60-90	0.99

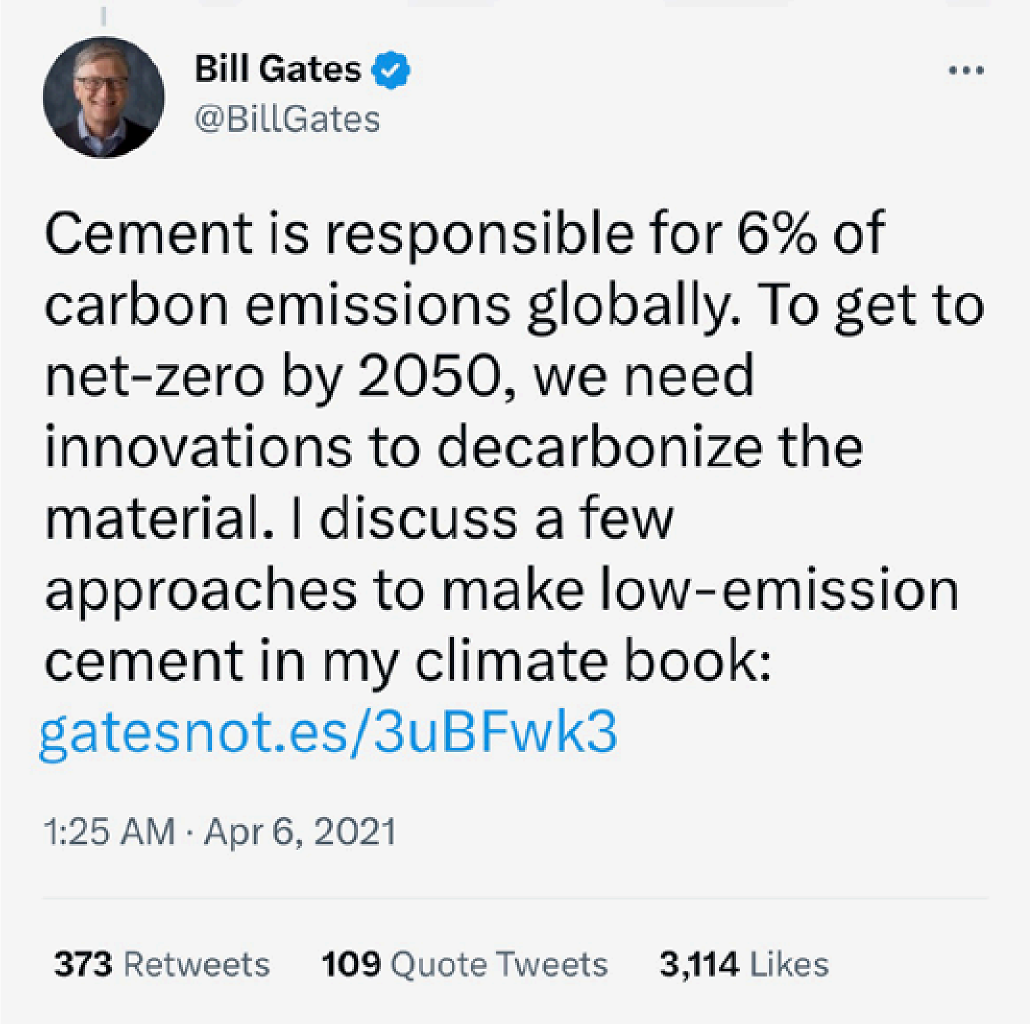


Average Cover Depth	73	mm
Assumed Design Life:		
1. Initial reduction radius (mm) from outer surface of Steel	25	mm
2. Chloride limit (within radius limit)	0.2	%w/w cement
3. Allowing for 50% of threshold limit immediately adjacent to the steel surfce	0.1	%w/w cement
4. Assuming 15 years of negligable ongoing penetration post application, time required to reach 0.4% w/w threshold	**33.5**	**years overall design life**
Total years = 15 + time for 35mm penetration + time to increase from 0.1 to 0.4%w/w cement		

Linear diffusion rate

Soffit	0.024	% per year at the level of the steel reinforcement
	17	**years to reach 0.4% w/w cement (@reo)**
	4.30	**mm penetration per year**

Towards Net Zero

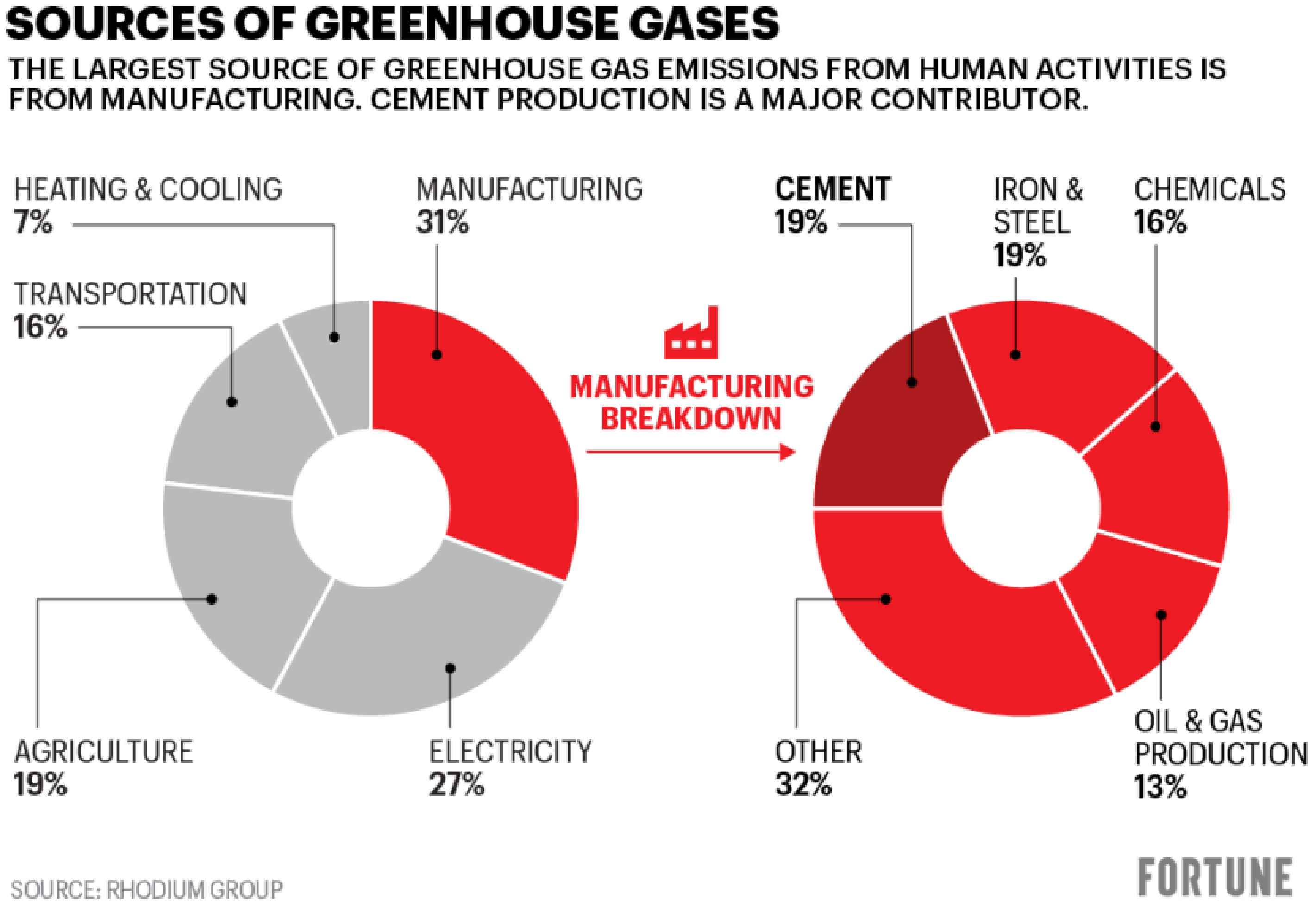


Bill Gates
@BillGates

Cement is responsible for 6% of carbon emissions globally. To get to net-zero by 2050, we need innovations to decarbonize the material. I discuss a few approaches to make low-emission cement in my climate book: gatesnot.es/3uBFwk3

1:25 AM · Apr 6, 2021

373 Retweets **109** Quote Tweets **3,114** Likes



Towards Net Zero

CO2 Emissions per m2 of steel protected via traditional CP Systems (considering power use)

20	mA	per m2
1	continuous cycle over 30 years	
5241.6	A.hrs	
6	Volts	
31.45	**KWh**	**over 30 years**
1.13	**Kg CO2/KWh**	
35.54	**Kg CO2 equivalent**	

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Towards Net Zero

CO_2 Emissions per m2 of steel protected via Innovative ECE Systems (considering power use)

600 A.hrs	per cycle
1.5 cycles	over 30 years
900 A.hrs	
18 Volts	average output
16.2 KWh	**over 30 years**
1.13 kg CO_2/KWh	
18.306 kg CO_2 equivalent	

48% reduction in CO_2 emissions/m2 steel protected

Additionally:

72.5kg CO_2 is saved per tonne of concrete removal eliminated

3.75kg CO_2 saved per man hour of labour

Net Result: a 60%+ reduction across the project lifecycle when substituting CP for ECE via the MCM GTS

MCM wishes to acknowledge our project partners

Thank you for your attention

MCM Marine & Civil Maintenance

MCM GreenTech

Association of Pacific Ports

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