PIANC

The Australian Northern Chapter of the World Association for Waterborne Transport Infrastructure

CONCRETE DURABILITY & MAINTENANCE IN MARITIME INFRASTRUCTURE

Program

Arrival and Registration	**3:45- 4:00 pm**
• check-in and collect guest name badge	
Introduction and Welcome to Country	**4:00 - 4:10 pm**
AS 3600 2025 Concrete Structure Code Update	**4:10 - 4:20 pm**
• Sam Mazaheri	
Presentation by Amanda O'Connor - Cementaid	**4:20 - 4:40 pm**
• The use of hydrophobic admixture to achieve maintenance-free design-life durability of pre-cast and in-situ maritime concrete. Case Study: Project Seabird 2003 - 2023 – Indian Naval Base.	
Presentation by Gitte Goffin - Aurecon	**4:40 - 5:00 pm**
• A review of durability design options for marine concrete structures on the basis of service life, maintenance and whole of life cost.	
Presentation by Brodie Chan - Port of Brisbane	**5:00 - 5:20 pm**
• History of the Port of Brisbane's asset base and asset management approach. Inspection, testing and renewal & life extension.	
Presentation by Jack McLean - Freyssinet	**5:20 - 5:40 pm**
• Corrosion of prestressed concrete – its impacts and mitigation techniques: Corrosion Under Stress: The Development & Application of Corrosion Control Solutions for Prestressed Concrete Structures. Case Study: BLB 1 project –NSW Ports	
Panel session Q & A	**5:40 - 6:10 pm**
• Engage with our speakers in an interactive Q & A	
Networking	**6:10 - 7:00 pm**
• Connect with peers and speakers over light refreshments	

Introduction and Welcome

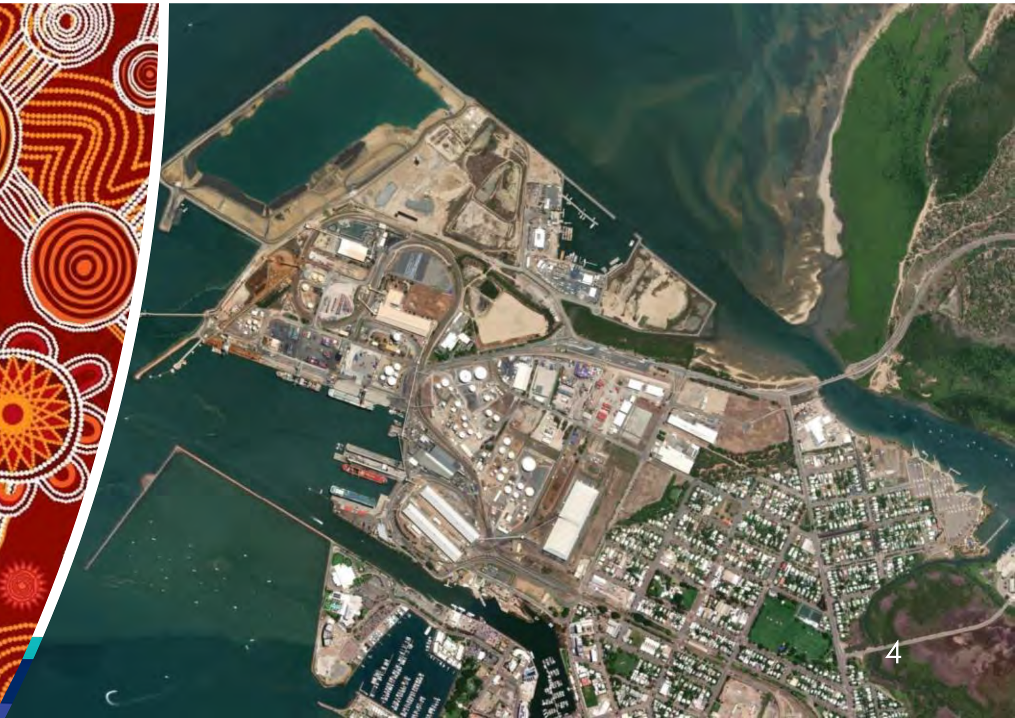
- Dr. Sam Mazaheri
- Chair, PIANC AU-NZ Northern Chapter (QLD & NT)

Acknowledgement of Country

PIANC

The World Association for Waterborne Transport Infrastructure

- PIANC AU-NZ acknowledges the Traditional Custodians of Country throughout Australia, including the land on which we gather and meet today, and recognises their continuing connection to land, waters, and community.
- We pay our respects to them, their cultures, and to elders past, present, and emerging.



PIANC - A Legacy of Leadership in Waterborne Transport

Where It All Began - A Historical Perspective

1885: First Navigation Congress in Brussels

Highlighting the growing need for international collaboration to address the challenges of expanding maritime trade

1914: Opening of the Panama Canal

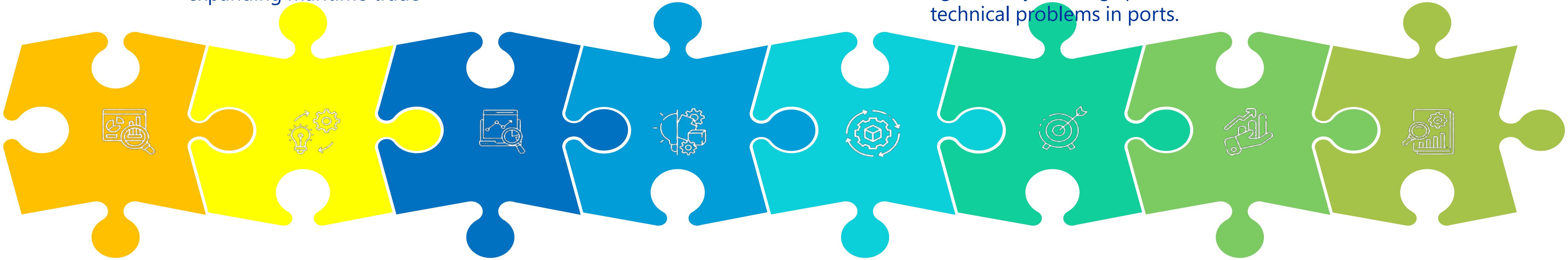
Further demonstrating the impact of infrastructure development on global trade.

2000-2010

During the first decade of the 21st century, the size and number of cruise and container vessels increased significantly, causing specific technical problems in ports.

2024

Technological advancement, Climate change and its impact on coastal and maritime infrastructure



1869: Opening the Suez Canal and building the Cutty Sark

Illustrating the rapid evolution of maritime technology..

1902: Formal establishment of PIANC

Showcasing its enduring legacy as a global leader in waterborne transport infrastructure..

1950s Container Ships: Revolution in Sea Transportation

In 1956 the first shipload of fifty-eight containers sailed from Newark to Houston.

2002

First Navigational Congress was held in Australia (Sydney)

At the opening ceremony of Congresses, there usually is reference to the culture of the host country. In Sydney, 2002, an aboriginal didgeridoo player gave a demonstration of traditional Australian music. At this Congress there were individual papers only.

The Changing world – Transition to a Sustainable Maritime Future

Key global trends

- Population growth and increasing demand for maritime trade
- Climate change and its impacts on coastal and marine environments
- Technological advancements and the drive for innovation in maritime transport.

PIANC AU-NZ Northern Chapter

Northern Chapter – Events in 2024

1. March: QGHL Technical Talk & Site Visit
2. April: Challenges and Opportunities for Hydrogen in the Port Industry, EA Auditorium, Brisbane
3. 3 June: Recent Developments in Design of Breakwaters, Griffith University, Gold Coast
4. 27 June: YP Industrial Breakfast, WGA, Brisbane
5. 4 July: Darwin Seminar & Port Tour
6. 24 July: Fender New Guideline, WG211, Jacobs, Brisbane
7. 27-30 Aug: PIANC APAC 2024
8. October (early): Offshore Wind Seminar, QU, Brisbane
9. October (24): Gladstone Technical Seminar and Port Tour
10. November (late): Final Year Celebration followed by Xmas Drinks, Brisbane



Northern Chapter – Events in 2025

1. Feb: Smartship Australia simulator Facility Visit
2. May: Climate Change workshop: The Impact of Climate Change and Extreme Events on Port Infrastructure
3. Collaboration with universities: UQ, CQU, Griffith
4. 19 June: Concrete Maintenance and Durability in Maritime Infrastructure
5. 2 July: Menard Oceania – Brisbane Site Tour and Networking
6. 30 July: Navigating through New Fender Guideline (WG211) – half-a-day
7. 18-21 Aug: Coasts and Ports
8. 16 Oct: Sustainability in Ports and Working with Nature (Darwin)
9. 30 October : YP Leadership Breakfast
10. November (late): Year End Celebration followed by Xmas Drinks, Brisbane

AS 3600 Concrete Code (2025) Outlook

Dr. Sam Mazaheri

Chair, PIANC AU-NZ Northern Chapter (QLD & NT)

The use of hydrophobic admixture to achieve maintenance-free design-life durability of pre-cast and in-situ maritime concrete. Case Study: Project Seabird 2003 - 2023 – Indian Naval Base. Amanda O'Connor - Cementaid

Synopsis – Achieving Maintenance-Free Durability in Maritime Concrete Using a Hydrophobic Admixture

Maritime infrastructure demands high-performance concrete capable of withstanding aggressive chloride environments without significant maintenance. This presentation explores the use of a pore-blocking hydrophobic admixture to achieve long-term durability in precast and in-situ marine concrete.

Bio: Amanda O'Connor is a Technical Sales Specialist with Cementaid, supporting projects across the Pilbara, Northern Territory, and Queensland. She works with engineers and asset owners to deliver durable, maintenance-free concrete solutions using hydrophobic admixture technology, particularly for challenging marine and remote environments.

A review of durability design options for marine concrete structures on the basis of service life, maintenance and whole of life cost, Gitte Goffin - Aurecon

Synopsis – This review focusses on durability design options for concrete in marine environments with high chloride concentrations. The impacts of various supplementary cementitious materials on the service life are discussed and compared to the effects of chemical inhibitors. Furthermore, the principles of cathodic protection are reviewed and design options compared in terms of maintenance and whole of life cost.

Bio - Dr Gitte Goffin is a senior civil materials engineer at Aurecon with over 13 years' experience in academic research and consulting. She has extensive experience in asset integrity and durability design of civil structures as well as expertise in non-destructive testing and corrosion science. She specialises in the durability design, service life modelling, condition assessment and rehabilitation of civil structures ranging from hydro dams and coal terminals to tunnels and marine structures.

History of the Port of Brisbane's asset base and asset management approach. Inspection, testing and renewal & life extension - Brodie Chan - Port of Brisbane

Synopsis – The Port of Brisbane is one of Australia's largest and most diverse ports, providing vital access to global import and export markets for trade communities along the east coast. Central to this activity are the Port's wharf assets. This critical infrastructure is not only of high operational importance and high capital value but situated in one of the most aggressive exposure environments. This presentation will explore the Port's asset management strategy, focusing on how it ensures reliability, resilience, and long-term serviceability throughout the asset lifecycle.

Bio - Brodie Chan is the Head of Asset Strategy for the Port of Brisbane Pty Ltd. He has extensive experience in the renewal, life extension and management of civil and maritime infrastructure for private and public sector clients throughout Australia, New Zealand, South-East Asia and the South Pacific region. This includes most recently as the Associate Director for Asset Advisory at ADG Engineers and the Manager Asset Services for the Port of Brisbane Pty Ltd. Brodie graduated from Griffith University in 2014 with a Bachelor of Civil and practices as a Registered Professional Engineer of Queensland, Chartered Professional Engineer and APEC Engineer.

Corrosion of prestressed concrete – its impacts and mitigation techniques: Corrosion Under Stress: The Development & Application of Corrosion Control Solutions for Prestressed Concrete Structures. Case Study: BLB 1 project –NSW Ports

Synopsis - Corrosion of Prestressed concrete elements can present substantial challenges for asset owners and managers. Being particularly aggressive and insidious in certain conditions, as well as difficult to identify by traditional visual inspection; The identification, management and control of this type of corrosion is of utmost importance for corrosion practitioners to ensure the future serviceability of these structures.

This presentation focuses on the challenges faced for asset owners and the mitigation techniques available to corrosion control practitioners when confronted with this issue. This will be discussed through the lens of a turnkey hybrid anode corrosion protection project, recently completed at the Bulk Liquids Berth No 1 (BLB 1) in Port Botany, NSW.

Bio - Jack McLean is the national engineering manager at Freyssinet Australia. Bringing a number of years of project management and technical expertise in both a contracting and consulting role, Jack is responsible for overseeing the successful delivery and management of remedial and cathodic protection projects across Australia. As part of this role, Jack is responsible for all methods engineering, durability engineering, condition assessment works, cathodic protection system design as well as all maintenance and monitoring programs nationally, within the Freyssinet business.

Panel Session Q & A

Sam Mazaheri, Chair, PIANC AU-NZ Northern Chapter (QLD & NT)

Amanda O'Connor, Technical Sales Specialist, CEMENTAID

Brodie Chan, Head of Asset Strategy, Port of Brisbane

Gitte Goffin - Aurecon

Jack McLean, National Engineering Manager, Freyssinet


70 Years
CEMENTAID
1954 - 2024

$80 BILLION BY 2030: THE COST OF CORROSION IN MARITIME INFRASTRUCTURE

- Australia’s maritime sector supports $75 billion in annual trade, with 99% of exports relying on ports, yet corrosion threatens infrastructure reliability *(Infrastructure Australia)*

- An estimated $80 billion is required by 2030 to upgrade and replace corrosion damaged concrete infrastructure, including ports, jetties, and seawalls. *(Infrastructure Australia’s Port Investment needs and corrosion studies)*

- Chloride induced corrosion affects over 80 % of marine concrete failures, reducing service life by up to 50% in tidal and splash zones *(ACA)*

- Corrosion related repairs for a single major port can cost millions for significant corrosion related projects (*Informa Australia)*

THE INDUSTRY CHALLENGE

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WHAT THE INDUSTRY IS DOING NOW

- Common strategies: low heat cement, cover depth, diffusion resistance
- Focus is on slowing down corrosion, not stopping it
- Water ingress remains the root cause of failure
- Maintenance cycles still locked in from the beginning
- Delays are not durability—they're deferrals

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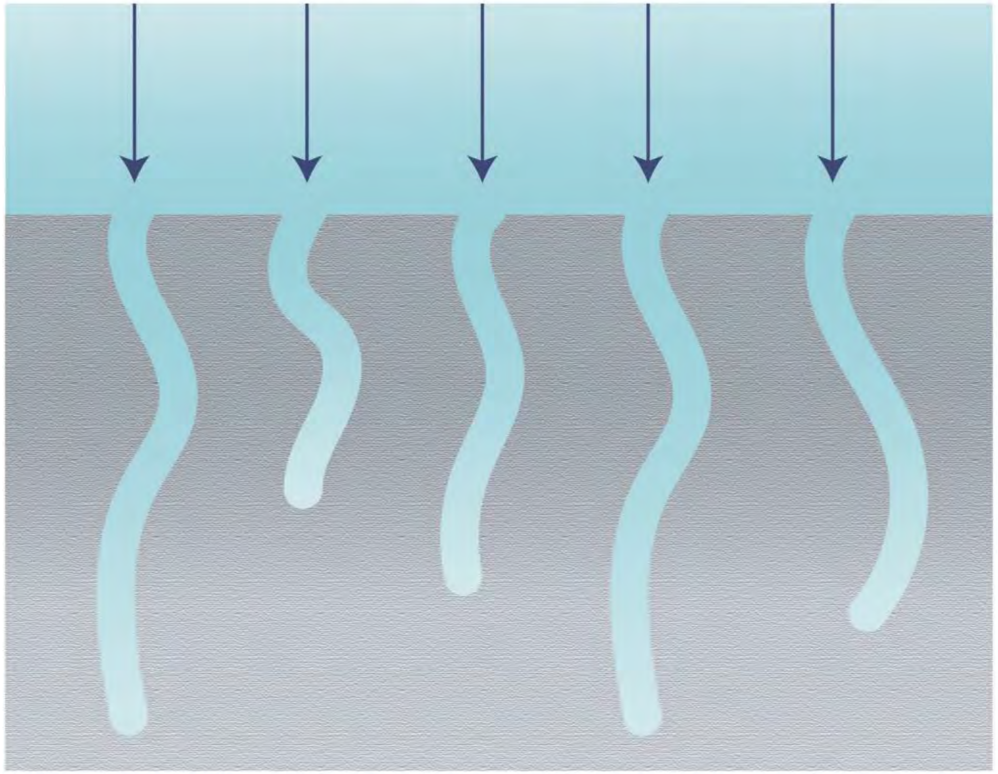
ADVANTAGES

OF HYDROPHOBIC CONCRETE

- If concrete were truly hydrophobic – it would be completely dry inside!
- Proofed against corrosion by sulphate, chloride & acid solutions
- Maintenance-Free
- Faster construction time
- Significant lower Design & Construction costs
- Easy to repair cracks, and other “holes” are simply filled
- No dampness
- No requirement for membranes

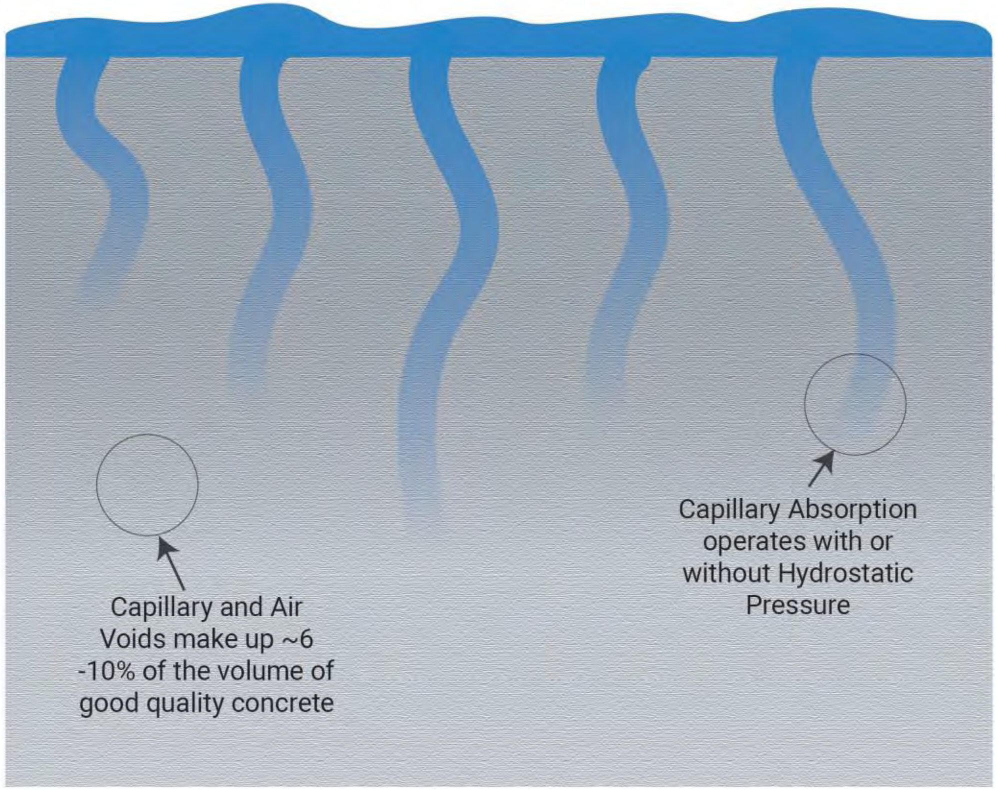
WATER PENETRATION INTO CONCRETE

HYDROSTATIC PRESSURE



Function of Saturated Concrete Test – Permeability

CAPILLARY ABSORPTION



Function of Un-Saturated Concrete Suction Through Capillary Action – Test Absorption

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CAPILLARY ABSORPTION BY CONCRETE

Q

Which is faster, capillary absorption or permeability?

A

Capillary Absorption is the primary mechanism by which water & chlorides infiltrate concrete.

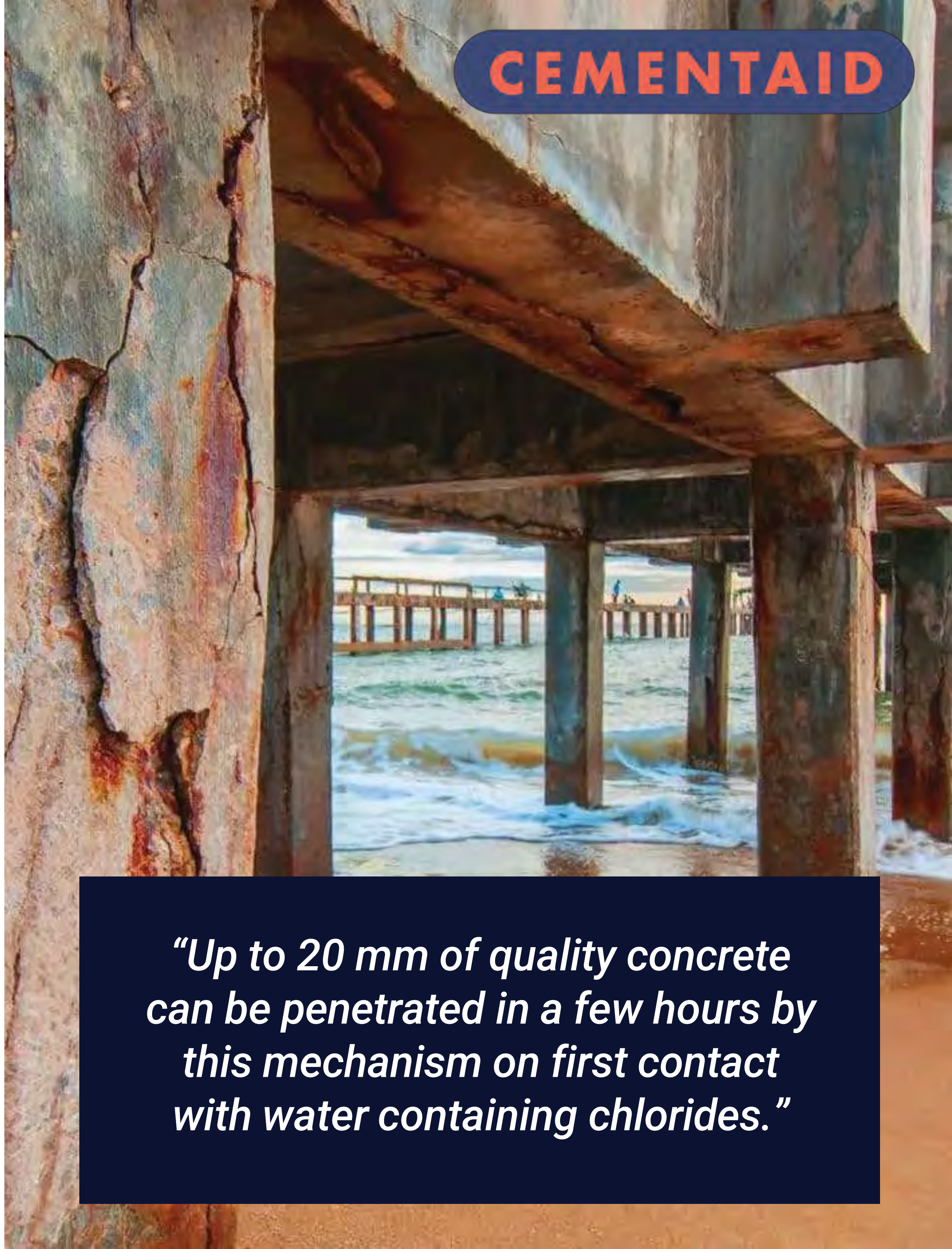
Q

How much faster is capillary suction?

A: 100 x
B: 1000 x
C: 1,000,000 x

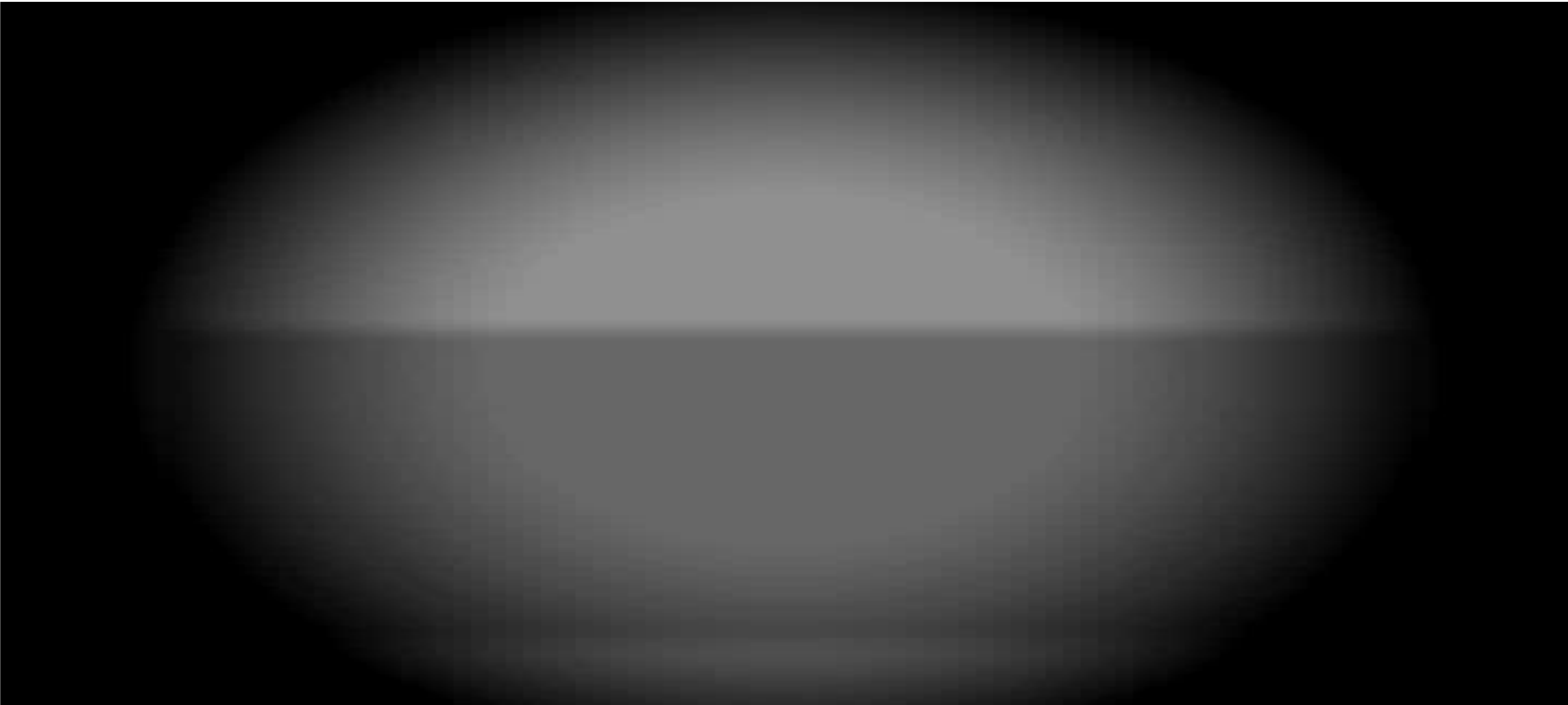
A

1,000,000 times faster



“Up to 20 mm of quality concrete can be penetrated in a few hours by this mechanism on first contact with water containing chlorides.”

HYDROPHOBIC **PORE-BLOCKING**



THE ULTIMATE TEST OF TIME

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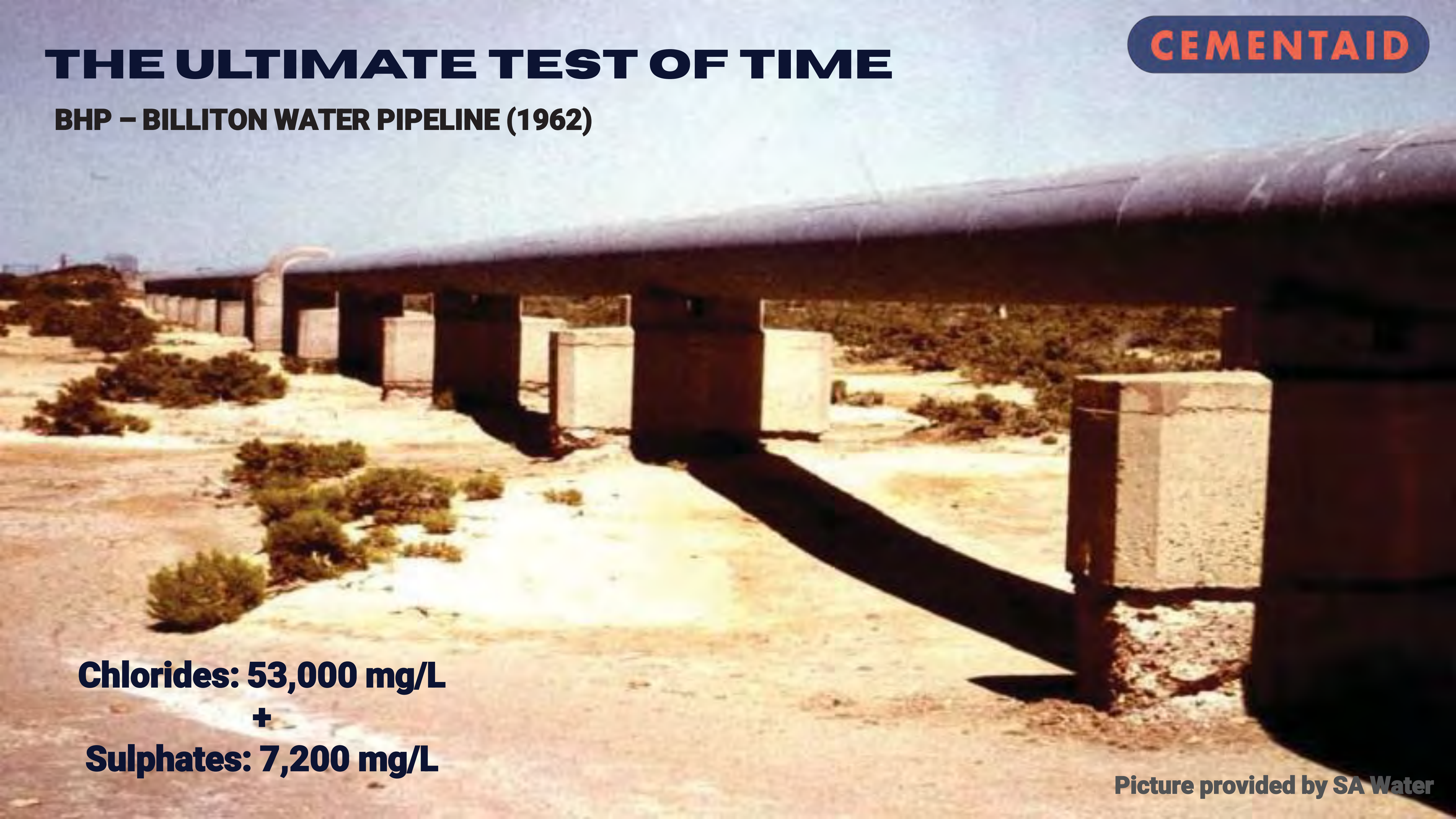
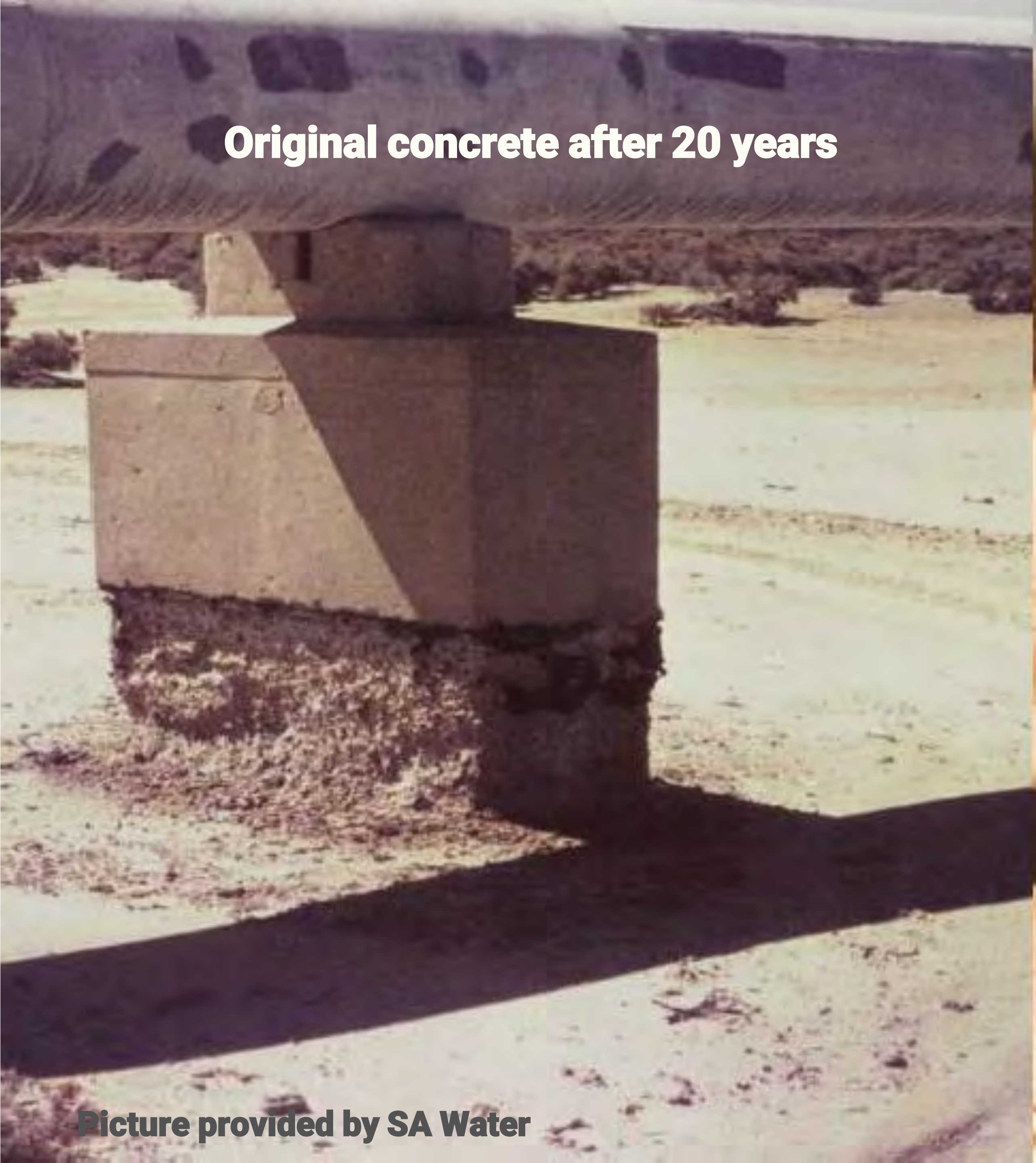
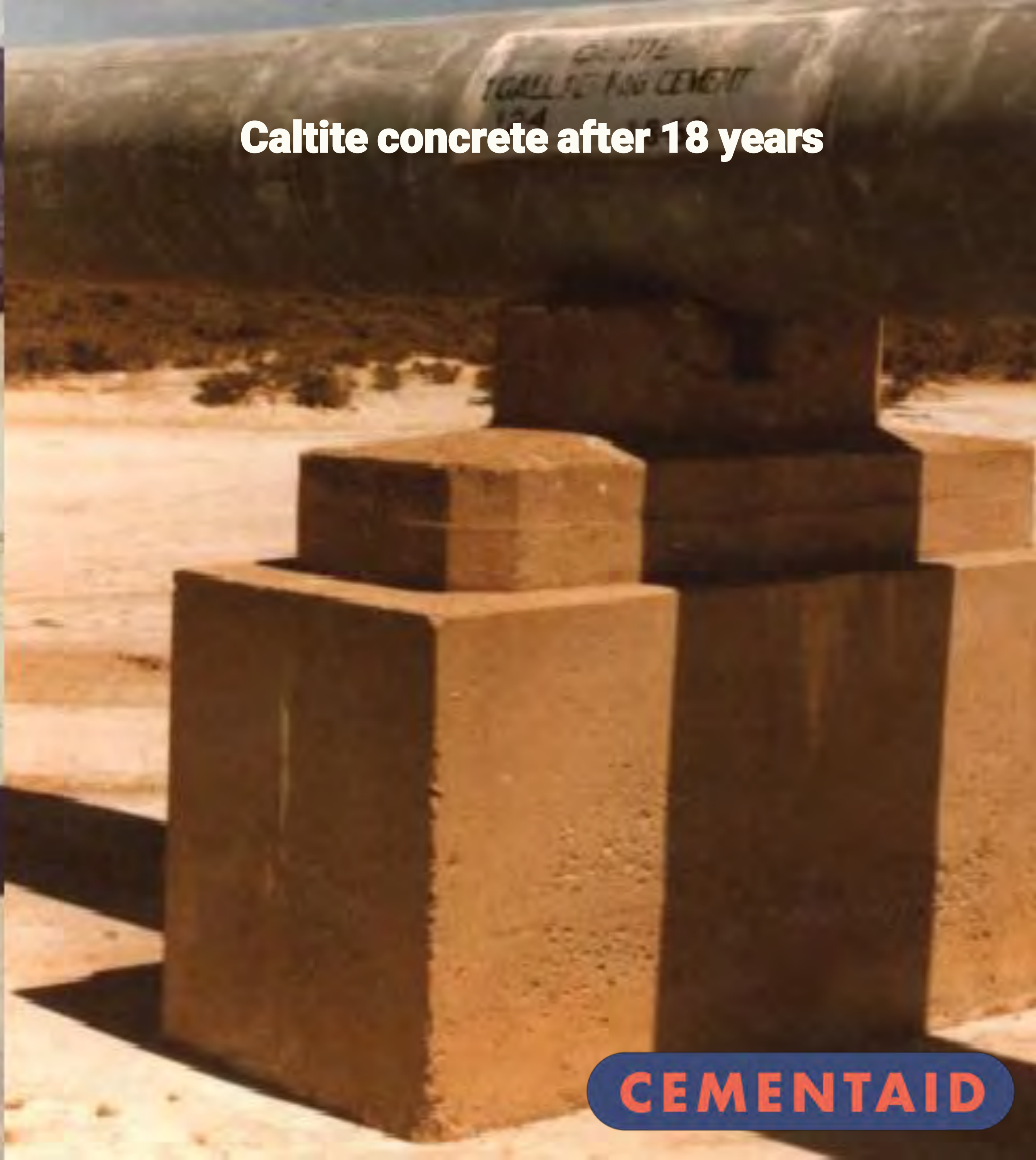
BHP – BILLITON WATER PIPELINE (1962)



Chlorides: 53,000 mg/L
+
Sulphates: 7,200 mg/L

Picture provided by SA Water


Original concrete after 20 years
Picture provided by SA Water


Caltite concrete after 18 years
CEMENTAID


60 YEARS
CALTITE
Picture provided by SA Water

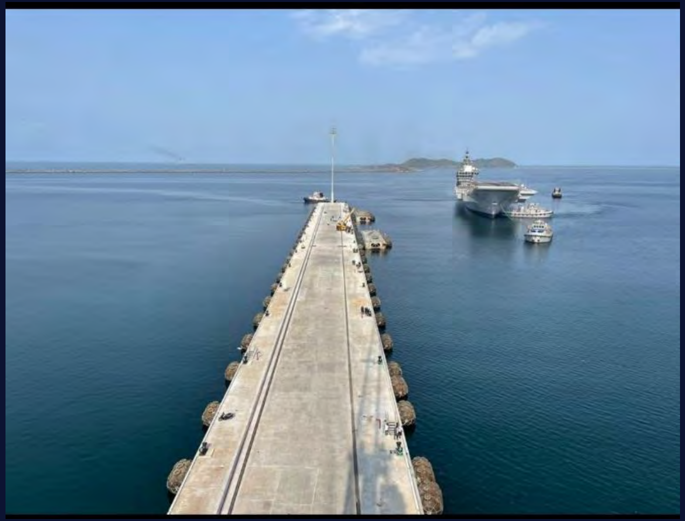
PROJECT SEABIRD NAVAL BASE, SHIP LIFT

KARWAR NAVAL BASE, INDIAN DEPARTMENT OF DEFENCE.

- Covering more than 8000 acres, it is the largest naval base east of the Suez Canal.
- Provides fleet support, maintenance and docking space for 30+ warships, Naval Air Station (including multiple runways, hangars, housing and ordinance handling areas)
- Dry berths for ships and submarines
- Caltite was specified throughout all 3 phases of construction and expansion from 2004, 2015-2017, 2023

CONSTRUCTION & EXPANSION PHASES

2004



- Pile caps
- Service duct base and walls
- Shiplift edge and support beams
- Light tower foundations
- Sewage / oils bilge intermediate storage tanks & waste collection pit
- Service ducts to Dry berth & Washdown berth
- Pipe outfalls

2015-2017

Black steel and Caltite used in all three stages

30,000 cu. M of concrete was supplied for testing, without a single non-conformance.

2023

Primary KPI was to achieve less than 1% absorption rate In the splash zone. A key issue essential to this design.

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WHY ABSORPTION TESTING?

While we may consider diffusion to be a key indicator of durability in a marine environment, the Quality Assurance standard at the time required absorption testing as the durability metric due to the reliance on alternative protection of the plain black steel reinforcement used.

Description	M55 Navy Standard Mix	Caltite Mix
Cement content (kg/cu.m)	410-450	410-450
Silica fume(kg/cu.m)	0-25	25-34
Water/cement ratio	0.35	0.33.0.35
Hydrophobic pore blocking agent Cementaid "Caltite" (litres/cu.m)	N/A	30
Superplasticizer (litres/cu.m)	7-8	7-10

Description	M55 Navy Standard Mix	Caltite Mix
Average Compressive Strength (28 Days)	64 Mpa*	62 Mpa*
Average Drying Shrinkage (28 days)	391 Microstrain	317 Microstrain
Average Absorption	N/A	0.68%

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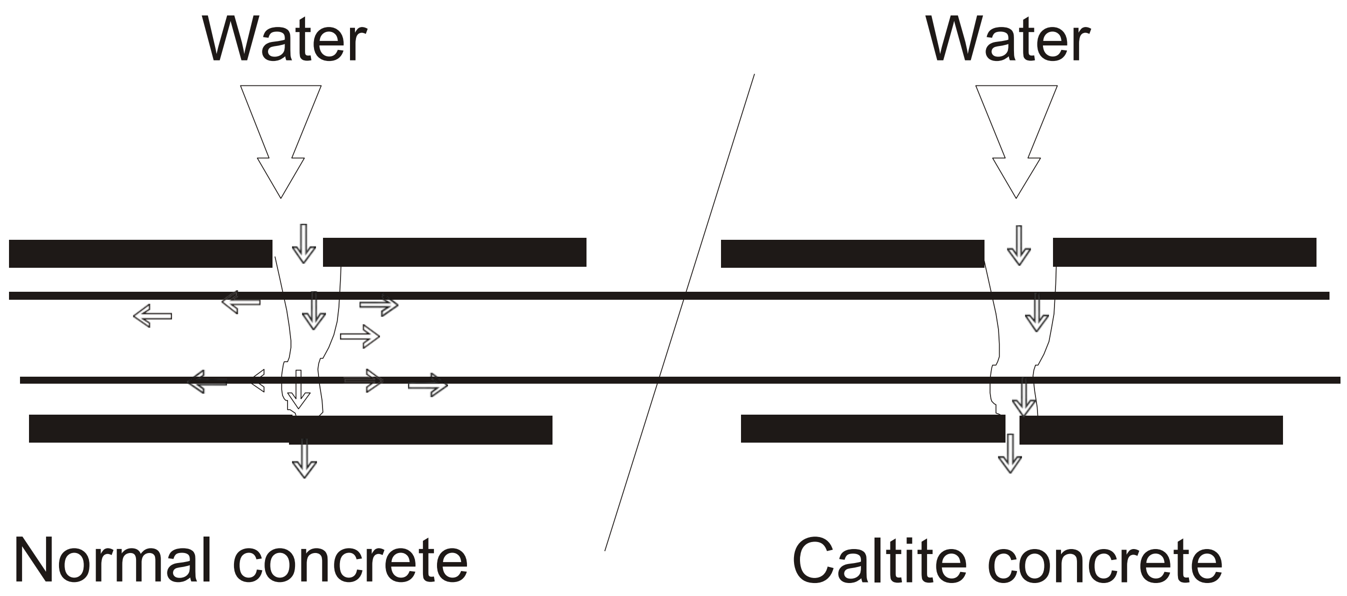
DURABILITY PROTECTION AT CRACKS

PLAIN CONCRETE VS CALTITE CONCRETE

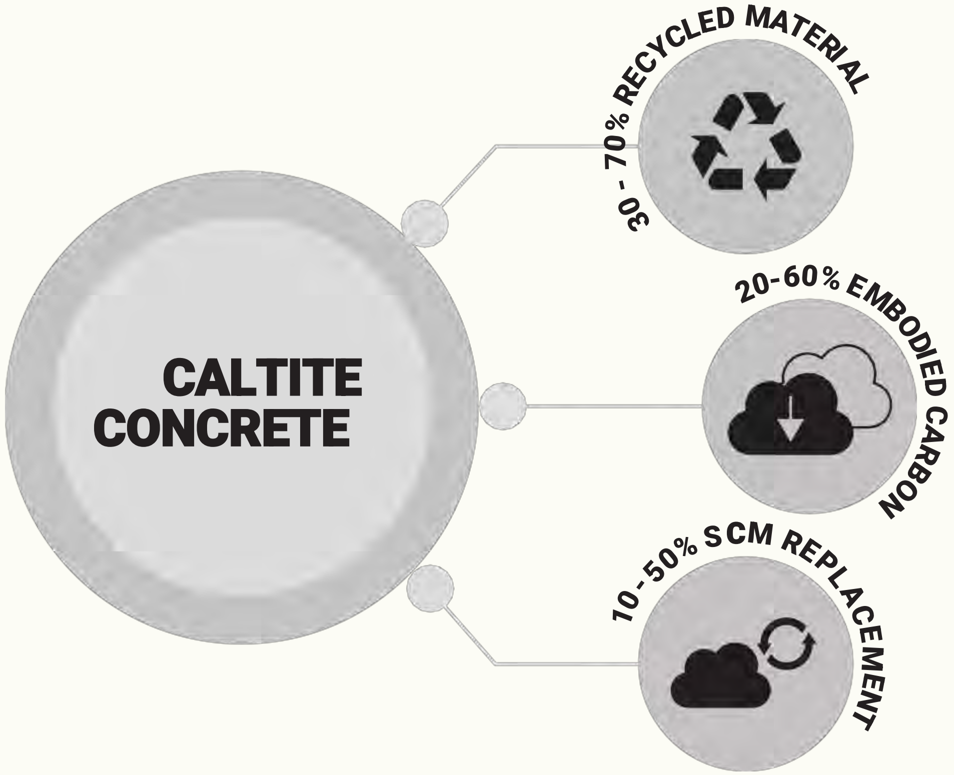


- Lateral water & salt movement into the matrix by absorption.
- This wets and electrically connects the remote points on bar.
- Establishes large "corrosion cells" with high corrosion current & rapid corrosion rate.

- No lateral water movement into matrix - Embedded steel remains permanently dry.
- Only minute section of bar exposed in crack space is subject to water.
- Negligeable corrosion current. Non-disruptive.

SUSTAINABILITY

Multiple envrionmental benefits of Caltite Concrete



- High-replacement SCM compatible
- Low embodied carbon
- Locally manufactured
- Contribute to circular economy
- Increases durability
- Reduces the need for constant repairs or replacement

SINGAPORE GREEN BUILDING PRODUCT
SGBC
EXCELLENT

Identifying and using the correct building materials is an important element of sustainable construction. A product that requires less maintenance over the lifecycle of the building will work out more cost-effective, especially if it also increased the performance of the building (Malin, 2000)

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A Review of Durability Design Options for Marine Concrete Structures

on the basis of Service Life, Maintenance and Whole of Life Cost

Dr Gitte Goffin

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Presentation Outline

- Corrosion Basics
- Supplementary Cementitious Materials
  - Effects on Durability
  - Risks
  - Design Life: Concrete Cover
- Chemical Inhibitors
  - Effects on Durability
  - Risks
  - Design Life: Concrete Cover
- Cathodic Protection
- Conclusions & Recommendations

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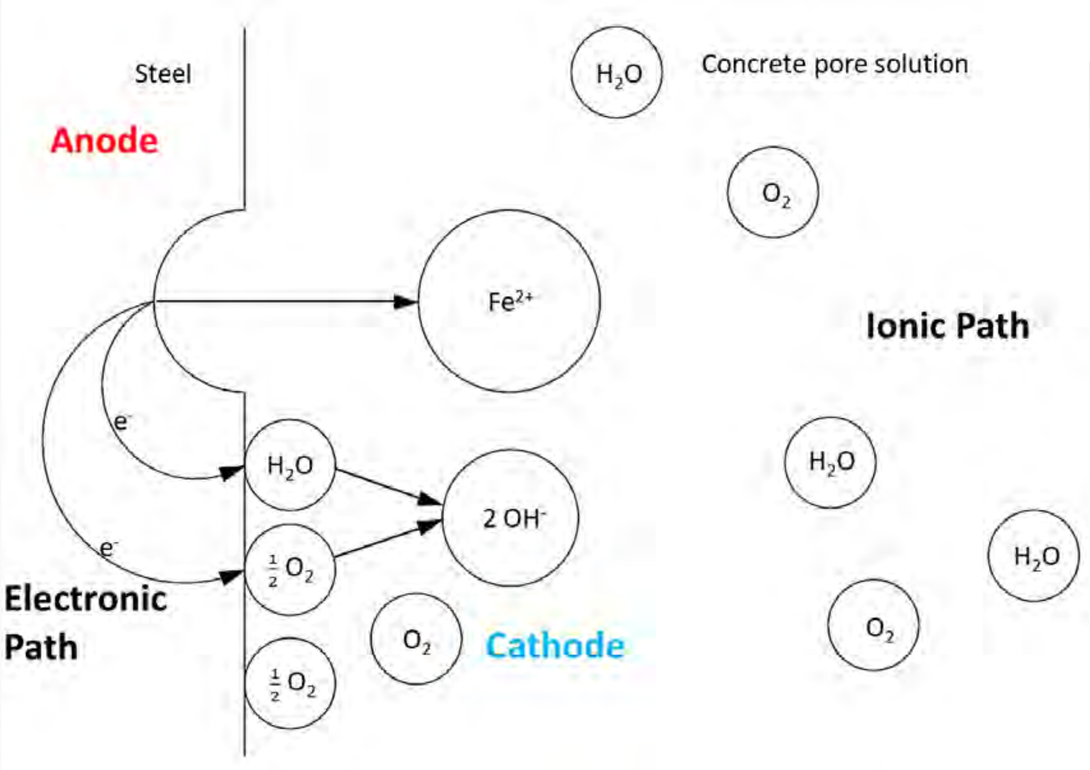
Corrosion

- ❑Corrosion
  - ❑ Oxidation of steel
  - ❑ Reduction of water
- ❑Passive layer
  - ❑ Passive Oxide layer formed due to high pH of concrete >pH12
  - ❑ Protects steel from corrosion
  - ❑ Not stable and may be de-passivated or degraded under aggressive circumstances (e.g. carbonation, chloride etc.)



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Design Options - SCM

❑ Supplementary Cementitious Materials:

- ❑ Industrial byproducts used to replace cement in concrete
- ❑ Admixed with concrete for new construction
- ❑ Increases chloride binding
- ❑ Reduces permeability and age-dependant apparent diffusion coefficient
  - ❑ Reduced porosity
  - ❑ Age effect: Less inter-connectivity between pores
    - Formation of secondary reaction products which fill up pores within the cement matrix

❑ Common SCMs:

- ❑ Coal industry: Fly ash (FA)
- ❑ Steel industry: Glass granulated blast furnace slag (GGBFS)
- ❑ Silicon industry: Silica fume (SF)

Design Options - SCM

- Effect on durability:
  - Reduced -
    - Embodied carbon
      - Use of industrial byproducts when compared to Ordinary Portlandite Cement alone
    - Heat of hydration – less thermal cracking
    - Permeability
      - Especially Silica fume due to its small spherical particles
      - Age effects – less pore connectivity
  - Increased -
    - Chloride binding
      - Reduction in the available free chloride
      - Especially slag
  - Increased resistance to sulphate attack and alkali-silica reaction

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Design Options - SCM

- Risks:
  - Reduction in carbonation resistance
    - Risk: Corrosion may initiate earlier
    - Prevention:
      - Application of anti-carbonation coating
      - Use GGBFS (over FA)
      - Increase cover
  - Reduction in workability (SF)
    - Risk: Improper placement, compaction and finishing
    - Prevention:
      - Use of high range water reducing admixtures
      - Limit to <8% SF in mix designs

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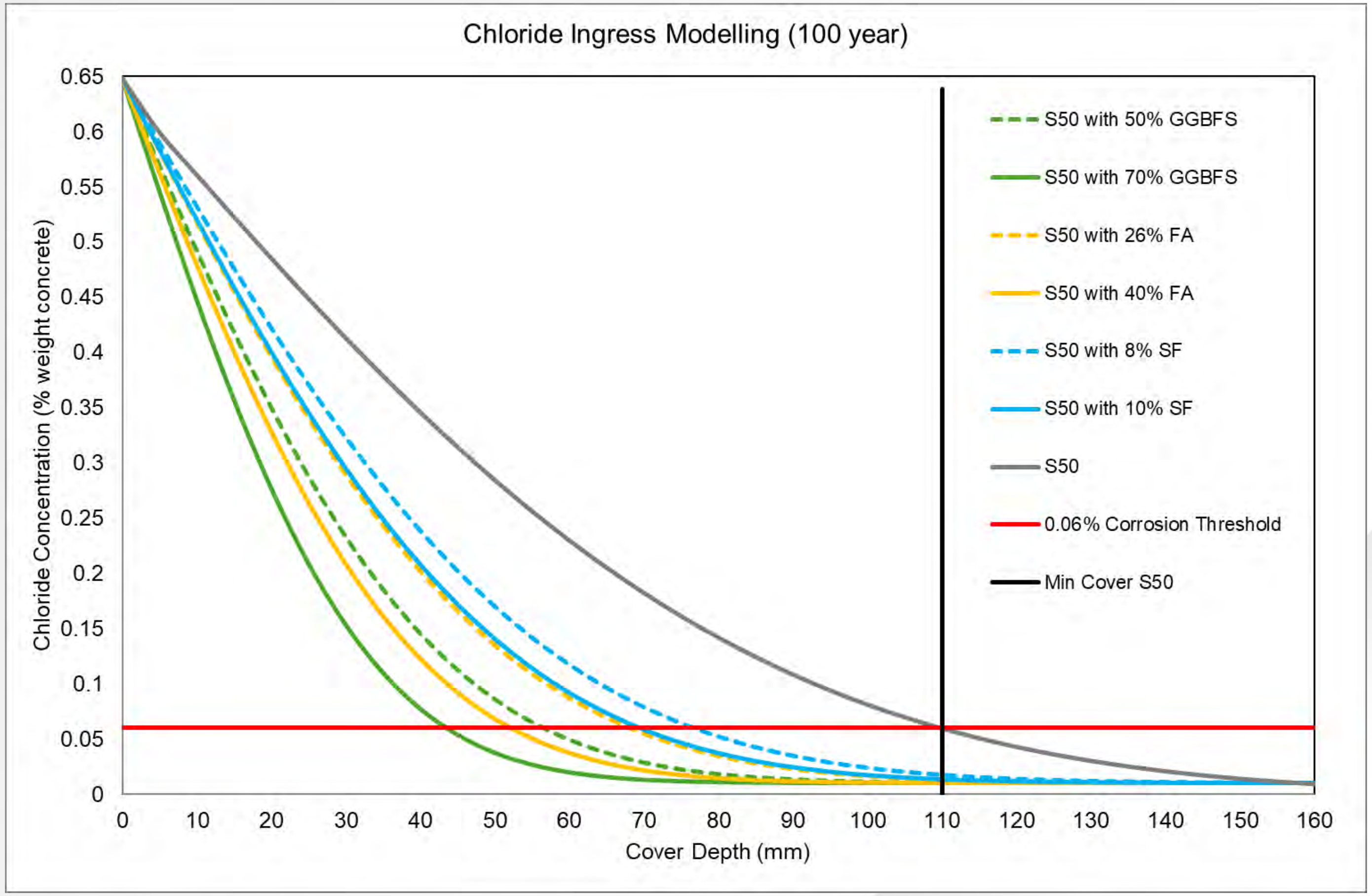
Design Options - SCM



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Design Options – Nitrite Inhibitors

- Chemical inhibitors:
  - Change the surface chemistry of the steel
  - Can provide corrosion protection even in the presence of high chloride concentrations
  - Dose rate dependant on expected chloride concentrations
- Nitrite inhibitors:
  - Inorganic, anodic type of corrosion inhibitor
  - Prevents the anodic reaction of the metal (i.e. corrosion of steel)
  - Admixed with concrete for new construction
  - Increased chemical stability of iron oxide passive layer by forcing free iron (Fe^{2+}) to form a stable oxide Fe_2O_3

Design Options – Nitrite Inhibitors

- Effects on Durability:
  - Reduction in corrosion rate with increasing dose rate
  - Increased time to corrosion initiation (hence service life) due to
    - Net reduction in corrosion rate
    - Increased resistance to chloride induced corrosion
  - Less effective in resisting carbonation induced corrosion
    - Still largely dependent on the pH

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Design Options – Nitrite Inhibitors

- Risks:
  - Reduction in concrete resistivity
    - Risk: Corrosion may propagate faster once initiated - particularly in saturated concrete
    - Prevention:
      - Dose rate specified to result in excess nitrites in the cement matrix – low risk
      - Regular monitoring to ensure net beneficial NO_2/Cl^- ratio is maintained
  - Can act as a set accelerator
    - Risk:
      - Placement and compaction issues if set initiates too quickly
      - Thermal cracking
      - Increased porosity/permeability
      - Reduced long term compressive strength
    - Prevention:
      - Use of set-retarding admixtures
      - Control of nitrite dose rates
      - Control of concrete temperature - prior to delivery and placement

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Design Options – Nitrite Inhibitors

- Risks:
  - Surface leaching in tidal / splash zones
    - Risk: Insufficient nitrite dosing to provide protection
    - Prevention:
      - Nitrite inhibitors are bound in the pore water / cement matrix and unlikely to back migrate / diffuse from the concrete
      - Testing to assess convection zone leaching
      - Dose rates typically specified to result in excess nitrites in cement matrix

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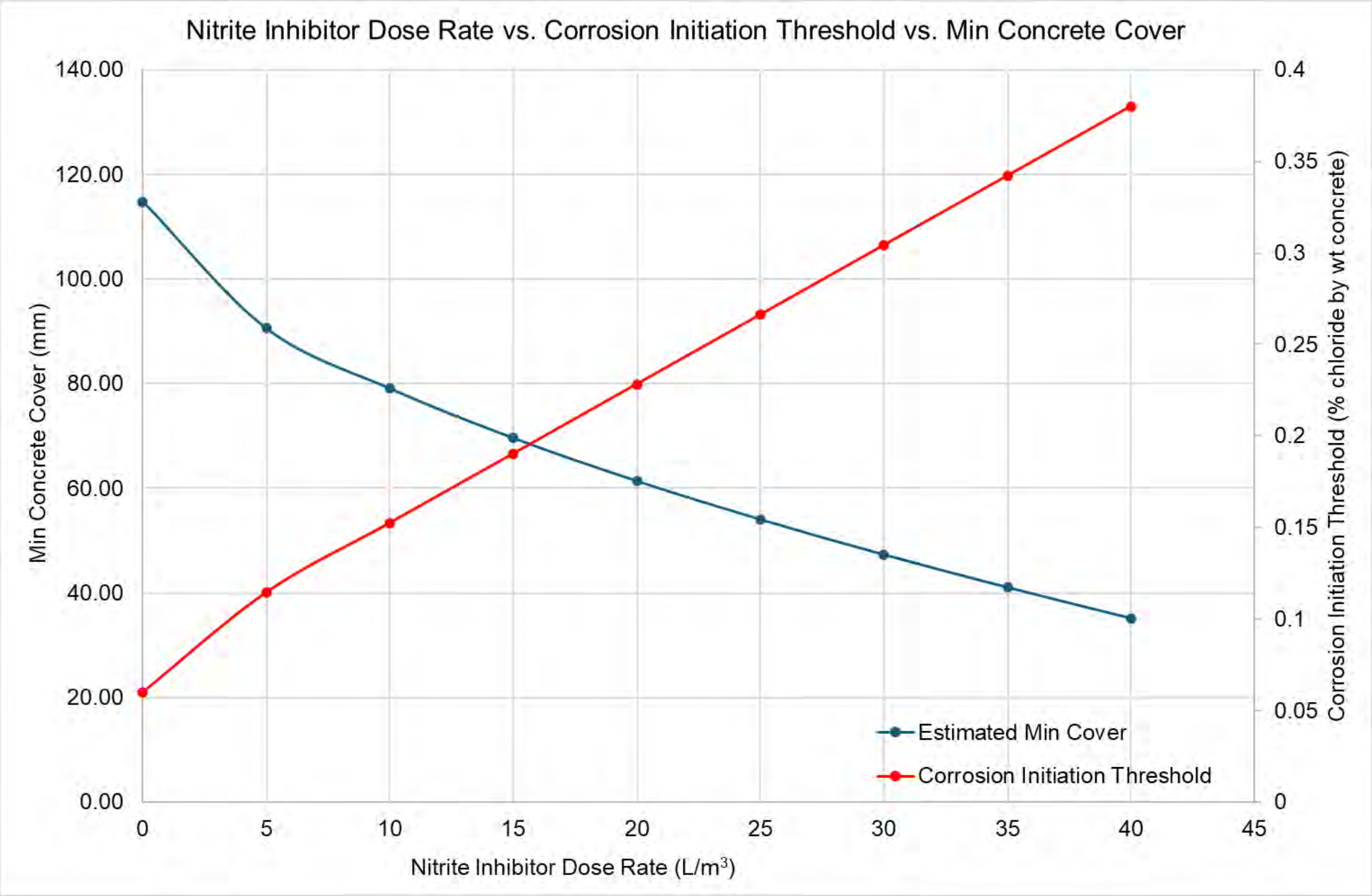
Design Options – Nitrite Inhibitors



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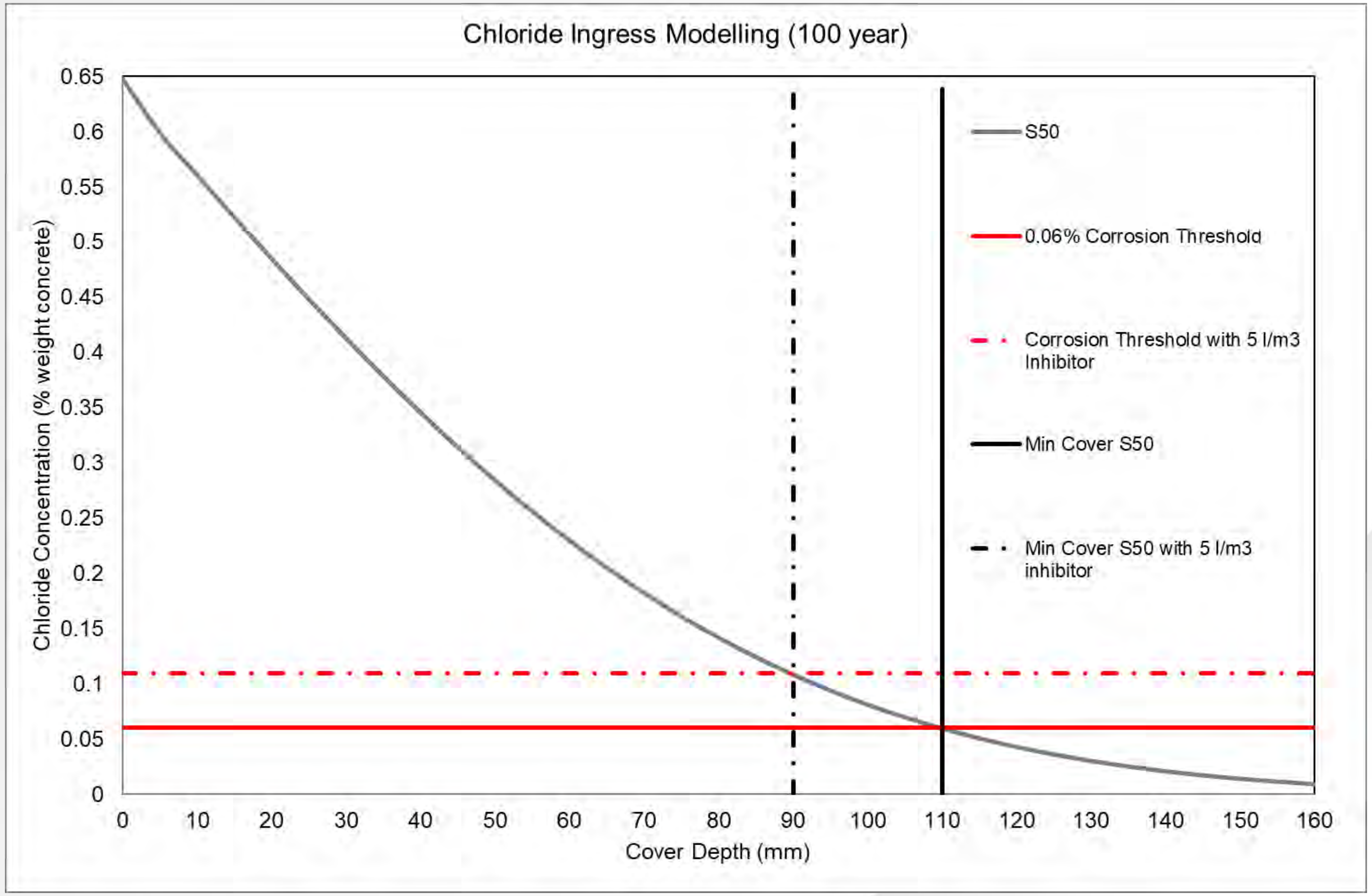
Design Options – Nitrite Inhibitors



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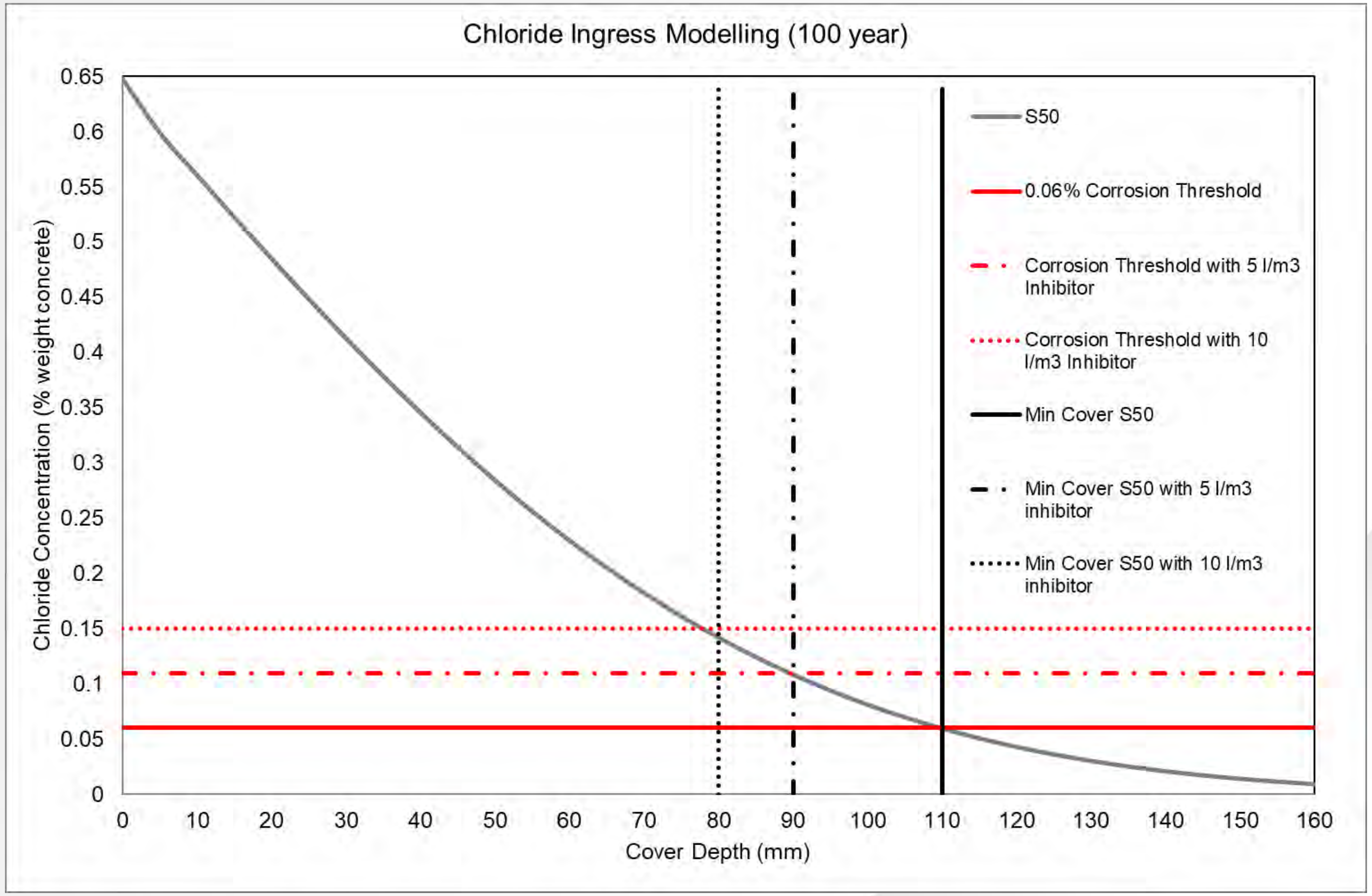
Design Options – Nitrite Inhibitors



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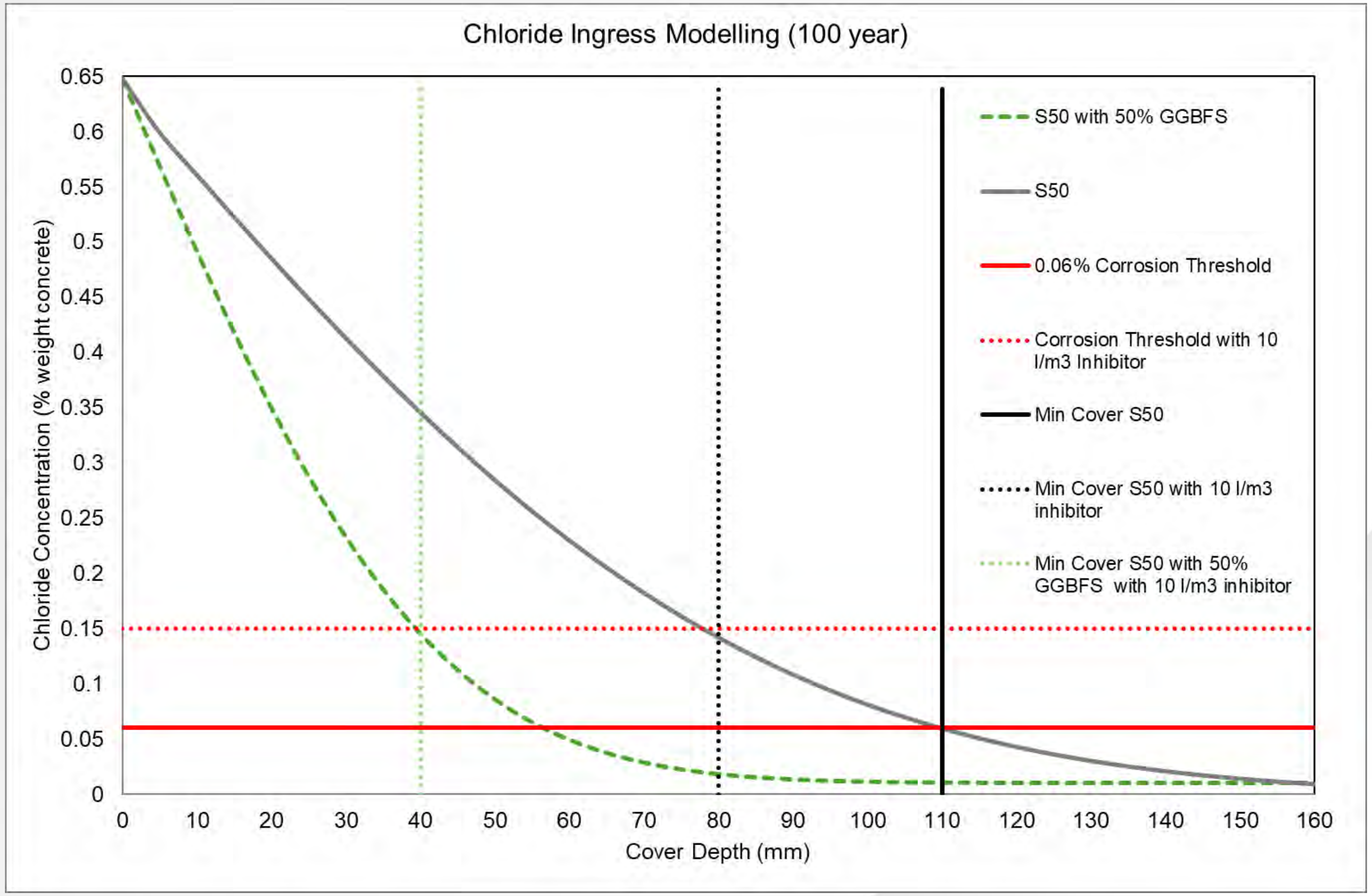
Design Options – Nitrite Inhibitors



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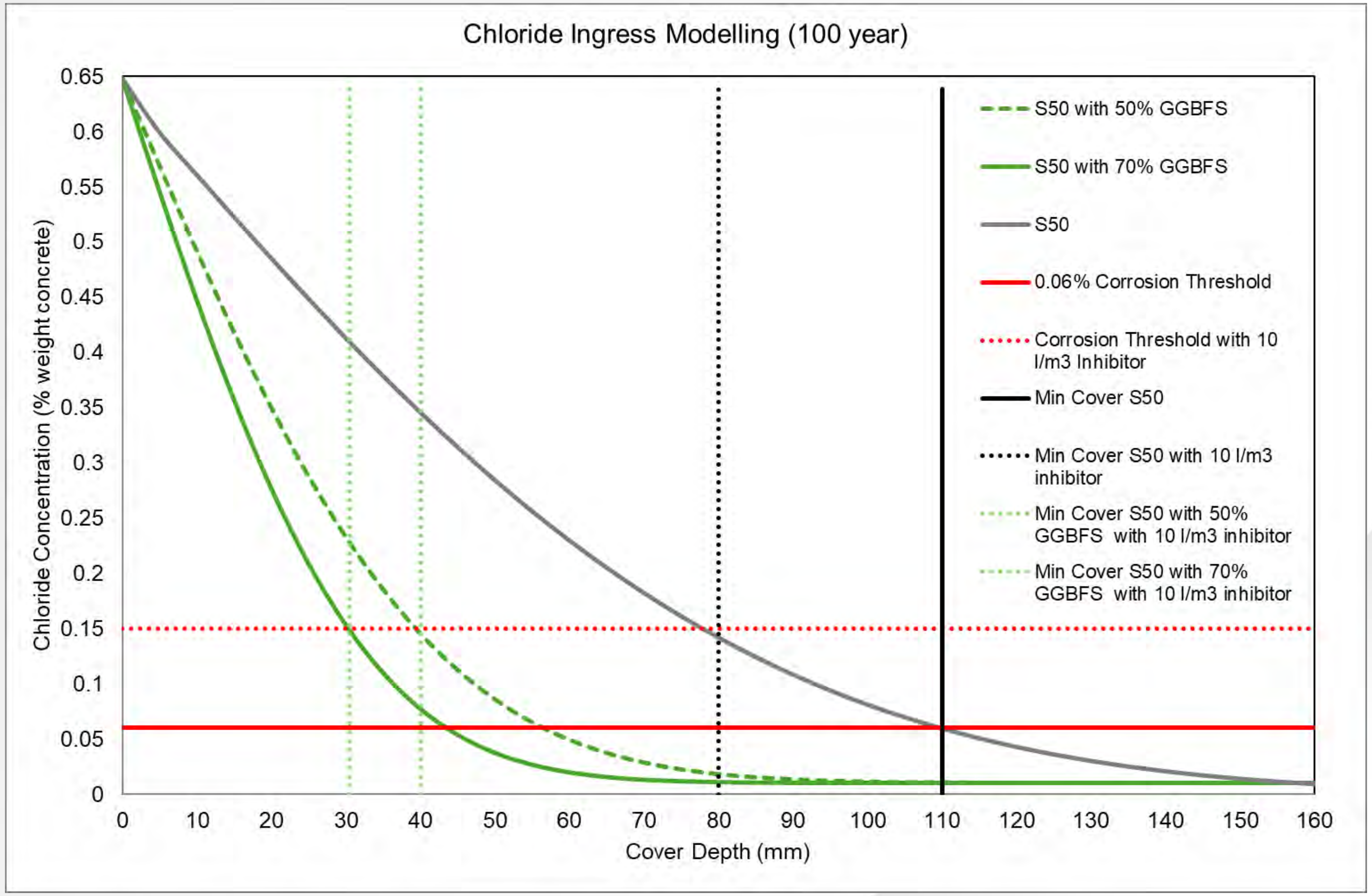
Design Options – Nitrite Inhibitors



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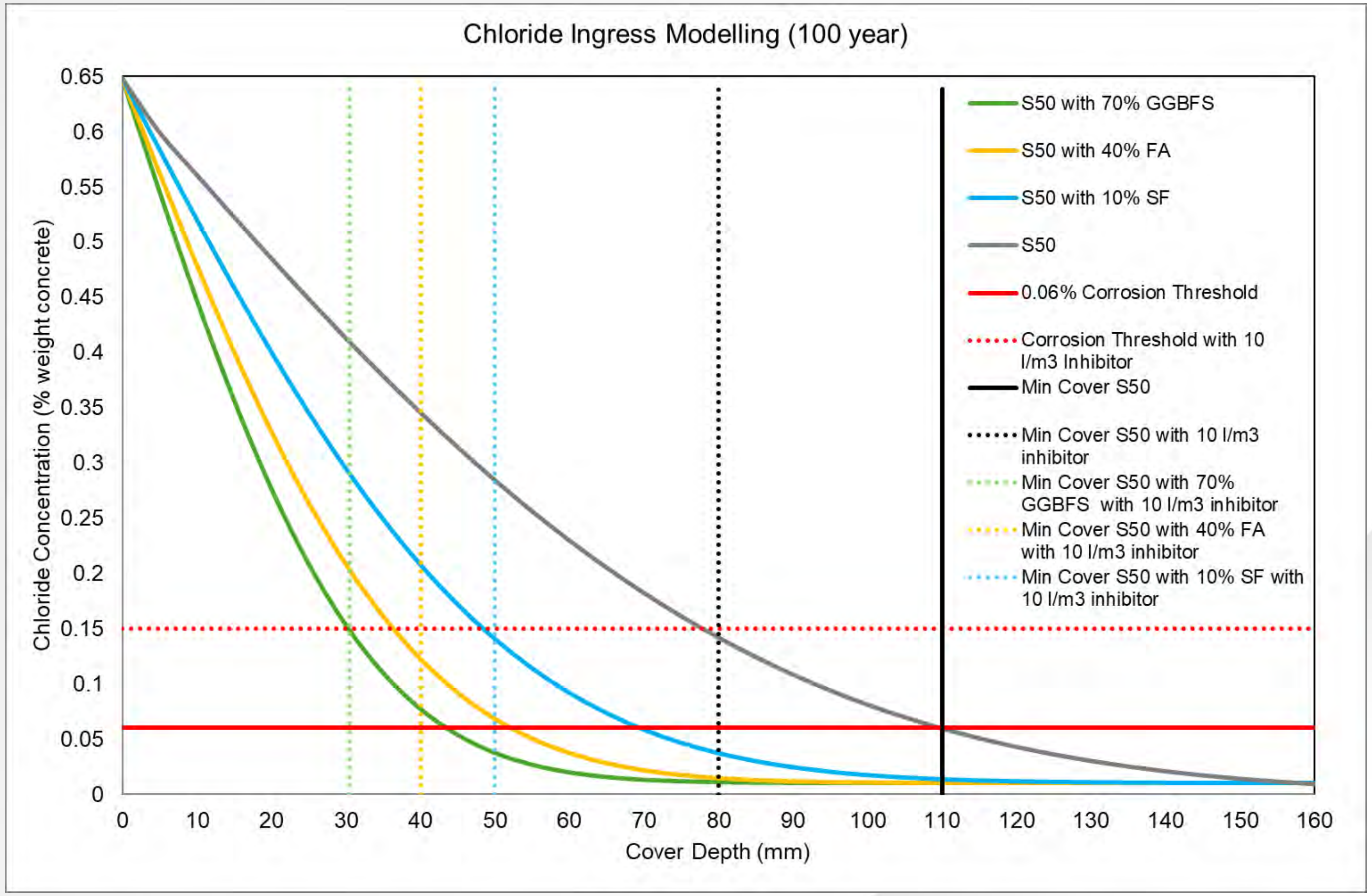
Design Options – Nitrite Inhibitors



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Design Options – Cathodic Protection (CP)

Option 1

- At design stage
  - Ensure reinforcement continuity
- Maintenance:
  - **During service life:**
    - Monitor chloride concentration
  - **Chloride threshold reached:**
    - Monitor half-cell potentials
    - Breakouts to confirm corrosion
  - **Active corrosion:**
    - CP system installation
    - Concrete patch repairs as required
    - CP maintenance (ref. Option 2)

Option 2

- At design stage
  - CP system installation
- Maintenance:
  - **During service life:**
    - ICCP
      - Monitor instant off potential etc.
      - Adjust current as required
    - SACP (Galvanic)
      - Monitor open circuit potential
      - Replace sacrificial anode as required (if water anodes)

Option 3

(not recommended, but is usually what happens)

- At design stage
  - No reinforcement continuity
- Maintenance:
  - **During service life:**
    - Monitor chloride concentration
  - **Chloride threshold reached:**
    - Monitor half-cell potentials
    - Breakouts to confirm corrosion
  - **Active corrosion:**
    - CP system installation
    - Concrete patch repairs as required
    - CP maintenance (ref. Option 2)

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Bringing ideas to life

Design Options – Cathodic Protection (CP)

Option 1

- At design stage
  - Ensure reinforcement continuity
- Cost:
  - Low upfront cost
  - Maintenance cost dependant on CP system
  - Low whole of life cost

Option 2

- At design stage
  - CP system installation
- Cost:
  - Highest upfront cost
  - Maintenance cost
    - High for ICCP
    - Low for SACP
  - Moderate whole of life cost
    - Higher for ICCP compared to SACP

Option 3

(not recommended, but is usually what happens)

- At design stage
  - No reinforcement continuity
- Cost:
  - Lowest upfront
  - High maintenance cost
    - Maintenance cost dependant on CP system
  - Highest whole of life cost

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Bringing ideas to life

Conclusions & Recommendations

- At design stage:
  - Ensure **reinforcement electrical continuity** for future CP
  - Adjust **SCM** ratios based on exposure specific service life models
  - Consider use of corrosion **inhibitors** for spray and / or tidal zone
  - Ensure the durability 3Cs: Cover, Curing, Compaction!

Conclusions & Recommendations

- Maintenance:
  - **During service life:**
    - Monitor chloride ingress concentration (regardless of design)
  - **Chloride threshold reached:**
    - Monitor half-cell potentials
    - Breakouts to confirm corrosion
  - **Active corrosion:**
    - Installation of CP
      - Postponed by **inhibitors** due to increased chloride threshold (if used)
      - Postponed by **SCMs** at the same cover depth due to reduced age dependant apparent diffusion coefficient
      - Increased current output of the anode by **inhibitors** due to reduced resistivity (consider in CP system design)
    - Maintenance of CP
      - Monitor potentials (instant off potential, open circuit potential etc.)
      - Adjust power supply current on ICCP systems as required or
      - Replace sacrificial anodes on SACP systems as required

aurecon
Bringing ideas to life

Conclusions & Recommendations

- Whole of Life Cost:
  - Moderate upfront cost
    - **SCMs** (standard practice): Negligible cost
    - **Inhibitors**: up to 90 $/m^3
    - CP continuity: Minimal additional cost
  - Low maintenance cost
    - **SCMs**: None
    - **Inhibitors**: None
    - CP installation: Moderate for SACP, High for ICCP
  - Low whole of life cost

aurecon

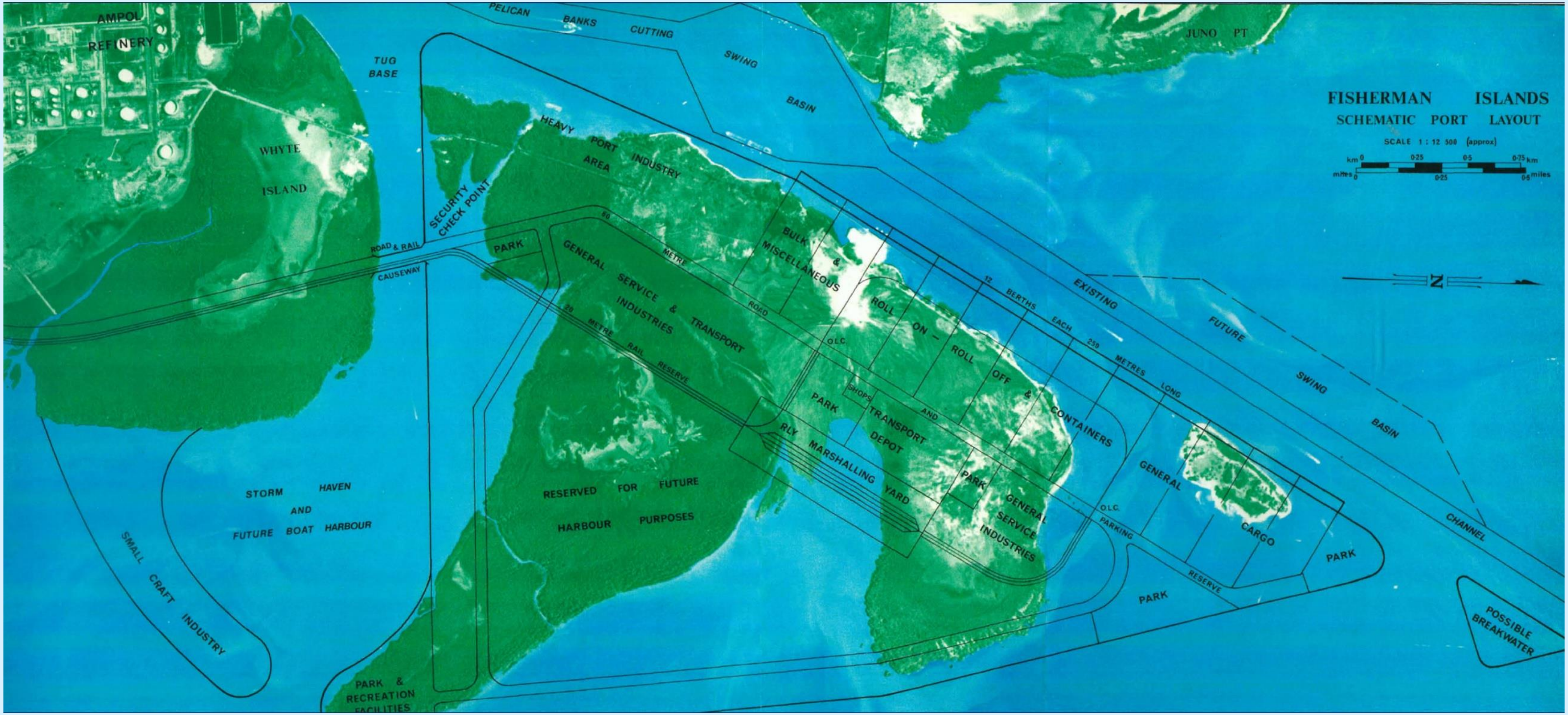
Bringing ideas to life

MANAGING OUR AGEING MARITIME ASSET BASE

Brodie Chan

Head of Asset Strategy

1976 Master Plan



Where our story began

Fisherman Islands 1978

Where we are today...

Fisherman Islands 2025

Where we are today...

2023/24 at a snapshot

A record
1.61m
containers

32.24m
tonnes of **cargo throughput**

Approx.
50%
of Queensland's **agriculture exports**

27
Wharf structures

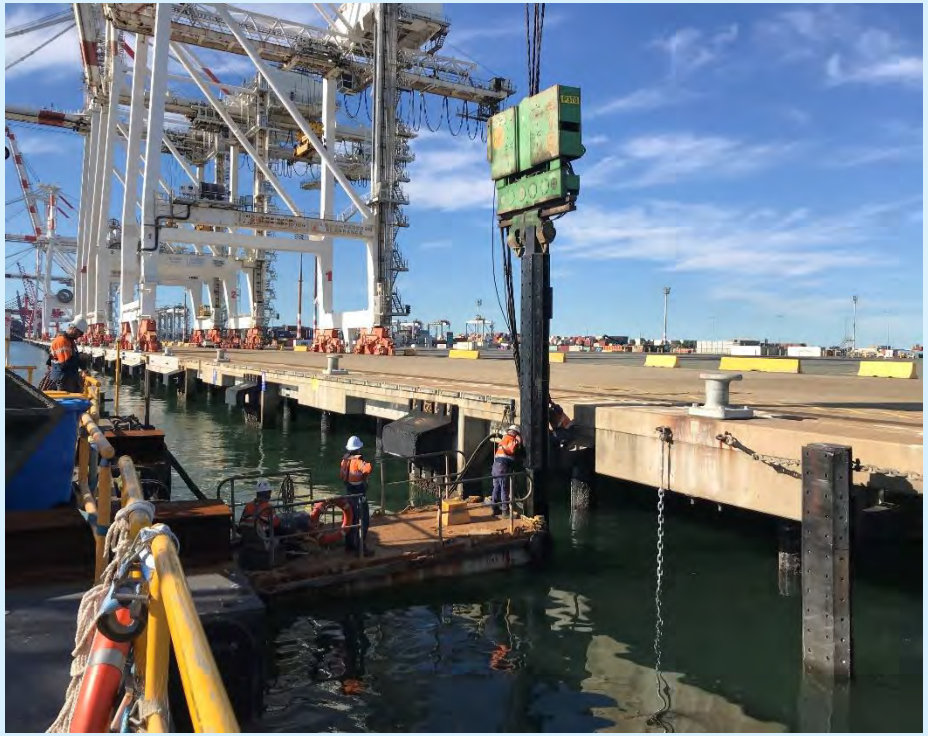
Approx.
5.3 km
of total wharf **quay line**

2,375
Vessel calls

Durability design through the years

1970-1990

- General Purpose (GP) cement concrete
- Higher diffusion rates
- High cement content (thermal issues)
- Bottom cover – min. 65mm
- Compressive strengths 30-40MPa
- Constructed lower to the water



Challenges with our older wharves

Pre-90's wharves

- Durability – time to corrosion initiation
- Cracking – higher serviceability crack widths
- Maintainability – wharf height
- Detailing – continuity, cover
- Historical records…

Durability design through the years

1996 -Now

- General Purpose / Fly Ash Binary blends
- Higher compressive strengths – 50MPa
- Increased design clear cover – 70mm min
- Increasing deck height above tidal zone – 2m
- Calcium nitrite (DCI) corrosion inhibitor
- Steel continuity**

Managing these assets

Routine visual inspection

Detailed condition investigations

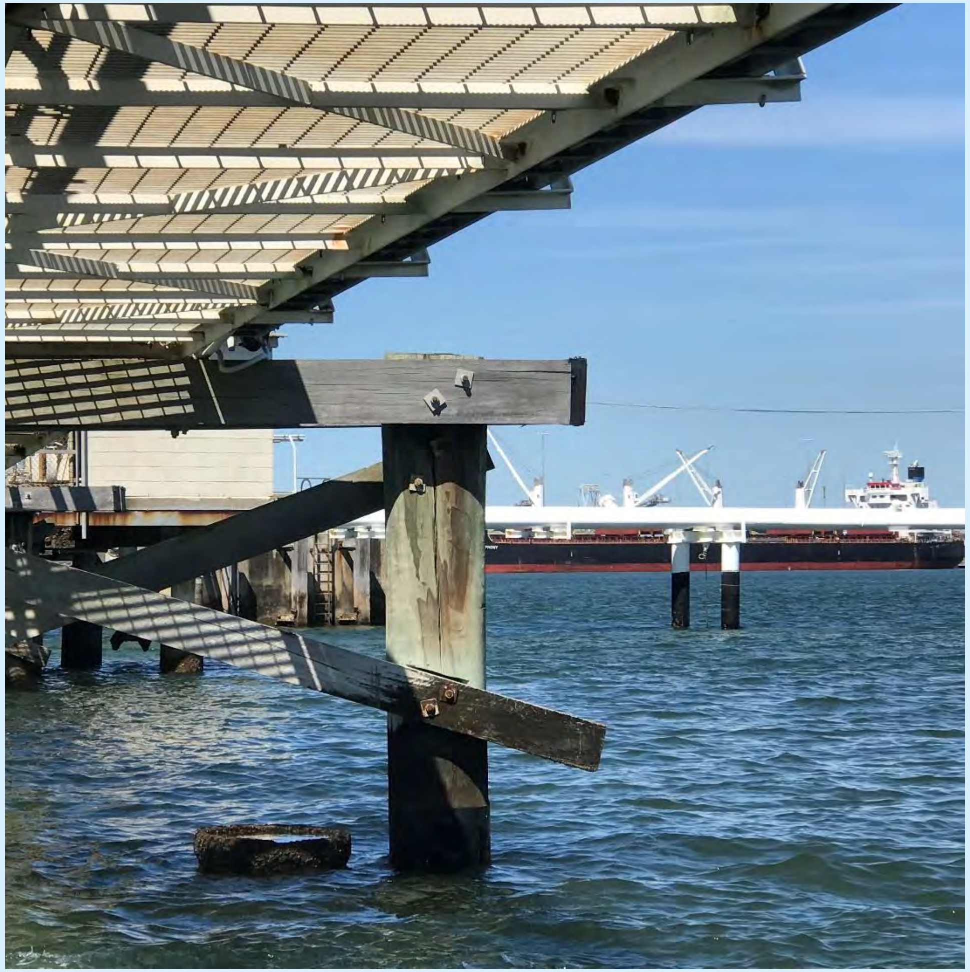
Asset Management Planning

Just-in-time intervention

Our approach

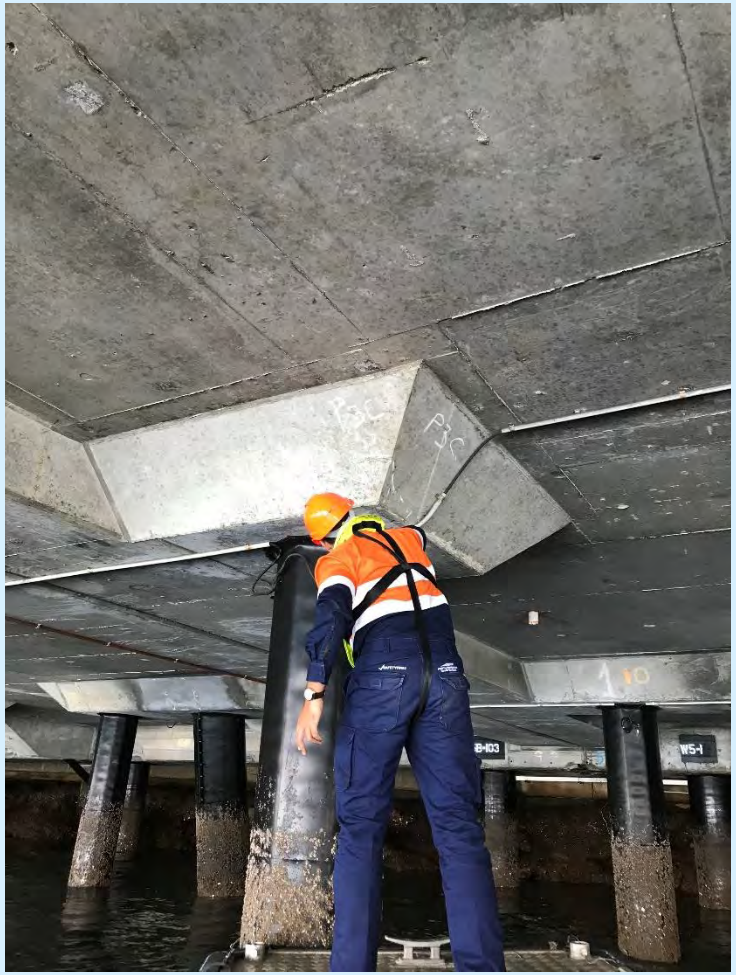
Routine visual inspection

- Annual
- Identify defects and condition
- Defect triage → Corrective maintenance (OPEX)
- Planned maintenance



Our approach

Detailed condition investigations

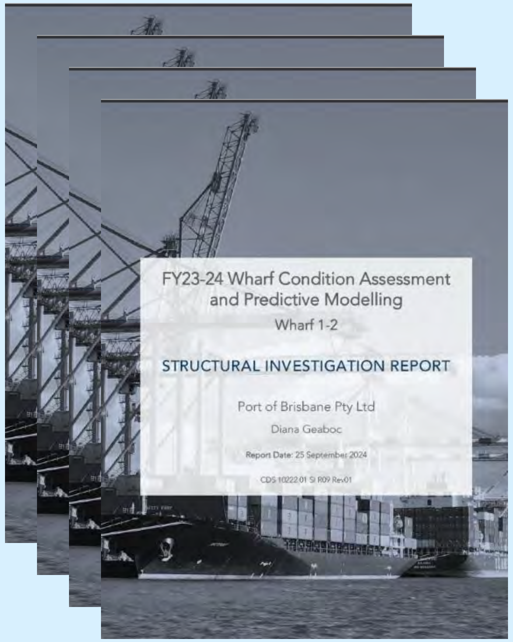


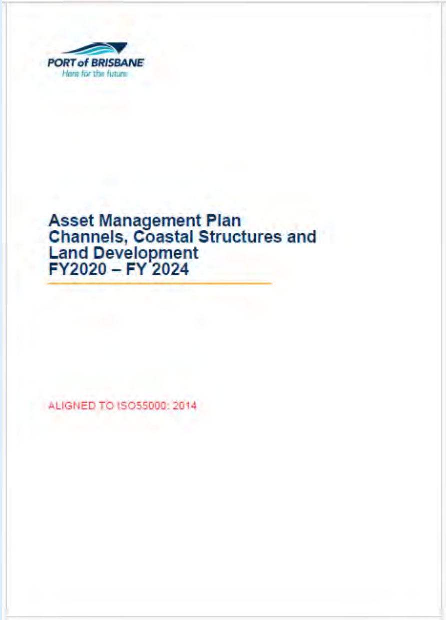
- Periodic – 5 year
- Destructive and non-destructive testing
- Predictive deterioration modelling
- Renewal forecast in line with asset management strategy

Our approach

Asset Management Planning

- Condition investigations translated into AMPs
- Informed decision making - integrated planning
- Long term forecast tracked through to delivery

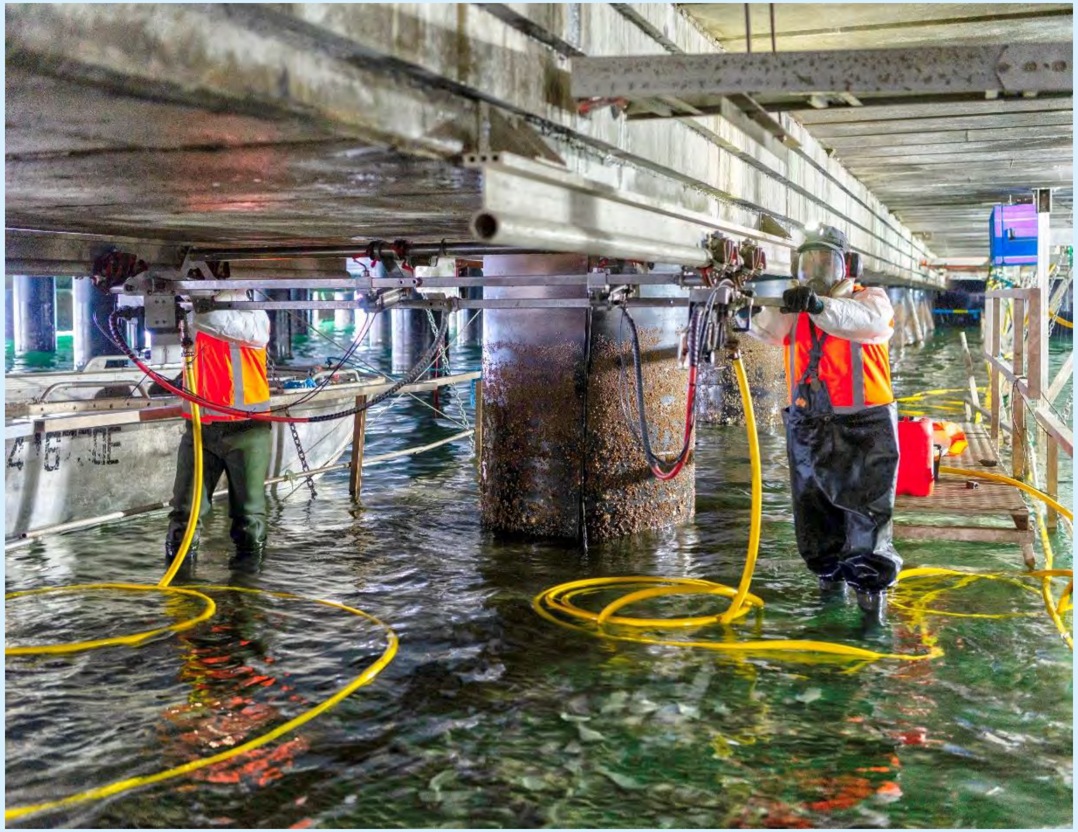




Our approach

Just-in-time intervention and life extension

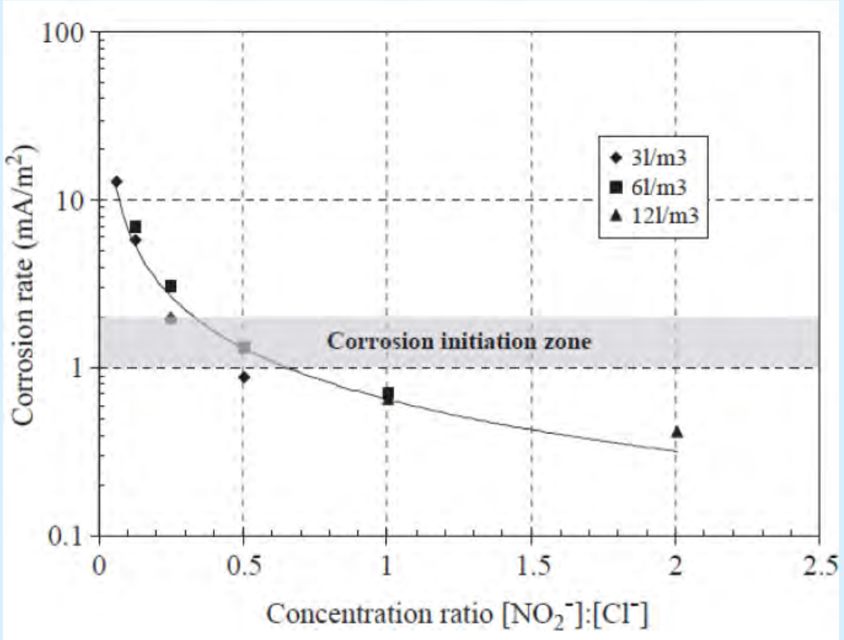
- At point of corrosion initiation
- Verification modelling
- State-of-the art review
- In-concrete ICCP



What we have learnt

By changing our design

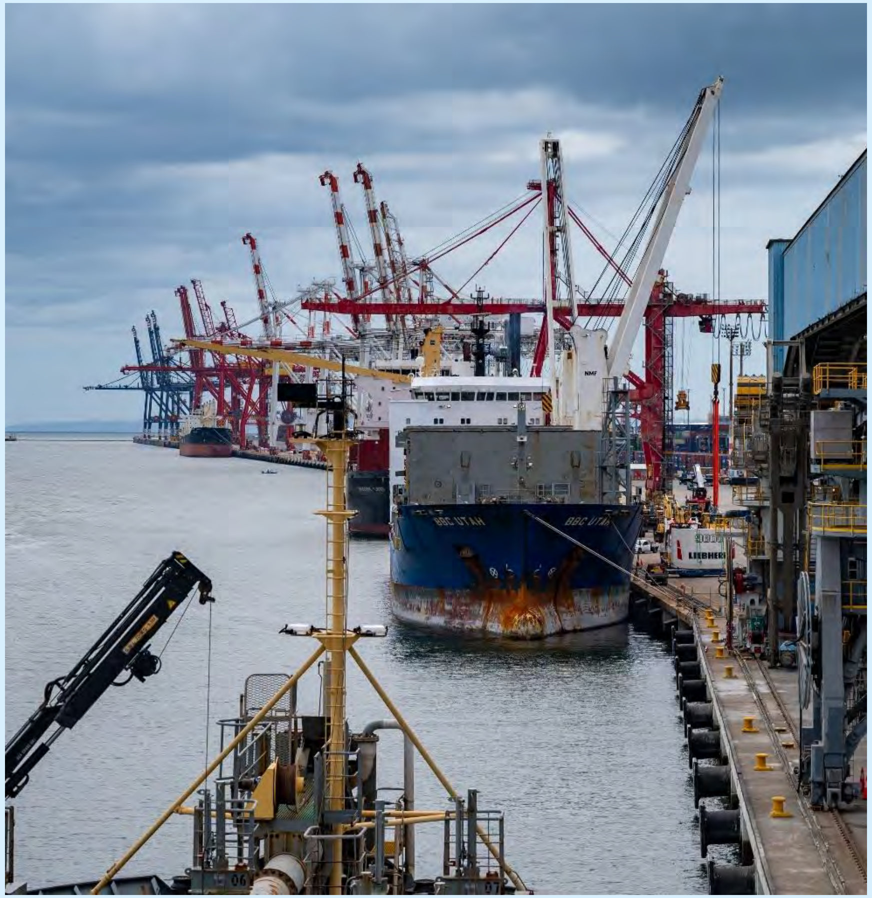
- Corrosion inhibitor
  - Time to corrosion increase >20yrs
  - Higher dosage = longer life
- Raising wharves
  - 40% reduction in surface chlorides
  - 80% reduction in chloride at cover depth



What we have learnt

The long-term view

- Less surprises = happier shareholders
- The battle of operations vs. maintenance
- Concrete coatings vs. impregnations
- 'Fine-tuning' ICCP design
- The simplicity in consistency



Thank you

Interested in hearing more about where to next?

CORROSION UNDER STRESS:

The Development & Application of Corrosion Control Solutions for Prestressed Concrete Structures

Jack McLean – Engineering Manager: Freyssinet Australia

FREYSSINET

OUTLINE

The Application of Corrosion Control Systems for Prestressed Concrete Structures

1. Corrosion of Prestressed Concrete: **Mechanisms** & **Implications**
2. Available Mitigation Strategies: **Pros** & **Cons**
3. Bulk Liquids Berth 1 – A Case Study:
    1. Diagnosis & Optioneering
    2. Mitigation Design
    3. Repair & Protect

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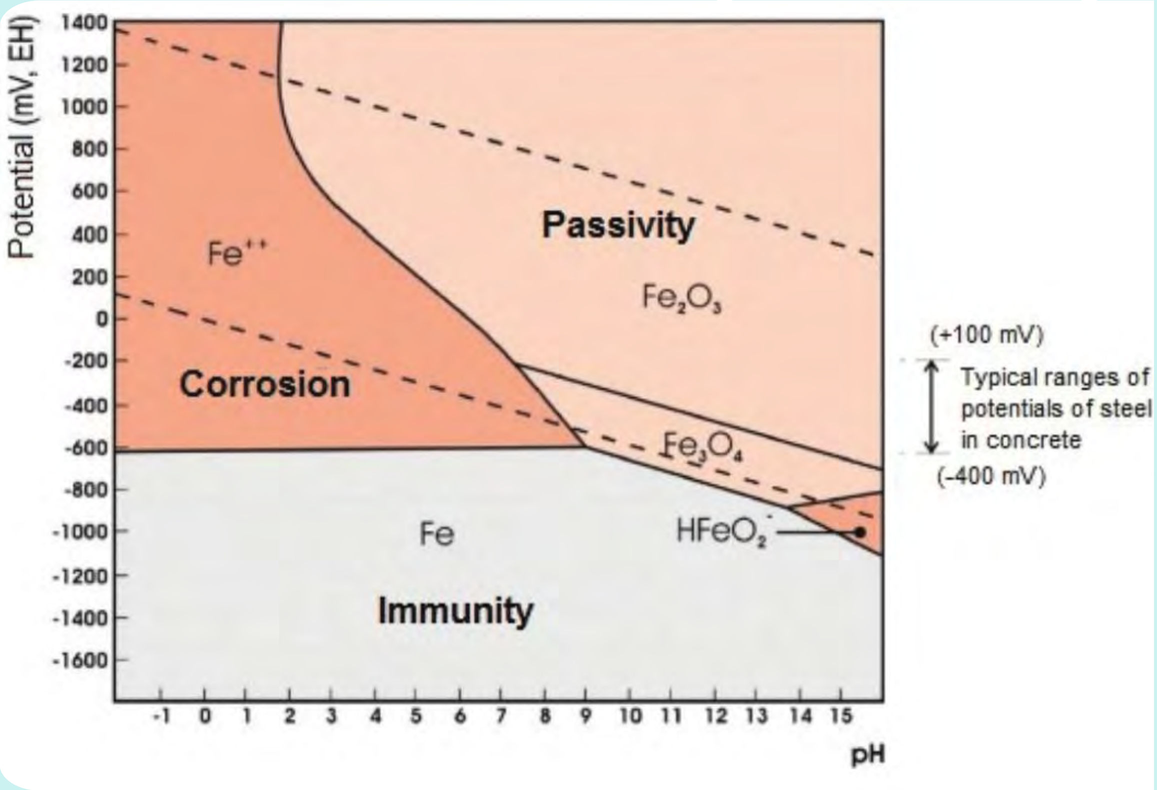
Corrosion of Prestressed Concrete: Mechanism & Implications

- Steel will **Freely Corrode** when exposed to **Most Electrolytes**
- Steel in Concrete however is mostly protected due to **Highly Alkaline Environment (pH 13-14)**
- The introduction of Cl- will **Break Down** the passive layer introducing pitting corrosion and lateral corrosion.
- **Corrosion Rate** will depend upon drop in resistivity, surface area ratio (anode/cathode) and water saturation level
- Prestressed Concrete is understood to have higher **Corrosion Resisting Properties** than RC Concrete



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Corrosion of Prestressed Concrete: Mechanism & Implications

- Whilst it is more resistant to corrosion, when it does occur, the implications are substantial.
- Corrosion of Prestressed Tendons can result in catastrophic failure of the element:
  - **Brittle Fracture** – Exceeding the load capacity
  - **Stress Corrosion Cracking** – Caused by anodic stress corrosion and hydrogen induced stress corrosion cracking.
  - **Fatigue and Corrosion Influences –** corrosion fatigue cracking & fretting corrosion
- In all instances, failure is caused by substantial loss of ductility and therefore, early identification is **imperative**.

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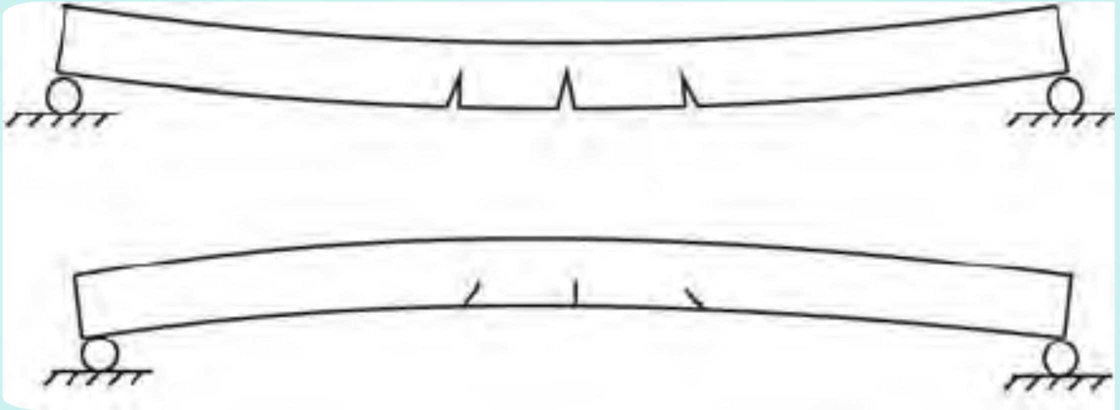
Corrosion of Prestressed Concrete: Mechanism & Implications

- Traditional RC corrosion is visually identifiable through cracking/spalling/delamination – **Easy to Identify**



- Prestressed elements corrosion is often more **difficult to identify**:
  - Corrosion Product Buildup within the voids between the strands, resulting in less volumetric expansion.
  - Hogging bending effects from prestressed steel – compressive forces at the bottom of the element, reducing the visibility of cracking

Mitigation Strategies: Augmentation, Mechanical, Electrochemical

- Generally, traditional remediation techniques do not apply to prestressed concrete
- Risk of Destressing or Damaging Very brittle strands
- Augmentation of Strand is not possible
- Supplementation of Structural Strength is required through external methods

- Carbon Fibre - Passive
- External PT – Active

- External Repair Methods have their own limitations and challenges and often will not be able to 100% "augment' existing condition.

Mitigation & Control is Best Addressed through Preventative Measures

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Mitigation Strategies: Augmentation, Mechanical, Electrochemical

- "Mechanical Protection" systems refer to Physical Barriers that prevent or delay the ingress of Cl-, O2, H2O.

- Penetrative Sealers – Silane/Siloxane
- Barrier Coatings – Epoxies, PU

- Effective at the early stages of contamination but are less effective once critical thresholds have been achieved.
- 10-15 year service life

Mitigation Strategies: Augmentation, Mechanical, Electrochemical

- Application of Cathodic Protection will serve two key purposes:

1. Draw the Cl- away from the steel ∴ **maintain alkalinity**
2. Lower the electro potential of the steel to within the **immunity zone**

- Most Effective Strategy once Cl- is at steel

- Complex/Expensive/Risky (Hydrogen Embrittlement)

An Effective Solution – Requires Lots of Consideration

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Case Study:

BLB 1

A Hybrid Solution

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Project Background

- **Bulk Liquids Berth – Constructed in the 1970's**
- Supply of Essential liquid products handling and distribution for NSW (Gas, Fuel, Bitumen etc)
- Traditional RC Wharf Structure with various pre-cast, prestressed concrete bridge elements – walkways, pipe bridges, catwalks etc.
- Aggressive Environment over 40 years since time of construction
- Considered a "Hazardous Area" due to volatility of the products being stored/handled on site.

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Problem Diagnosis & Developing the Business Case

- **The asset owner uses an asset management framework that includes a Marine Structures Inspection Program.**

- Two Yearly Structural Condition Assessments for different elements, including:

    - Visual Inspection & Crack Mapping
    - Ferric Covermeter & GPR Scanning
    - Potential Mapping
    - Surface-Mounted Resistivity Analysis
    - Chloride Profiling & Diffusion Modelling
    - Carbonation Testing, and
    - Alkali Silica Reaction (ASR) Testing

- **Ongoing/Worsening Corrosion Activity was identified to the majority of the precast, prestressed elements.**

To Maintain Use of the Structure A Life Extension Strategy Was Required

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The Decision Making & Optioneering Process

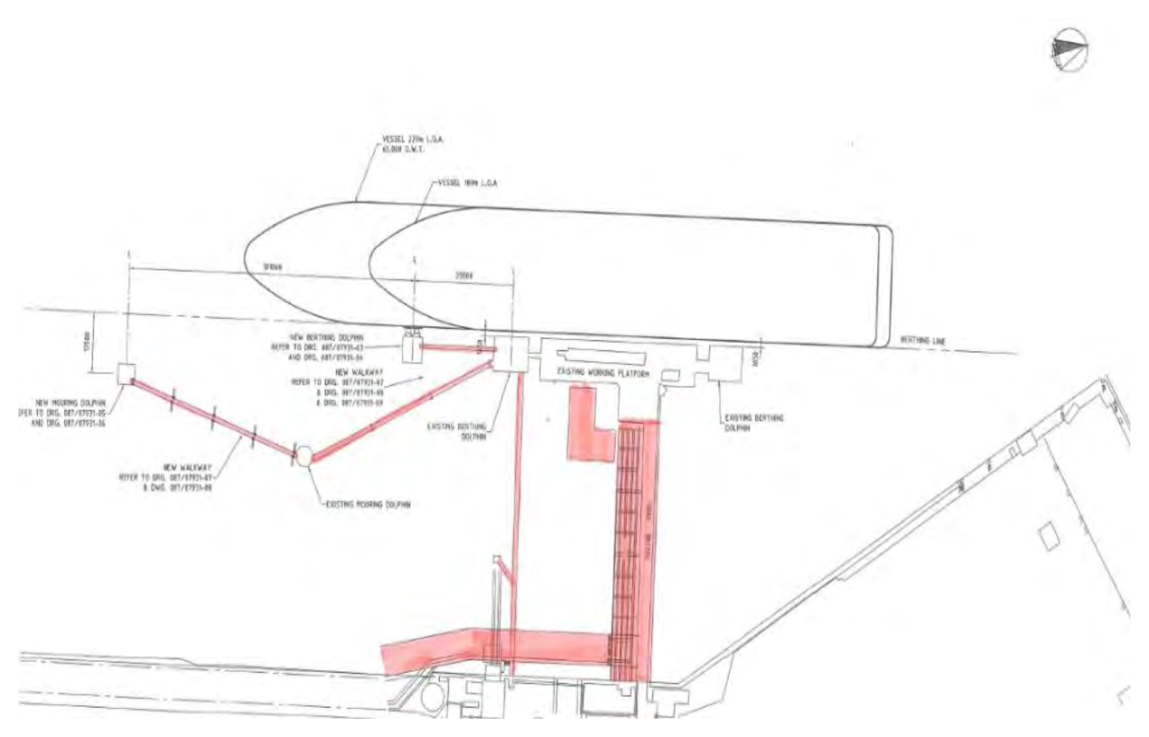
- To ensure informed decision making, a detailed optioneering process was undertaken – Assessing Technical, Financial, Environmental, Operational and Reputational impact to the facility and its stakeholders.

  - Option 1 – **Do Nothing** : 10 to 20 years

  - Option 2 – **Concrete Repair & CP** : 30+ years

  - Option 3 – **Replace Structures** : 30+ years

- Each Option was assessed via a **Quantitative Risk Assessment** and a **Net Present Value (NPV)** lifecycle Cost assessment



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The Decision Making & Optioneering Process

- **Option 2** (Electrochemical Treatment with Concrete Repair) **–** Highest Value solution
- Lowest Risk Outcome over the life of the asset
- **Acceptable $$$ (Capex & Opex)**
- **Minimal Disruption** to the Operation of the Facility
- **Business Case** was Prepared and submitted to the board of the port authority **for Approval**

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The Design Process – A Challenging Environment

- **Further Optioneering was undertaken, and a Hybrid Corrosion Protection Solution was adopted:**

- Stage 1 – Energisation (Extract Cl- away & Repassivate Steel)
- Stage 2 – Galvanic Stage (Maintain low Corrosion Rates through Galvanic *Zinc* Anode Arrangement)

- Reduced Risk to the structure – Minimal Chance of Hydrogen Embrittlement
- Simplified Maintenance & Monitoring Requirements

- Design included provision of 35,000 + Hybrid Anodes, 188 Zones - across the total structure

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The Design Process – 50 Year Design Life

- **Hybrid Corrosion Protection – Relatively New** (~12 Years at the time this project was underway)
- Risk of further chloride ingress & redistribution of Cl- : depassivation of steel over design life.
- Design Calculations were carried out to verify sufficient capacity for **additional impressed current treatments** over the design life:
- Impressed Current Energisations at:
  - Year 0
  - Year 15
  - Year 30
- System Zoned & Wired in such a way as to allow for ad-hoc monitoring/energisation over this period

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The Design Process – Avoiding Embrittlement of Prestressing

- The **Energisation Phase** of Hybrid Corrosion Protection is when the structure is at the **Highest Risk of Embrittlement.**

- For RC Structures – Energisation is typically applied at a constant voltage ~ 8V dc (7-28 days)
- For Prestressed Concrete – This must be much lower.

Design Considerations were made to reduce this risk through:

- Limiting the size of zoning - more control/resolution
- Increasing qtty of permanent reference electrodes
- Adopting a conservative potential limit -800mVssc
- Specifying an alarmed, monitoring system

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Repair & Installation Challenges: Working With Prestressing

- As with all CP systems, **extreme care** is required during installation to eliminate risks of short-circuits, discontinuity, poor quality backfilling or electrical works
- With Prestressed Concrete, the risks associated with these considerations are amplified.
- Robust Quality Control systems are required, Routine inspections, hold points, verification
- **Test, Test, Test… Then Proceed.**
- Working with prestressed concrete presents some unique challenges.

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Repair & Installation Challenges: Staging & Managing Repairs

- If not completed correctly, repairs to prestressed concrete can risk **Destressing** the tendons.
- **Staging is key** to minimize any temporary reduction in structural capacity and limit the quantity of concrete material for removal at any one time.
- During the BLB 1 project consultation from structural engineers was sought to develop standard repair guidelines to inform the works.
- **Additionally,** Use of cutting grinders & Percussive jackhammers can risk damaging the tendons
- Ultra-High Pressure Water jetting **(Hydrodemolition)** was used .
- **Whilst Highly Effective; expensive for small repairs, safety considerations and high noise levels.**

Planning is Key

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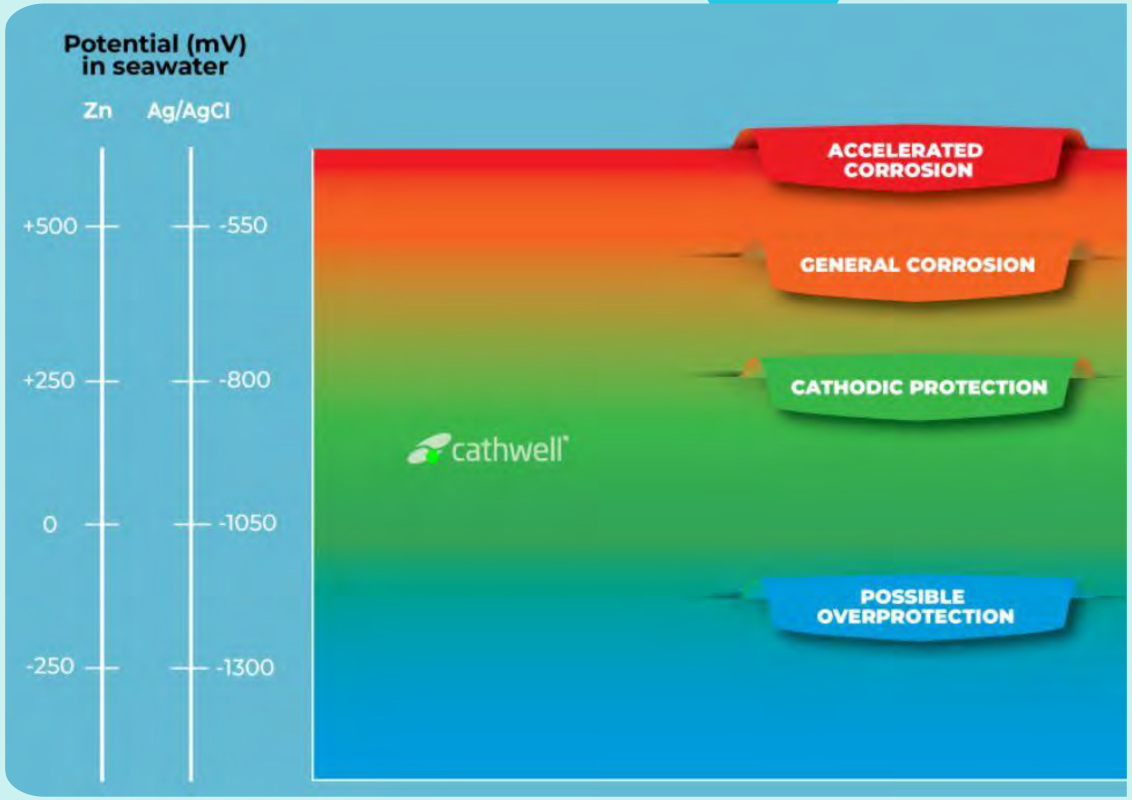
Repair & Installation Challenges: Preventing “Overprotection”

- “Overprotection” occurs when the reinforcing steel is polarized beyond optimal levels and can result in hydrogen embrittlement of the steel – **Reducing Ductility!**

- The Energisation phase of the Hybrid Process presents very real risks of overprotection if not managed properly.

- BLB 1 Project adopted a sophisticated remote monitoring and control system for all temporary power supplies
    - Alarms (Email & SMS)
    - Voltage & Current Limiters
    - Data Logging & Assessment

- **Full Project Visibility – All Stakeholders**



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In Summary

1. The implication of corrosion of prestressed concrete can be catastrophic and is not to be underestimated
2. Management & Control requires a Proactive Approach from Asset Owners and corrosion practitioners
3. Whilst there are complexities with designing and installing electrochemical treatments for these structures, it is a viable – long term solution

FREYSSINET

Thank You

Jack McLean

0439 013 254

jmclean@Freyssinet.com.au

AS3600 - 2025 Concrete Code Structure

Dr. Sam Mazaheri

Who writes AS 3600?

- Standards Australia Committee BD-002
- Consulting Engineers
- Engineers from Manufacturers or Suppliers
- Engineers from Universities
- Builders
- Engineering Software Developers
- ABCB Representative

History of Structural Concrete Codes in Australia

- First published as AS CA2-1934
- Second Edition AS CA2-1958
- Third Edition AS CA2-1963
- Fourth Edition AS CA2-1973
- Revised and redesignated AS 1480-1974
- Second Edition AS 1480-1982
- **Revised incorporating AS 1481 as AS 3600-1988**
- Second Edition AS 3600-1994
- Third Edition AS 3600-2001
- Fourth Edition AS 3600-2009
- Fifth Edition AS 3600-2018 Amdt 1and 2
- Sixth Edition AS 3600-2025

What's New in AS3600-2025

WHAT HAS CHANGED

WHY IT HAS CHANGED

WHAT IT MEANS TO YOU

Major Changes to AS3600

Design for Earthquake Actions – addressing lessons from the Christchurch Earthquake

Fire provisions updates – updates for columns and spalling

Serviceability provisions – revised for shrinkage, creep, crack width, and deflection

Higher strength steels – further development of design factors

Punching shear – updated rules for slabs

Design life – recognition of periods longer than 50 years

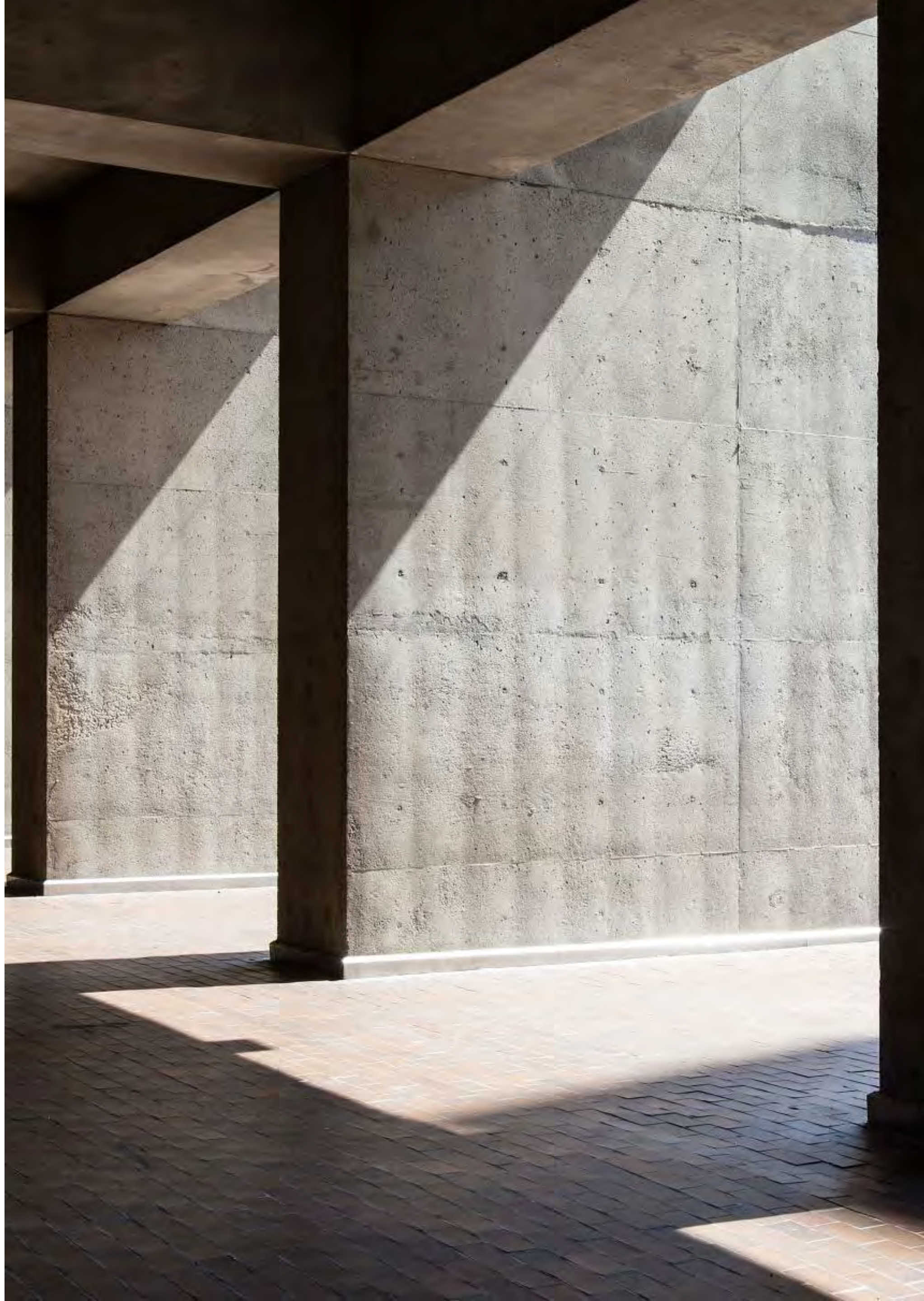
Curvilinear stress blocks – introduced for software compatibility

Prefabricated concrete elements – now in a new and expanded section

Assessment of existing structures – addressed in an appendix

Design for Earthquake Actions

- Includes extensive changes in Slabs, Walls and Earthquake Sections
- Structural integrity reinforcement in slabs and band beams extensively revised to reduce the additional reinforcing required.
- Aspect ratio defining transition from flexural to squat walls reduced.
- Upper bound on shear strength of walls introduced.
- Concept of Critical Detailing Regions introduced for areas such as plastic hinges across walls and earthquake Sections
- Guidance added on buildings where ductility varies vertically.
- Vertical reinforcement in critical detailing regions reduced by 15%.
- New clause recognising the ductility of footings supporting structural walls .
- Specific requirements for prefabricated walls for limited and moderately ductile conditions.
- New clause permitting low rise buildings with squat walls to adopt a system where ductility can be developed in the footings.
- Modelling and scaling requirements set down for non-linear pushover analysis.
- Reinforcement and confinement provisions on Boundary Elements extensively updated and relaxed.

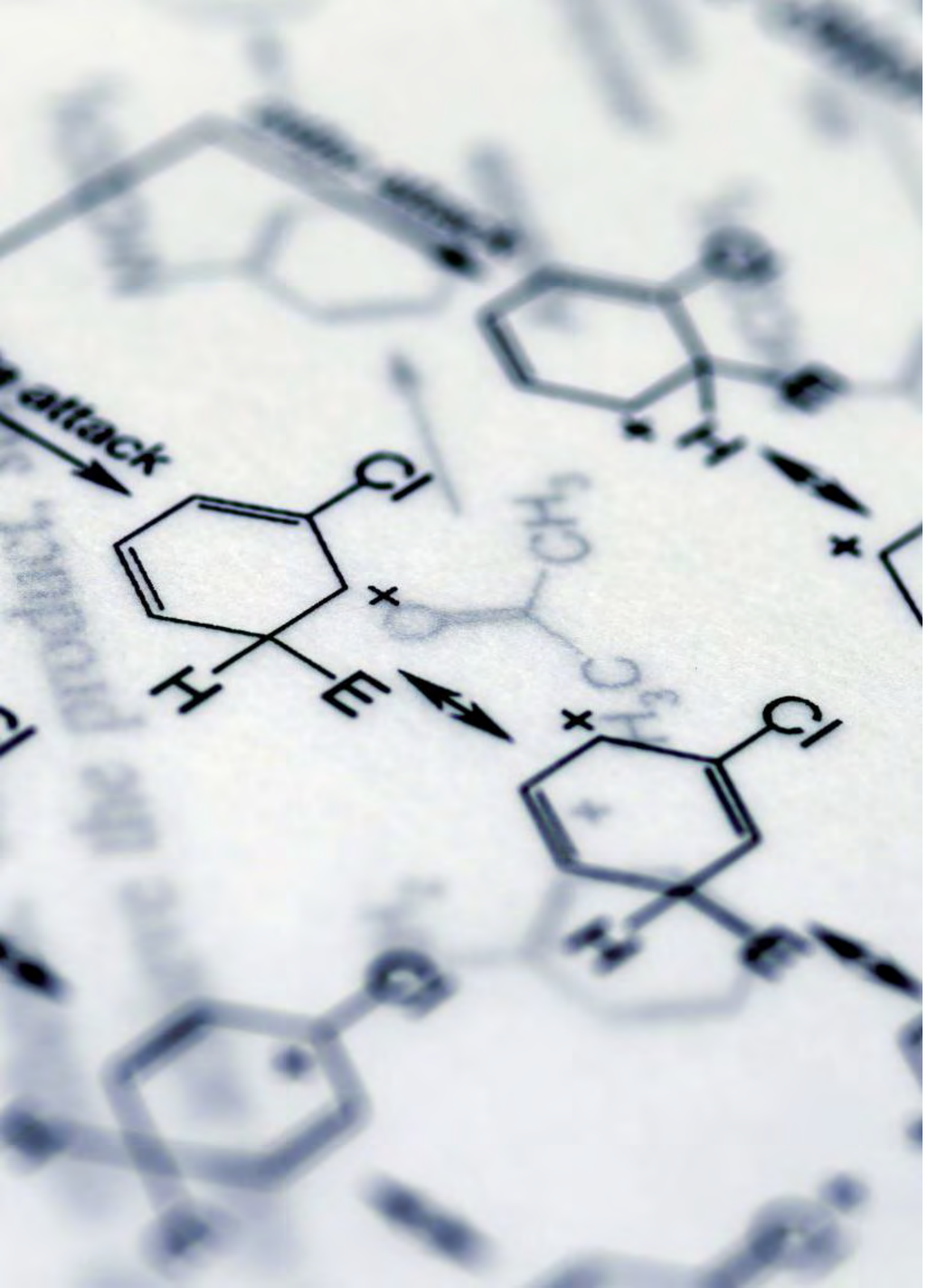


Strength and Analysis

- Provisions for designing with **600 and 750Mpa** steels in columns, shear, anchorage and stress development
- Increase in Phi for slender columns to 0.65 making it consistent with stocky columns.
- Option of using **curvilinear stress** block for linear elements for easier transition between SLS and ULS.
- New rules for punching shear in slabs to bring it in line with **MCFT**.
- Additional guidance on design for concentrated forces developing tension within the element.
- Consideration being given to new rules for use of 750Mpa reinforcing steel in as shear reinforcement

Construction, Tolerances, Detailing and Quality

- New Section on Prefabricated Concrete Elements and Structures added, and all references to ‘Precast' moved from other Sections and expanded.
- Waterproofing and Weatherproofing defined.
- Weatherproofing added in detail to enable Deemed to Satisfy status in NCC.
- Design for Safety added to align with NCC.
- Durability specified for cast in fittings and fastenings.
- Factor for undue or differential settlement in slabs on ground added



Durability

- Longer design life in excess of 50 years for specific structural components included in Notes
- Clarifications and clearer descriptions on Exposure Classifications.
- Adjustment of entrained air for 10 and 20mm aggregates and removal of entrained air for 40mm aggregate.
- Changes to Notes to make more consistent with AS5100.5
- Changes to concrete cover requirements for Exposure Class A2 to account for the increased carbonation rate in concrete with high supplementary cementitious material (SCM) content
- Required cover for Stainless Steel Reinforcement added.
- Required cover for Galvanised Steel Reinforcement added.

Serviceability

Shrinkage and Creep factors added for 120Mpa concrete.

Minor changes to deflection of floor beams for serviceability limit state.

The specified procedure for calculating crack widths in beams and slabs at the serviceability limit state has been improved, covering elements both with and without fibres.

Assessment of Existing Structures

New content added as an Appendix.

Sustainability and Economic considerations.

Existing structures should not be arbitrarily demolished because they might not comply with the fine details of current codes.

Follows the principles established in **fib Model Code**.

Digital Transformation and Artificial Intelligence

Add hyper-links or modal for cross-references	Add hyper-links or modal to definitions for important terminology	Inline, linked, or side-by-side commentary
Hover over graphs for exact values	Additional diagrams, videos, or other learning content in online view	Dedicated webpage listing learning materials
Dropdowns to look up table data	Digital note-taking shared within organisations	Side-by-side comparison between document revisions
	Calculators for full design	

Digital Transformation and Artificial Intelligence

- Calculators for individual equations
- Flowcharts with clause links for common workflows
- Smart searching capabilities
- Worked examples of workflows for typical designs
- Conformance & compliance requirements from other codes
- Sponsored learning materials in the document
- FAQ for AS 3600
- Add hyper-links to the Commentary
- Moderated knowledge sharing
- Markup format where you can make your own notes.
- Video's & / or photos linked to the commentary
- Interactive diagrams & formulae

What is the current status of AS 3600-2025?

- Final draft of AS 3600-2025 was completed in May 2025.
- The draft is expected to be released for public comment in mid-2025
- The final edition is scheduled for publication in late 2025
- AS3600-2025 is expected to be recognized by ABCB as complying with NCC
- A new edition of the commentary is currently under way.

Future Expectations – Opportunities for Contribution in AS3600

The impact of Artificial Intelligence (e.g., Chat GPT) on future codes?

Technology Updates

Geopolymer Concrete

FRP Reinforcing Bars and Mesh

Non-metallic Fibres

Continuous Digital Transformation

Climate Change Considerations

Maritime Structures

Sprayed Concrete

Links between codes and the design software

Summary and Concluding Remarks

- AS 3600-2025 brings Australia in line with modern and international practice.
- Opportunity for the maritime industry and PIANC to contribute further to future codes (e.g. adding a maritime section to the code, linking the code to PIANC guidelines).
- Digital transformation and implementation will dominate future codes

Thank you

Dr. Sam Mazaheri
Sam.Mazaheri@dbct.com.au
Sam.Mazaheri@bia-co.com