SIMCO

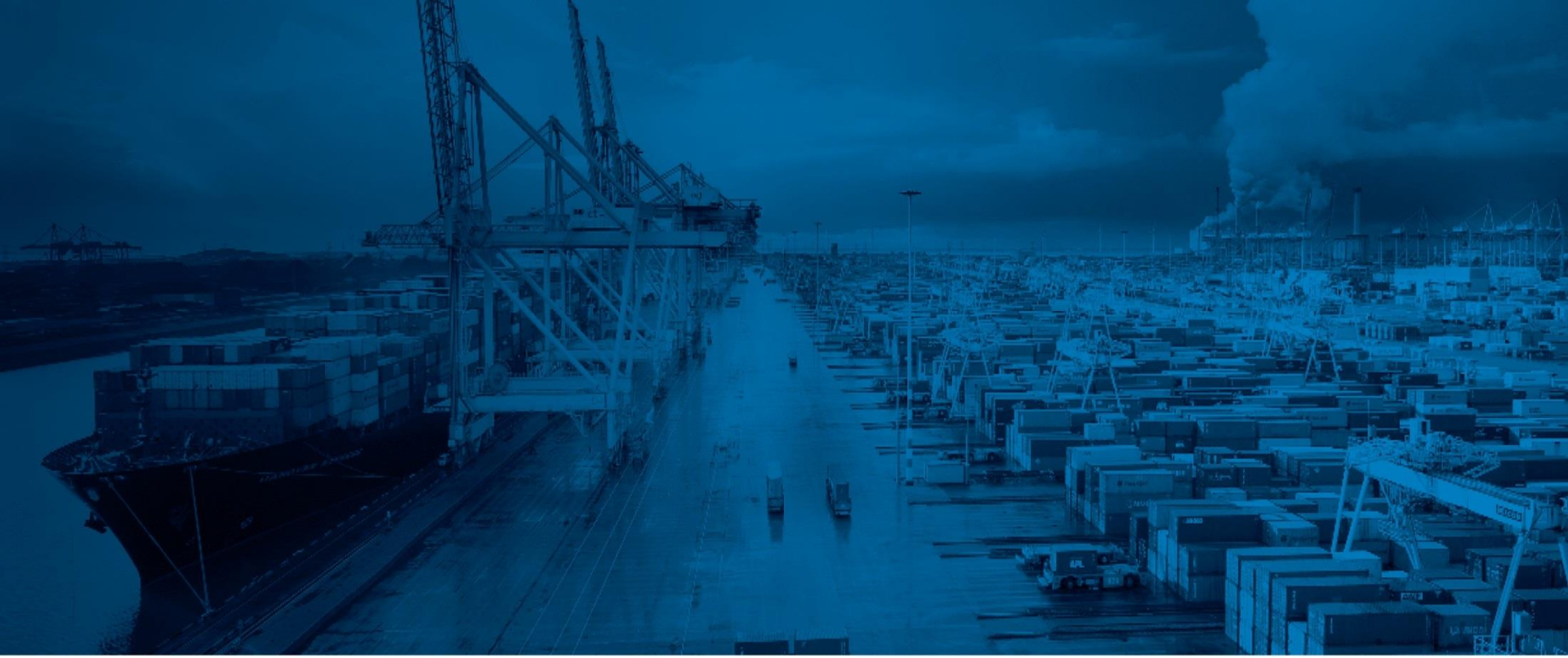
MIDDLE EAST

Saudi Concrete Conference

Using Numerical Modeling To Design New Concrete Construction that Meets Stringent Durability Requirements

J. Marchand, P. Eng, Ph.D., E. Samson, P. Eng., Ph.D., G. Schaefer, BS and MBA

May 2016



Unified Facilities Guide Specifications

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USACE / NAVFAC / AFCESA / NASA

UFGS-03 31 29 (February 2010)

Preparing Activity: NAVFAC

Superseding
UFGS-03 31 29 (November 2009)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2010

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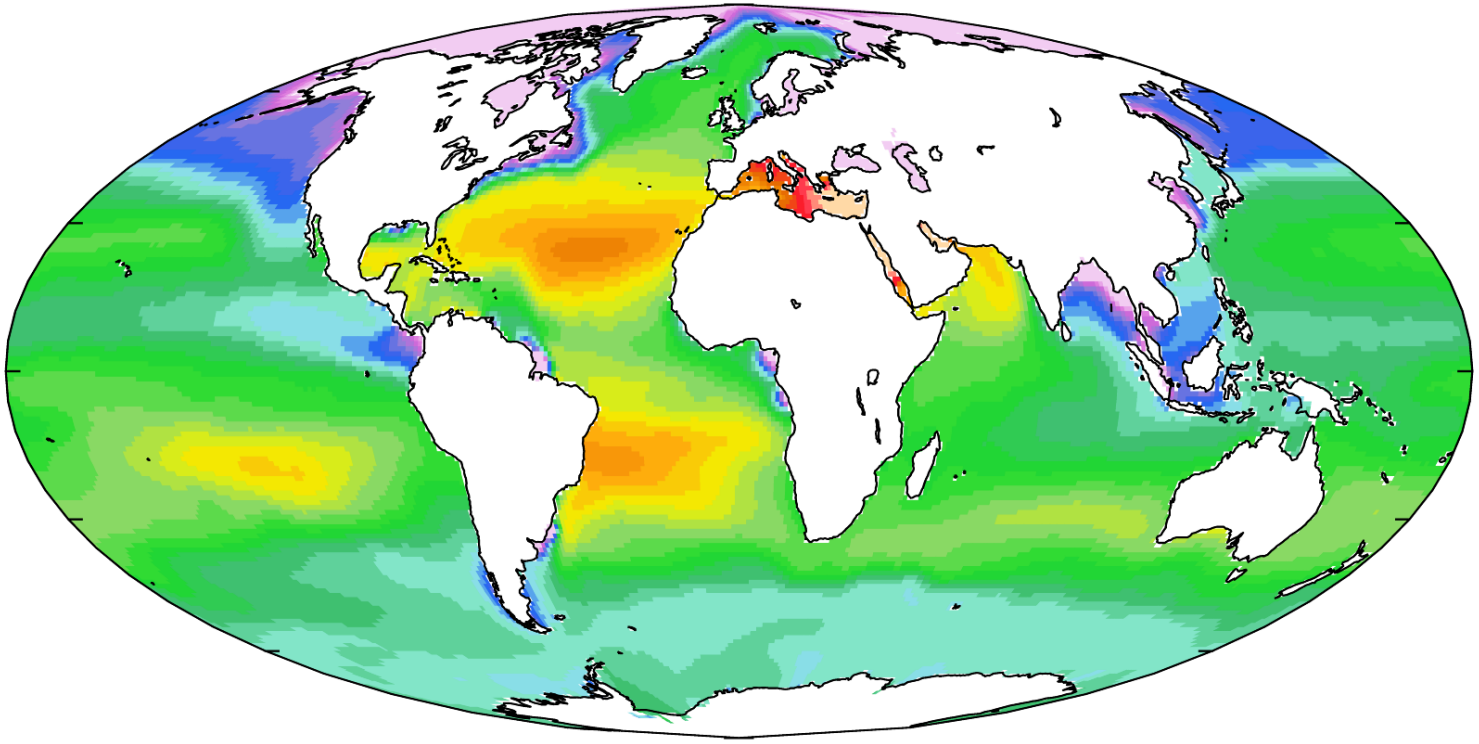
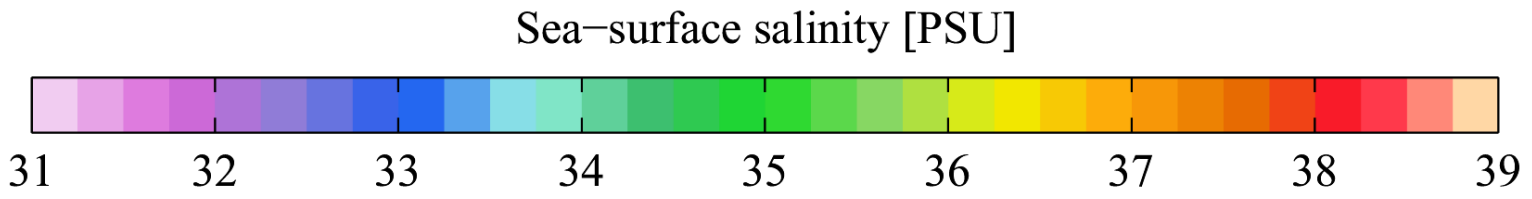
Submarine Base | GROTON, CT

Pier 5 Replacement | NORFOLK, VA

Kilo Wharf Extension | U.S. Navy, Guam

Salinity of Seawater Around the World





From http://en.wikipedia.org/wiki/Seawater

The Development of the UFGS

2000
Cases of Premature Failures

2001
Joint Development of the Approach

2006
Validation on Existing Structures

2008
B-Testing Guam Project

2010
First Release

2013
1st Update

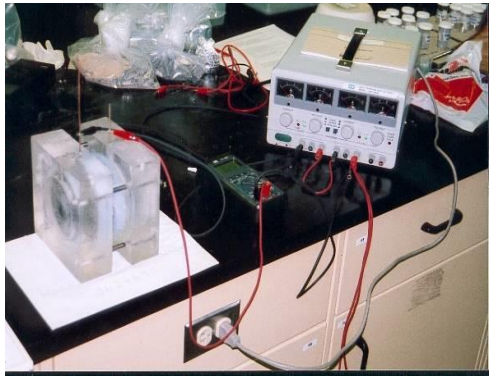
Performance Specifications

What is a Performance Specification?

A performance specification is a set of instructions that outlines the functional requirements for hardened concrete depending on the application. The instructions should be clear, achievable, measurable and enforceable.

C. Lobo, L. Lemay, K. Obla (2005), The Indian Concrete Journal, V. 79, p. 13-17.

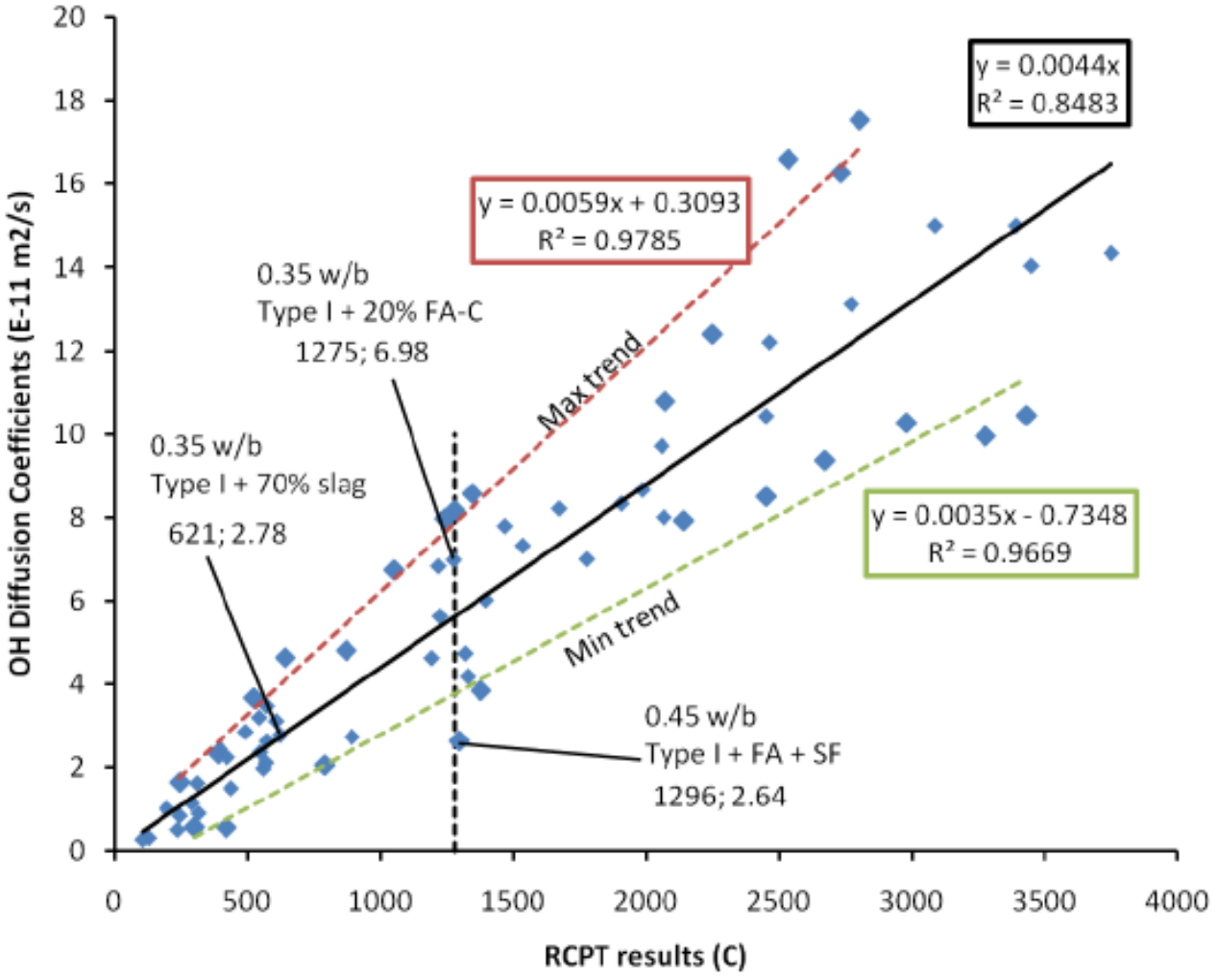
In MPa (or Psi)?



In Coulombs?

In years?

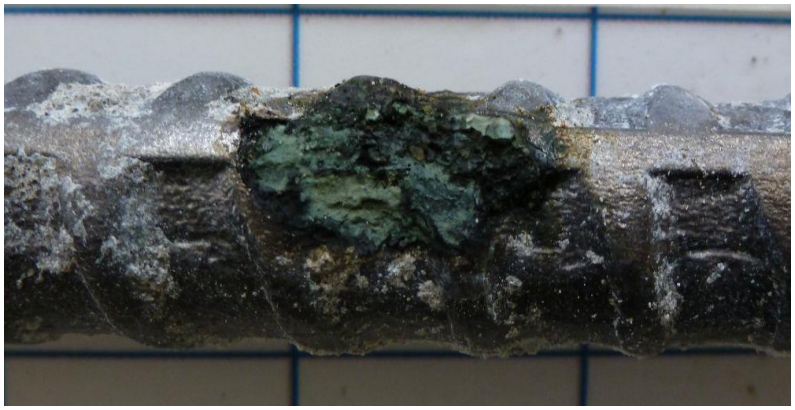
ASTM C1202 As A Performance Indicator?



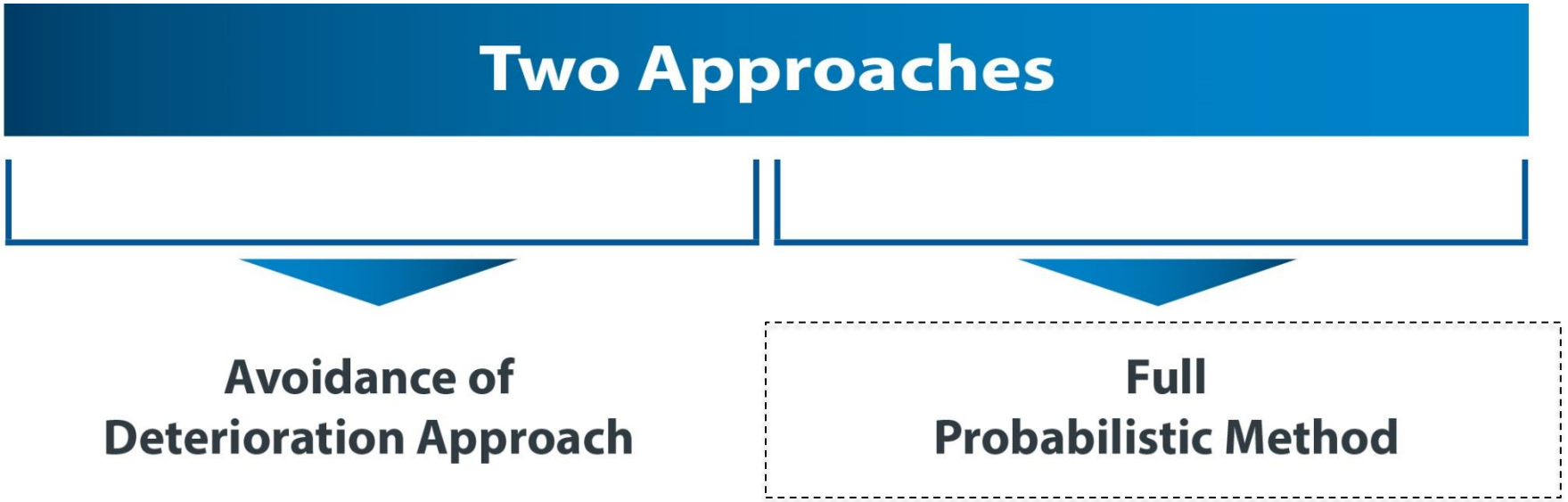
Clear Definition of Expectations

- "Service life" is the functional target performance expectation for the various reinforced concrete elements. This has been defined as 75 years before major restoration with minimal maintenance.

- Major restoration is defined as repairs requiring jack hammering or any destructive means of concrete preparation.



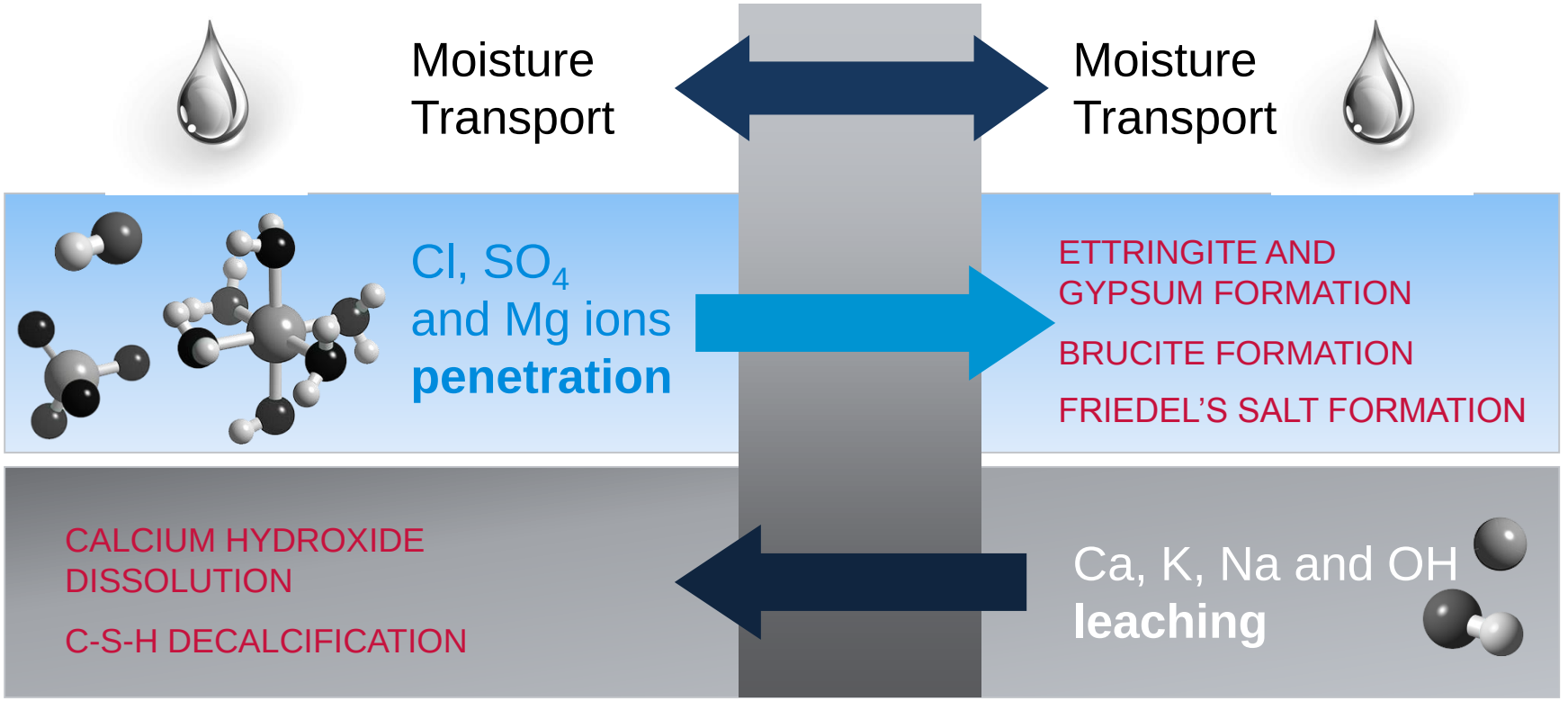
The Concrete Durability Matrix



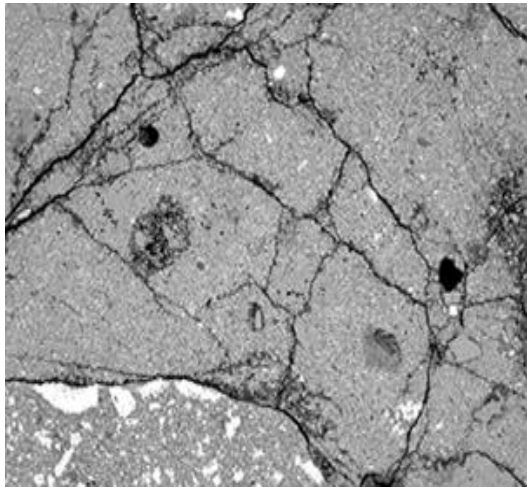
The approach varies with the type of degradation phenomenon considered

- FIB Document N-34 Model Code For Service Life Design
- ISO 2394 - General principles on reliability for structures

The Calculation Tool – Coupled Phenomena



The Calculation Tool – Coupled Phenomena



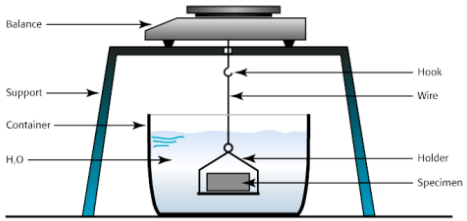
Internal degradation + moisture and heat transfer

Contamination and chemical degradation problems

Corrosion initiation + propagation problems

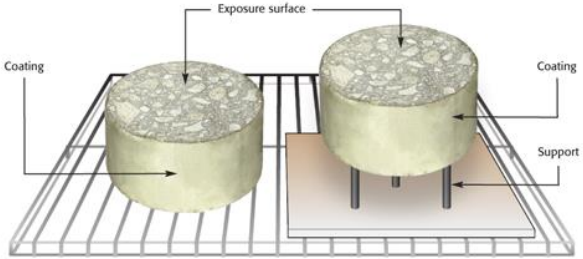
The Bottom-Up Approach

Volume of Permeable Voids



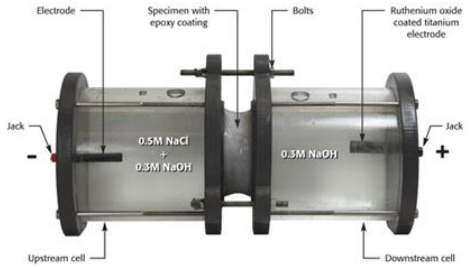
ASTM C642

Moisture Permeability



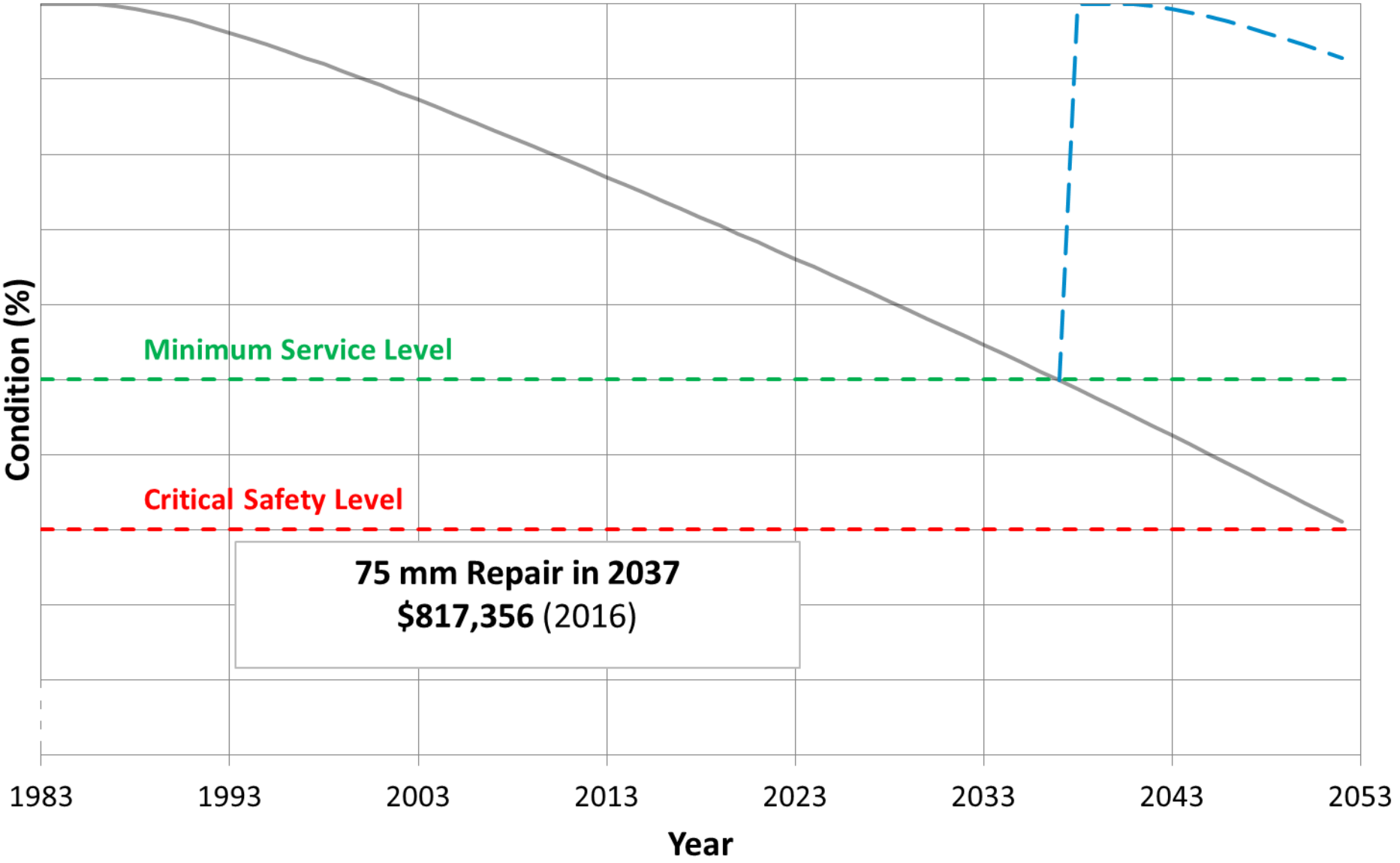
ASTM C1792

Diffusion of Contaminants

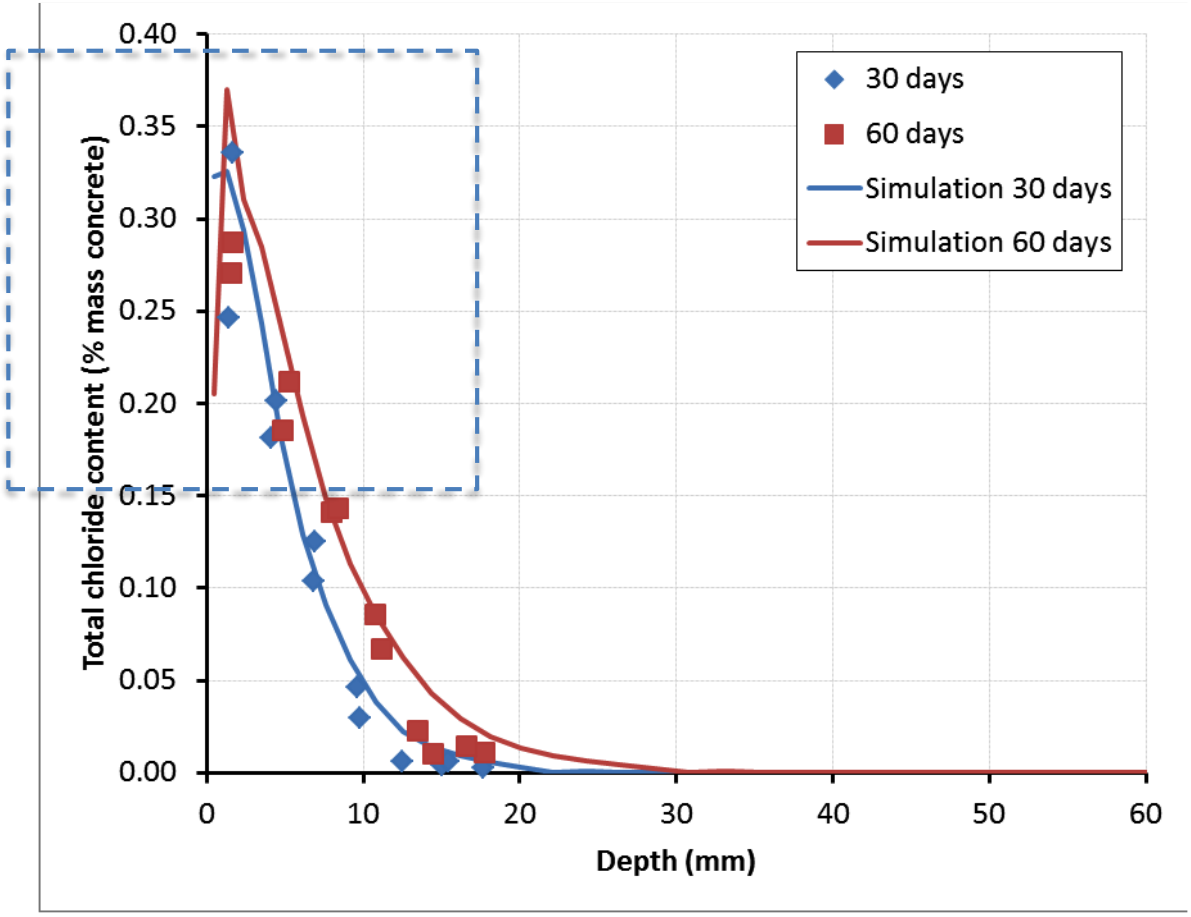


ASTM C1202-Modified

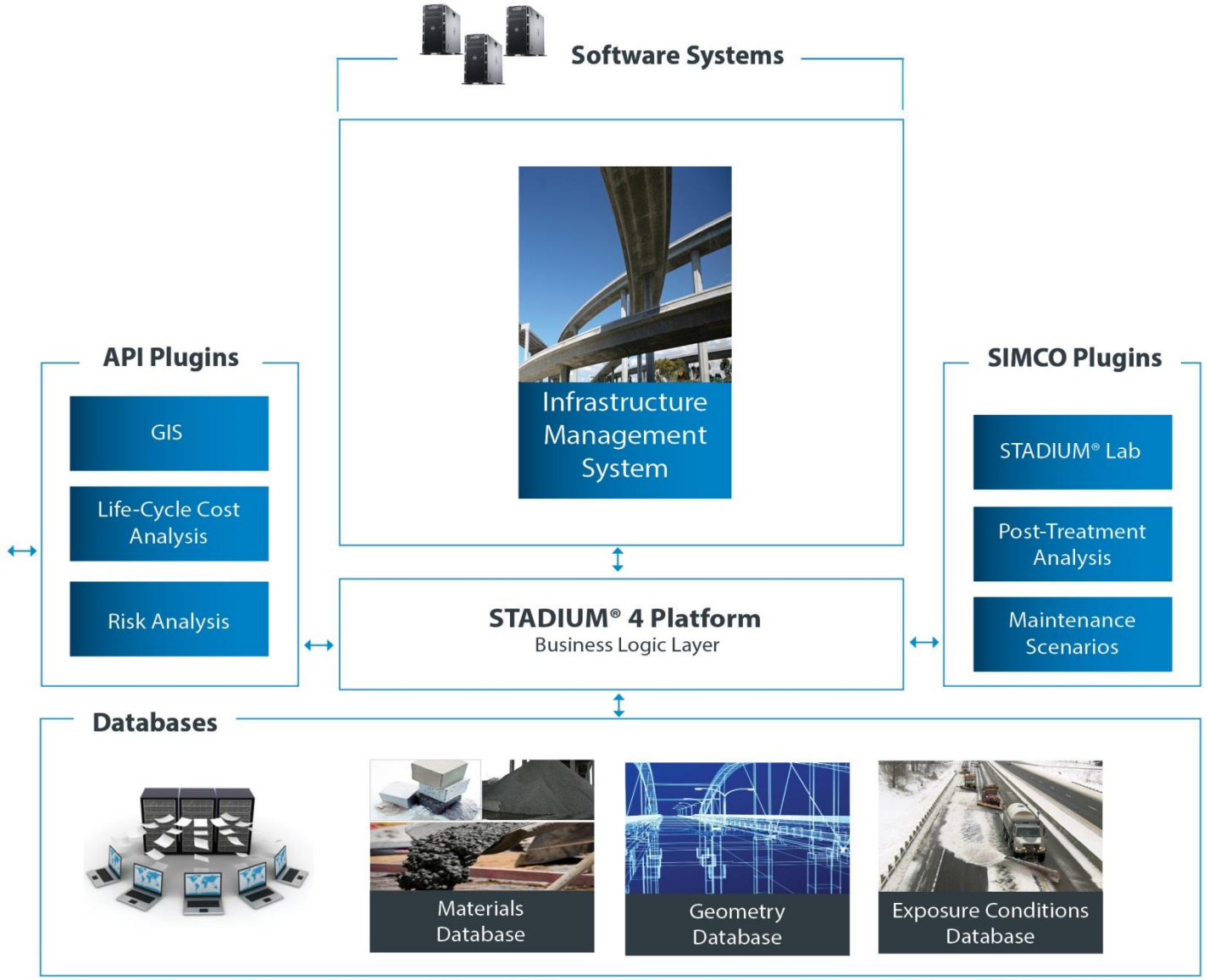
Degradation Curves – Top Deck



Independent Validation of Results



The Calculation Tool



Life-Cycle Cost Analysis

Option	Cost of Interventions	Value at End of Contract	Net Value (NV)
1 - 75 mm repair in 2057	$817,356	$5,709,351	$4,891,995
2 - 50 mm repair in 2036	$796,620	$3,070,917	$2,274,297
3 - Cathodic protection in 2036 (impressed current)	$1,349,148	$3,478,048	$2,128,900

The Three-Step Approach

1

DESIGN

Feasibility Study
Service life objectives
Local exposure conditions
Local materials

Specification
Client expectations
Methodologies

2

APPROVAL
Concrete submittal
Trial production
Mock-up structure

Performance Evaluation Tool

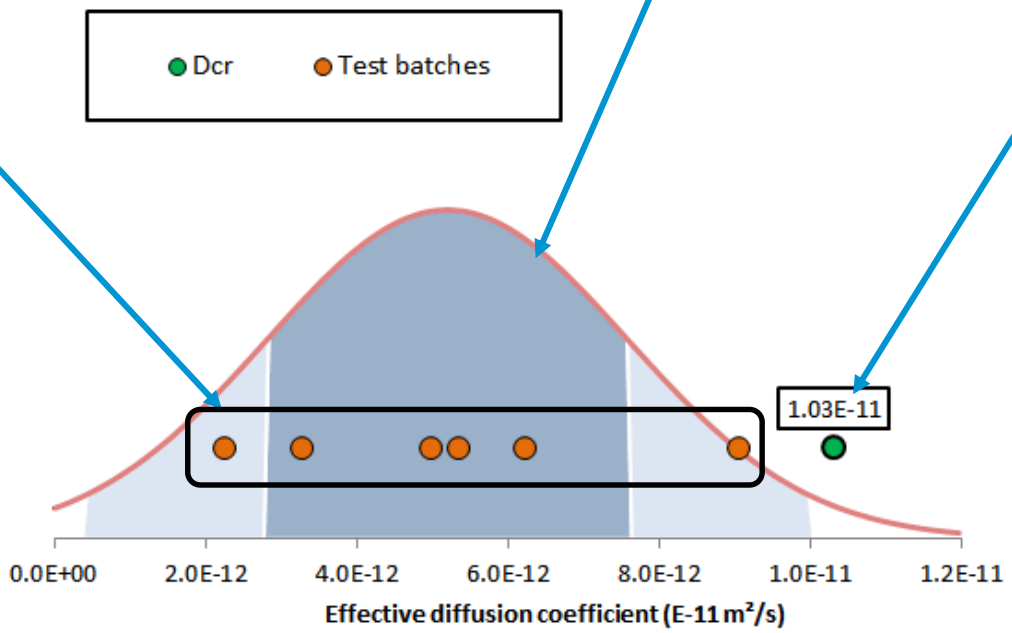
3

CONSTRUCTION

Quality Assurance
Testing and metrics
Evaluate variations
Design criteria validation

Determination of Concrete Variability

Trial Batches → Transport Properties Calculation → Statistical Analysis → Characteristic Values

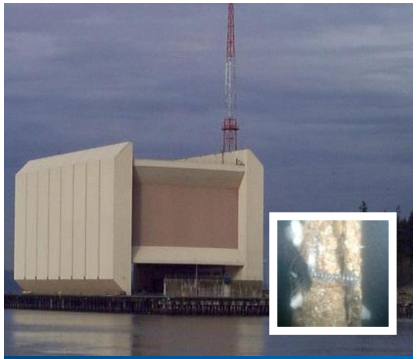


U.S. Navy Projects - UFGS

Kilo Wharf Extension, Guam

Pier 31, CT

Admiral Clarey Bridge, HI



Explosive Handling Wharf, Bangor WA

Modular Hybrid Pier

Pearl Harbor, HI

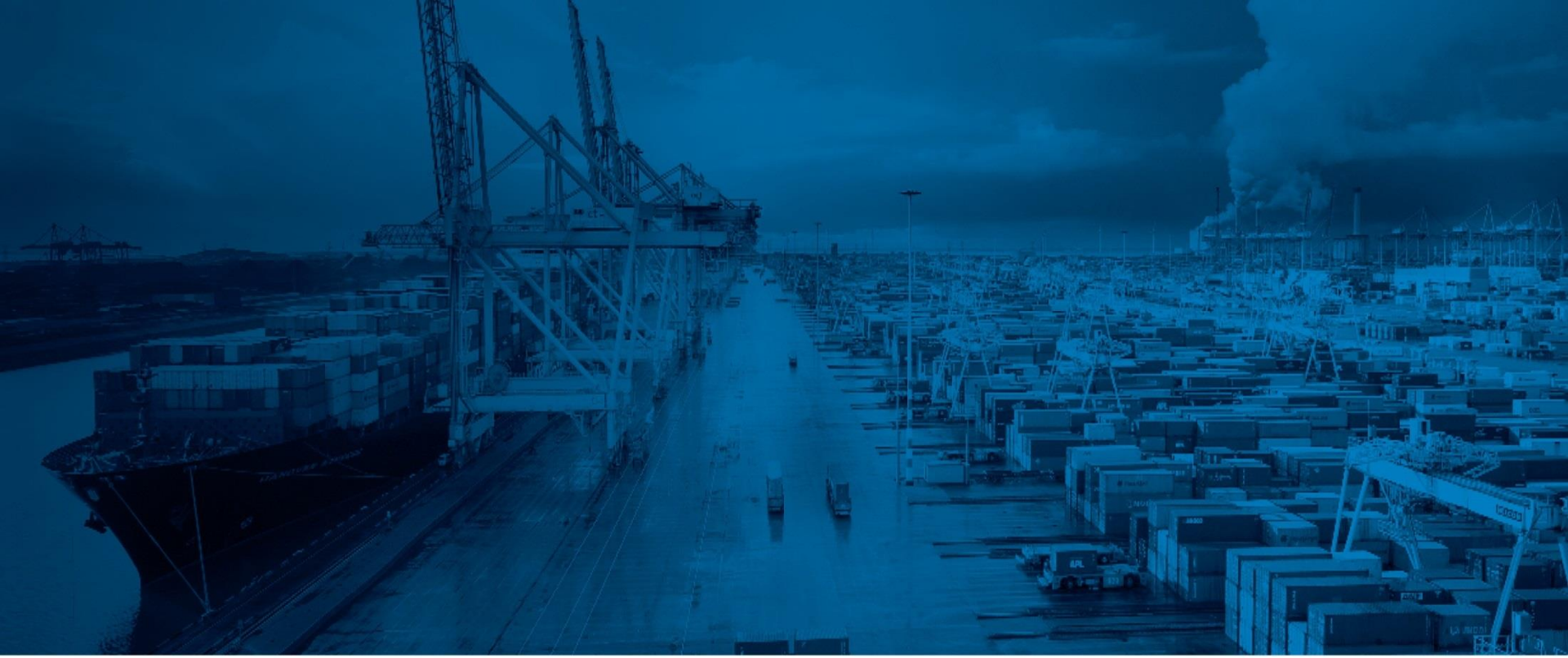
Pier 5 Replacement, VA

U.S. Naval Station, CA

New Bridge on Saint Lawrence River

A 125-year service life required for the most critical structural elements

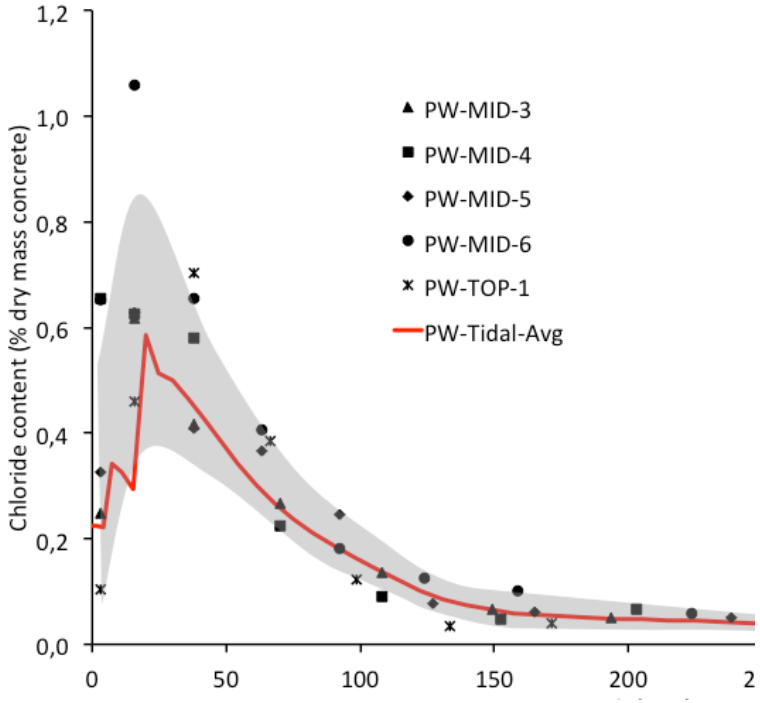
- Severe exposure conditions:
  - De-icing salts
  - Freezing and thawing cycles
  - Wetting and drying cycles
  - Abrasion
- Pre-cast and cast-in place elements
- Massive and relatively thin elements
- Different types of steel
- Different placement methods
- Different curing methods



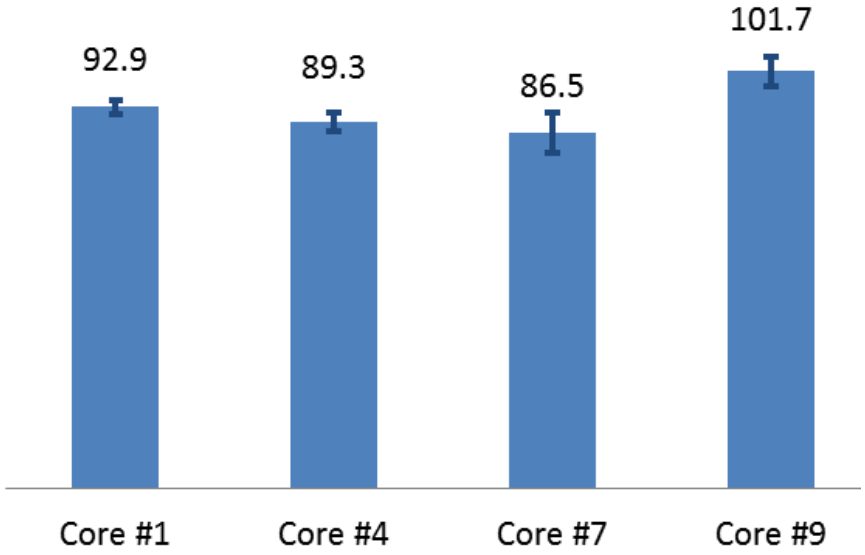
Thank You!

Validation of The Calculation Tool

Chloride Contamination Analysis

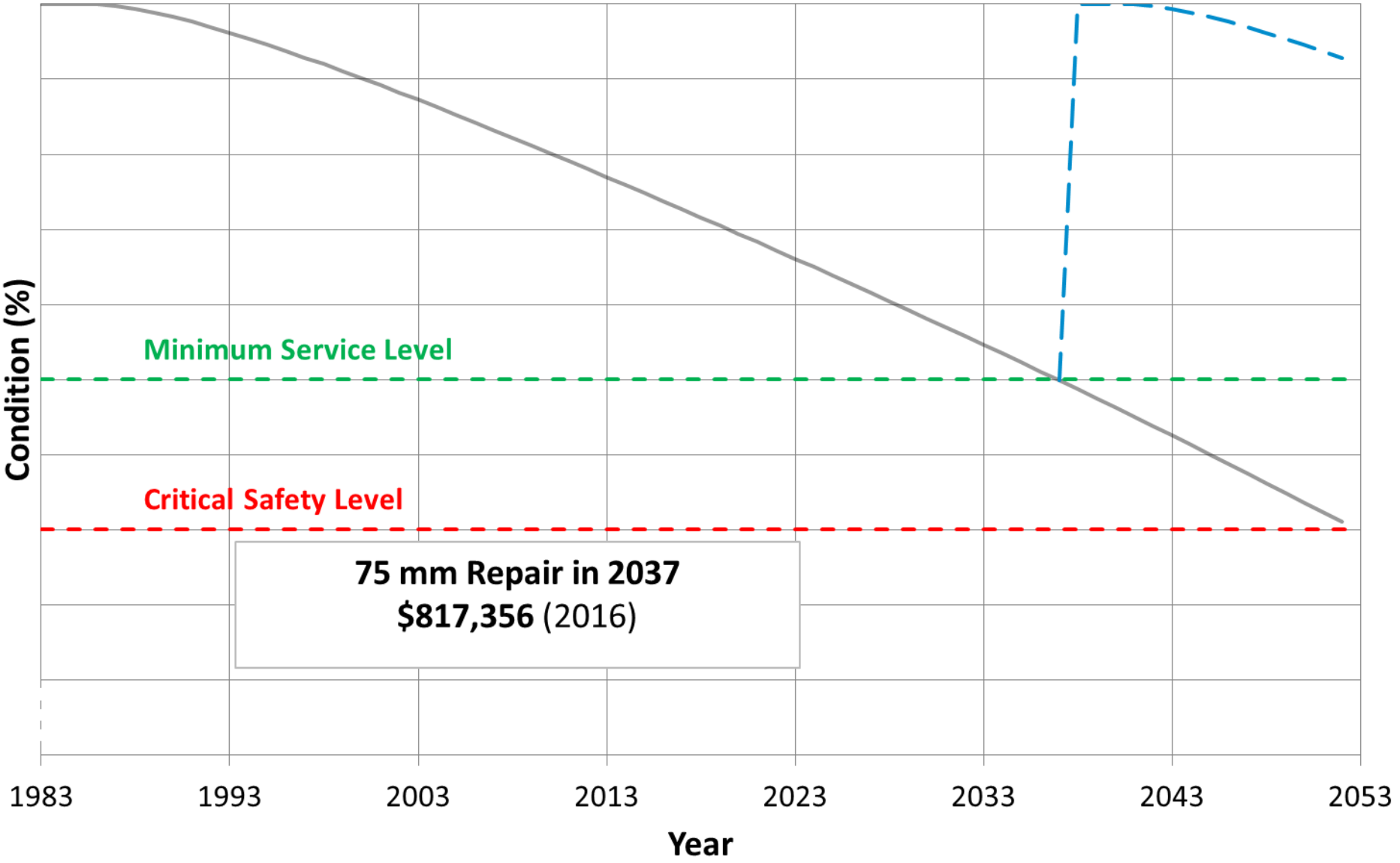


Resistivity and Corrosion Rate Analysis



Corrosion Rate Analysis {mpy}	# of readings	%	Level
Values that are <0.0457	0	0%	Passive
Values between 0.0457 & 0.2285	1	8%	Low
Values between 0.2286 & 0.4578	5	42%	Medium
Values >0.4578	6	50%	High
Total Number of readings	12	100%	

The Calculation Tool – Degradation Curves



The Bottom-Up Approach

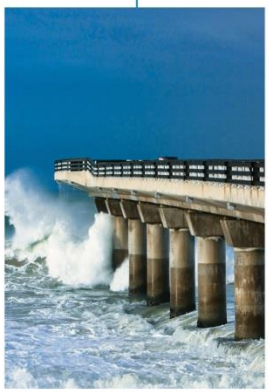
Preliminary Design of the Structure

Identification of Construction Methods

- Type of Elements
- Type of Placement
- Type of Curing

Identification of Local Exposure Conditions

- Moisture Conditions
- Chemicals (Types & Concentration)
- Temperature



Identification of Critical Elements

- Simple - 1D
- Complex - 2D & 3D

Determination of Durability Limit States

- No Corrosion
- Damage < 20%
- Rating < 5

No Cracking → Simulations

Cracked Element → Simulations

Final Recommendations

- Material Selection
- Mix Design
- Minimum Cover
- Protection Solutions
- Maintenance

β Testing Project – Kilo Wharf Extension

Kilo Wharf Extension | U.S. Navy, Guam

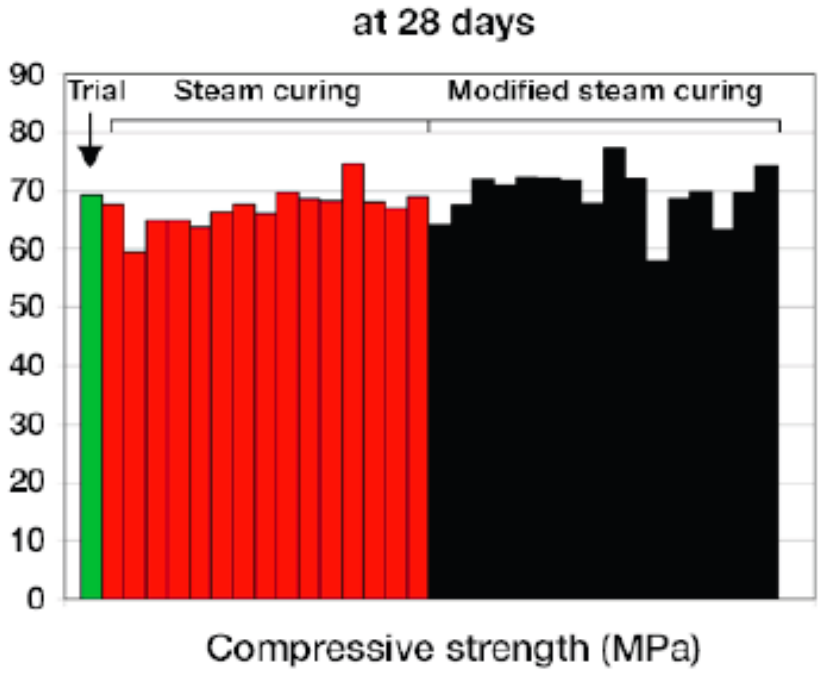
β Testing Project – Kilo Wharf Extension

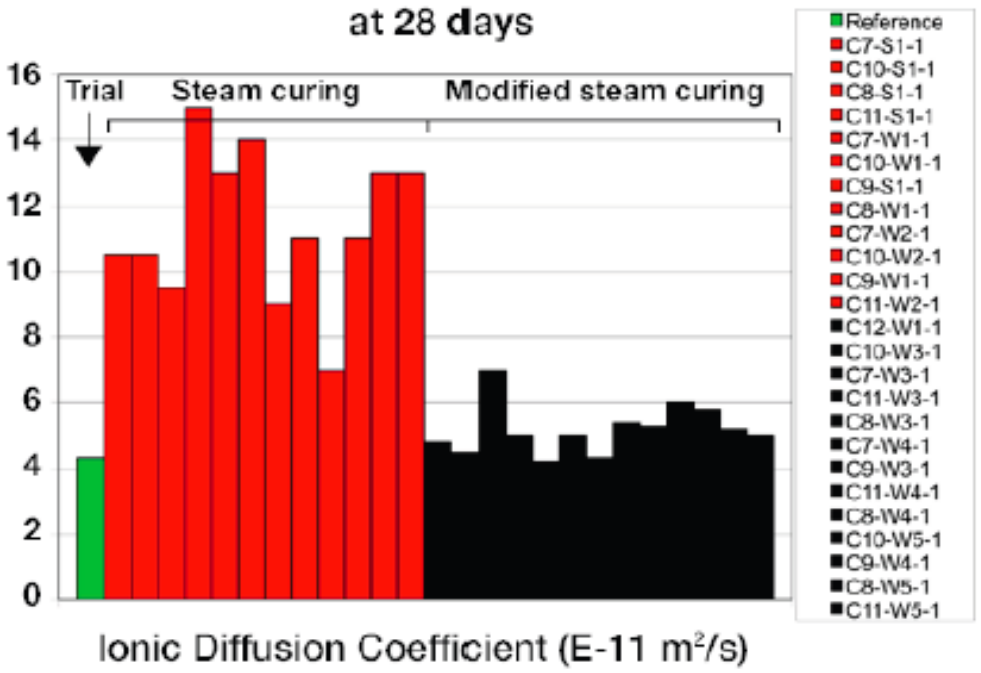
Kilo Wharf Extension | U.S. Navy, Guam

β Testing Project – Kilo Wharf Extension

Kilo Wharf Extension U.S. Navy, Guam

On-Site Quality Control





β Testing Project – Kilo Wharf Extension

Kilo Wharf Extension U.S. Navy, Guam