STADIUM Software Overview

Durability and Service Life of Concrete Structures

Eric Samson

Cementitious Barriers Partnership

SIMCO Technologies Inc.

August 2014

CBP
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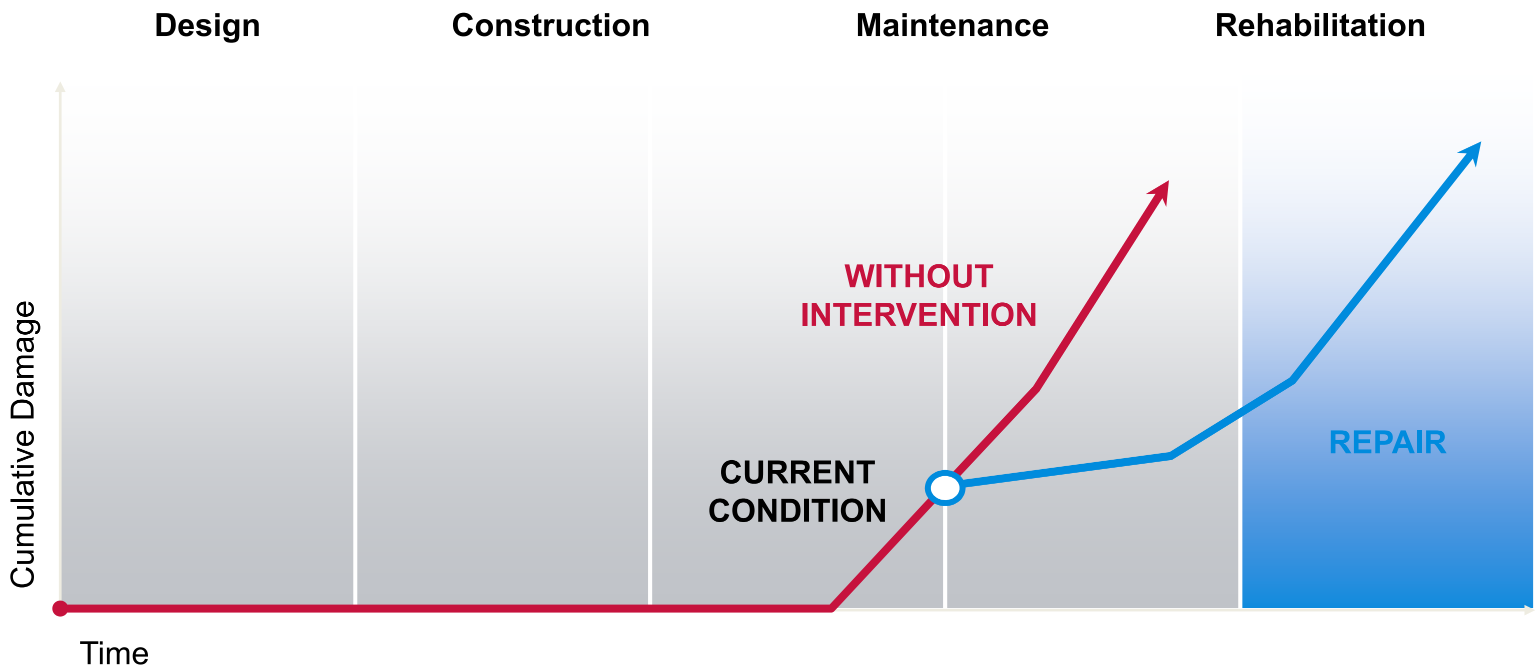
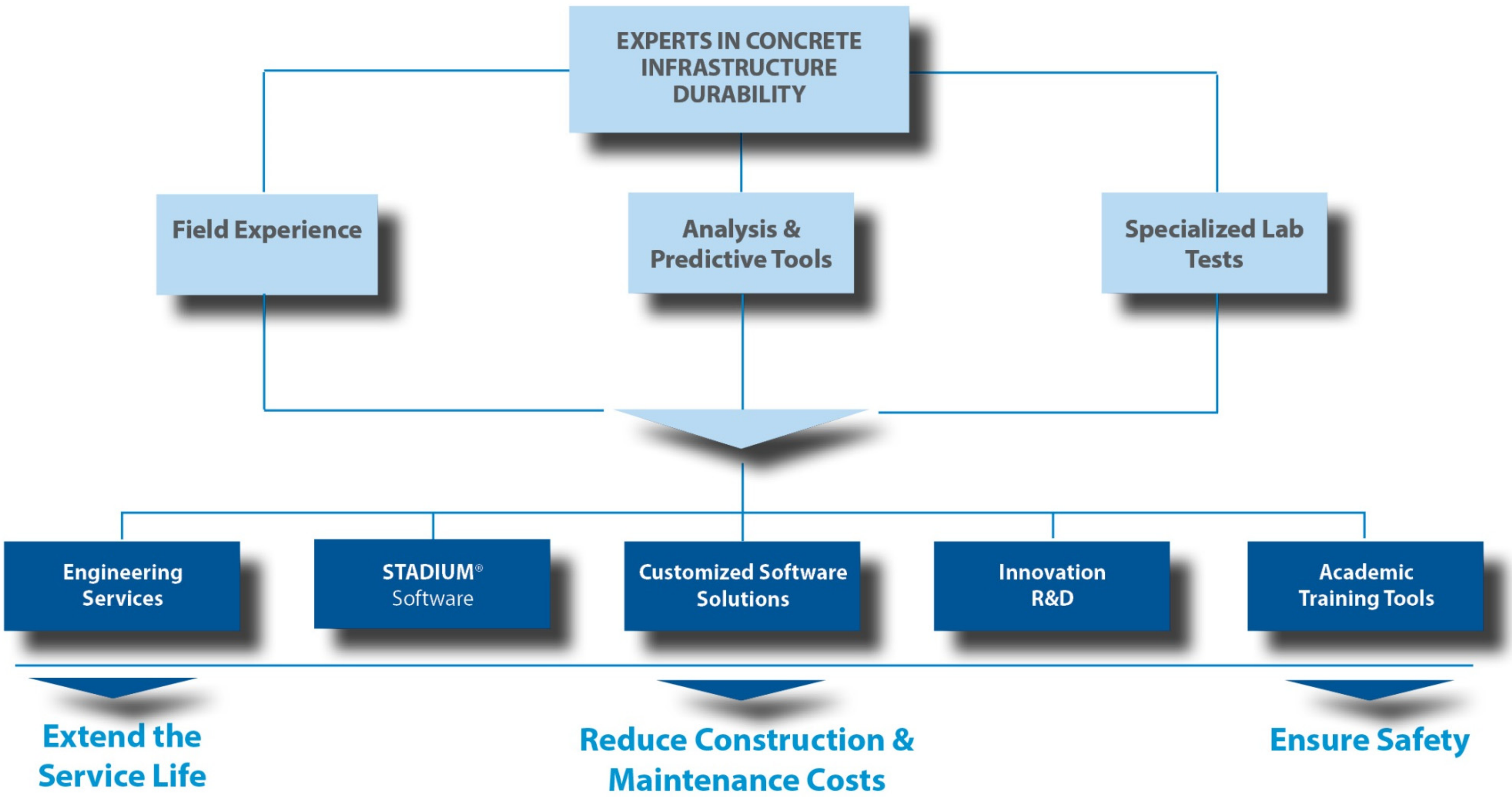
Who we are

SIMCO is a specialized engineering firm entirely dedicated to the durability of concrete structures.

Who we are

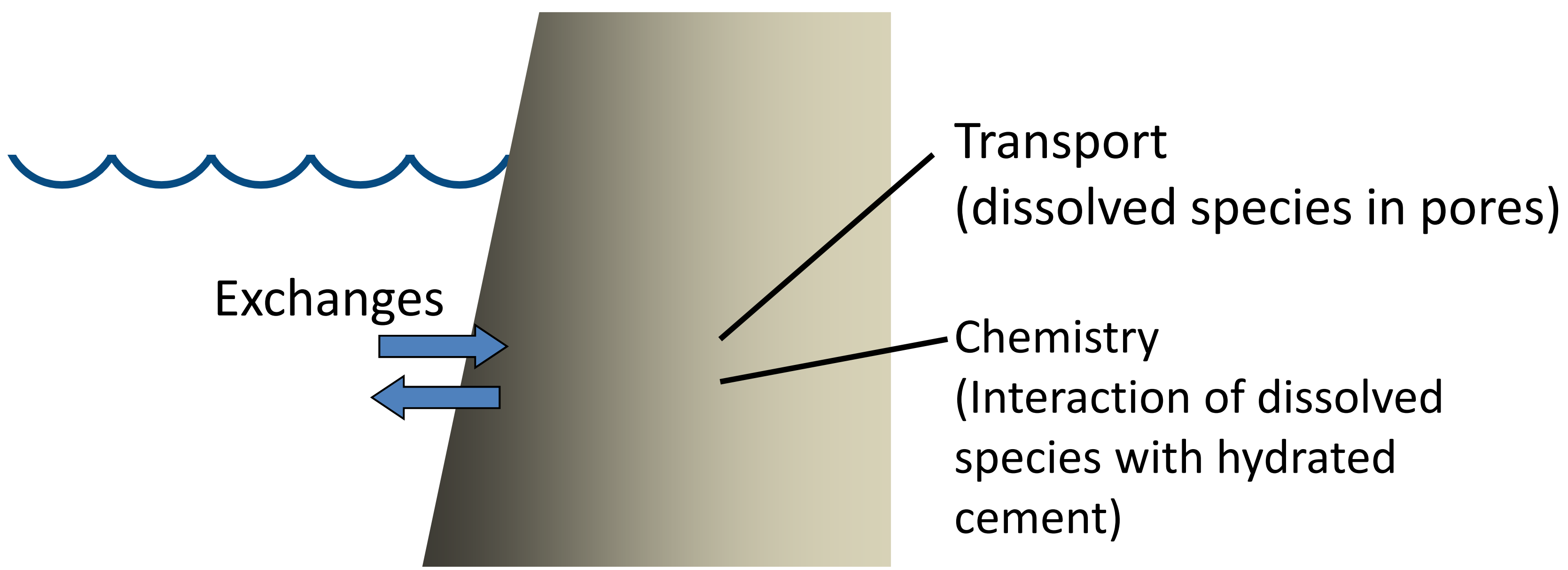

Design
Construction
Maintenance
Rehabilitation
WITHOUT INTERVENTION
CURRENT CONDITION
REPAIR
Cumulative Damage
Time

Who we are


EXPERTS IN CONCRETE INFRASTRUCTURE DURABILITY
Field Experience
Analysis & Predictive Tools
Specialized Lab Tests
Engineering Services
STADIUM® Software
Customized Software Solutions
Innovation R&D
Academic Training Tools
Extend the Service Life
Reduce Construction & Maintenance Costs
Ensure Safety

STADIUM Overview

STADIUM® models the transport of chemical species in **cementitious materials** resulting from exchanges at the material/environment interface.



STADIUM Overview

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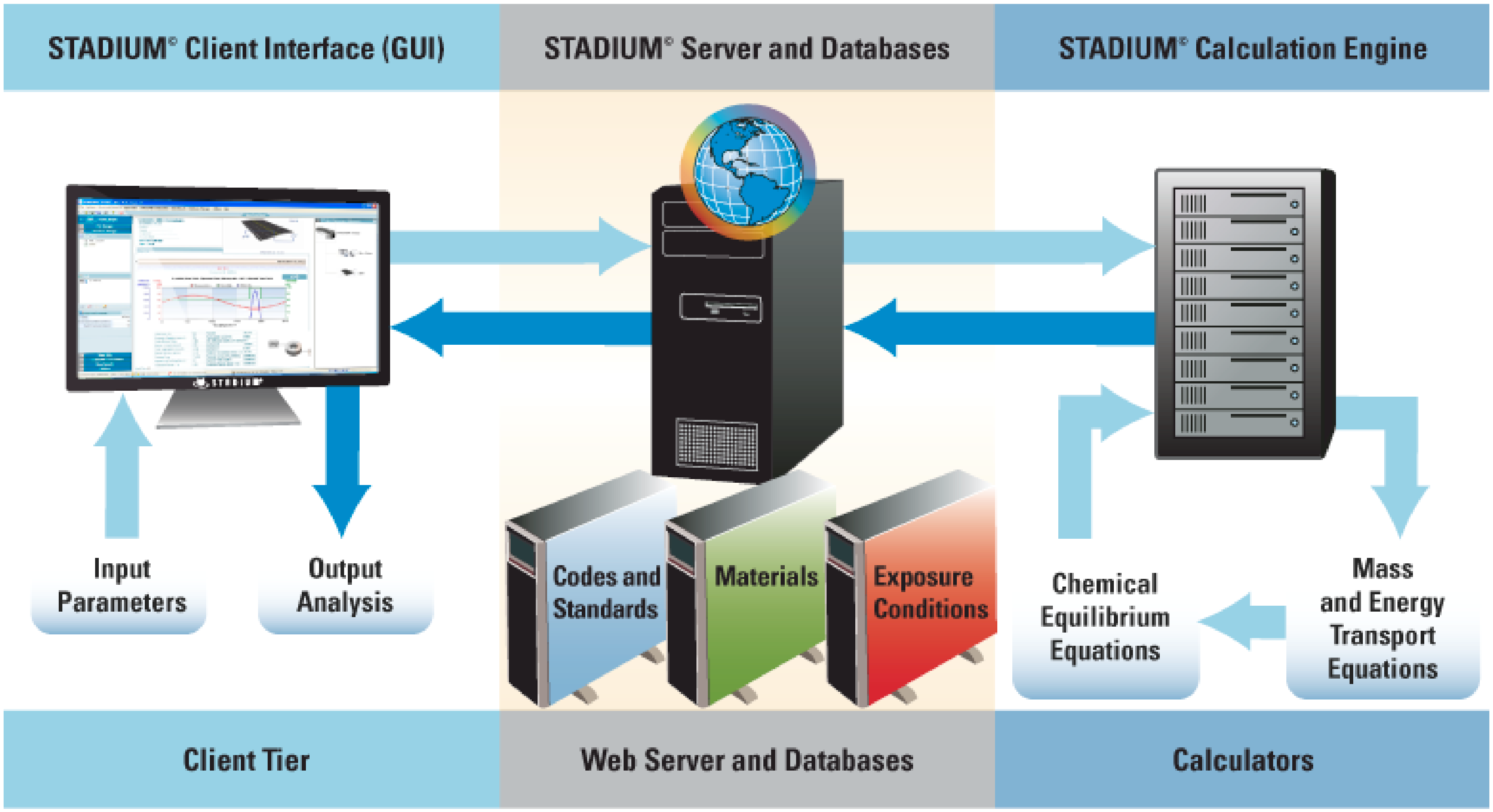
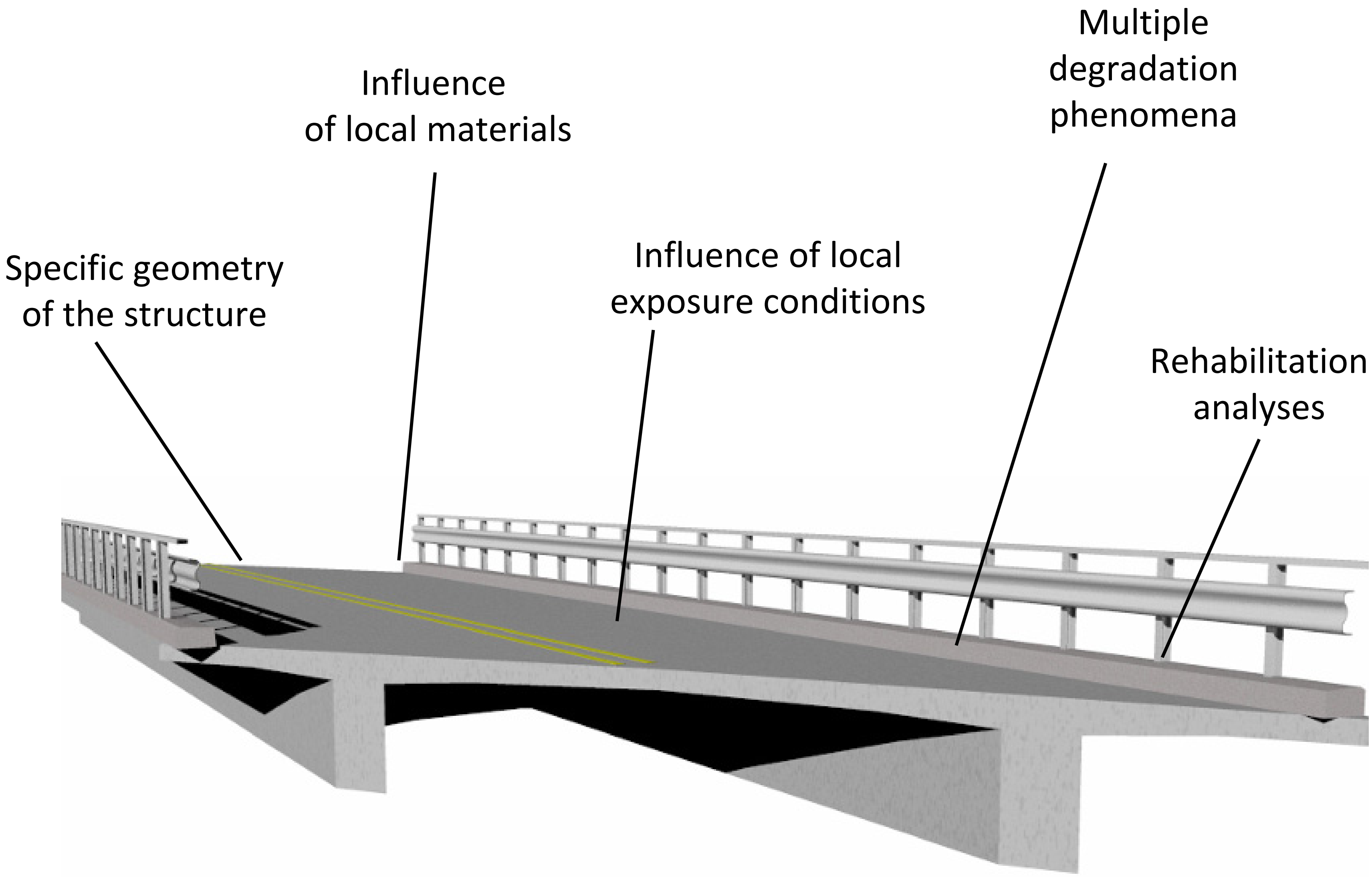


STADIUM Overview

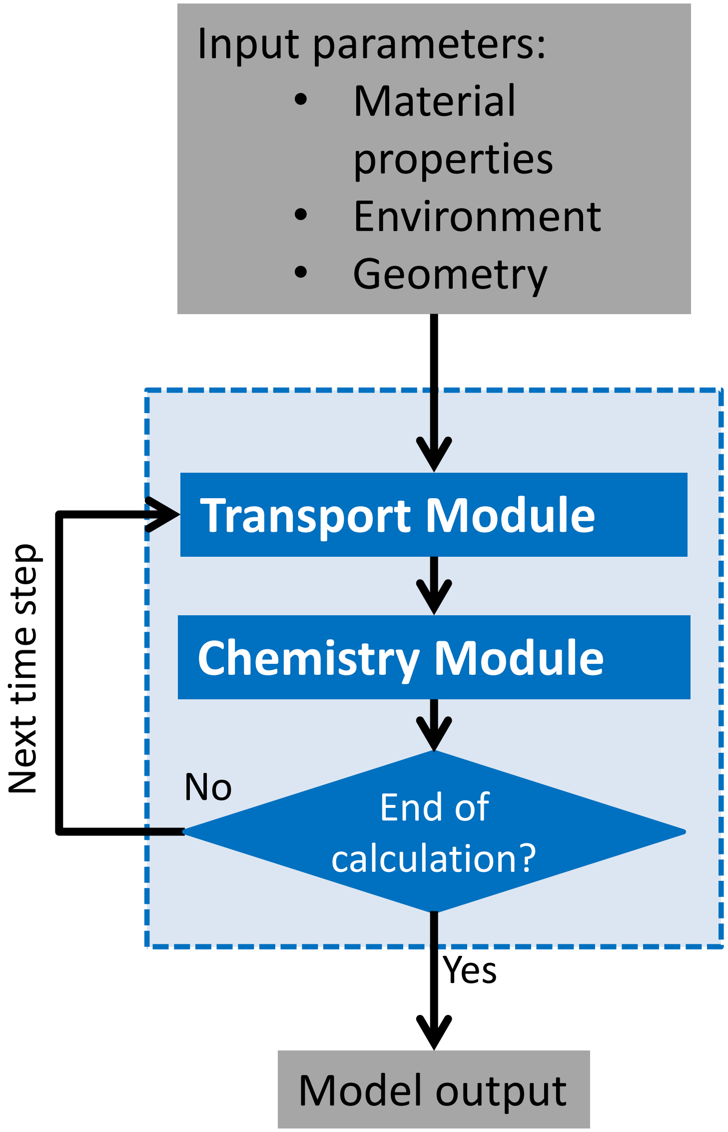


STADIUM Overview

- The U.S. Department of Defense recognizes STADIUM® as the only accurate numerical solution for the prediction of long-term behavior of reinforced concrete structures exposed to marine environments.
- Since 2010, STADIUM® is specified in the Unified Facilities Guide Specifications (UFGS).
- It is used to select concrete mixtures for marine applications, based on specified performance targets.

Specified by the
US NAVY
UFGS-03 31 29

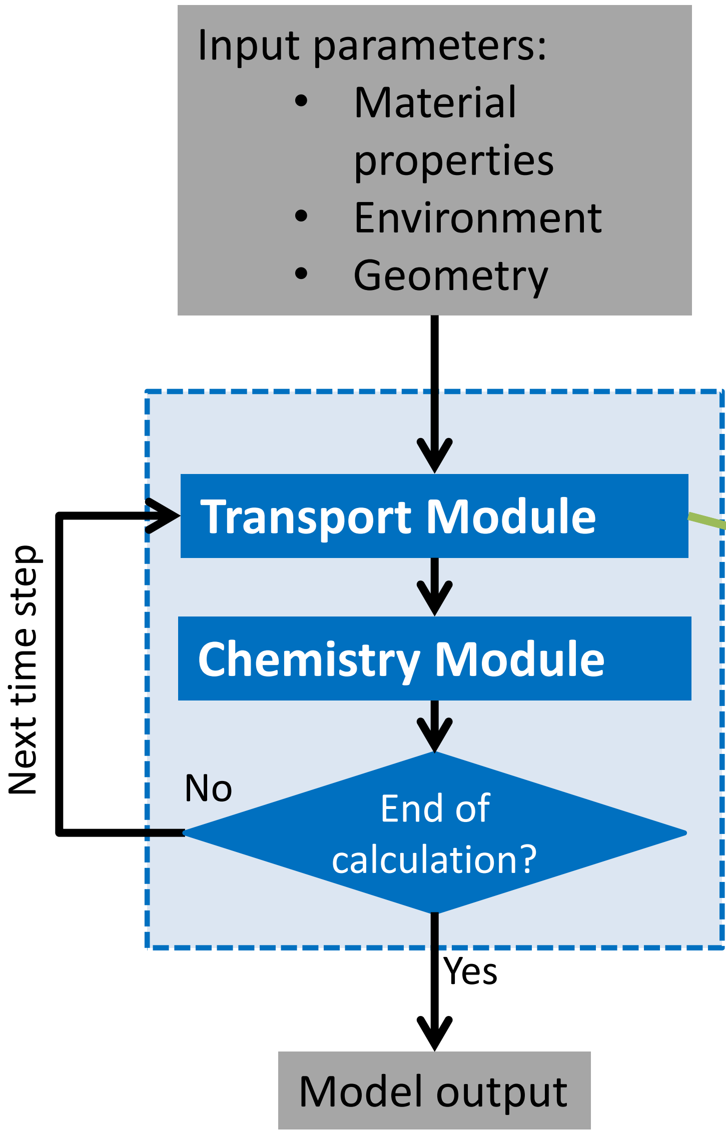
STADIUM Overview



The model is divided in 2 main modules:

- The transport module makes the species move during one time step,
- The chemistry module simulates the reactions between species in the pores and the hydrated paste.

STADIUM Overview



- Coupled species diffusion
- Moisture/Temperature coupling
- Transport of main species
- Feedback effect
- Time-dependent transport properties (hydration)
- Time-dependent B.C.

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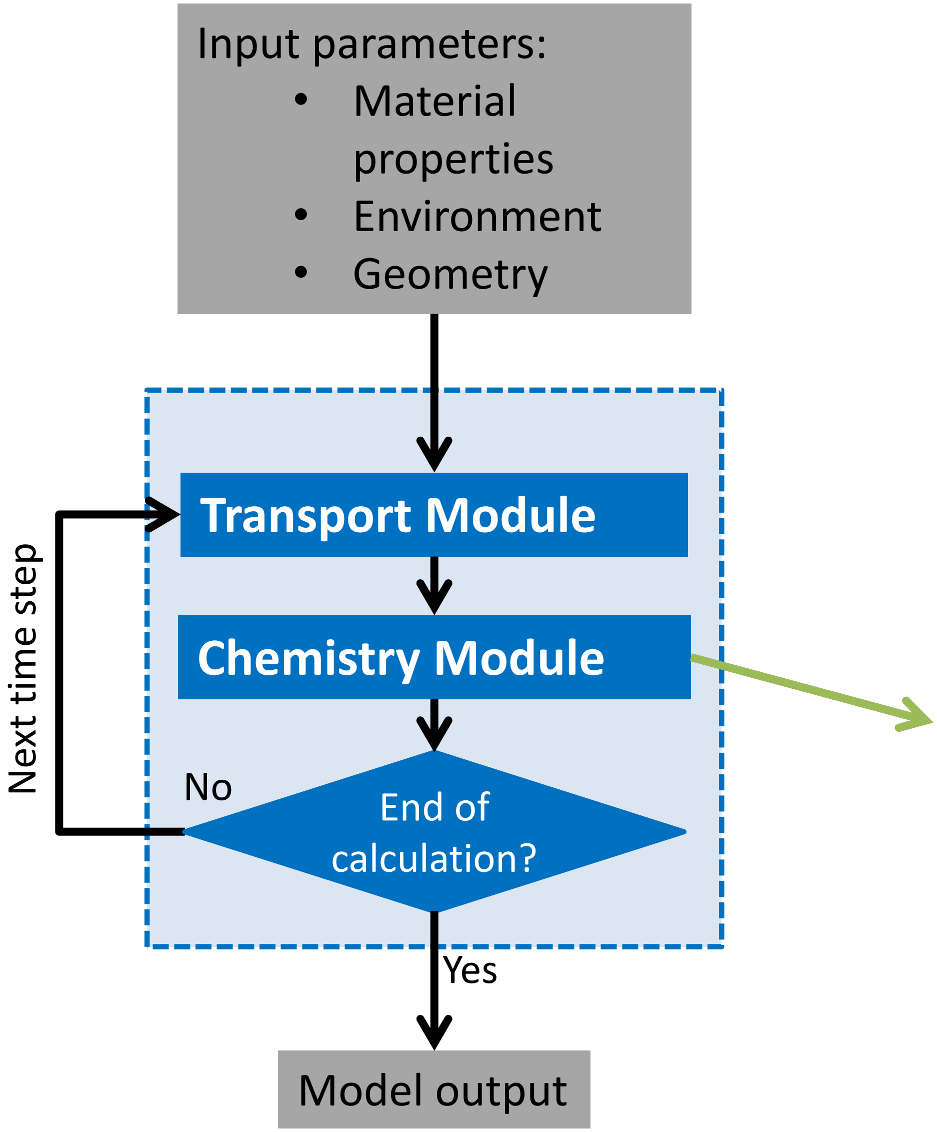
STADIUM Overview



- Local Equilibrium Assumption
- Dissolution/precipitation
- Solid solutions
- Chemical/Pitzer database in separate text file
- Effect of temperature on chemistry

STADIUM Lab Modules

Characterization of concrete mixtures

Evaluation of transport properties – Input to STADIUM®

STADIUM® MTC

Drying test

Permeability
Moisture isotherm

STADIUM® IDC

Migration test

Tortuosity
Diffusion coefficients

STADIUM Lab Modules

The test methods are part of Unified Facilities Guide Specifications (UFGS) 03 31 29 (February 2010) test protocol

- US Navy (NAVFAC ESC)
- USACE
- USAF
- NASA

STADIUM Input

Transport equations

Mechanisms	Properties	Lab tests
Electrodiffusion of species	Diffusion coefficient	Migration test
	Porosity	ASTM C642
Moisture transport (liquid & vapor)	Permeability	Drying test
	Moisture isotherm	Drying test
Heat conduction	Thermal conductivity	Estimated
	Heat capacity	Estimated

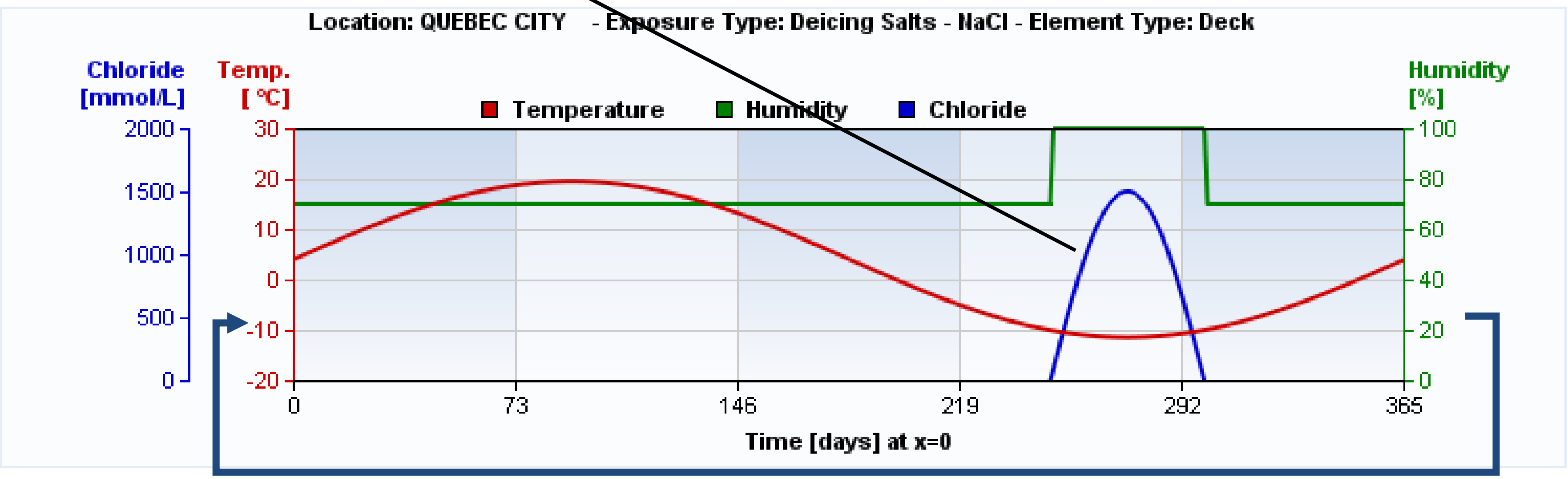
STADIUM Input

Chemistry

INPUT TO CHEMISTRY MODULE		CALCULATED PARAMETERS
• Mix composition • Cement chemistry • SCMs chemistry • Chemistry database • Pitzer parameters	→	• Hydrated cement paste composition • Pore solution composition

Time-dependent boundary conditions

Exposure to deicing salts during winter



After a one-year cycle, the model goes back to the beginning of the year. The cycle is repeated.

Using STADIUM

STADIUM®

New structures

Input values

Calculations

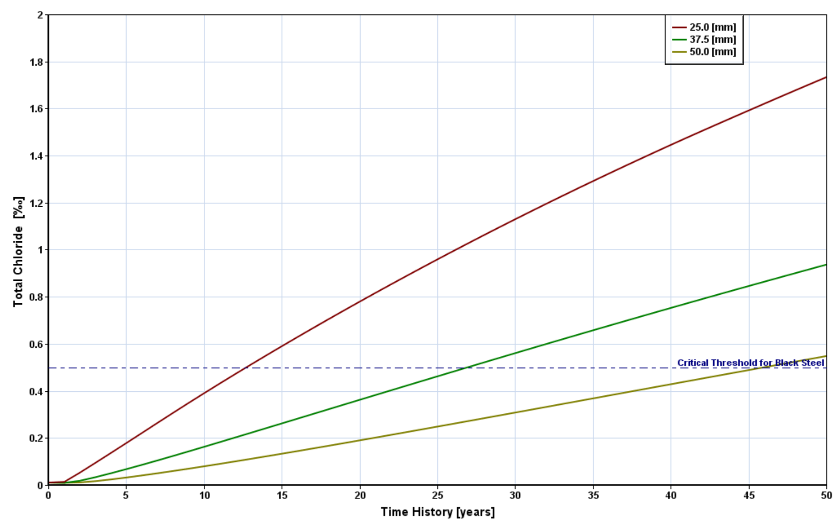
OUTPUT

Existing structures

Input values

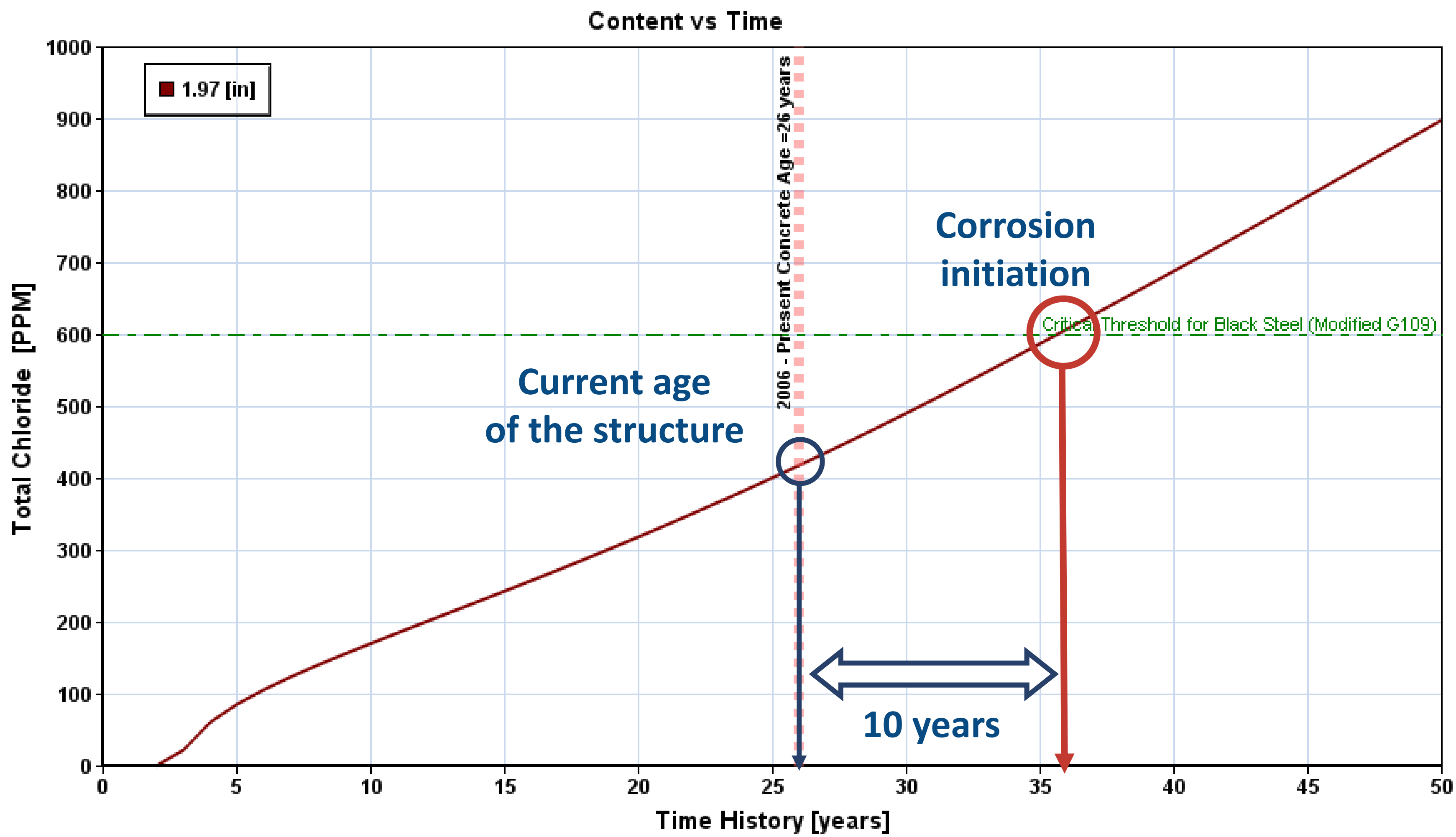
Calculations

OUTPUT



Using STADIUM – Existing Structures

Time to initiate corrosion



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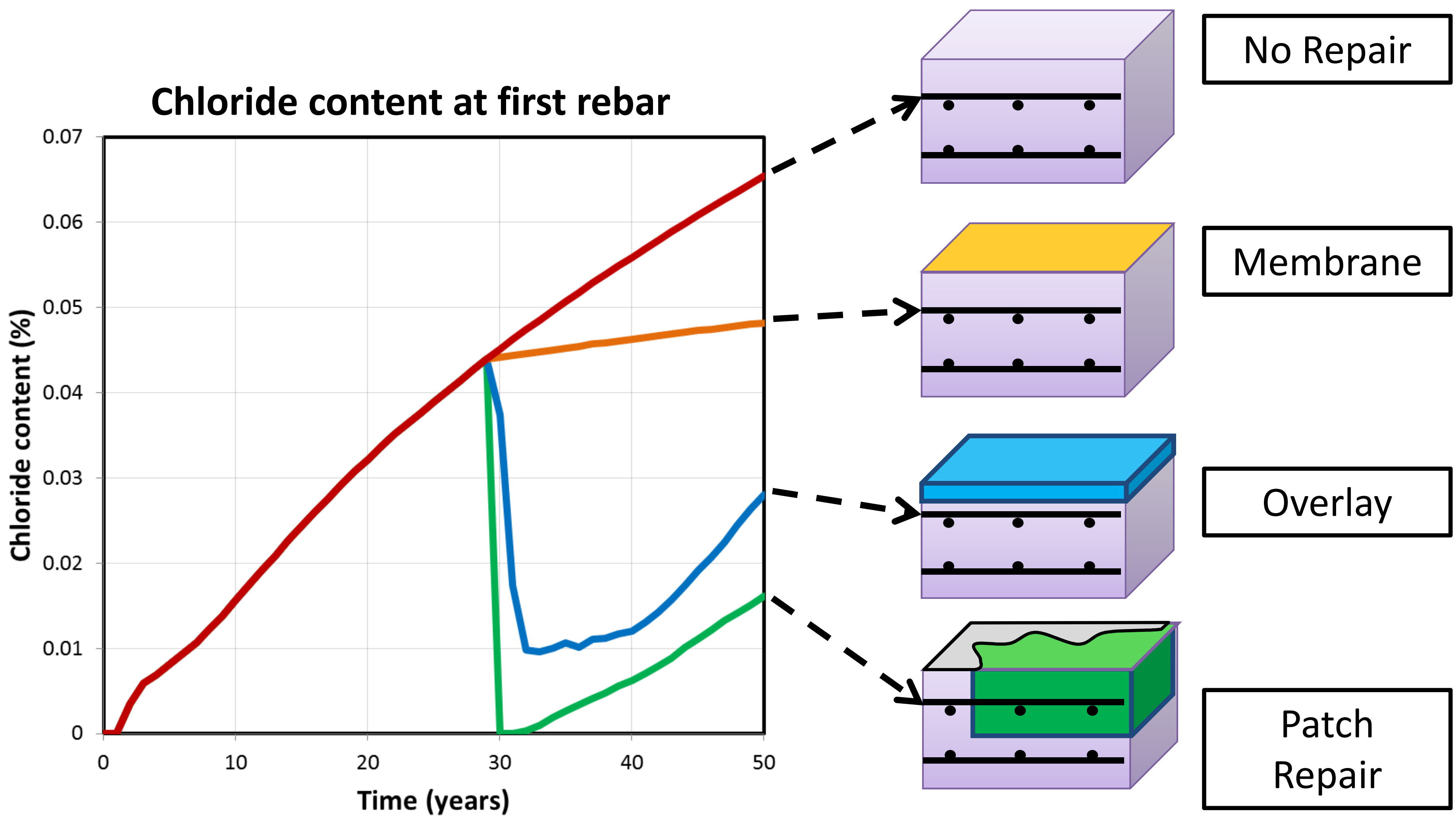
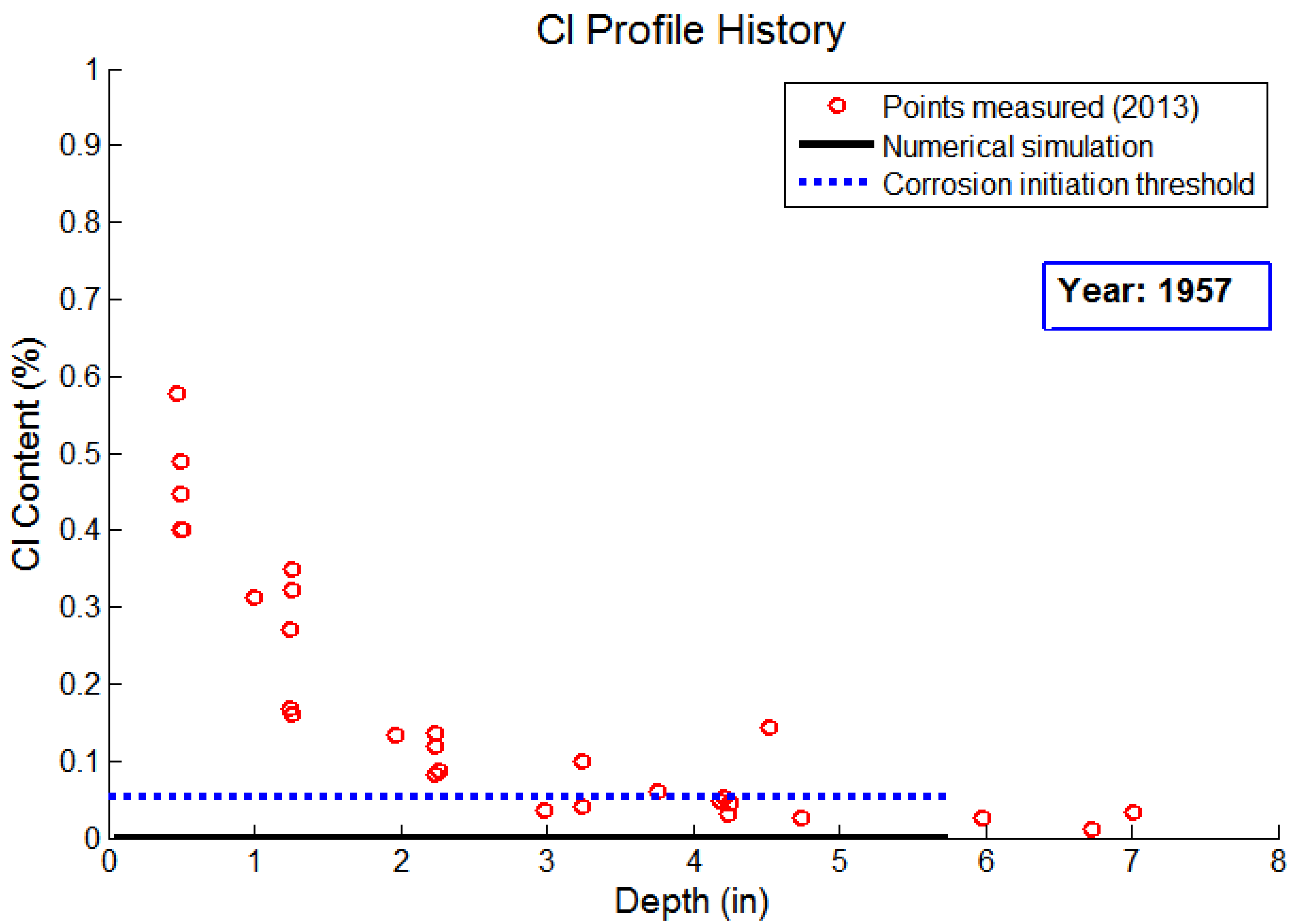
Using STADIUM – Existing Structures

Maintenance options



Using STADIUM – Existing Structures

Simulating past exposure sequences



Using STADIUM – Existing Structures

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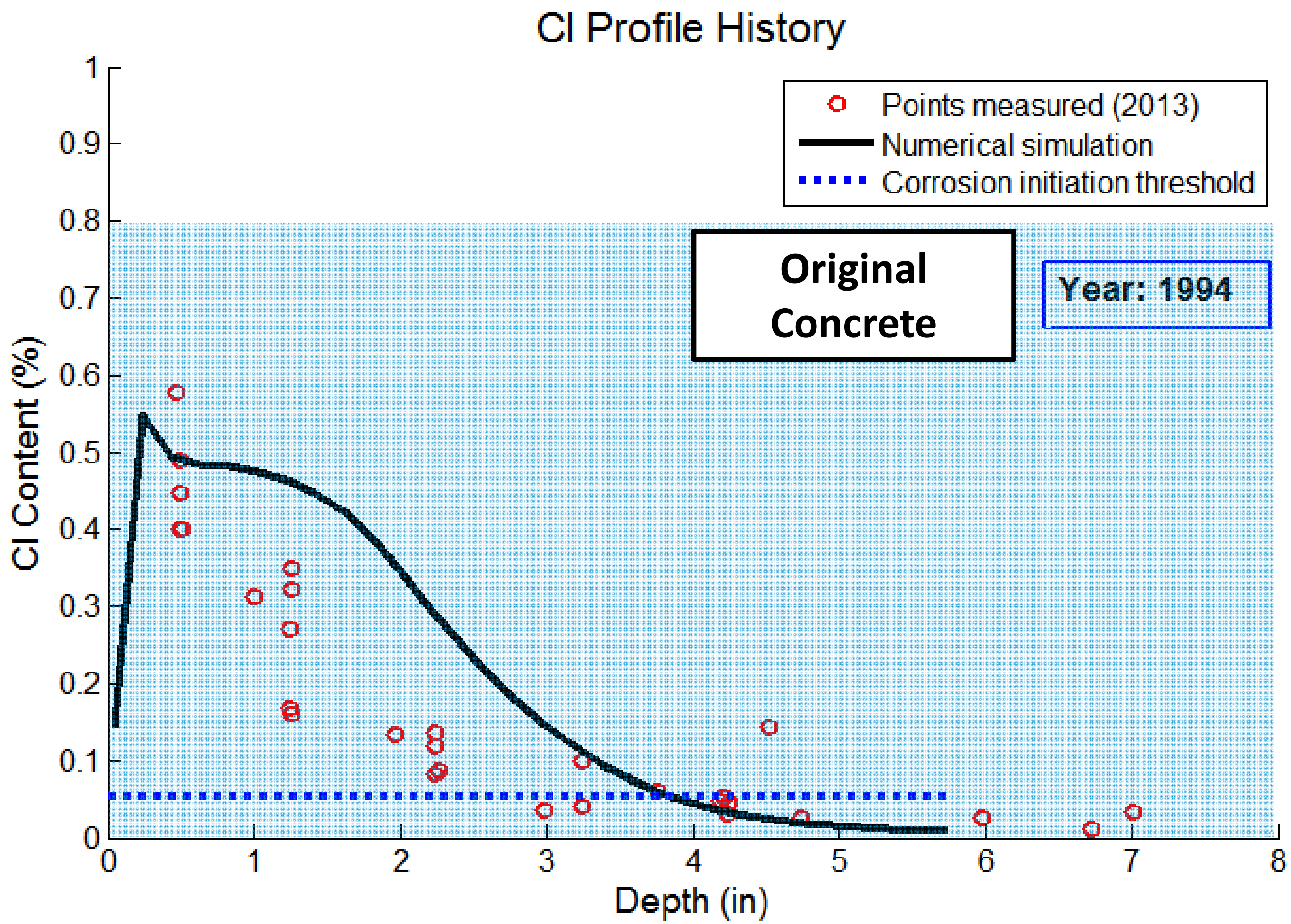
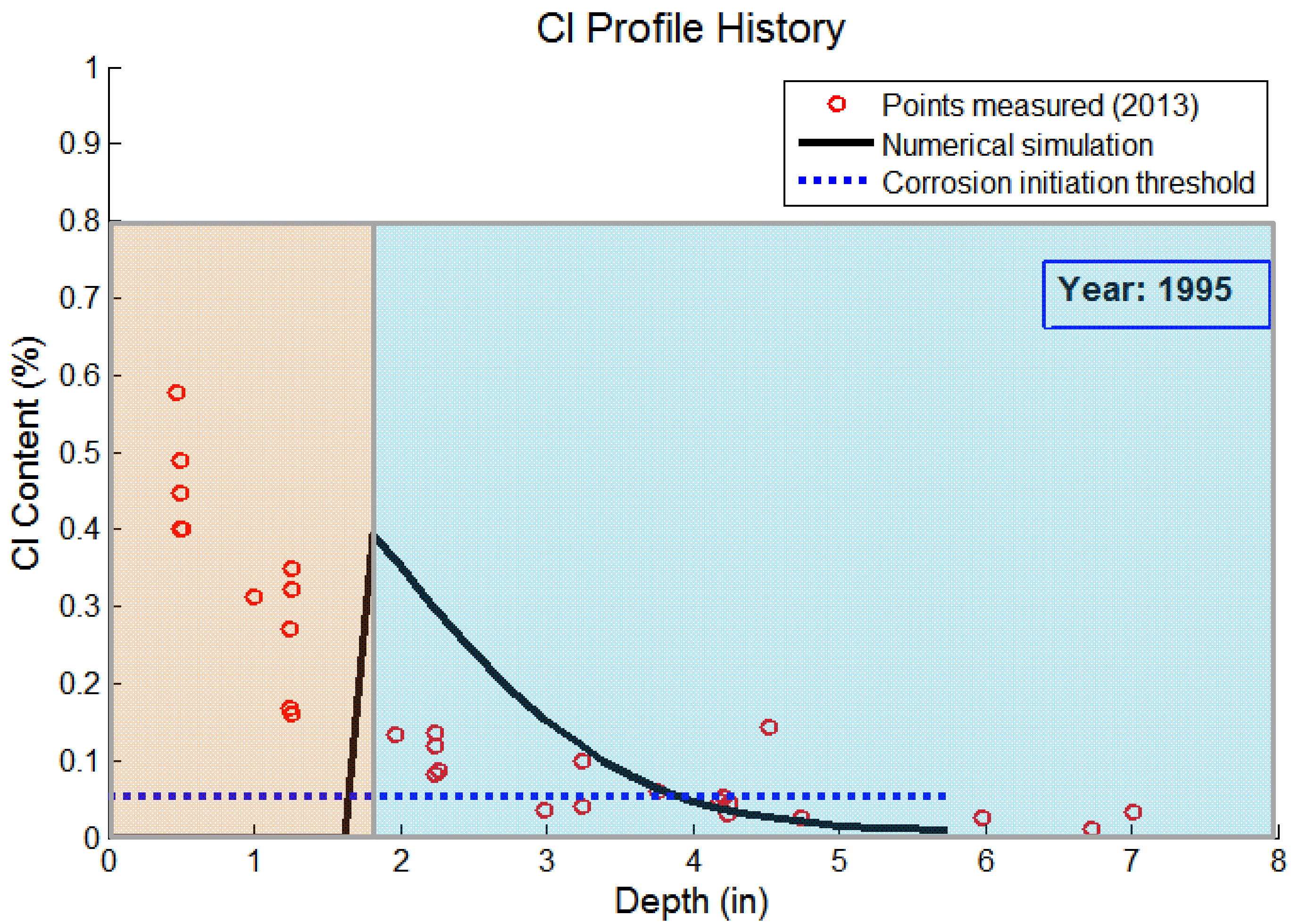


Using STADIUM – Existing Structures

Simulating past exposure sequences



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Using STADIUM – New Structures

Case Studies

Kentucky University – Concrete Mix Design

Using STADIUM – New Structures

Kilo Wharf Extension | US NAVY, GUAM

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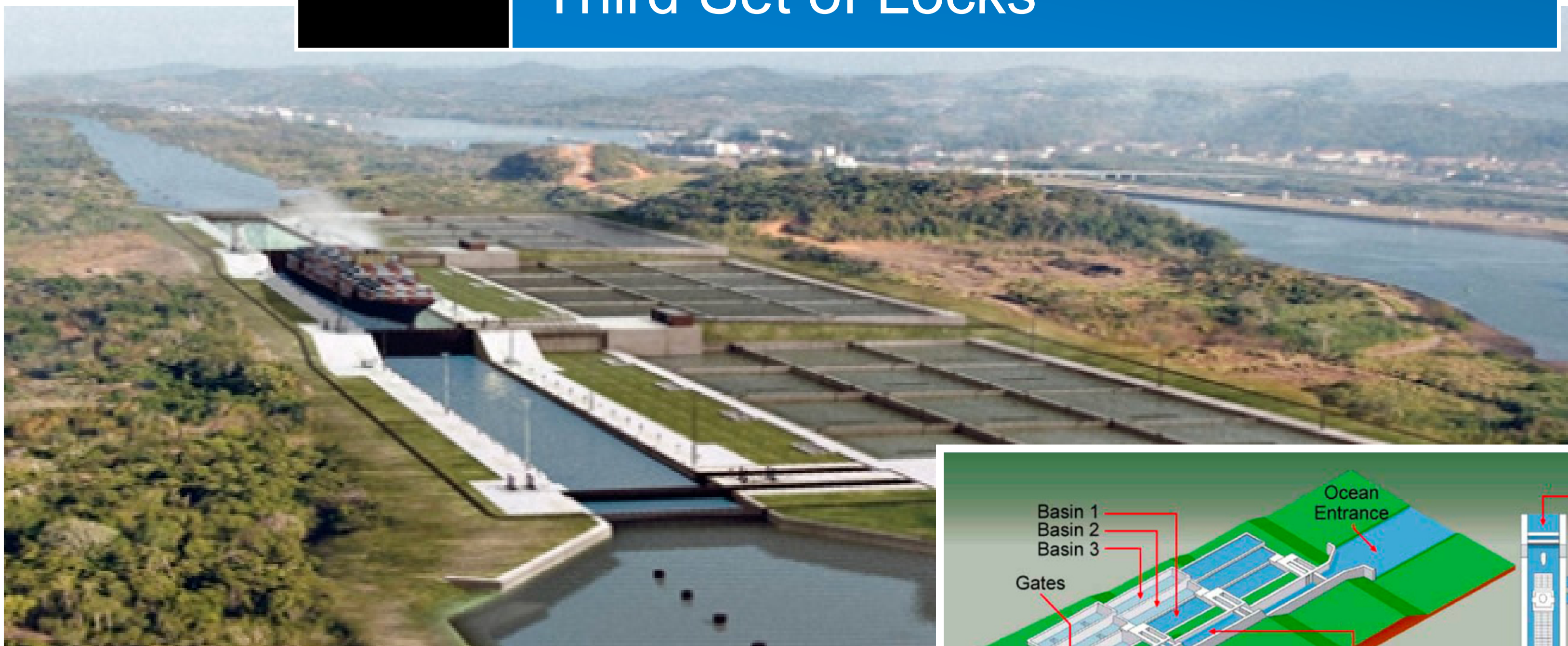
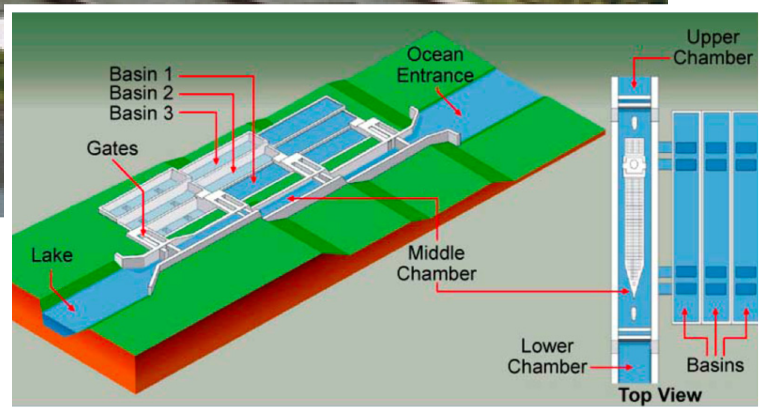
Using STADIUM – New Structures

Case Studies

Panama Canal – Third Set of Locks

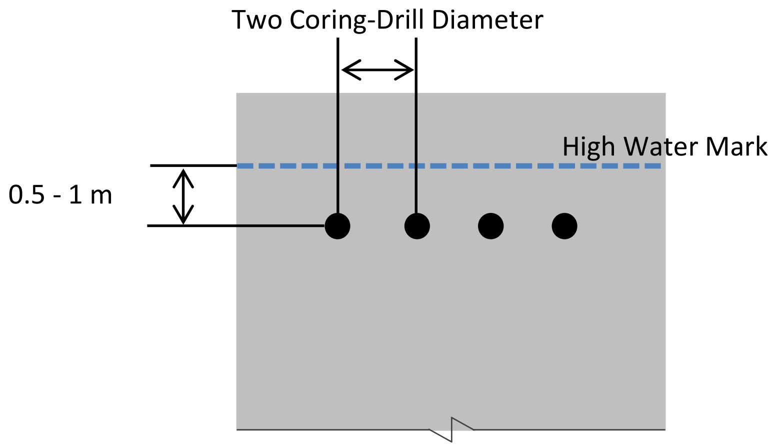


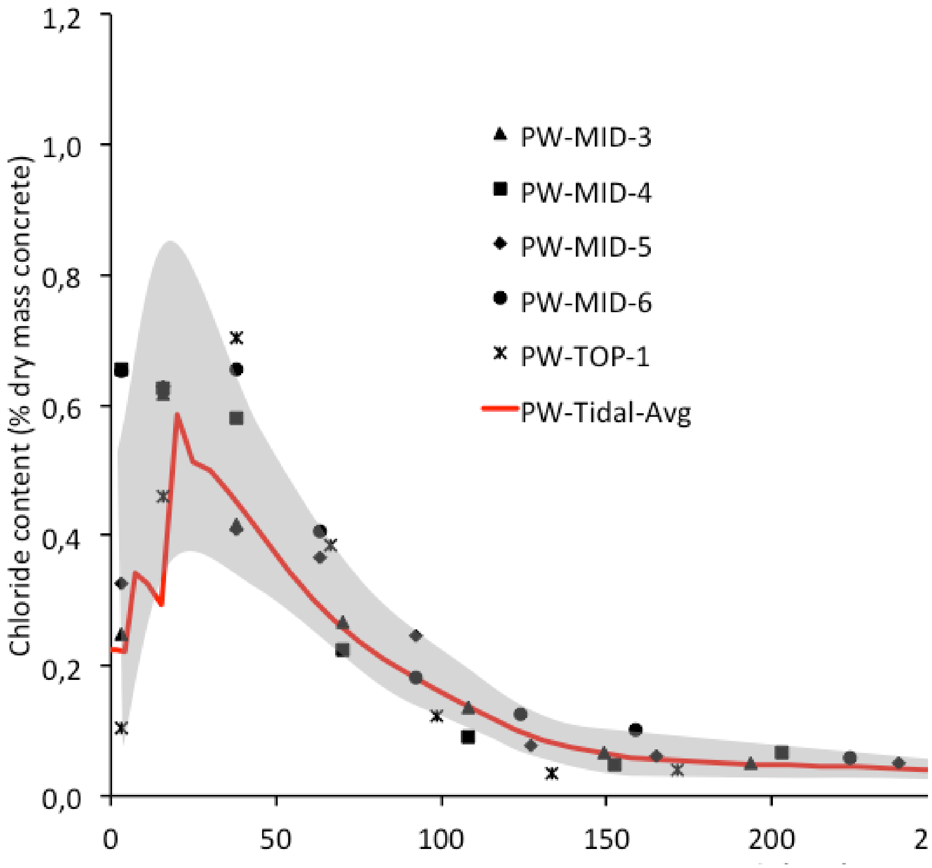


GRUPO UPC
UNIDOS POR EL CANAL

Using STADIUM – New Structures

Case Studies | **Panama Canal – Third Set of Locks**

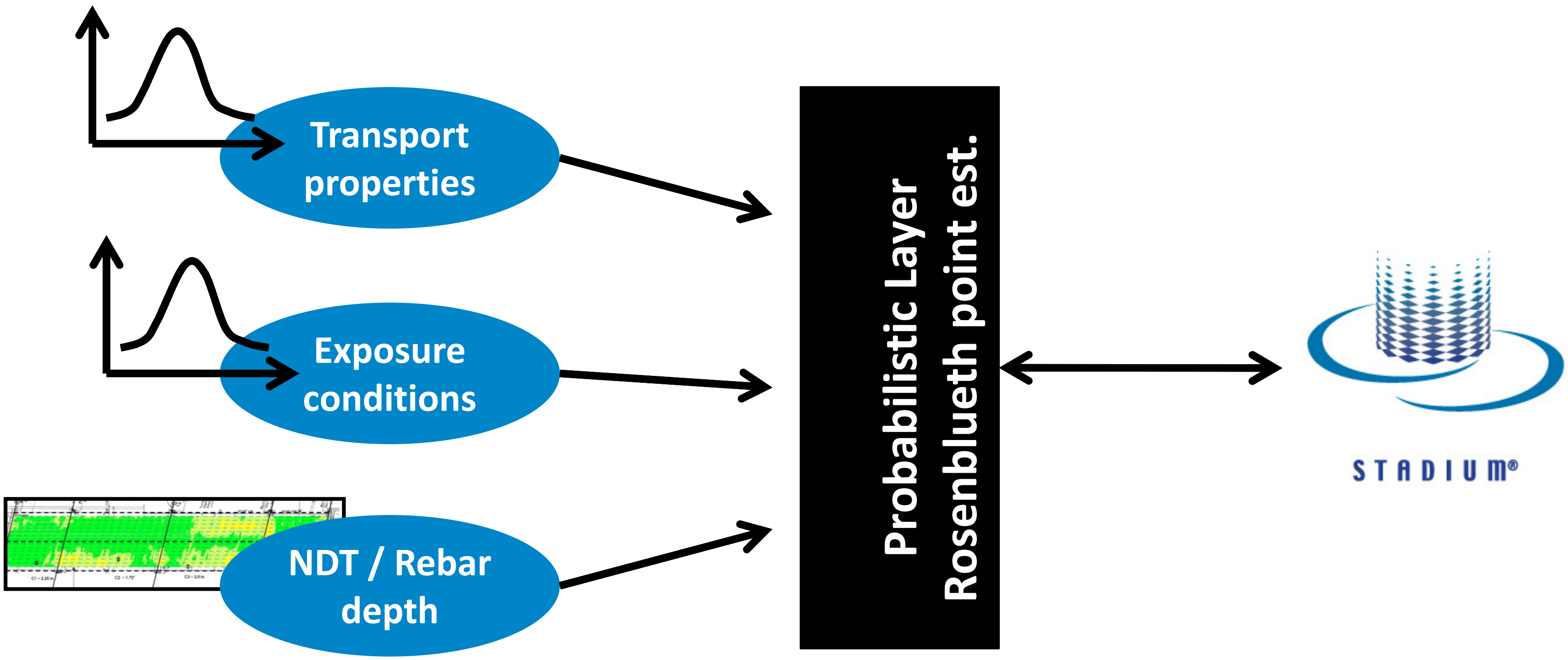




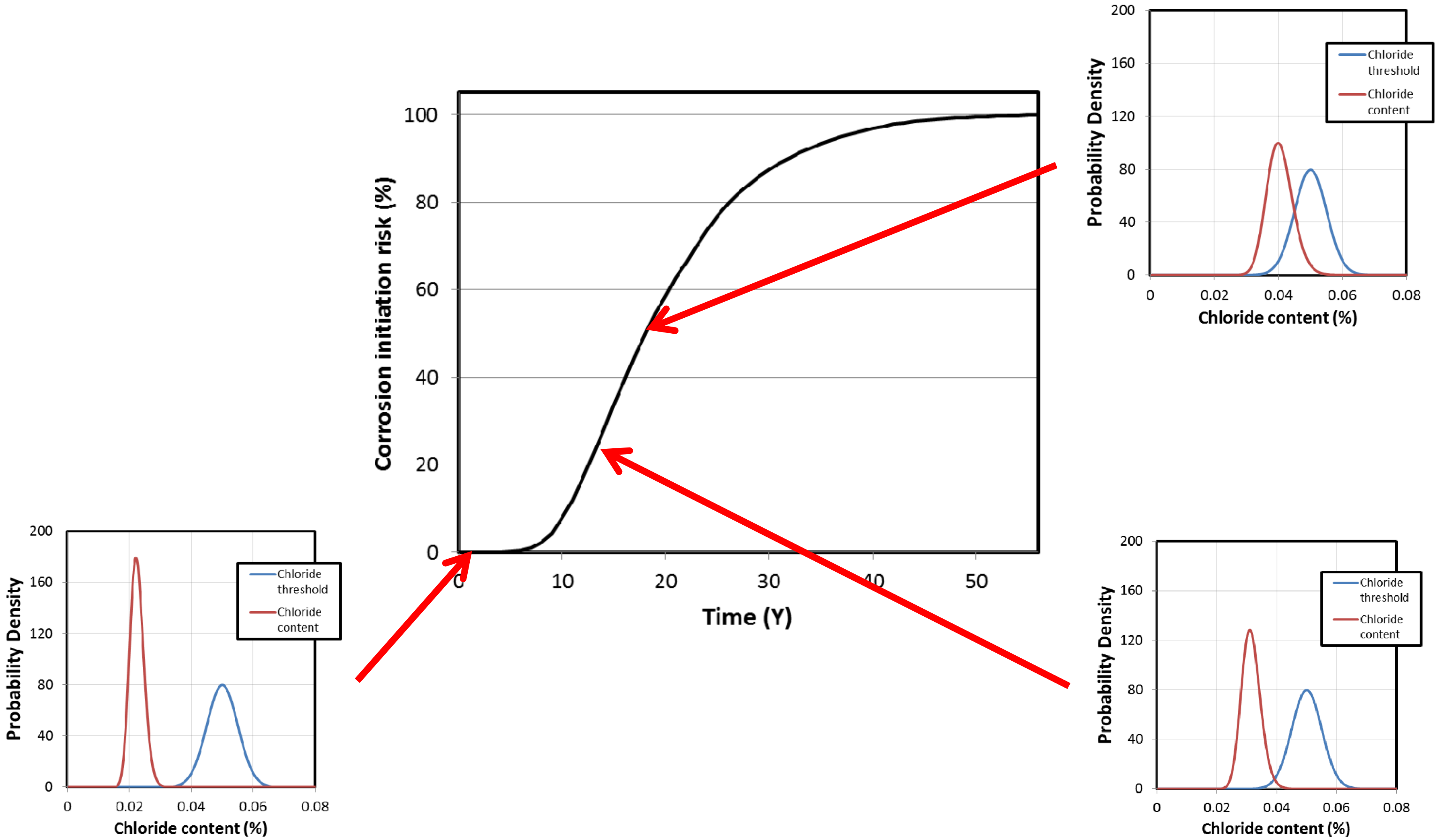
Probabilistic approach

A probabilistic engine can handle calculations considering the distribution of key parameters:

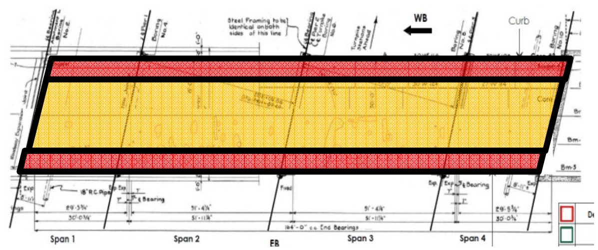
- Transport properties,
- Concrete cover,
- Exposure conditions,
- Corrosion threshold.

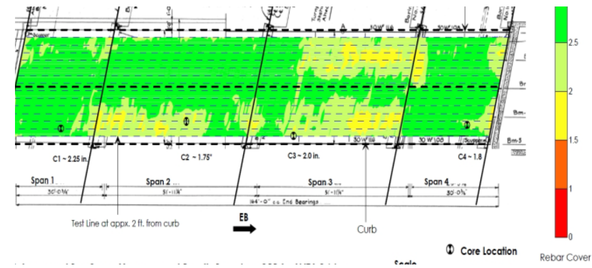


Probabilistic approach



Probabilistic approach



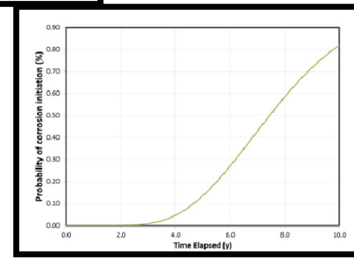


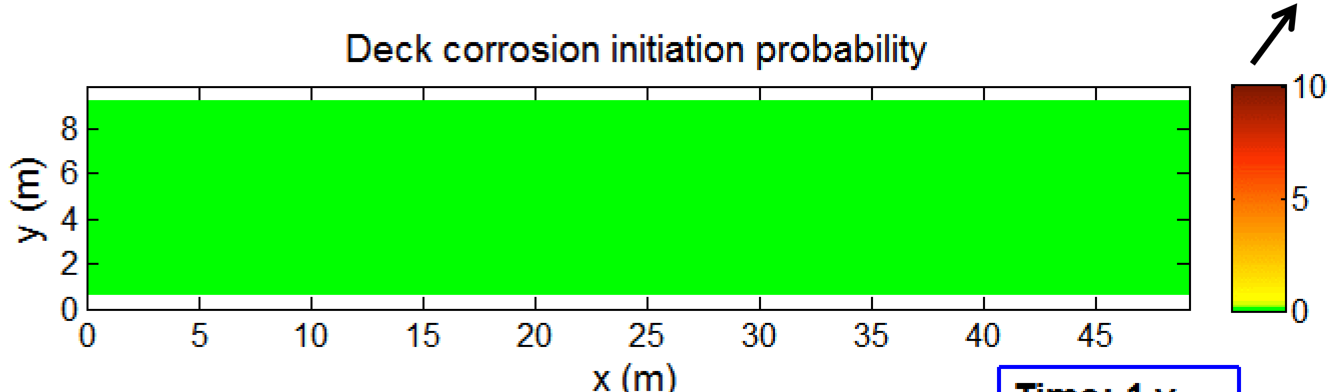
TRANSPORT PROPERTIES

EXPOSURE MAP

REBAR DEPTH

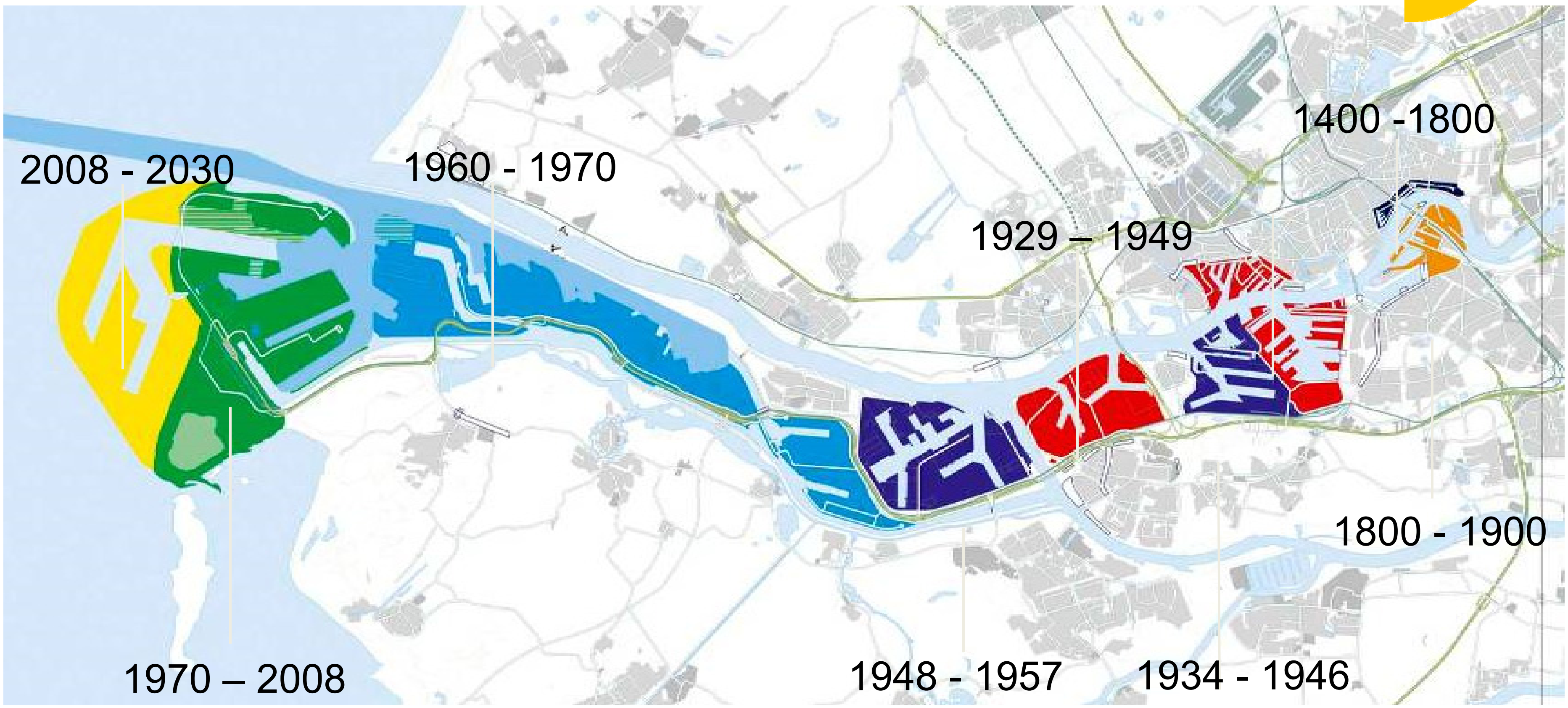
STADIUM®
Corrosion Simulations





Asset Management

KMS - Kademuren Modellering Systeem



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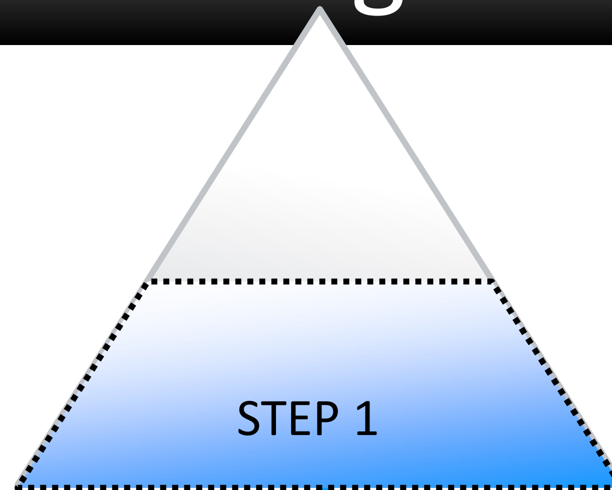
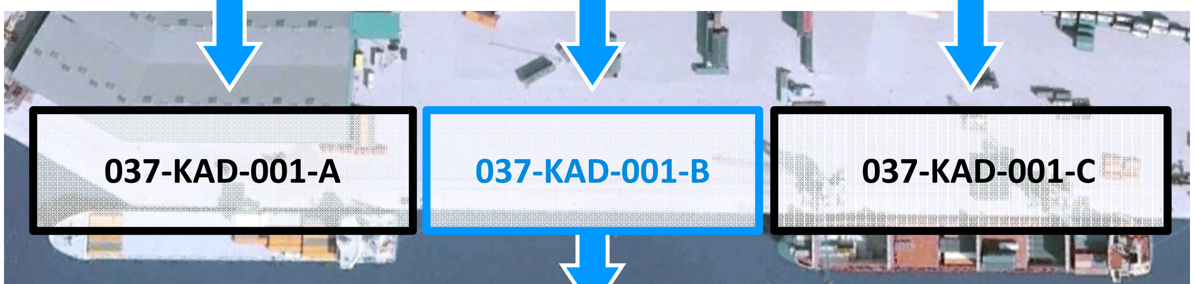




Inspection Request

- **Concrete**
  - Coring
    - Mechanical Testing
    - STADIUM® Testing
  - Visual Inspection
- **Steel**
  - Corrosion Measurements
  - Pitting Evaluation

KMS - Kademuren Modellering Systeem

STEP 2

Degradation Analysis per Zone and Element
Evaluate Degradation with STADIUM®

Post Treatment Analysis

For each Zone/Element combination

Select the most critical Zone/Element combination

Schedule Next Inspection

Close Monitoring Required

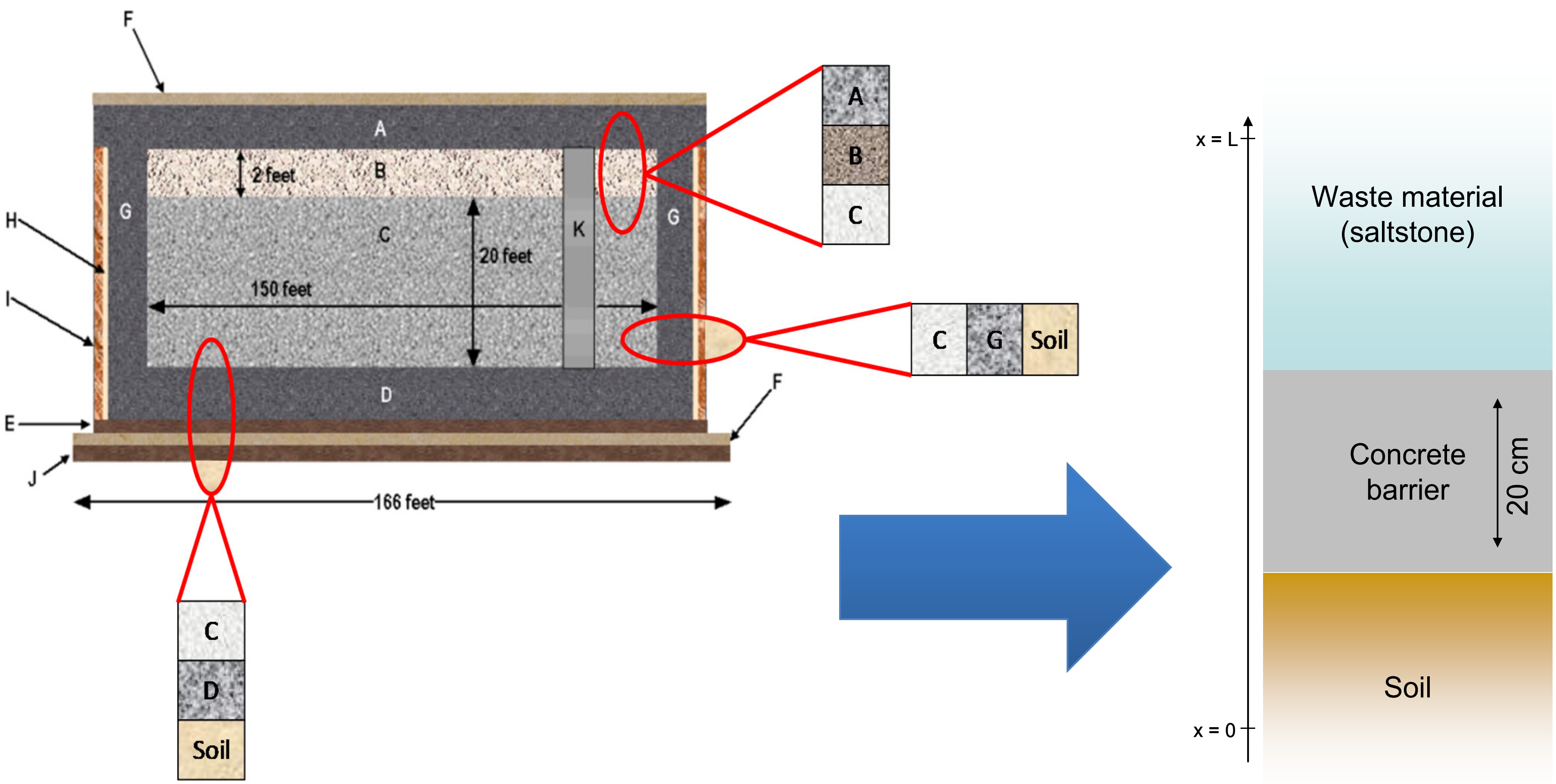
Repair

Critical Year (Trigger/Intervention)

Maintenance Proposal

CBP Test Case

Concrete in contact with saltstone



CBP Test Case

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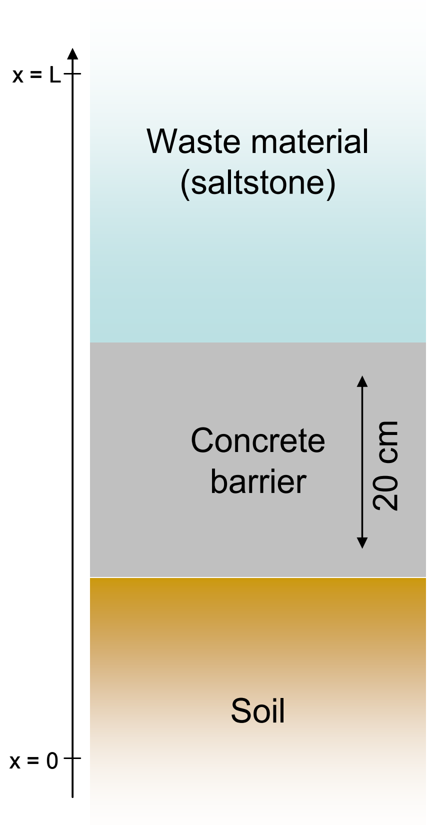

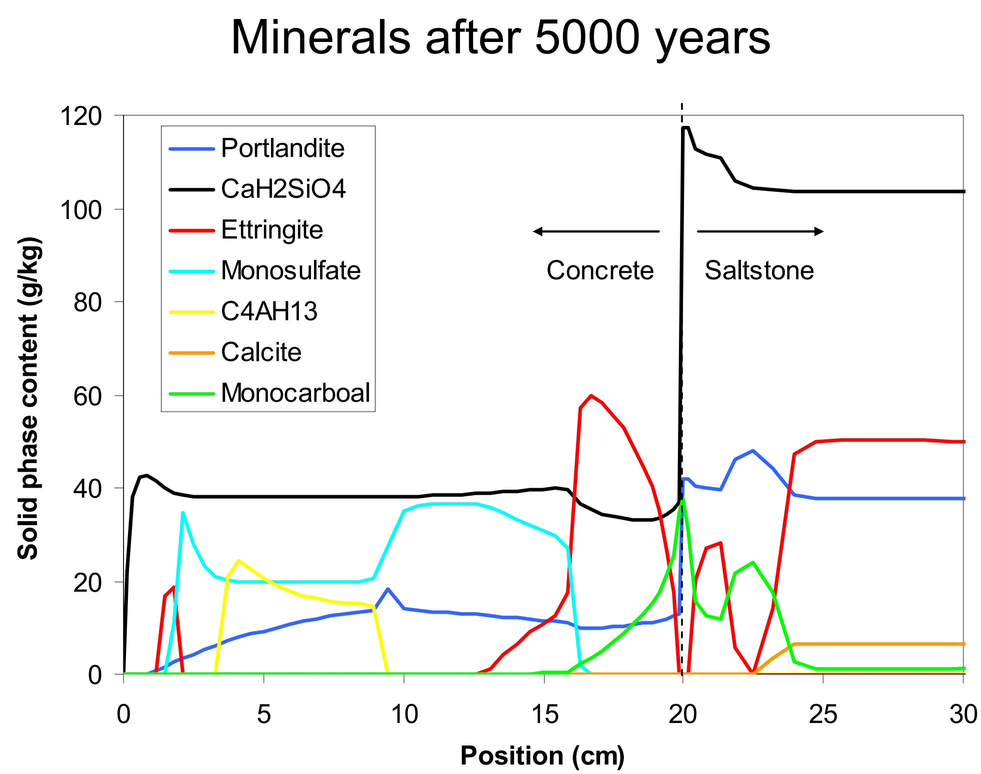

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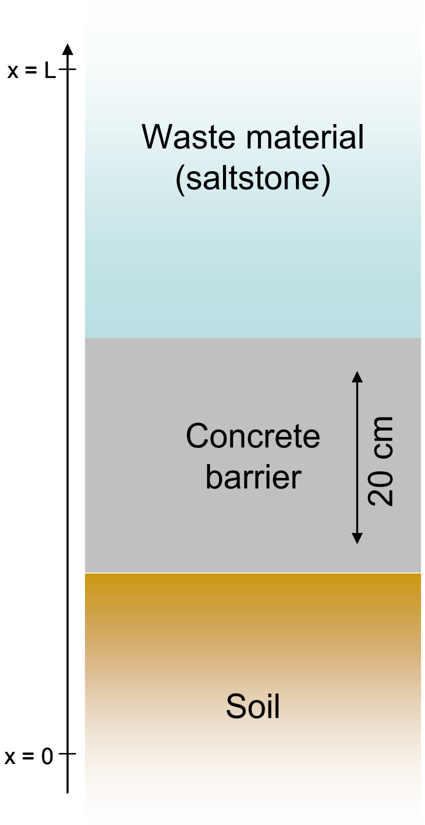

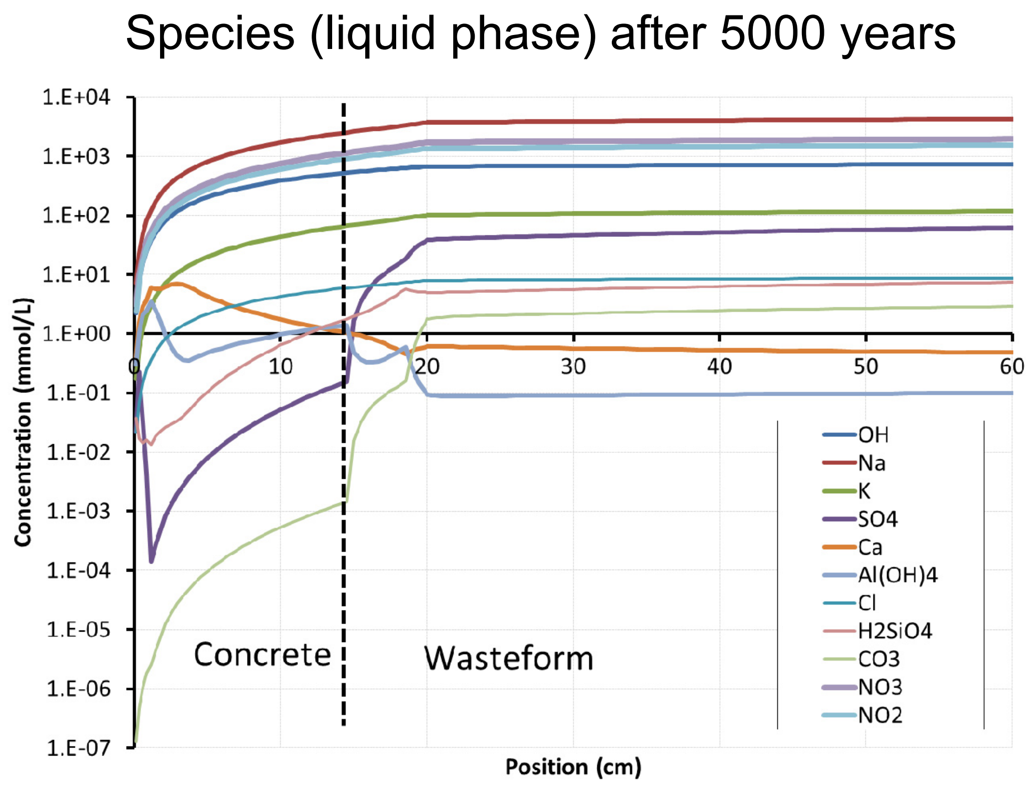

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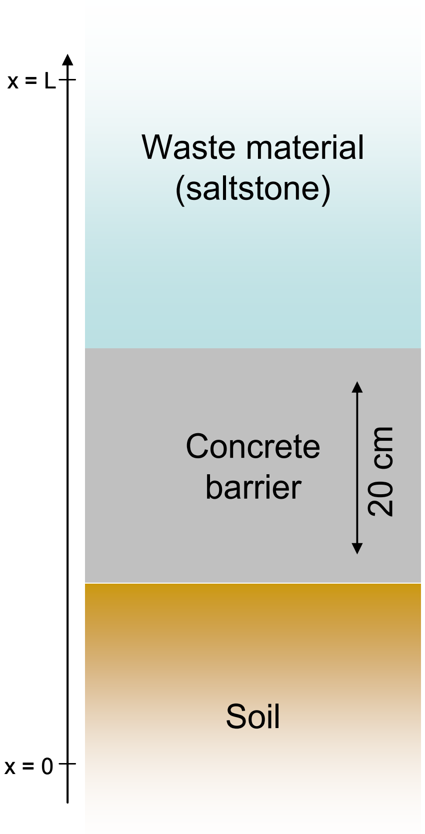

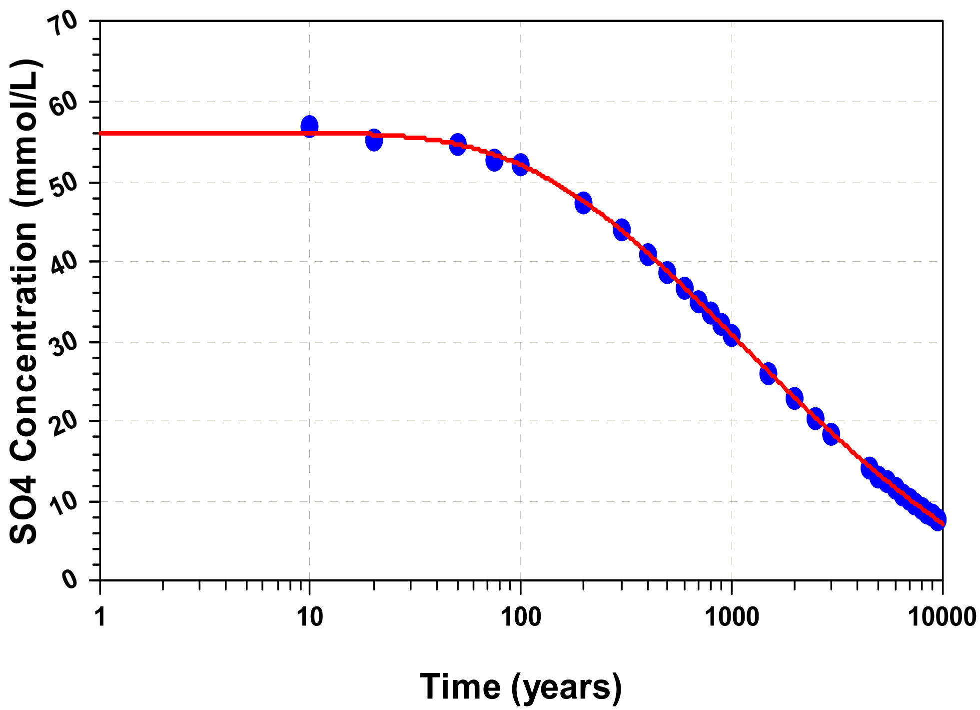

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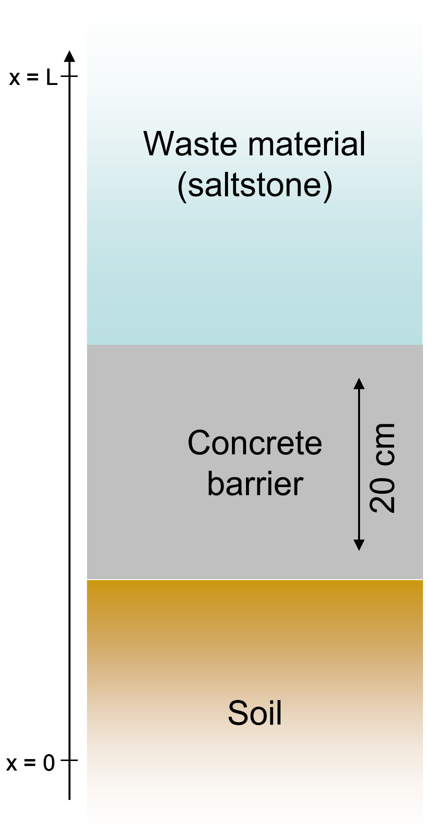

Position of the ettringite front