

The logo for SIMCO, consisting of the word "SIMCO" in white, bold, sans-serif capital letters on a dark blue rectangular background.

SIMCO

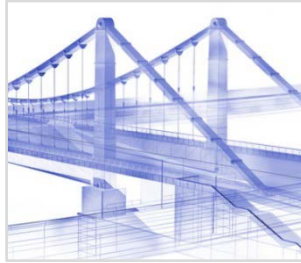
The main title of the presentation, "Service Life Modeling – Demystify STADIUM®", displayed in white text on a semi-transparent blue horizontal band. The background of the entire slide is a collage of blue-tinted images related to infrastructure and engineering, including a port with a large ship, a curved tunnel, an oil pumpjack, a suspension bridge, a dam, construction workers, a road under construction, a hand holding a pipe, an airplane, and a group of workers on a construction site.

Service Life Modeling – Demystify STADIUM®

Dennis Burns, P.Eng., M.Sc.

AAPA – Facilities Engineering Seminar
Vancouver – November 2013

A Comprehensive Approach



Pre-Design

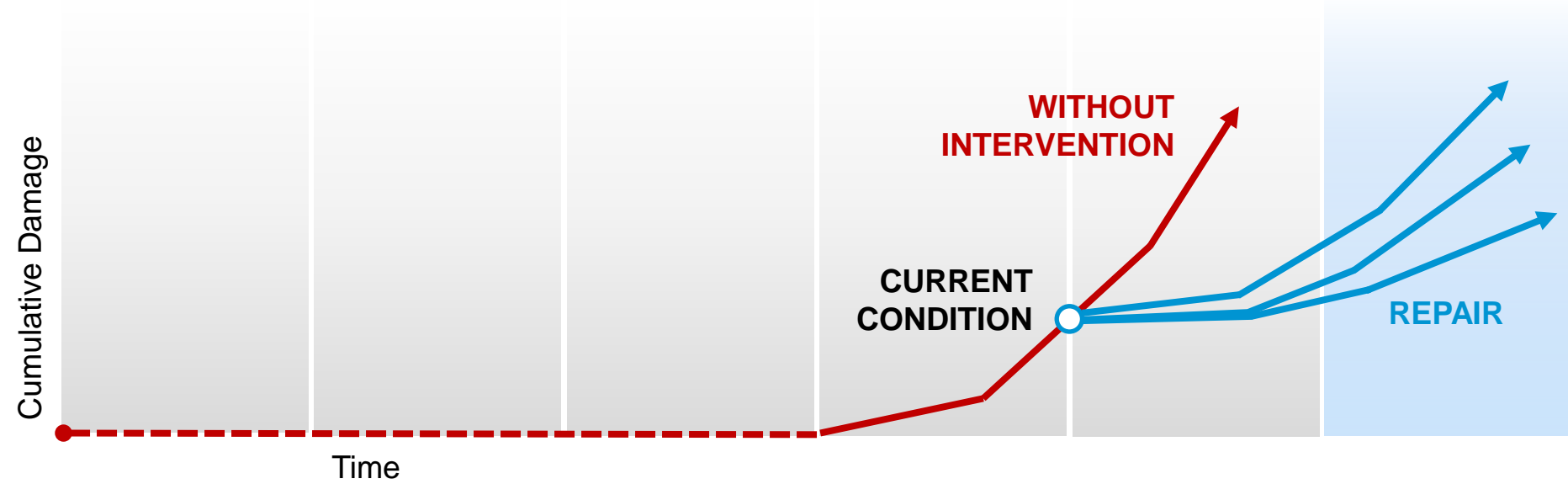
Design

Construction

Maintenance

Rehabilitation

Recycling





DoD UNIFIED FACILITIES GUIDE SPECIFICATIONS

SIMCO's STADIUM® software is the only service-life prediction tool recognized and specified by the U.S. DoD for the design and construction of new maritime works



Modular Hybrid Pier



Kilo Wharf Extension



Pier 31, Groton

The use of service-life prediction technology leads to 25% life extension of DoD waterfront facilities

STADIUM® Software Solutions



**Commercial
Software Solutions**



**Software Solutions
Used Inhouse**

Durability Engineering

Primary Objectives

Optimize Performance

Reduce Risks

Control Costs

- ✓ Sound and proven analytical techniques
 - ✓ Reliable testing methods
- ✓ Comprehensive knowledge of local materials



Cement



Aggregates



Reinforcing Steel

Service-Life Verification & Documentation

Two Approaches

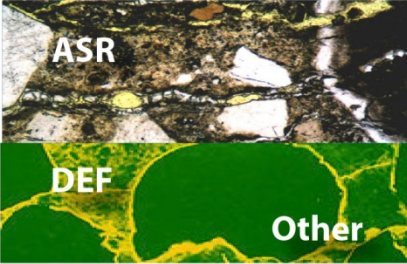

The diagram consists of a blue header bar with the text 'Two Approaches'. Below this bar is a white horizontal line with a double vertical line in the center. Two blue downward-pointing arrowheads are positioned below the line, one on the left and one on the right, pointing towards the two approach names below.

**Avoidance of
Deterioration Approach**

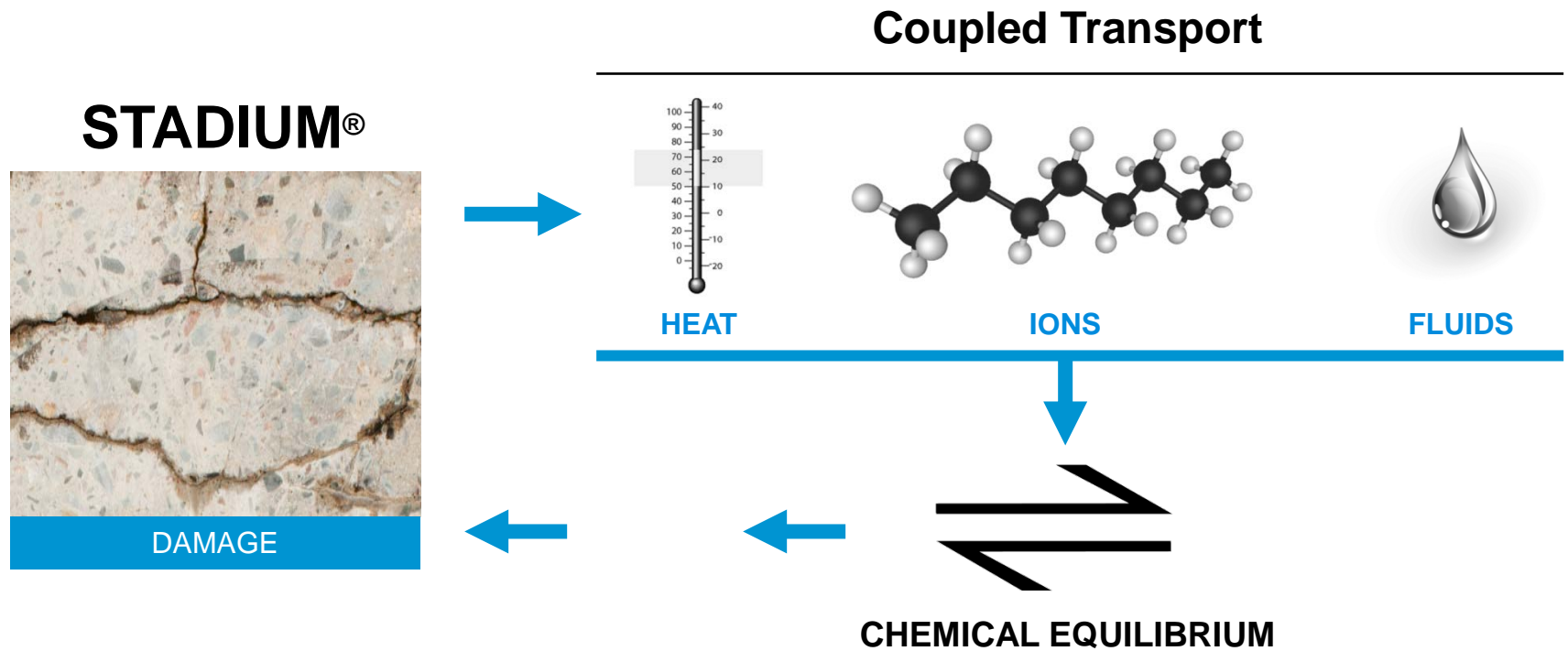
**Full
Probabilistic Method**

The approach varies with the type
of degradation phenomenon considered

Concrete Durability Matrix

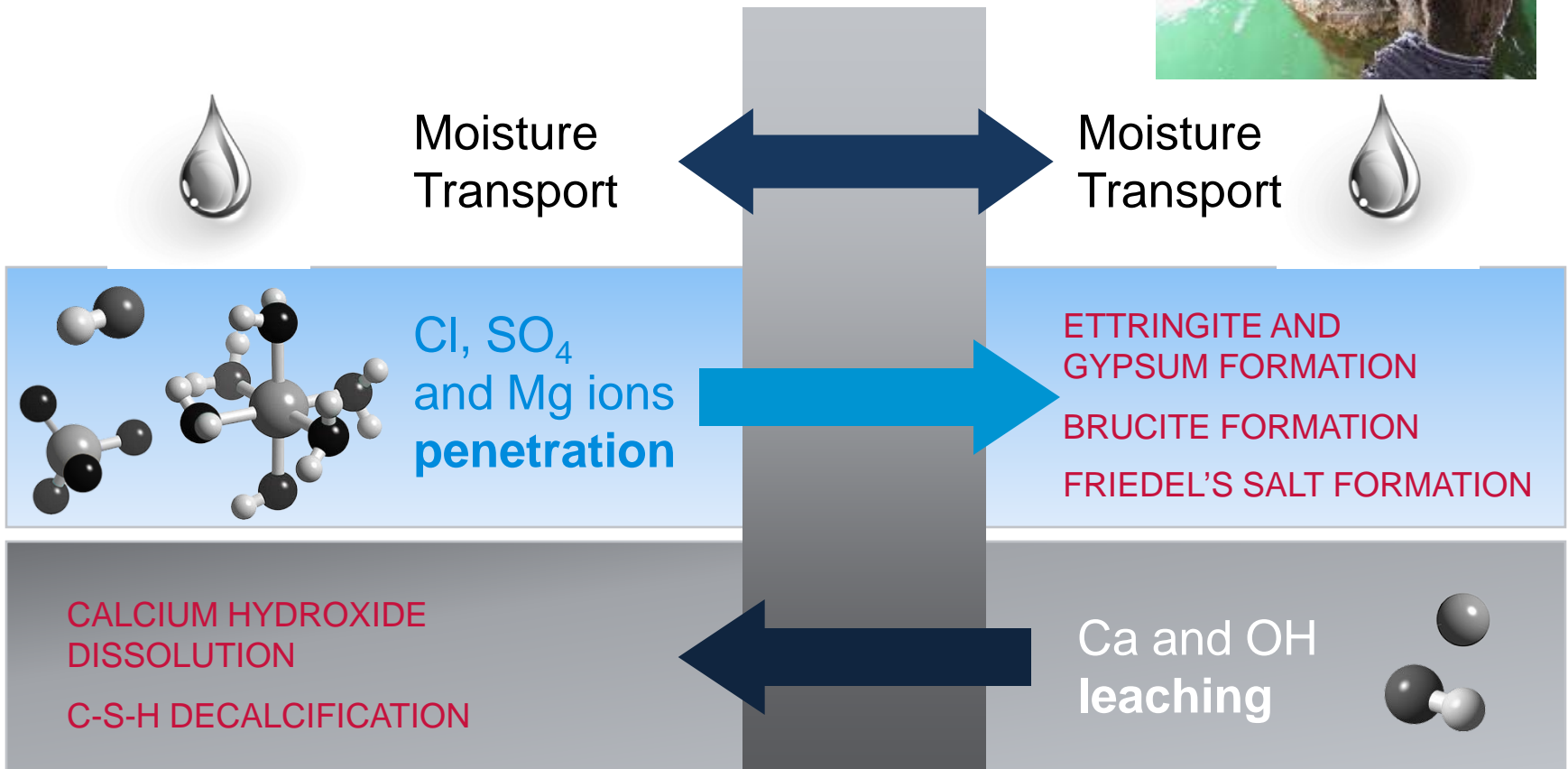
	Type	Example	Verification Method	Solution			
A	Internal Deterioration Reactions		Avoidance of Deterioration Method	<ul style="list-style-type: none"> Proper Materials Selection Optimum Mix Designs Selection of Production & Placement Methods 			
		Physical Mechanisms				Avoidance of Deterioration Method	<ul style="list-style-type: none"> Optimum Mix Designs Selection of Production & Placement Methods
					External Contamination		

STADIUM[®] Calculation Algorithm



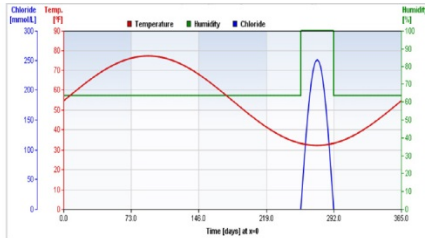
STADIUM[®] Approach

Coupled Transport



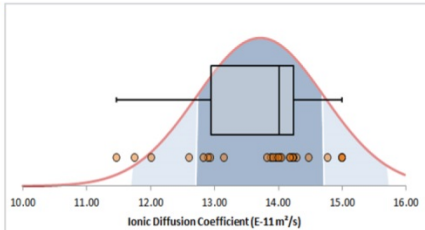
Full Probabilistic Approach

LOADING

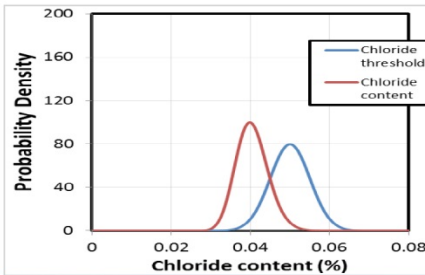


Exposure Conditions

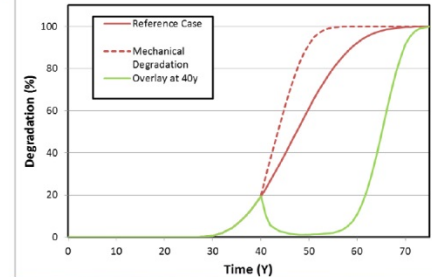
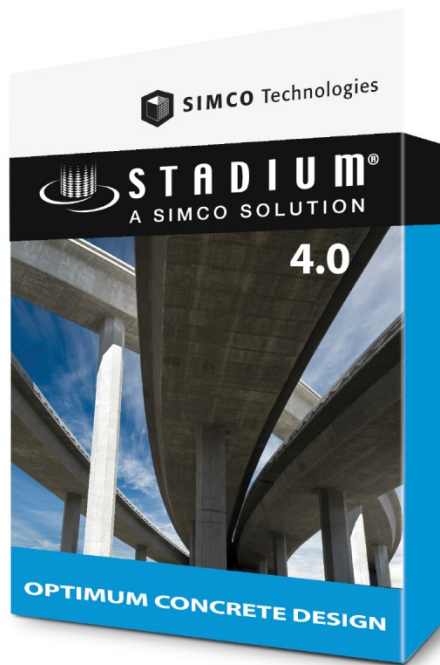
RESISTANCE



Material Properties



Chloride Threshold & Cover Variation



Degradation Curves

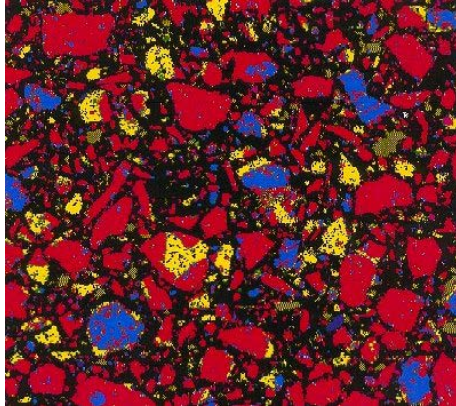
	INSIGNIFICANT	MINOR	MODERATE	MAJOR	SEVERE
LIKELIHOOD					
ALMOST CERTAIN	M	H	H	E	E
LIKELY	M	M	H	H	E
POSSIBLE	L	M	M	H	E
UNLIKELY	L	M	M	M	H
RARE	L	L	M	M	H

Risk Analyses

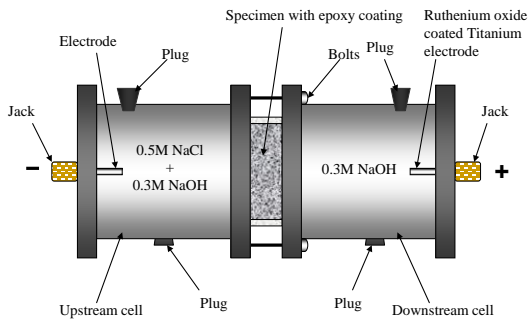


Lifecycle Cost Analyses

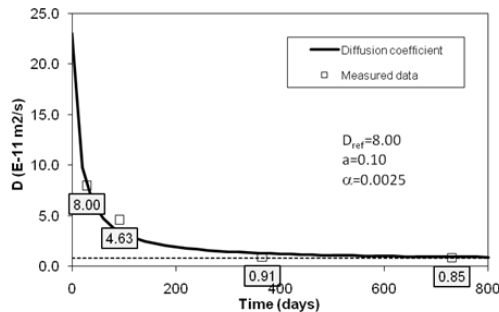
Input Data Determination



Mineralogical
Composition



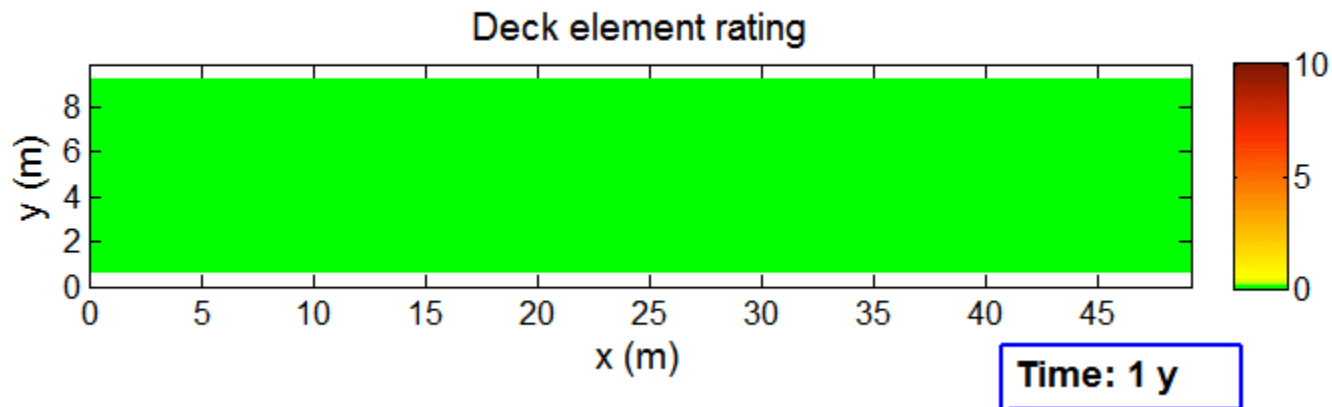
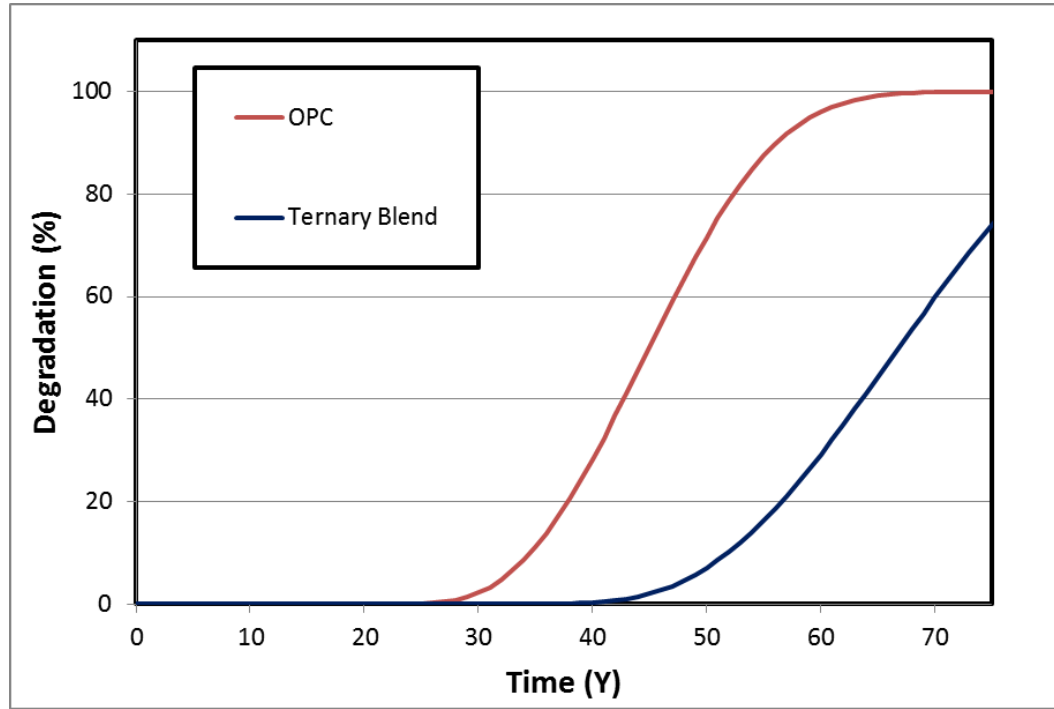
Transport
Properties



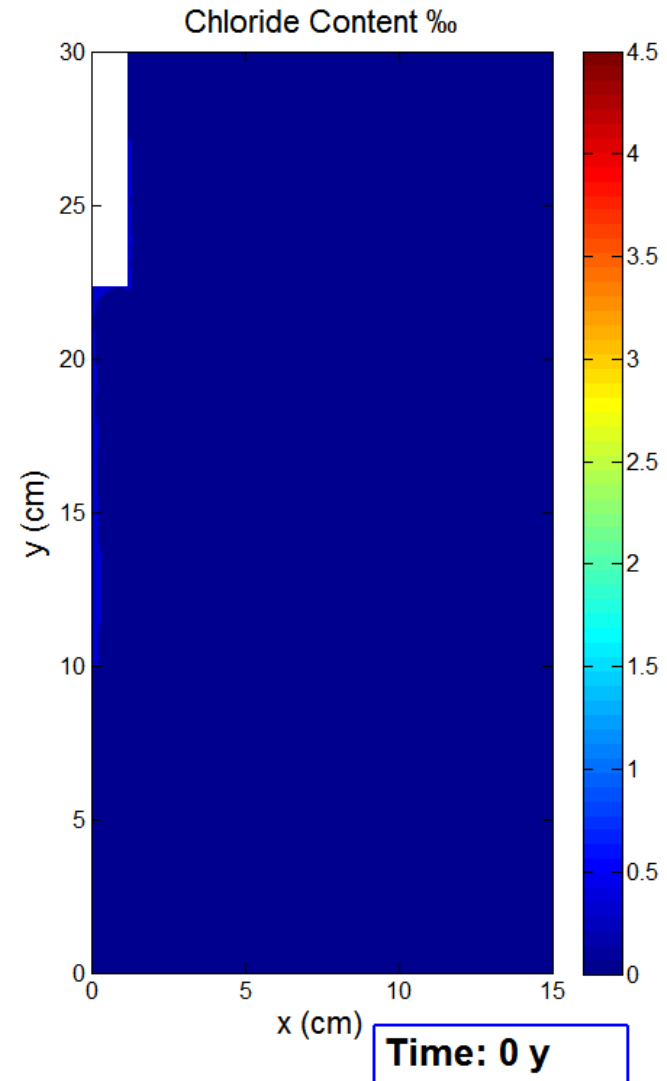
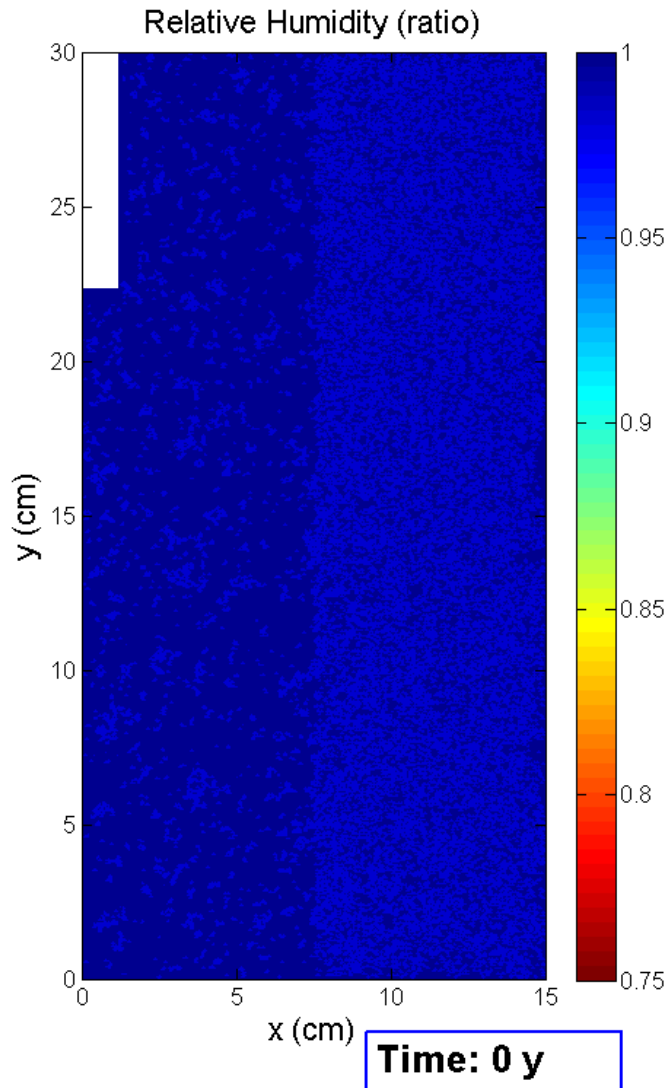
Properties
Evolution



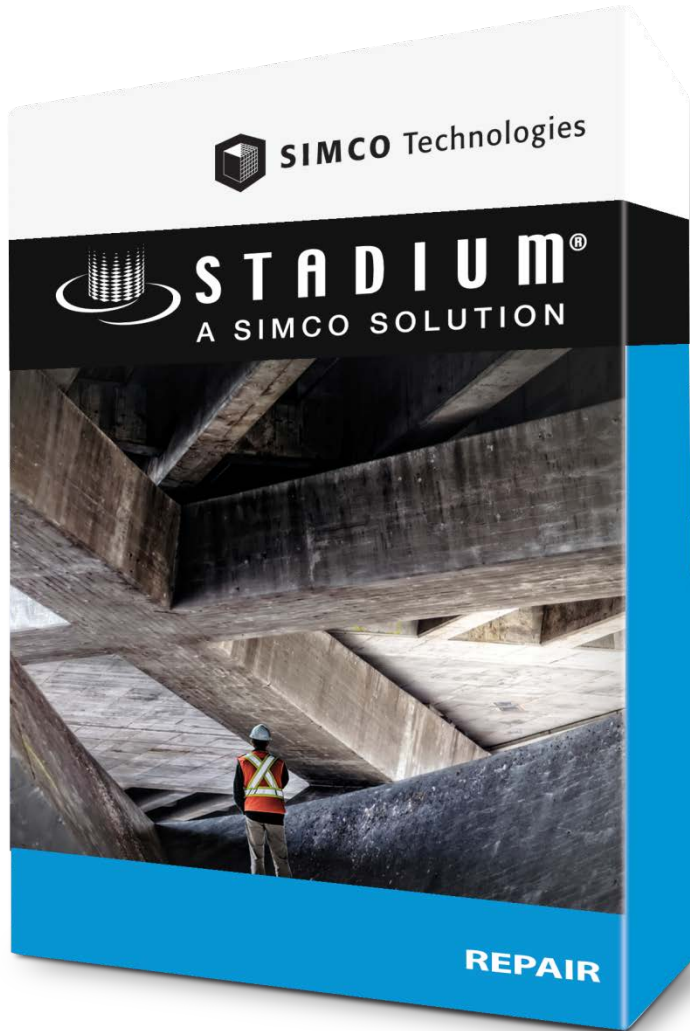
Future Degradation Curve – Minimal Maintenance



Future Degradation Curve – Critical Areas



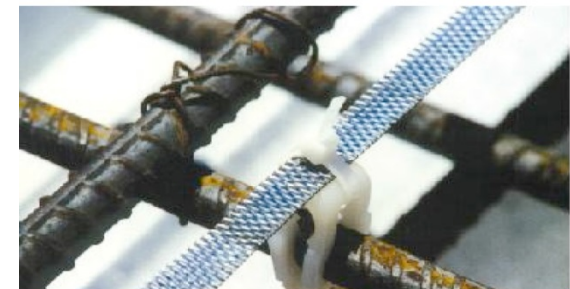
Future Degradation Curve – Maintenance Options



Patch Repair

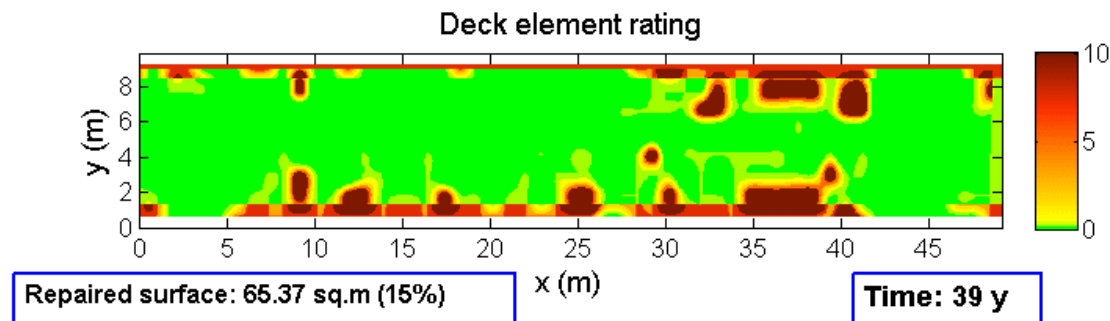
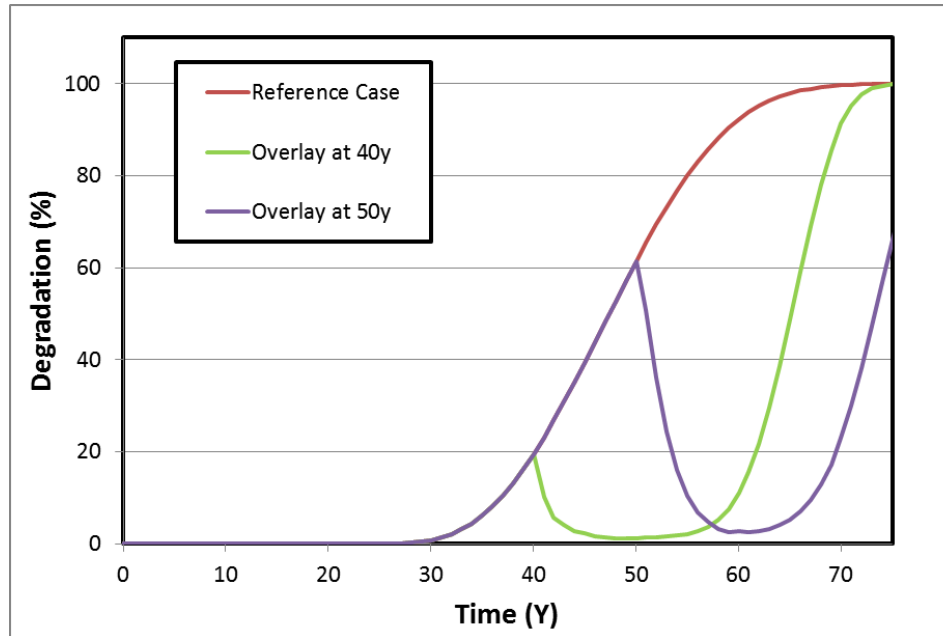


Concrete Overlay



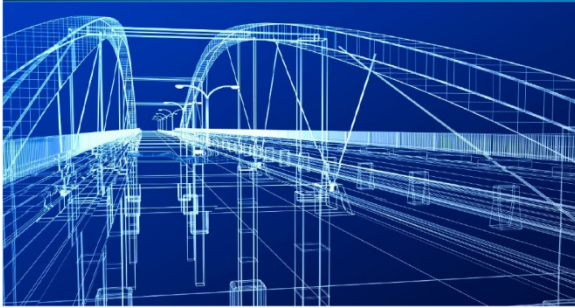
Cathodic Protection

Future Degradation Curve – Optimum Maintenance



Design-Build Project Approach

Pre-Design



Design



Construction



Analysis of Documents

Clear Definition of Service Life

Evaluation of Different Design Options using Database

Materials Selection

Application of the Durability Matrix to Final Design

Concrete Submittal

Optimum Maintenance Plan

QA / QC Protocols

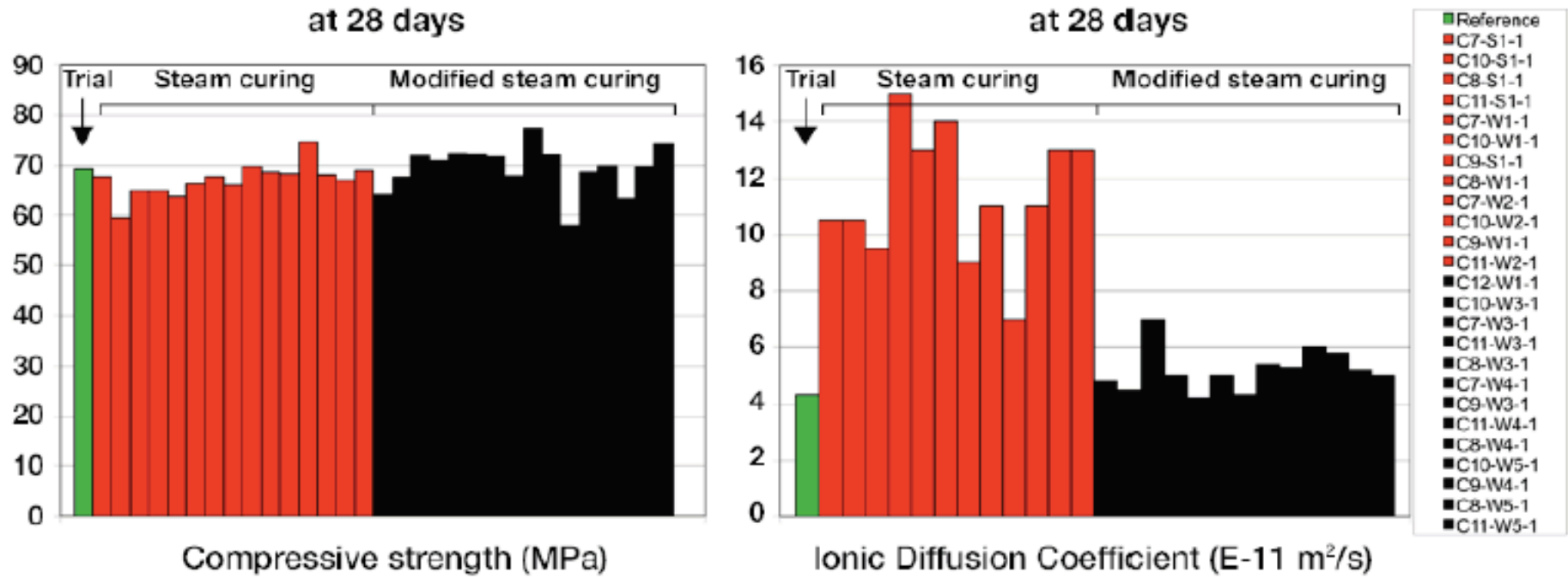
Proactive Quality Control

Remediation Strategies for Non-Compliant Results

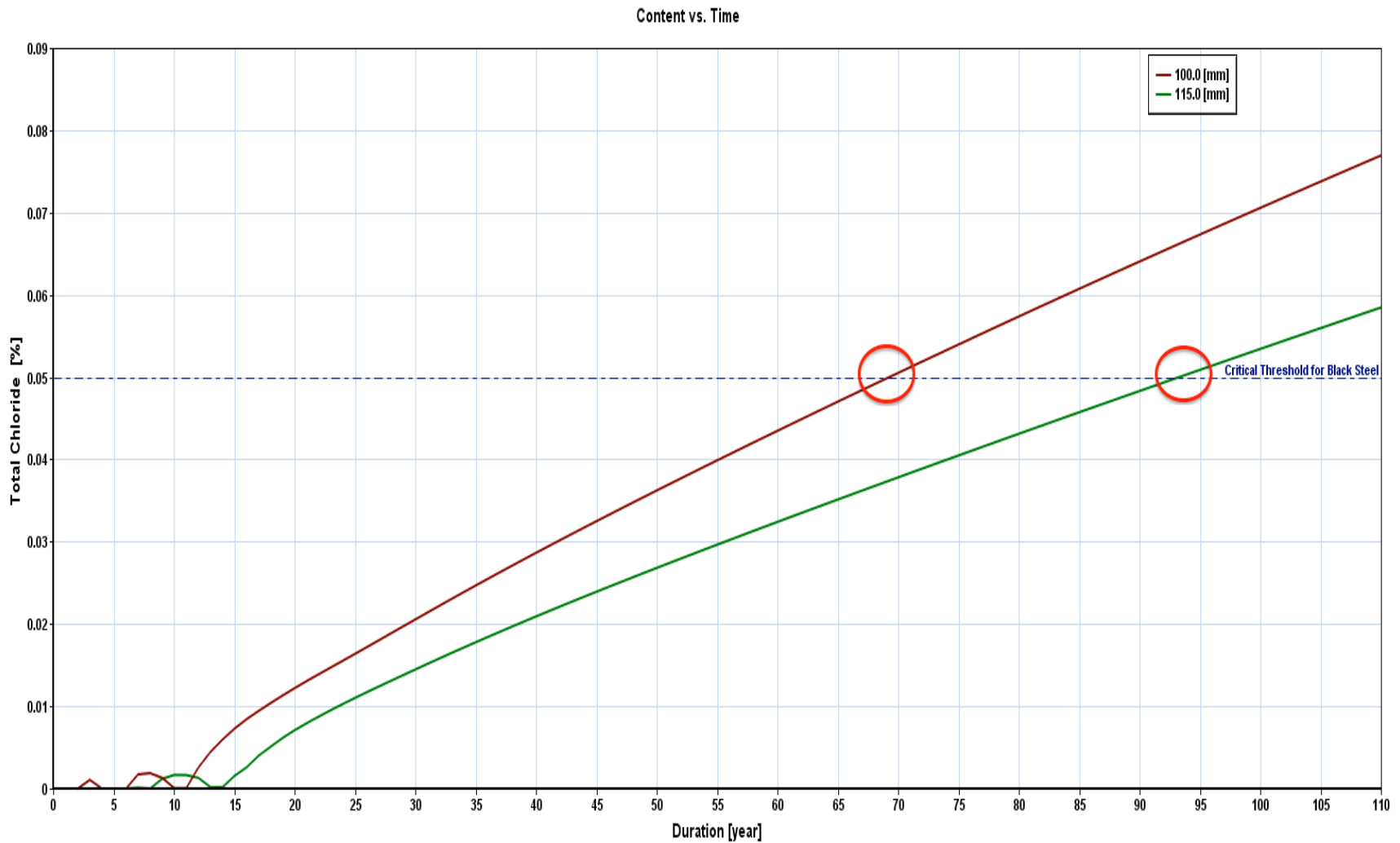
Final Design Stage - Mixture Design Optimization



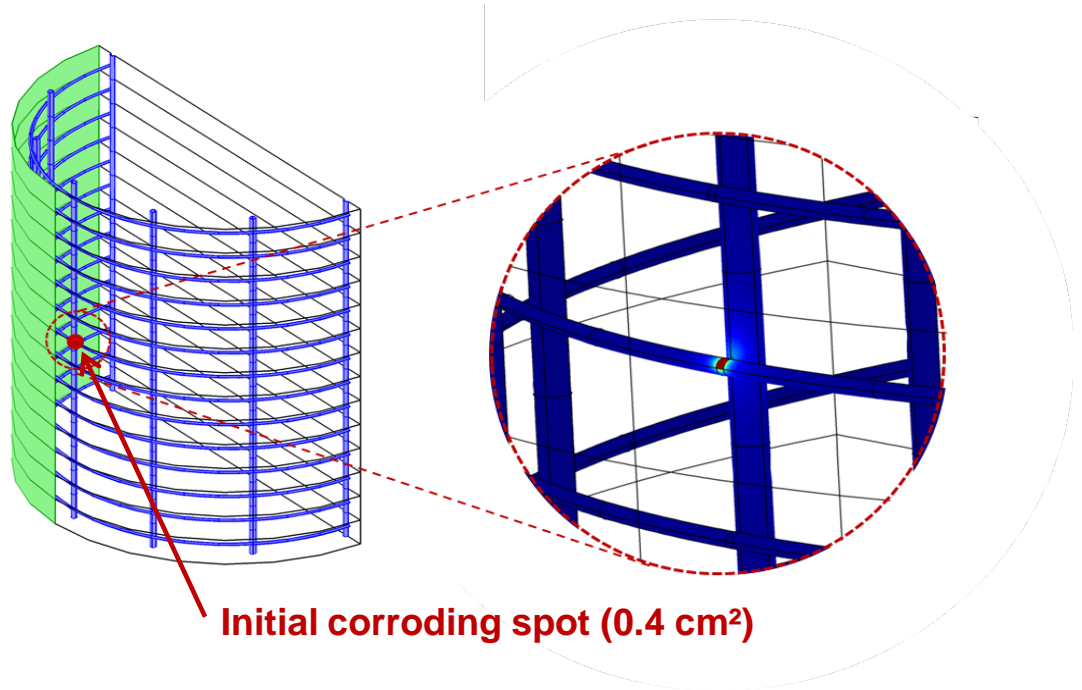
Construction Stage – Proactive Quality Control



Time to Initiate Corrosion Simulations



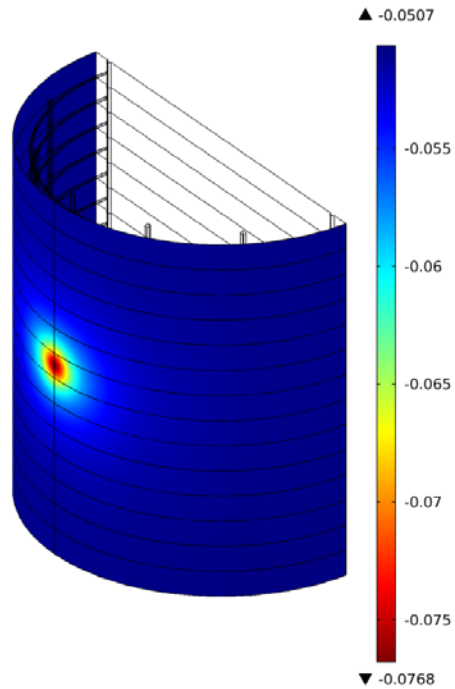
Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface



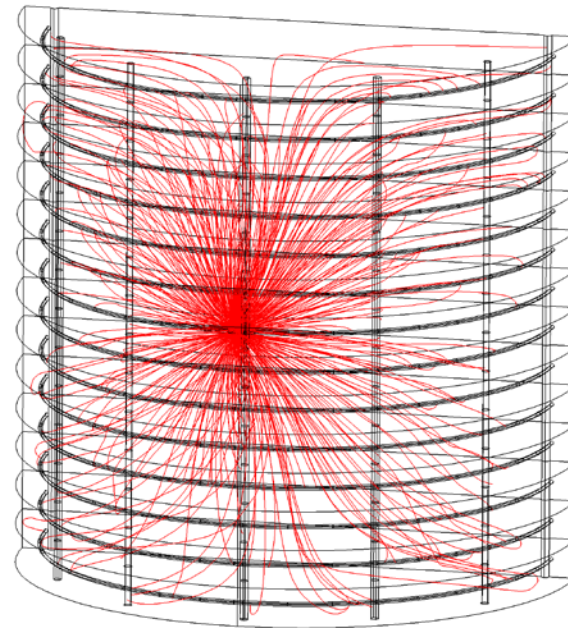
Numerical simulation:
Finite elements software Comsol Multiphysics®

Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

Examples of output data of corrosion simulations



Half-cell potential field / concrete surface (V/SCE)

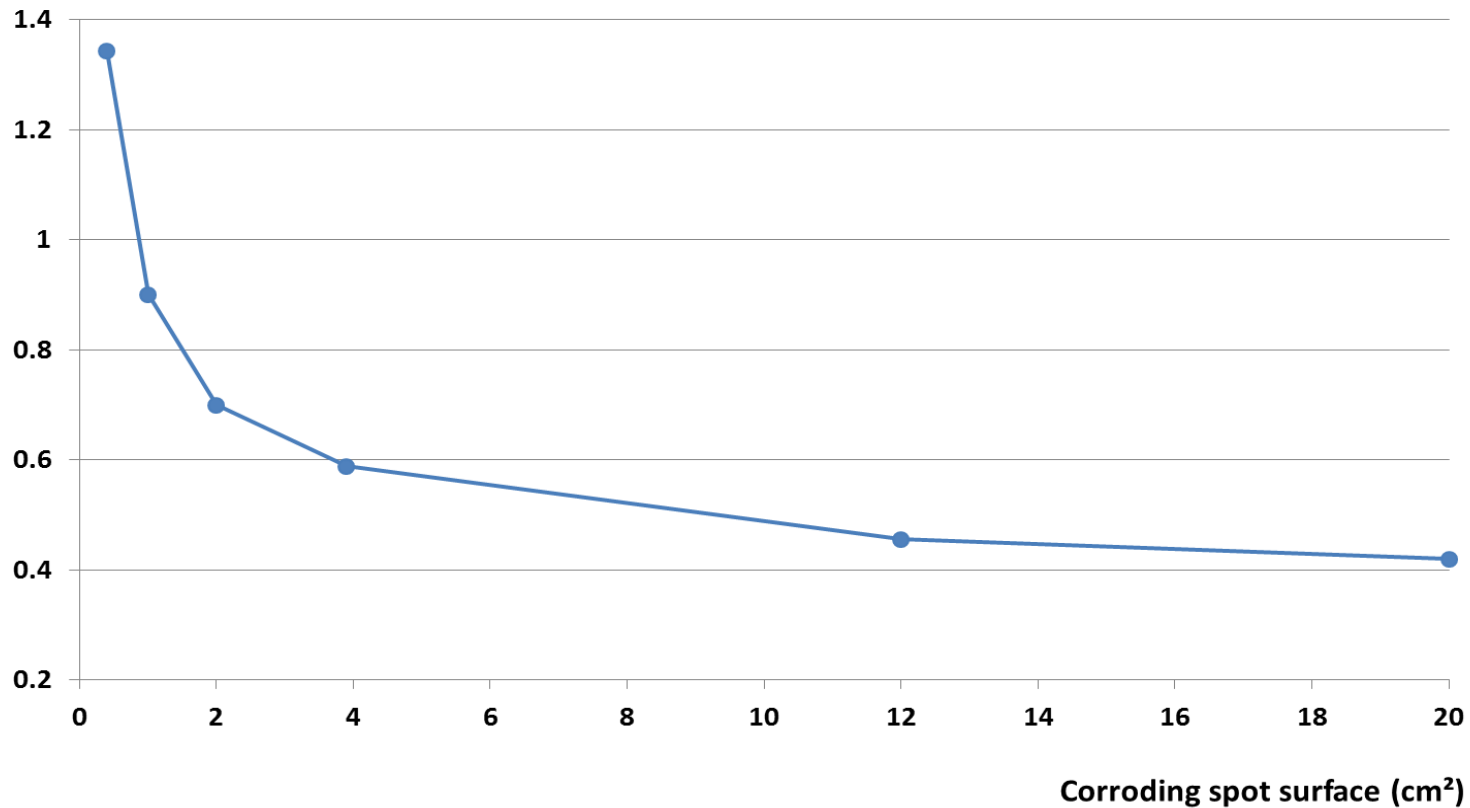


Corrosion current streamlines

Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

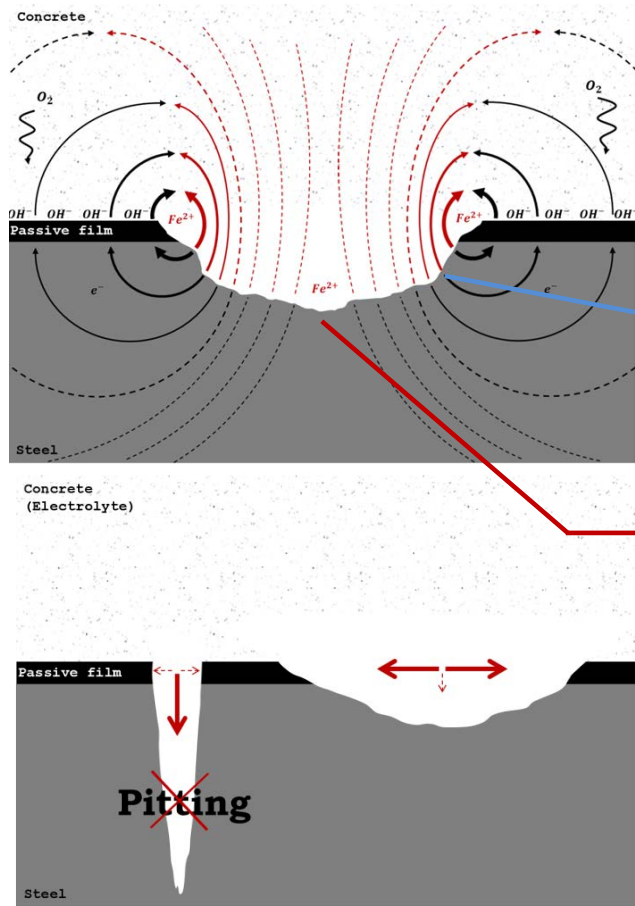
Corrosion rate

Average corrosion
current density
(A/m²)

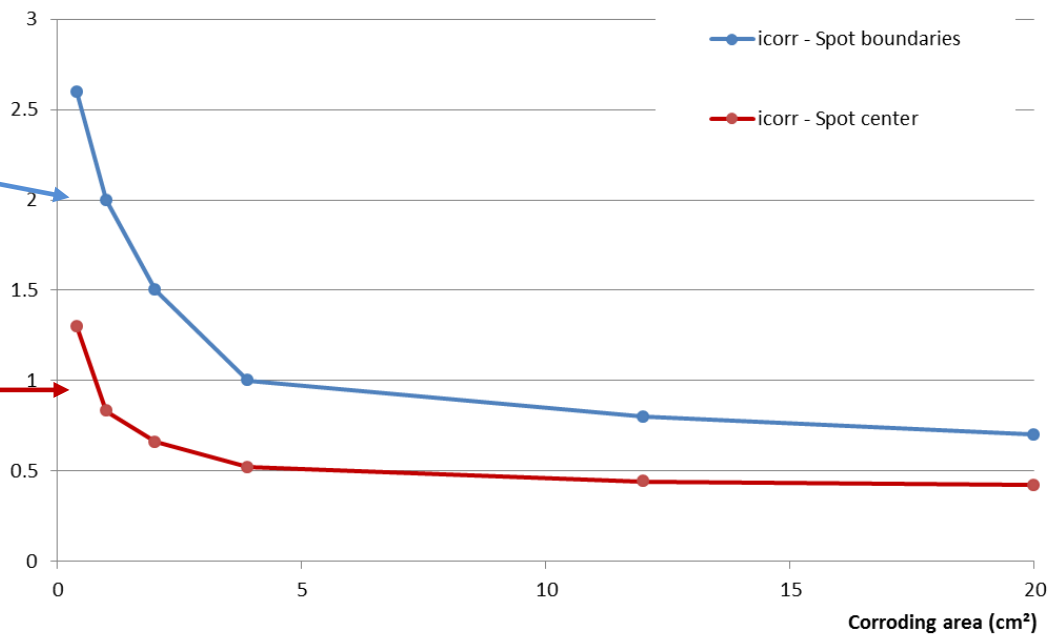


Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

Corrosion rate



Corrosion current density (A/m^2)

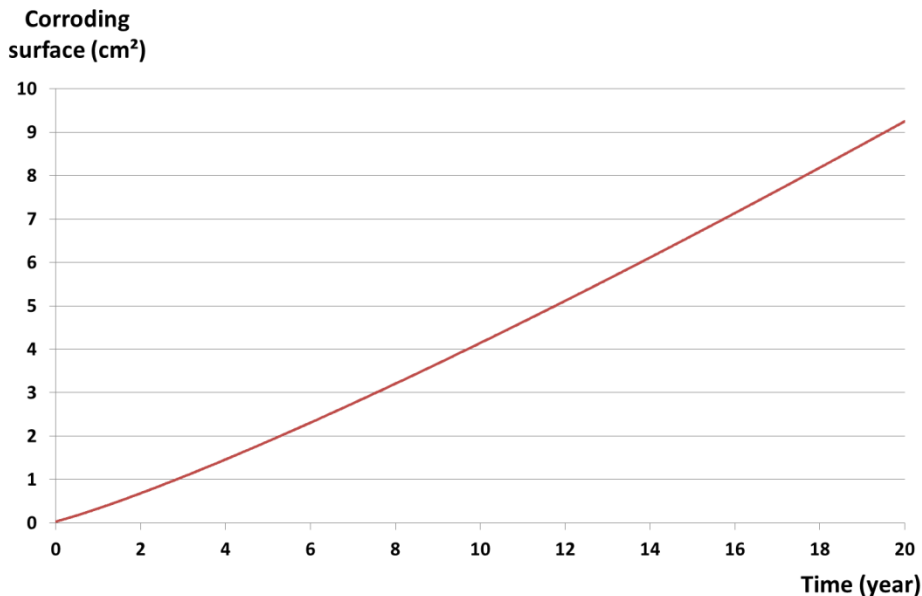


Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

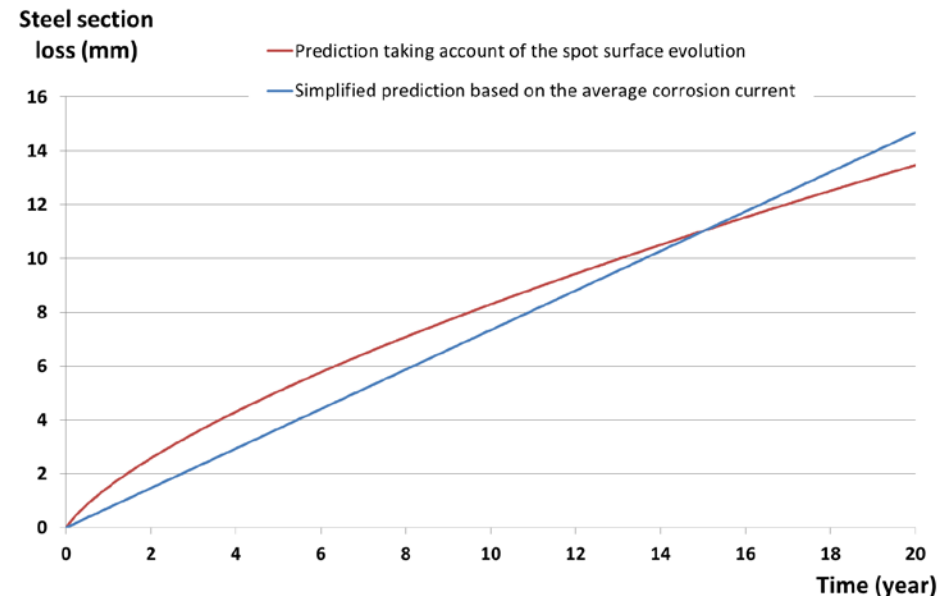
Corrosion rate

Assessment of corrosion propagation

Surface expansion of the initiated corrosion spot



Rebar section reduction
Depth expansion of the initiated corrosion spot

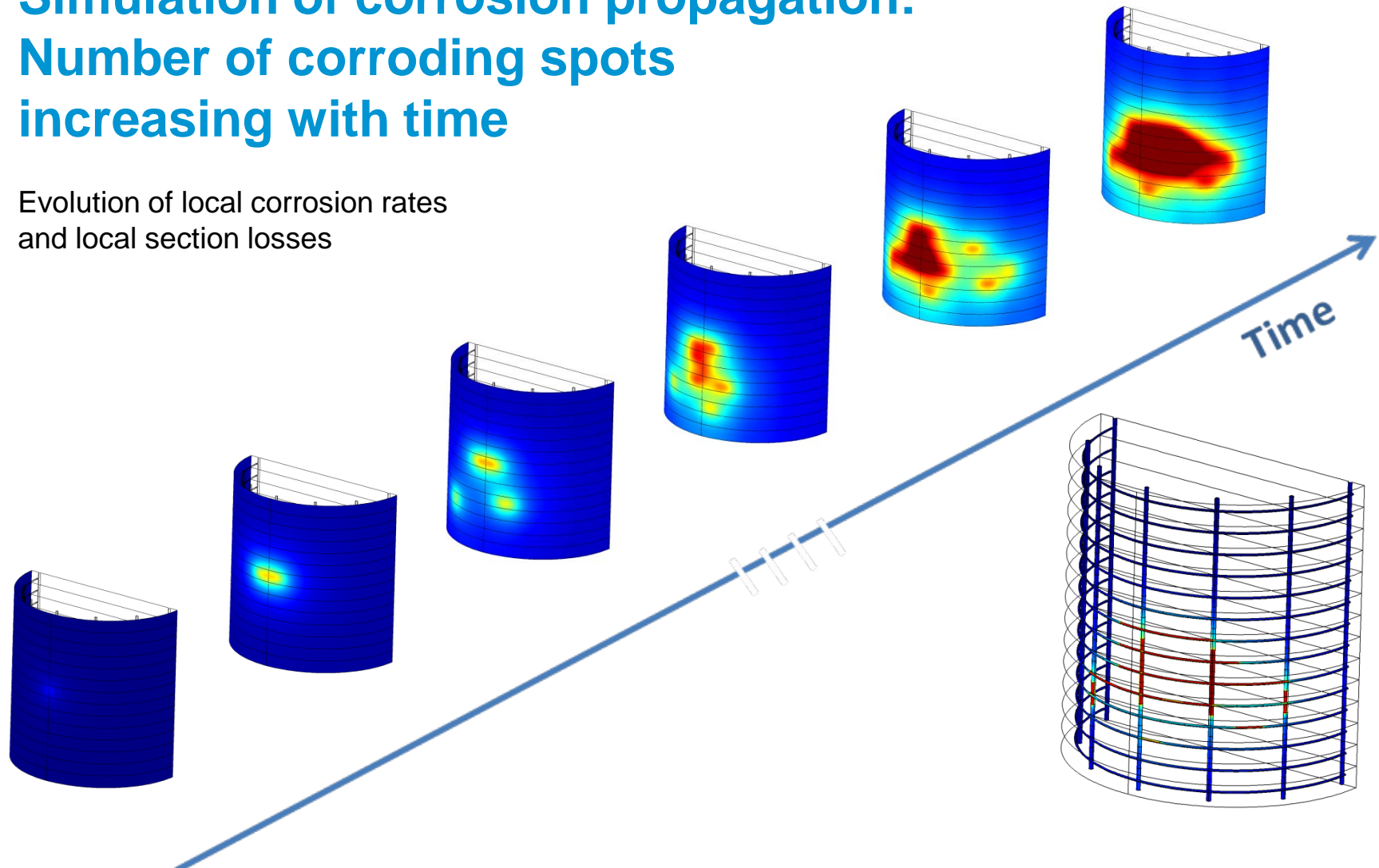


* The evolution is very sensitive to the electrical resistivity of concrete

Corrosion Simulation: Realistic Multi-spot Scenarios

Simulation of corrosion propagation: Number of corroding spots increasing with time

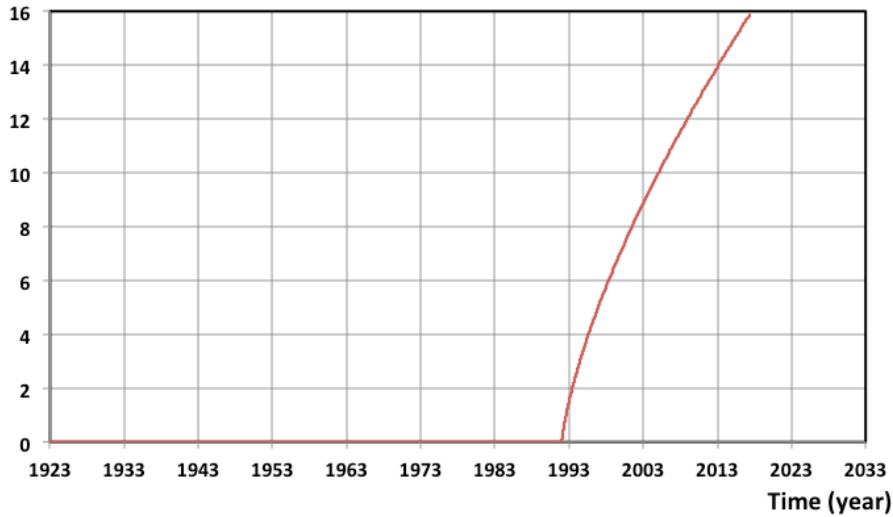
Evolution of local corrosion rates
and local section losses



Rebar Section Loss Simulations

Steel section
loss (mm)

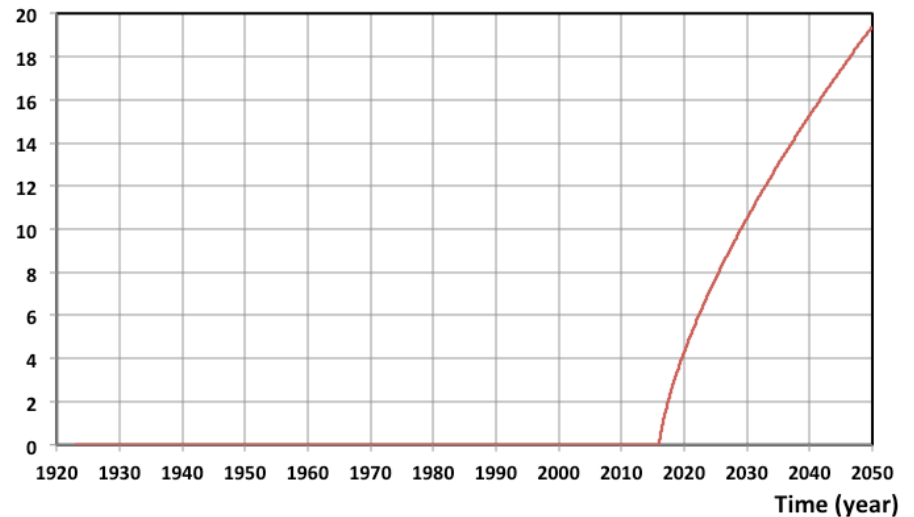
— Prediction taking account of the spot surface evolution



Stirrup

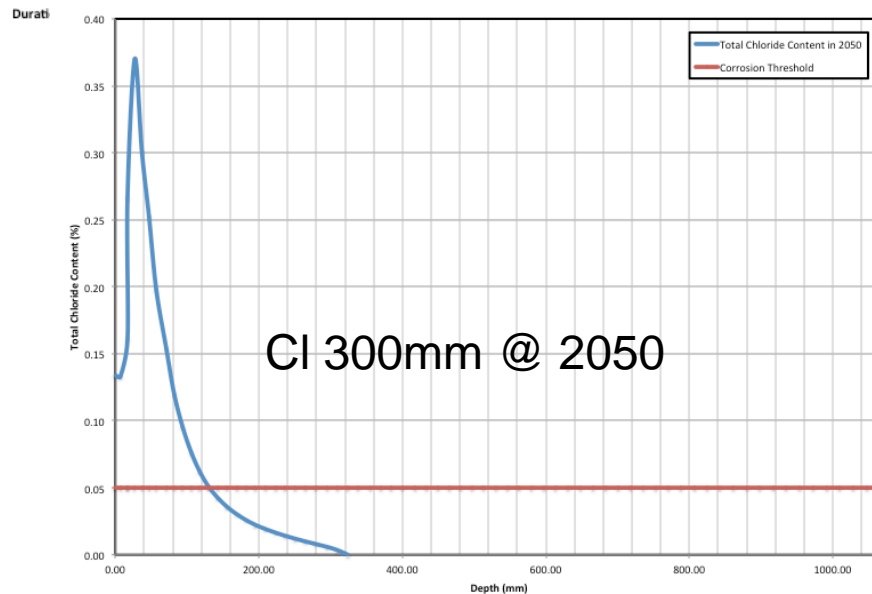
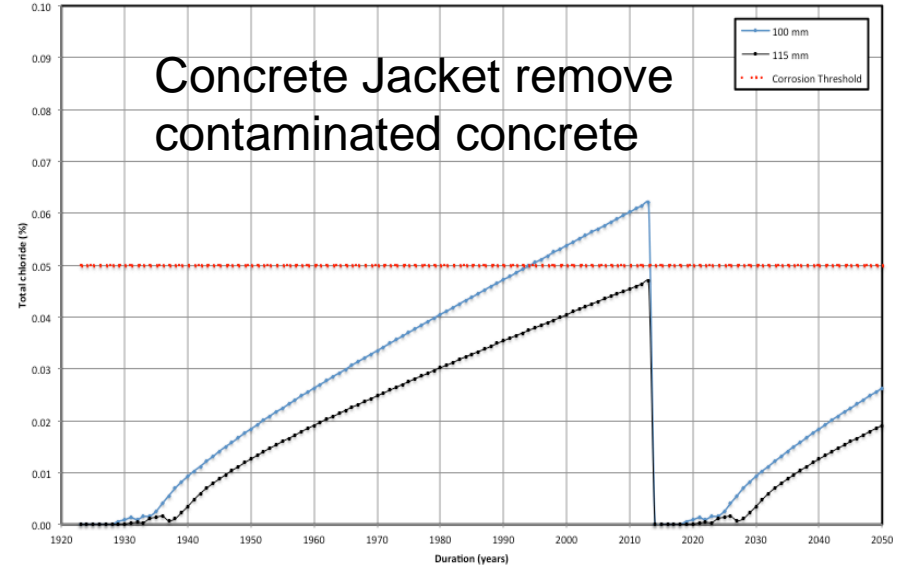
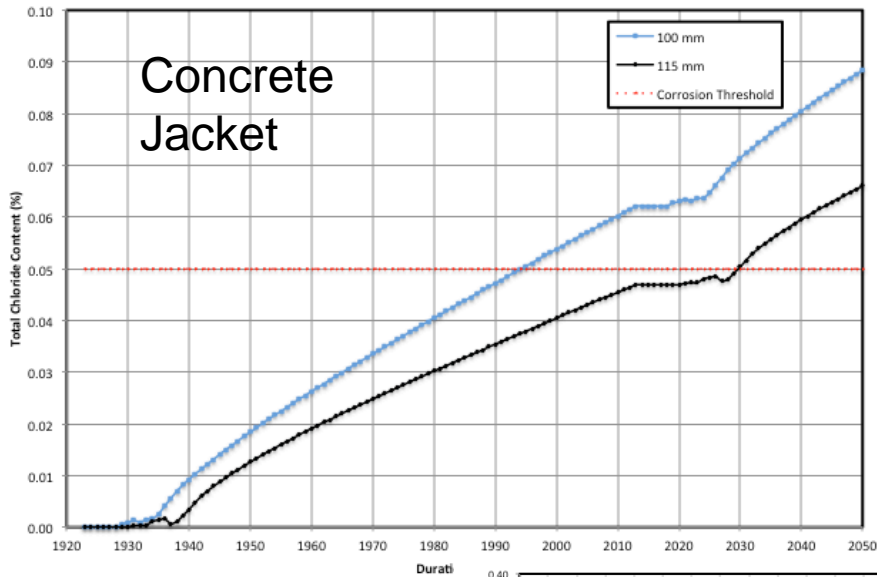
Steel section
loss (mm)

— Prediction taking account of the spot surface evolution



Vertical Rebar

Repair Alternative Simulations



Anchor Bolts

The SIMCO logo is displayed in white, bold, uppercase letters within a dark grey rectangular box. The background of the entire slide is a low-angle, blue-tinted photograph of a modern building's concrete structure, featuring large columns and beams that create a strong geometric pattern.

SIMCO

Thank You