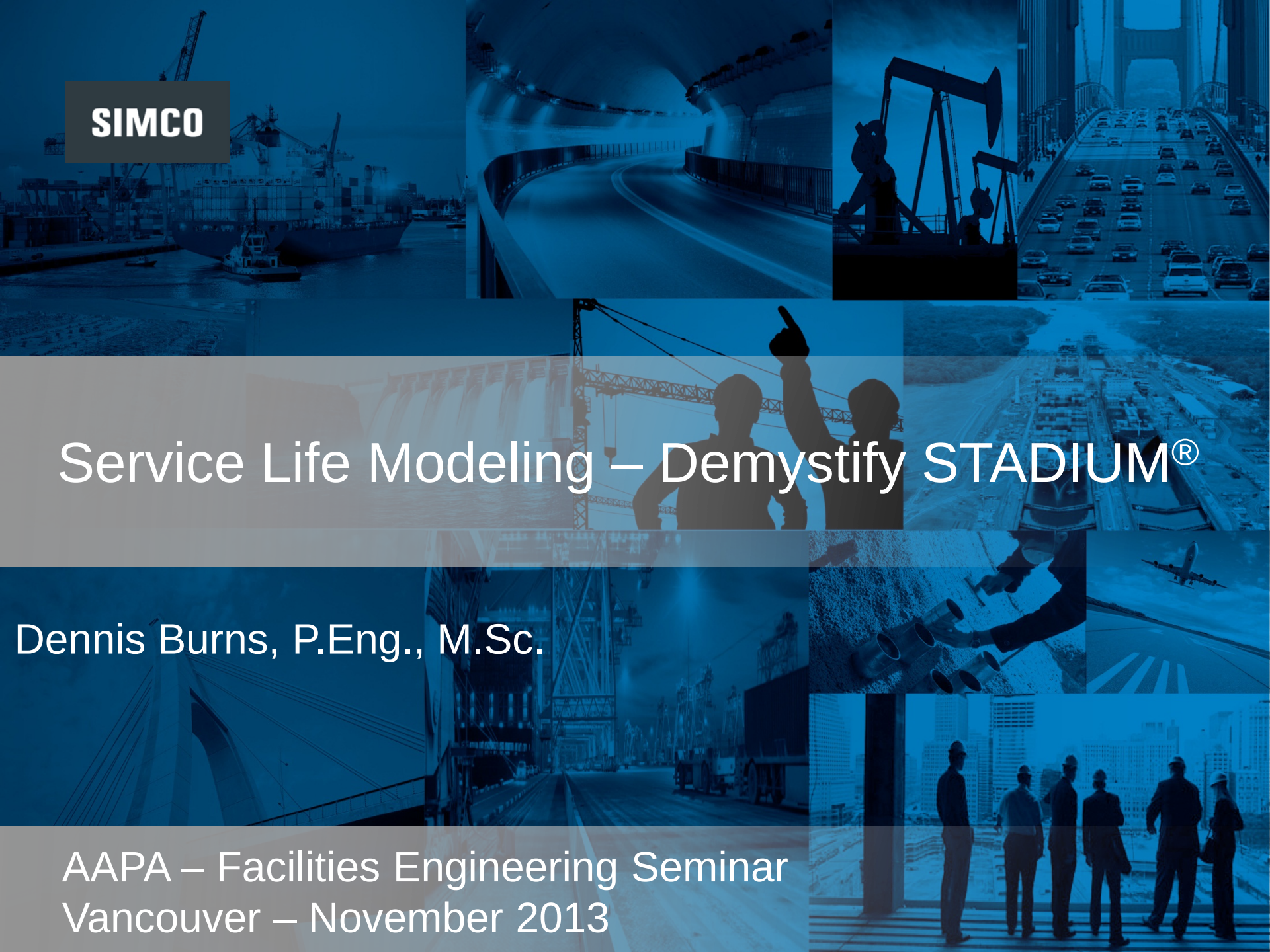


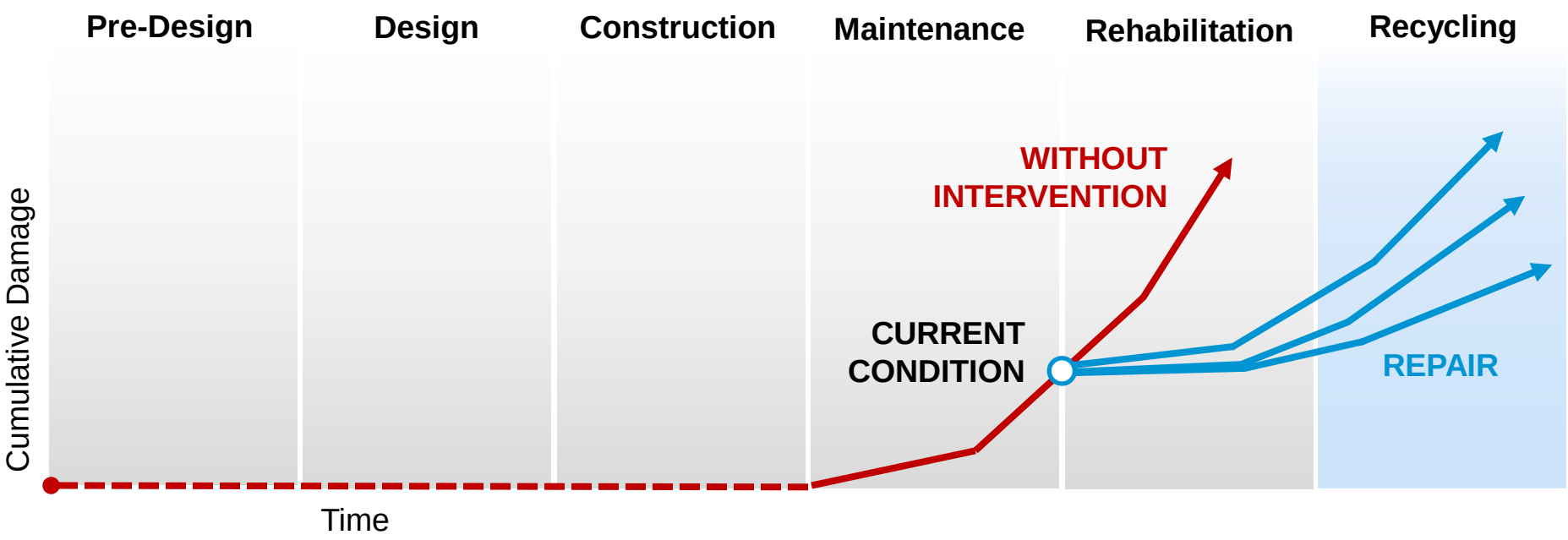
SIMCO

Service Life Modeling – Demystify STADIUM®

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

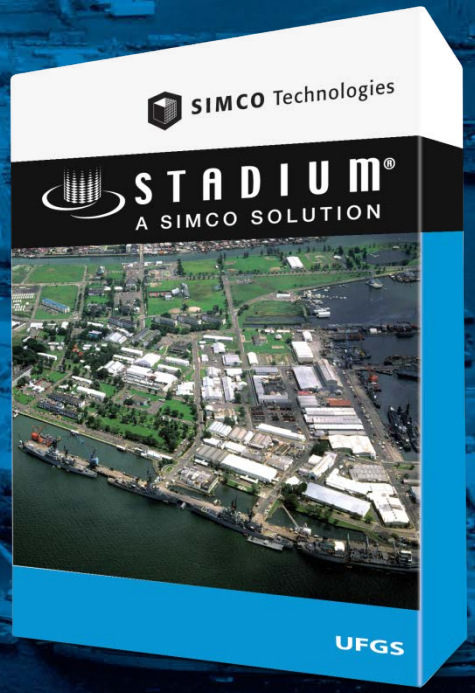
AAPA – Facilities Engineering Seminar
Vancouver – November 2013

A Comprehensive Approach



SPECIFIED BY THE US DEPARTMENT OF DEFENSE

UFGS-03 31 29



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

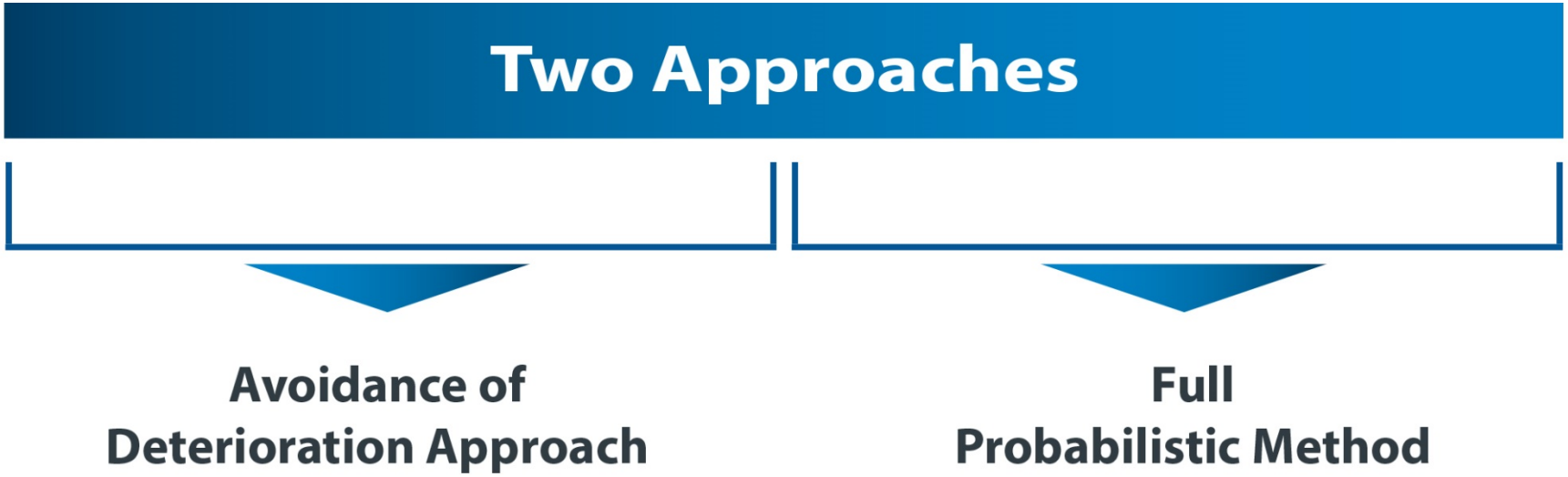
Durability Engineering

Primary Objectives

- **Optimize Performance**
- **Reduce Risks**
- **Control Costs**

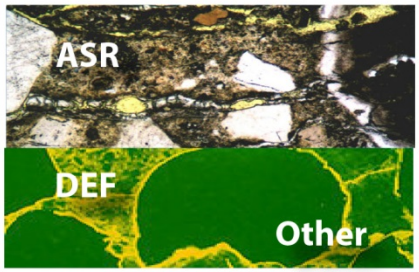
✓ Sound and proven analytical techniques
✓ Reliable testing methods
✓ Comprehensive knowledge of local materials

Service-Life Verification & Documentation



The approach varies with the type of degradation phenomenon considered

Concrete Durability Matrix

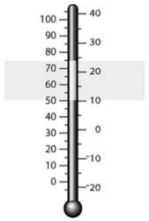
	Type	Example	Verification Method	Solution
A	Internal Deterioration Reactions		Avoidance of Deterioration Method	▪ Proper Materials Selection ▪ Optimum Mix Designs ▪ Selection of Production & Placement Methods
B	Physical Mechanisms		Avoidance of Deterioration Method	▪ Optimum Mix Designs ▪ Selection of Production & Placement Methods
C	External Contamination		Full Probabilistic Method	▪ Proper Materials Selection ▪ Optimum Mix Designs ▪ Selection of Protection Solutions

STADIUM® Calculation Algorithm

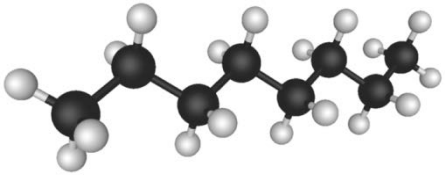
STADIUM®

DAMAGE

Coupled Transport



HEAT



IONS

FLUIDS

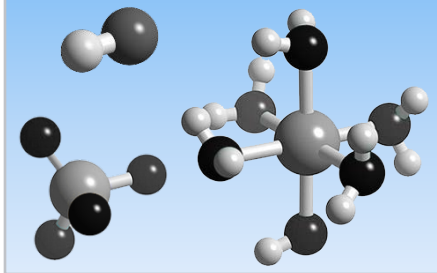
CHEMICAL EQUILIBRIUM

STADIUM® Approach

Coupled Transport

Moisture Transport

Moisture Transport



Cl, SO_4 and Mg ions **penetration**

ETTRINGITE AND GYPSUM FORMATION

BRUCITE FORMATION

FRIEDEL'S SALT FORMATION

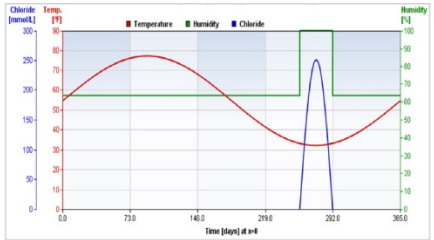
CALCIUM HYDROXIDE DISSOLUTION

C-S-H DECALCIFICATION

Ca and OH **leaching**

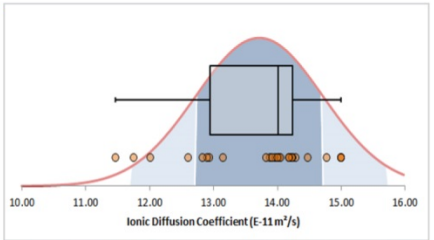
Full Probabilistic Approach

LOADING

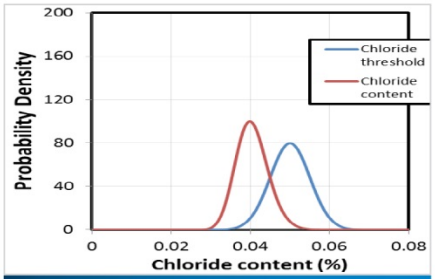


Exposure Conditions

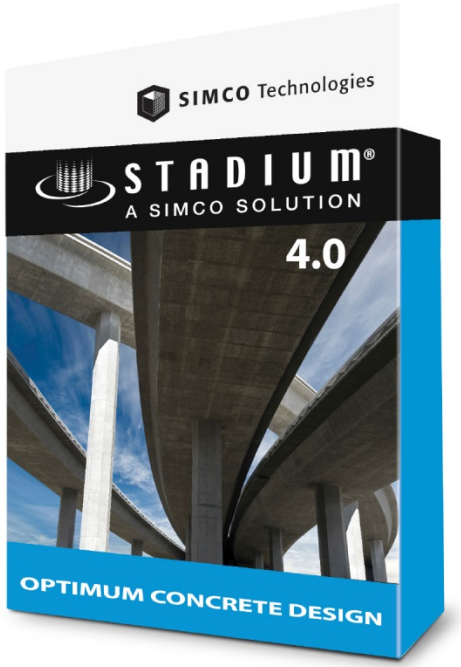
RESISTANCE

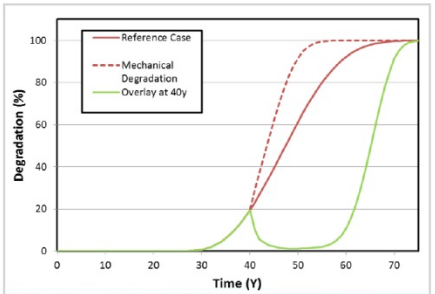


Material Properties



Chloride Threshold & Cover Variation





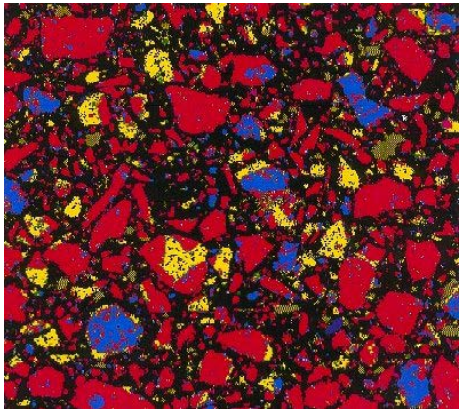
Degradation Curves

LIKELIHOOD	INSIGNIFICANT	MINOR	MODERATE	MAJOR	SEVERE
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

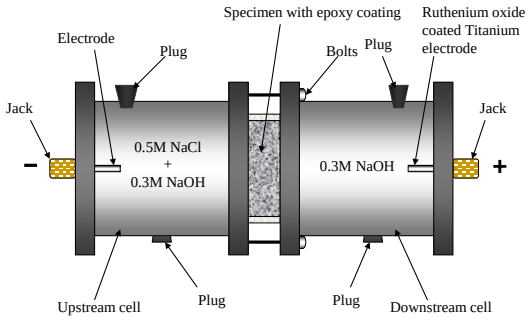
Risk Analyses

Lifecycle Cost Analyses

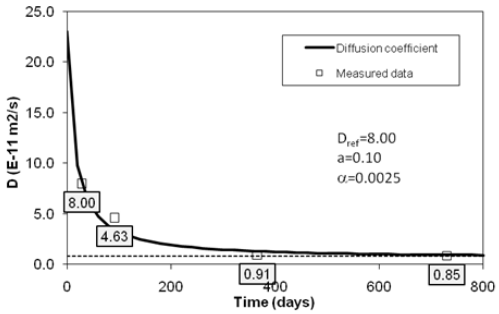
Input Data Determination



Mineralogical Composition

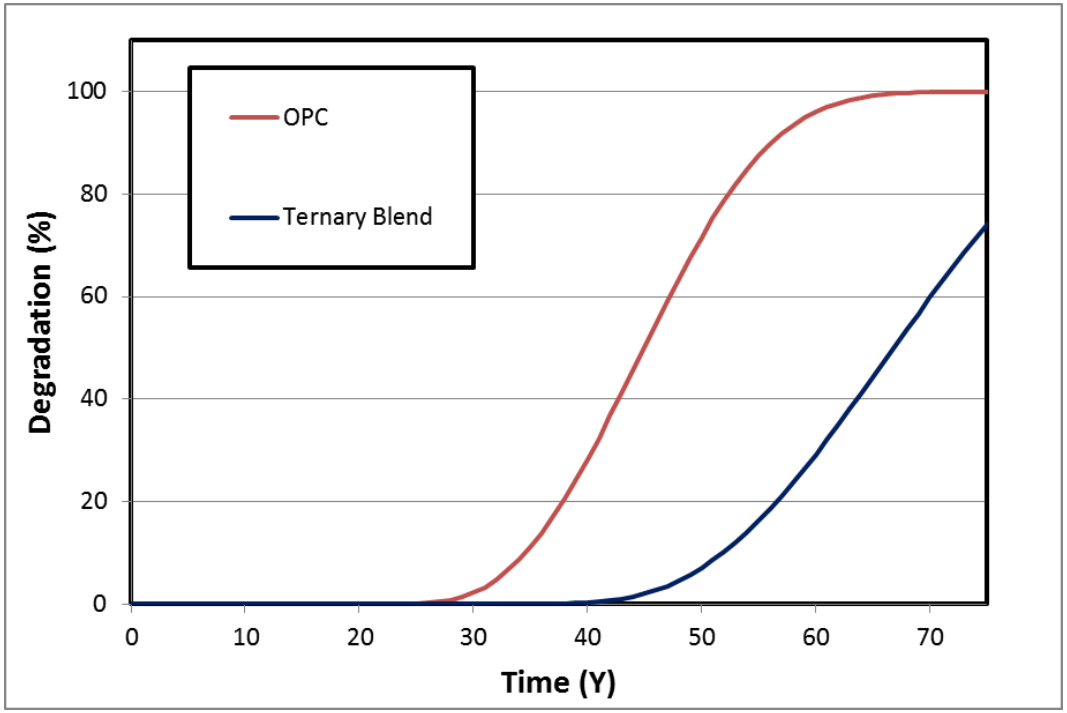


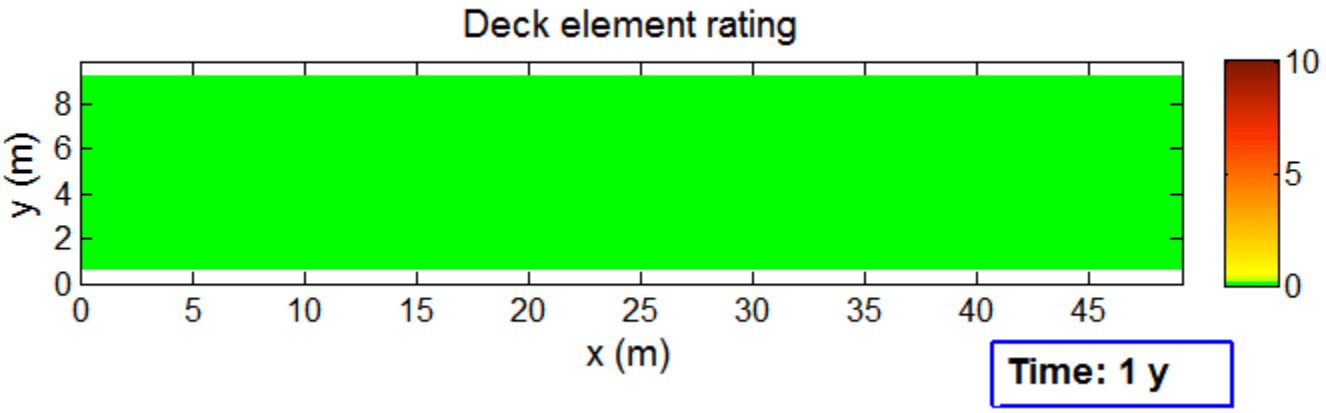
Transport Properties



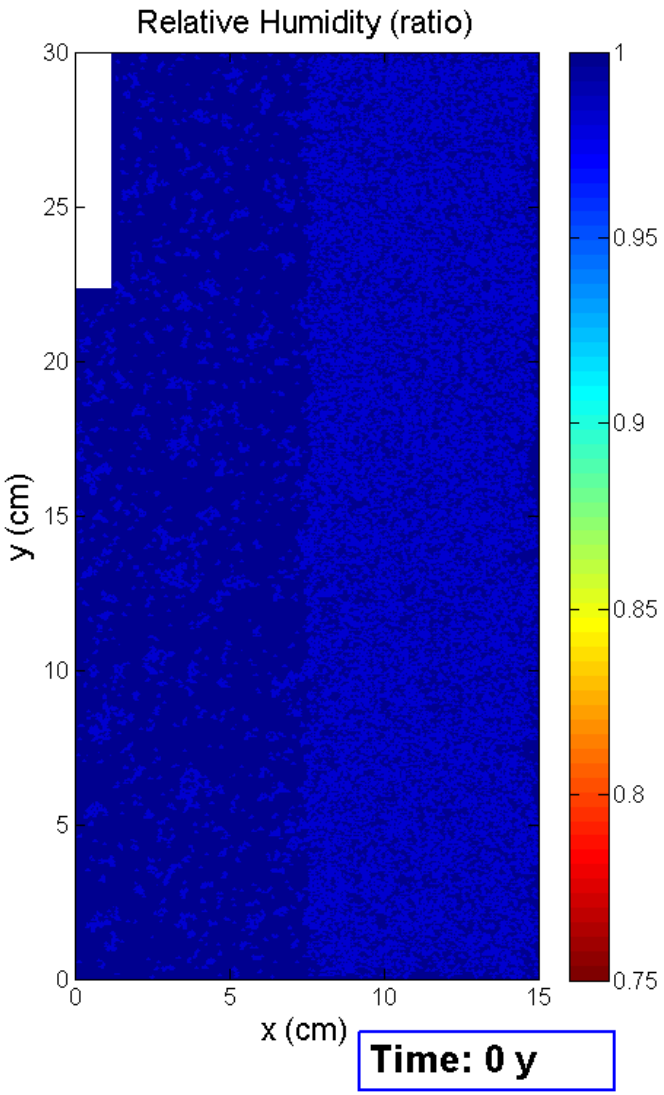
Properties Evolution

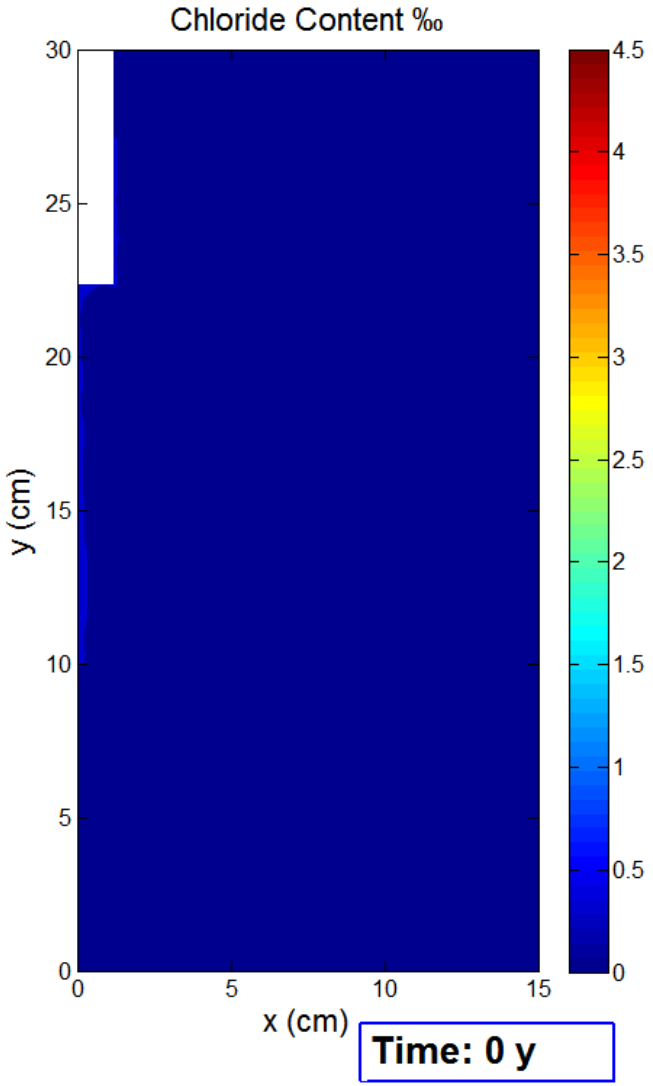
Future Degradation Curve – Minimal Maintenance



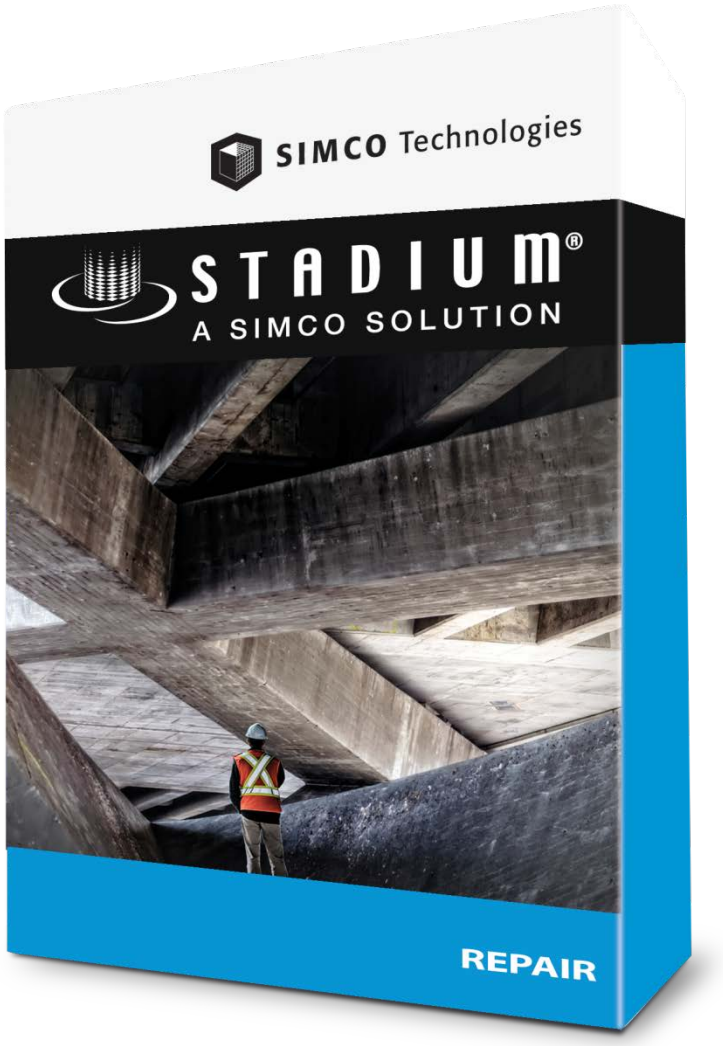


Future Degradation Curve – Critical Areas





Future Degradation Curve – Maintenance Options

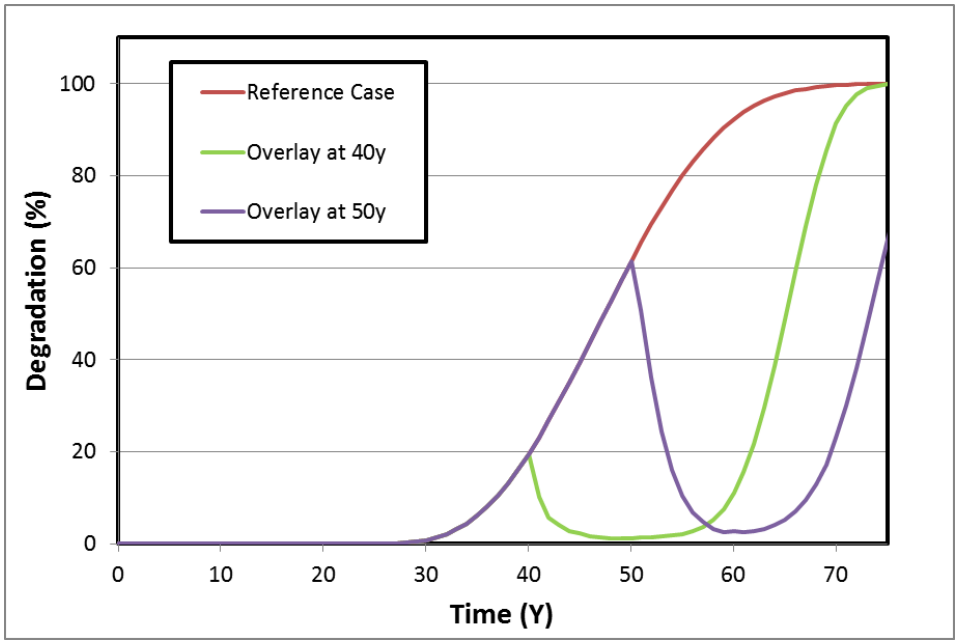


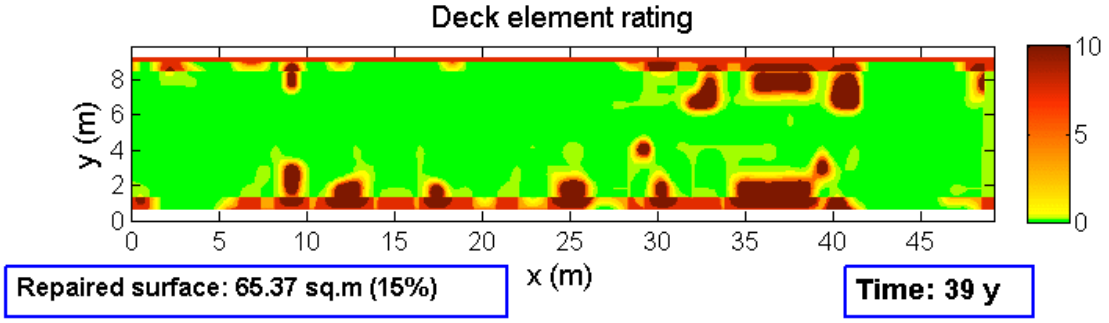
Patch Repair

Concrete Overlay

Cathodic Protection

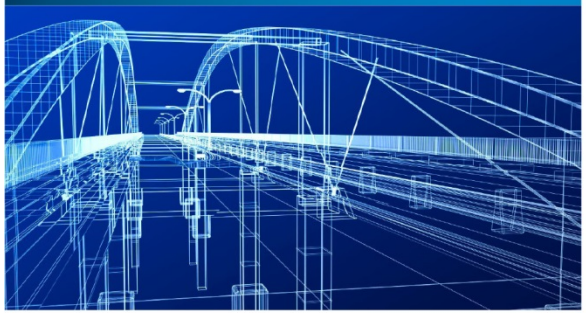
Future Degradation Curve – Optimum Maintenance





Design-Build Project Approach

Pre-Design



- Analysis of Documents
- Clear Definition of Service Life
- Evaluation of Different Design Options using Database

Design

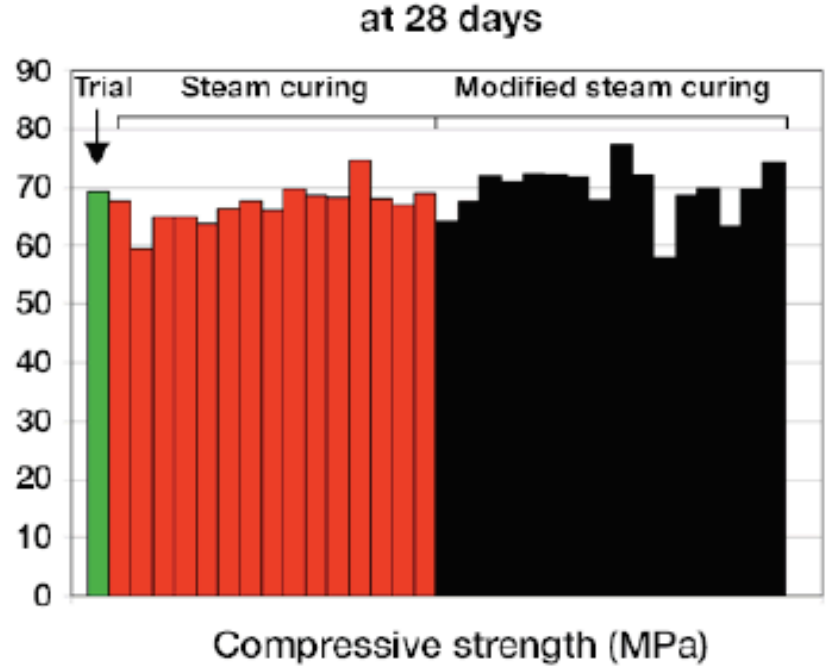
- Materials Selection
- Application of the Durability Matrix to Final Design
- Concrete Submittal
- Optimum Maintenance Plan

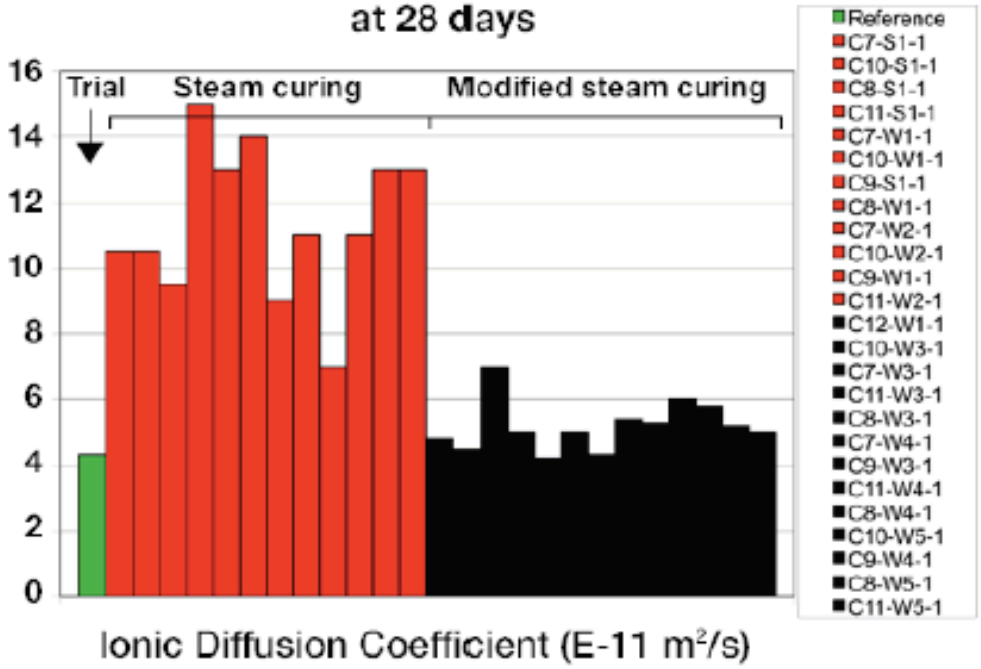
Construction

- QA / QC Protocols
- Proactive Quality Control
- Remediation Strategies for Non-Compliant Results

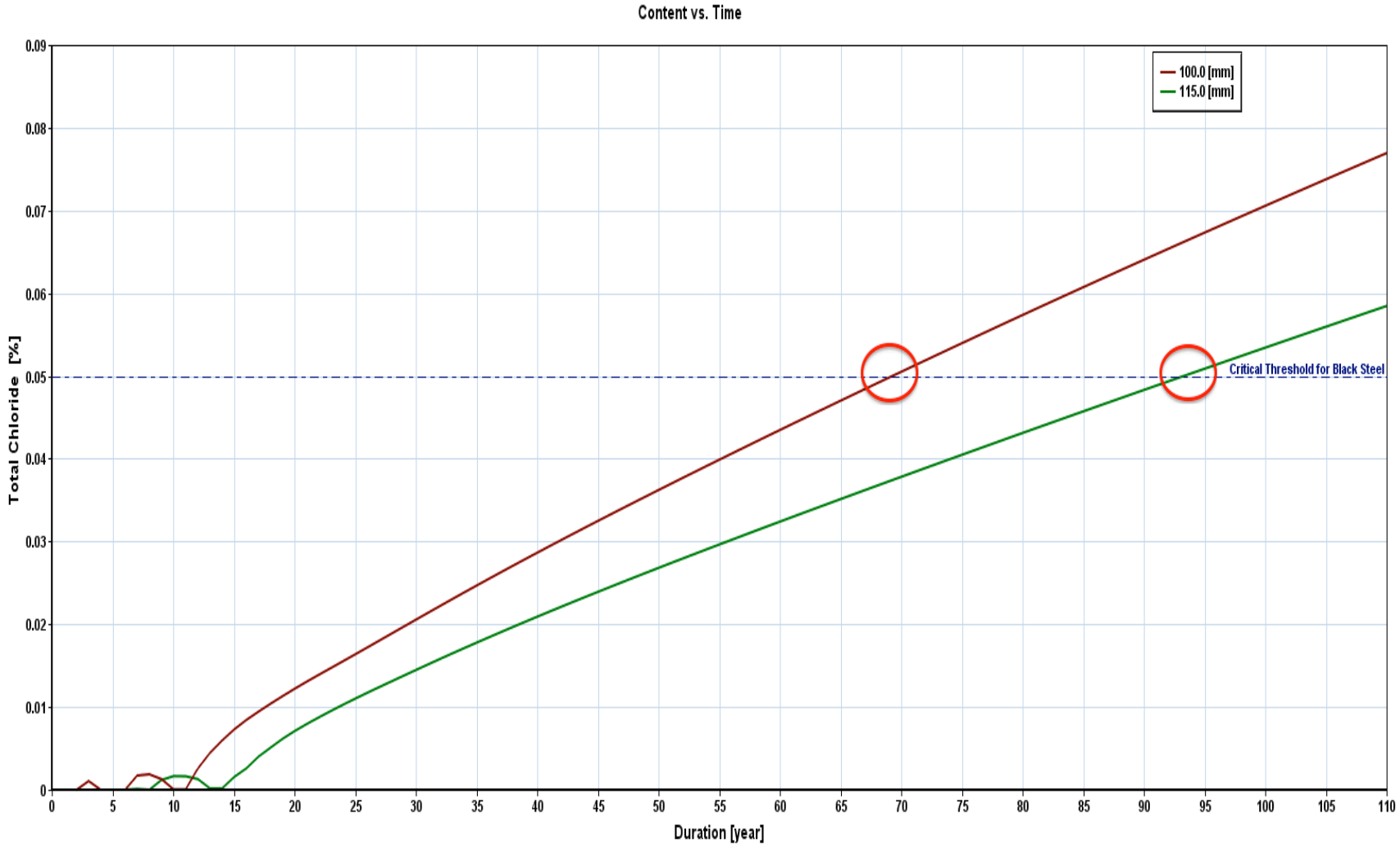
Final Design Stage - Mixture Design Optimization

Construction Stage – Proactive Quality Control

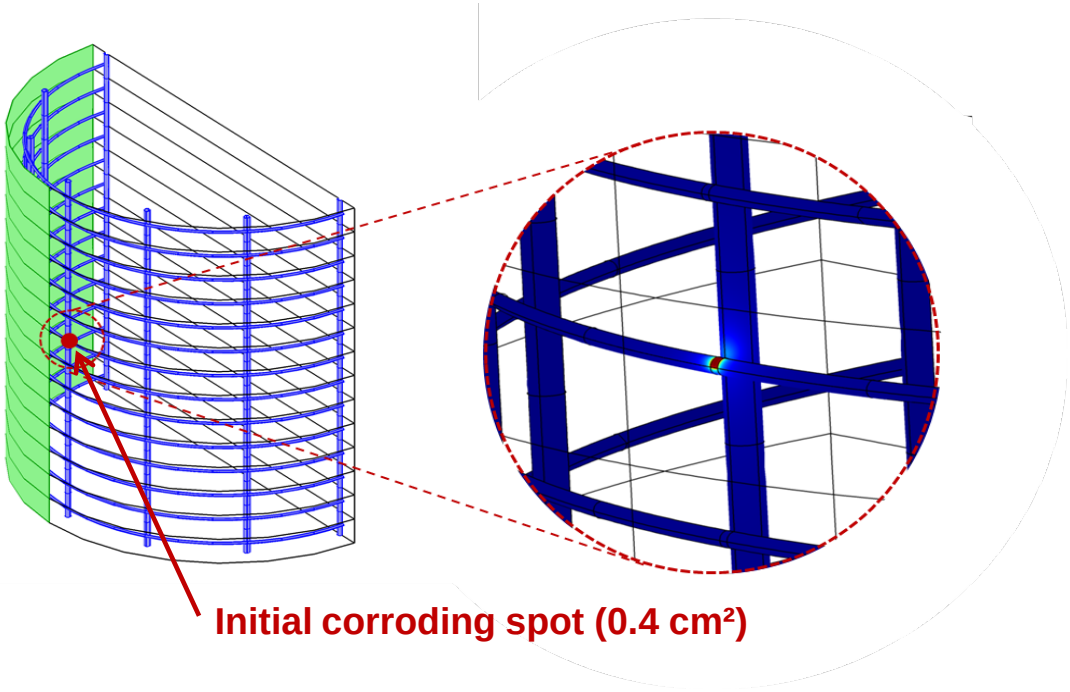




Time to Initiate Corrosion Simulations



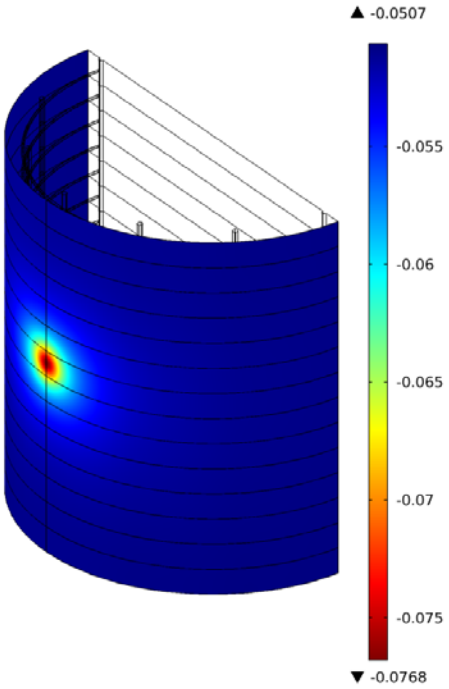
Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface



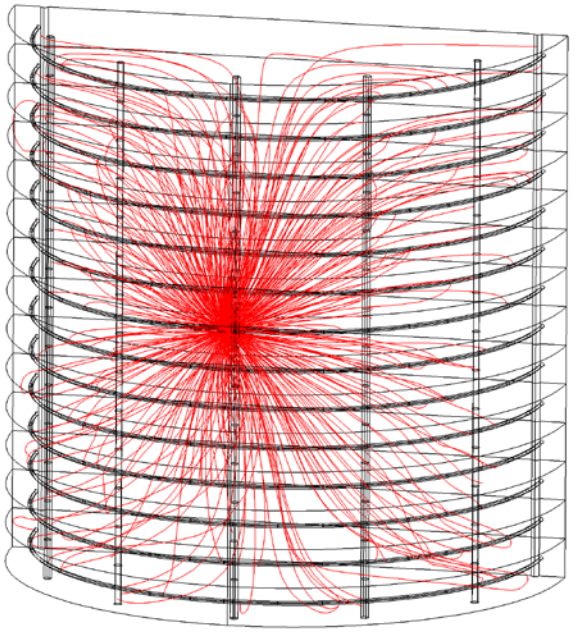
Numerical simulation:
Finite elements software Comsol Multiphysics®

Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

Examples of output data of corrosion simulations



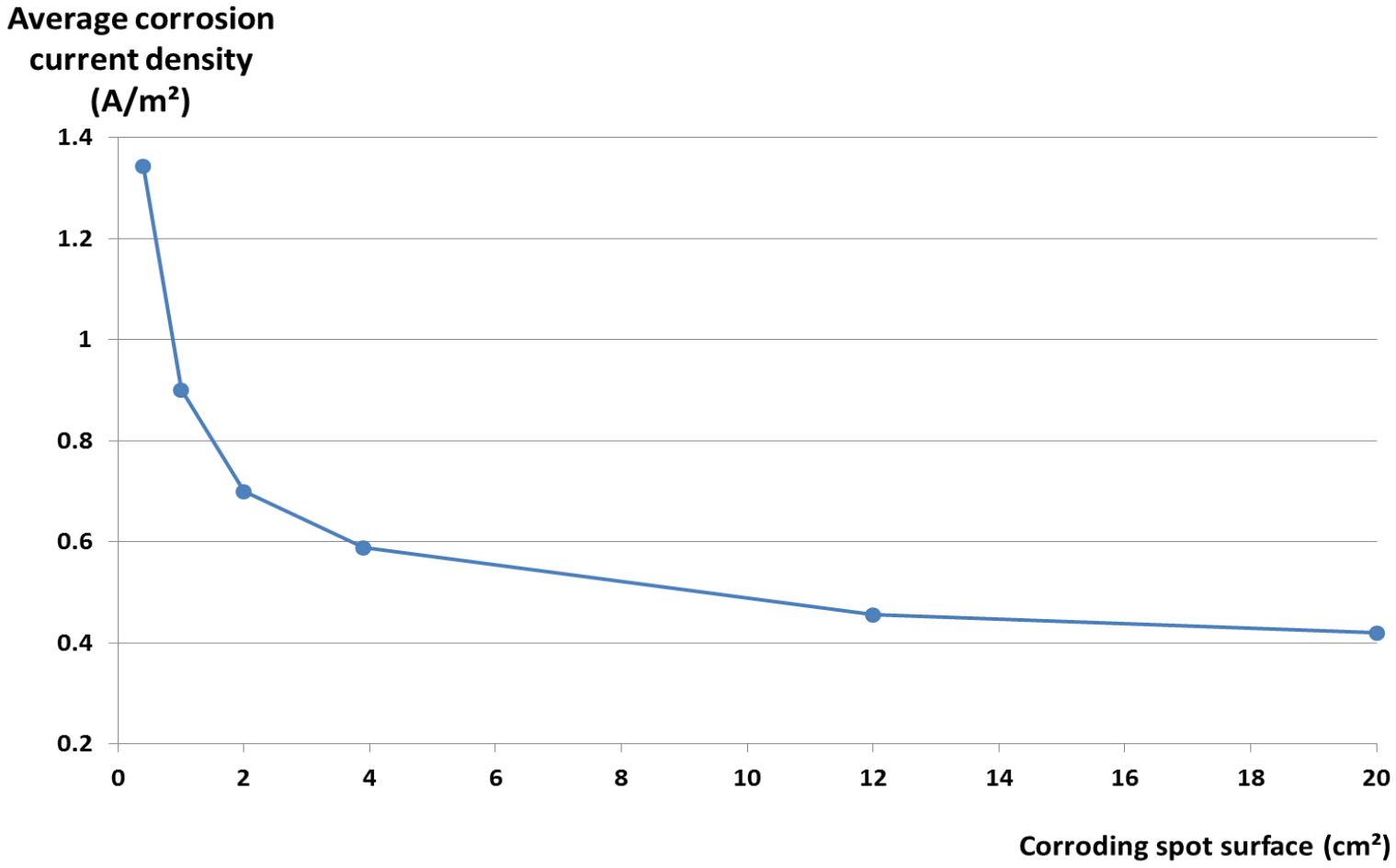
Half-cell potential field / concrete surface (V/SCE)



Corrosion current streamlines

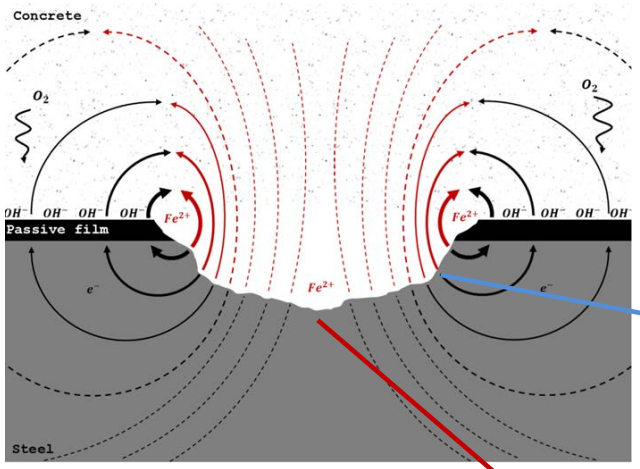
Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

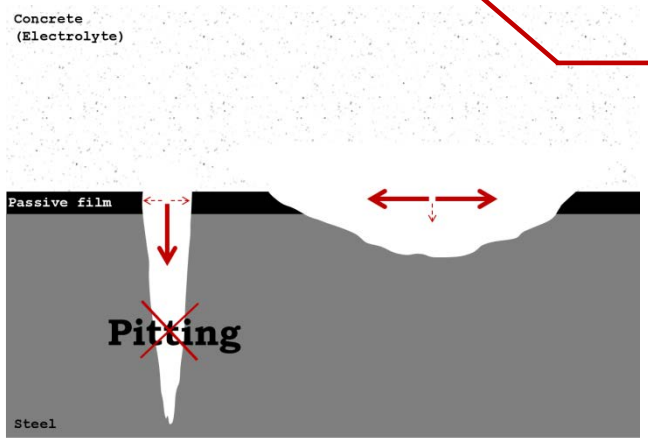
Corrosion rate

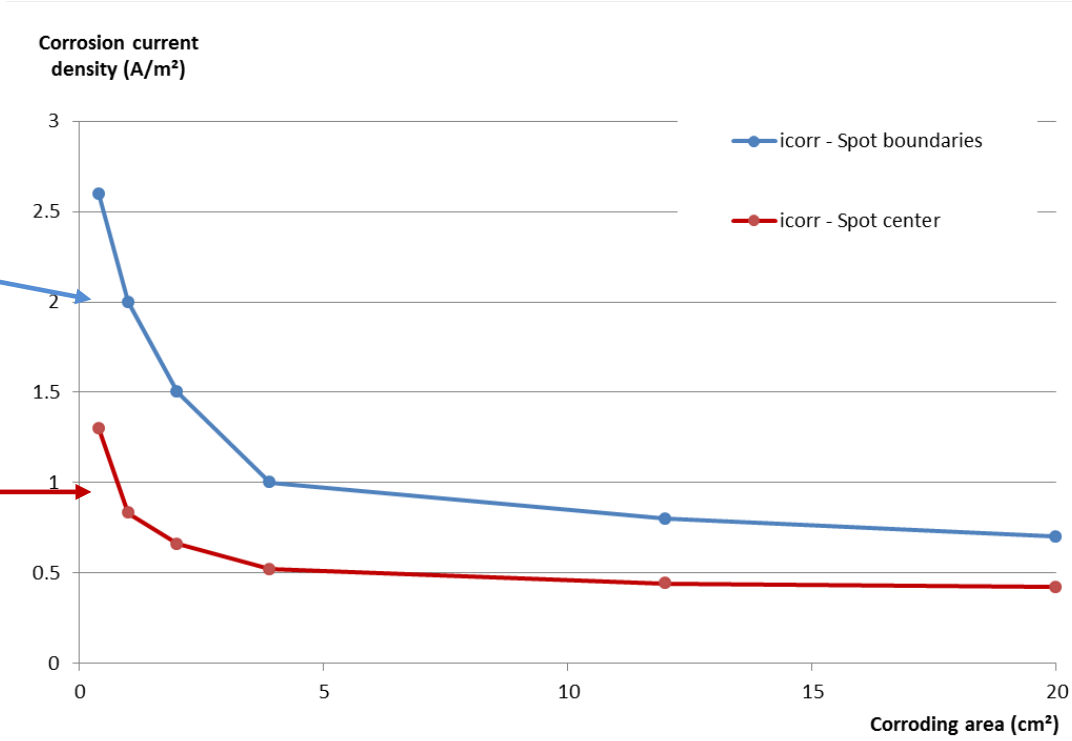


Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

Corrosion rate





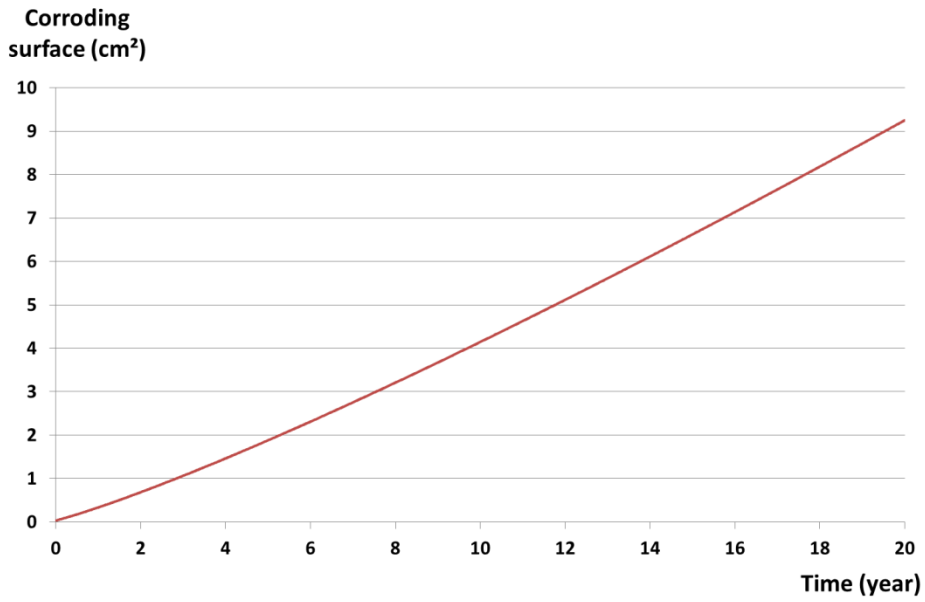


Corrosion Simulation: Single-spot Scenarios with Increasing Anodic Surface

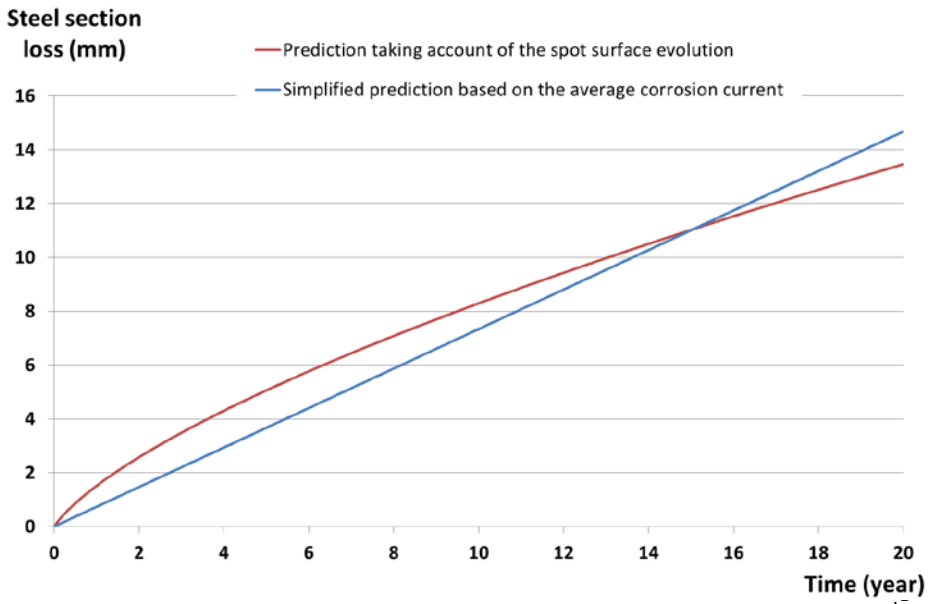
Corrosion rate

Assessment of corrosion propagation

Surface expansion of the initiated corrosion spot



Rebar section reduction
Depth expansion of the initiated corrosion spot

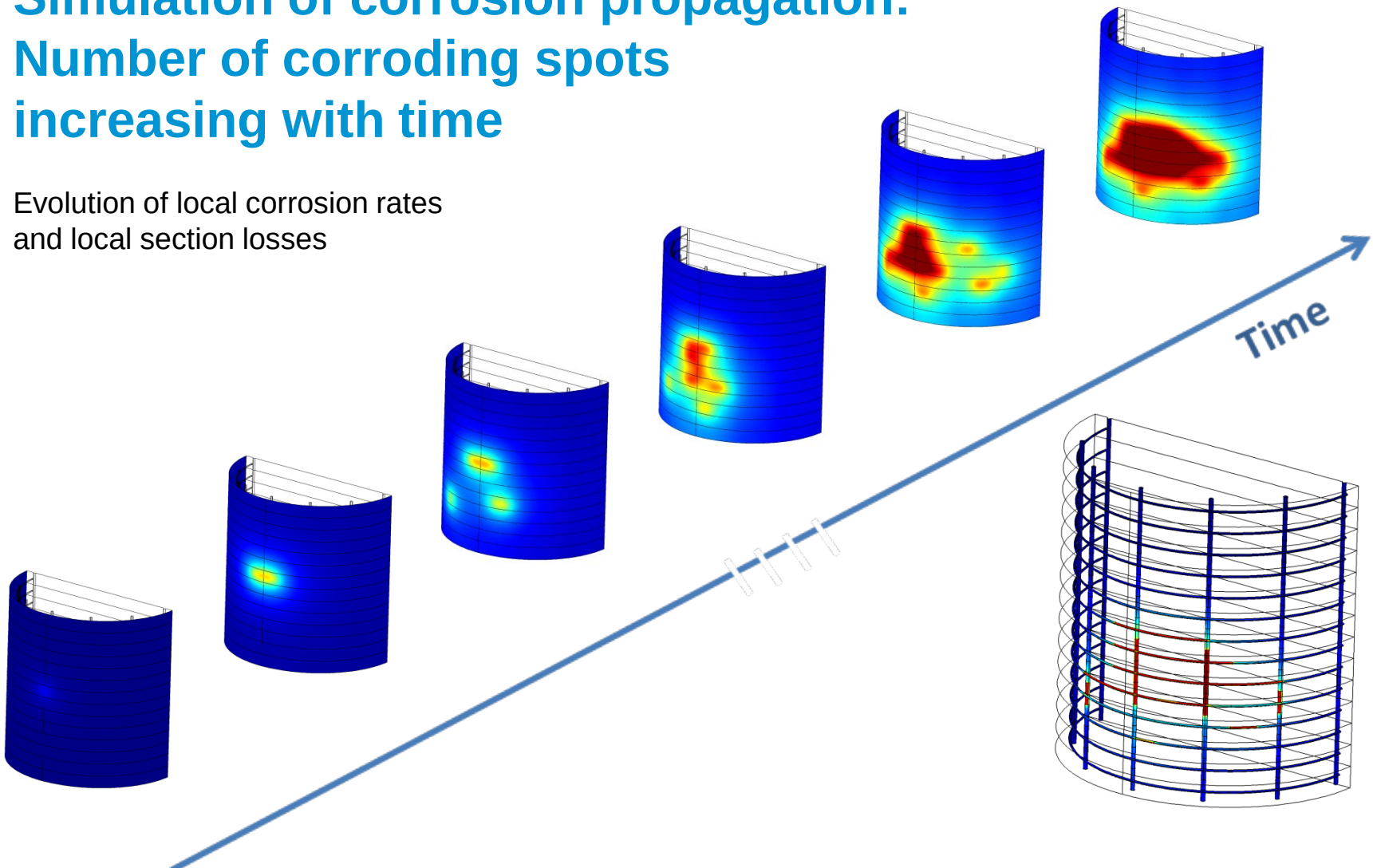


*** The evolution is very sensitive to the electrical resistivity of concrete**

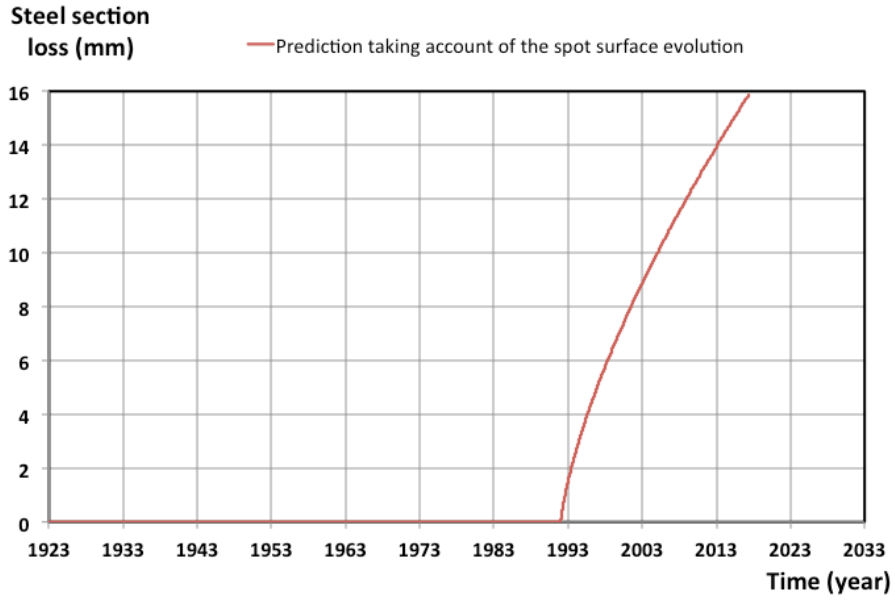
Corrosion Simulation: Realistic Multi-spot Scenarios

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

Evolution of local corrosion rates
and local section losses

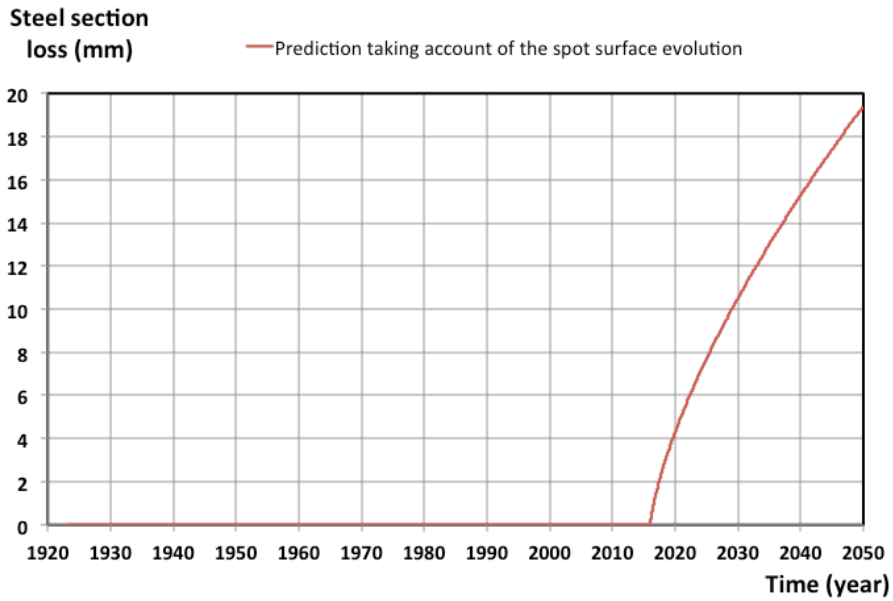


Rebar Section Loss Simulations

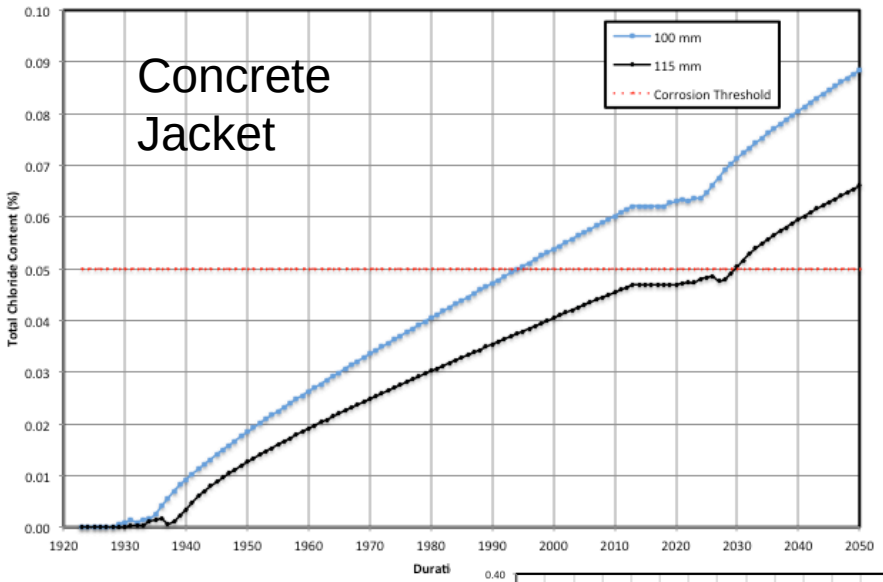


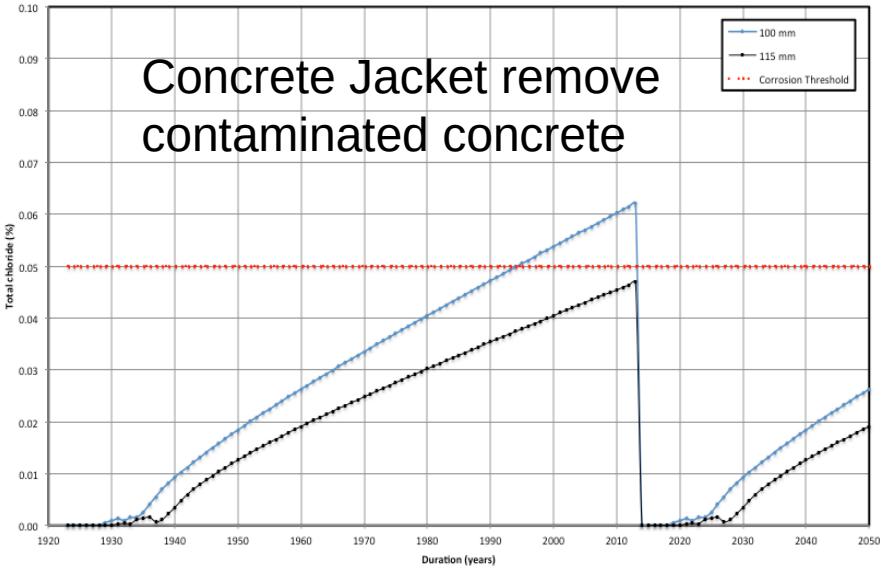
Stirrup

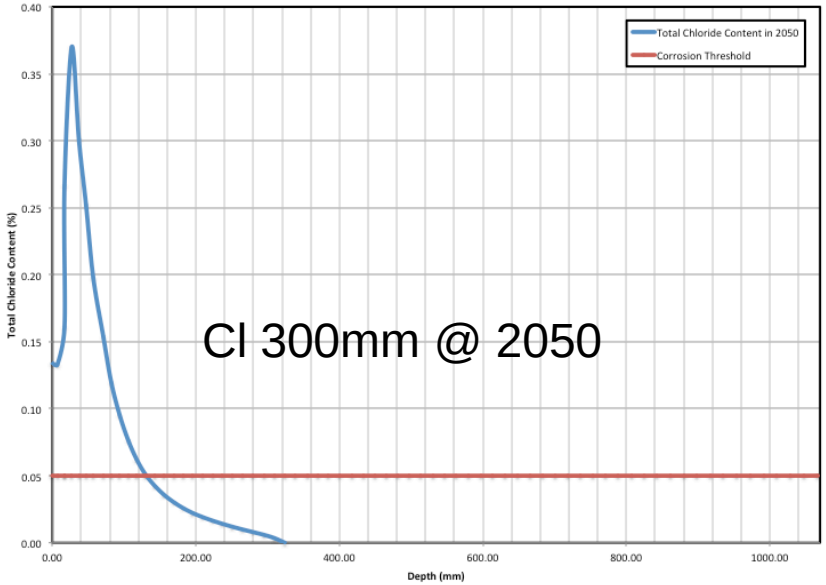
Vertical Rebar



Repair Alternative Simulations







Anchor Bolts

SIMCO

Thank You