SIMCO

An Introduction to STADIUM®

Service Life Prediction Software
for Optimal Management of Concrete Infrastructure

SIMCO

The Challenge

- Most Design/Build and Signature Bridge Projects have design criteria requiring structures to be designed for a 100 year (or longer) service life
- Current U.S. codes & standards provide little guidance to assist engineers in achieving those requirements

Design Life
vs Service Life*

Design Life
Period of time on which the statistical derivation of transient loads is based (75 years)

→ **Safety**

Service Life
Period of time that the bridge is expected to be in operation

→ **Durability**

*** AASHTO LRFD Bridge Design Specifications – Section 1.2 – Definitions**

SIMCO

STADIUM® vs Others

Considered Mechanisms	Others	STADIUM® 2.99	STADIUM® 3.0 (2012)
Multiple transport mechanisms (coupled)		✓	✓
Chemical activity effects		✓	✓
Chemical degradation		✓	✓
Local conditions (humidity and temperature)	Temp. only	✓	✓
Local materials		✓	✓
Unsaturated/Saturated conditions		✓	✓
Existing structures		✓	✓
New structures	✓	✓	✓
Chloride induced corrosion	✓	✓	✓
Sulfate attacks		✓	✓
Membrane/Sealers	Simplified	Advanced Mode	✓
Repair options			✓
Life-cycle cost analysis	✓		✓

SIMCO

STADIUM®

KNOW YOUR CONCRETE™

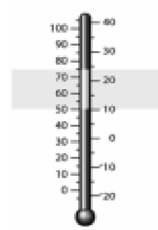
A multiphase transport and reaction model that can predict the degradation of cement-based materials exposed to a wide range of aggressive environments

SIMCO

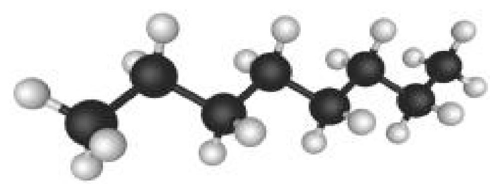
STADIUM® Approach

COUPLED TRANSPORT

STADIUM® →



HEAT



IONS

MOISTURE

↓

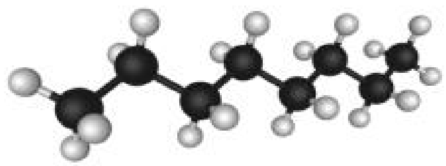
CHEMICAL EQUILIBRIUM

←

CHEMICAL DAMAGE

STADIUM® Approach

Advanced Modeling



IONS

ION TRANSPORT IN UNSATURATED MEDIA

$$j_i = -wD_i \mathrm{grad}(c_i) - \frac{D_i z_i F}{RT} w c_i \mathrm{grad}(\psi)$$

$$-wD_i c_i \mathrm{grad}(\ln \gamma_i) - \frac{D_i c_i \ln(\gamma_i c_i)}{T} w \mathrm{grad}(T)$$

$$-c_i D_w \mathrm{grad}(w)$$

MOISTURE

MOISTURE TRANSPORT

$$\frac{\partial w}{\partial H}\frac{\partial H}{\partial t} + \frac{\partial w}{\partial T}\frac{\partial T}{\partial t} -$$

$$\mathrm{div}(D_{mH}\mathrm{grad}(H) + D_{mT}\mathrm{grad}(T)) = 0$$

CHEMISTRY

CHEMICAL EQUILIBRIUM MODULE

$$K_m = \prod_{i=1}^{N} c_i^{\nu_{mi}} \gamma_i^{\nu_{mi}}$$

DISSOLUTION/PRECIPITATION

$$K_{ss} = \frac{(\mathrm{Cl})^2}{(C_{ss})^{2/|z|}} \frac{\chi_{ss}}{\chi_{\mathrm{Friedel}}} f_{ss}$$

SOLID SOLUTION

SIMCO

STADIUM® Approach

Coupled Transport

STADIUM®

Moisture Transport

Moisture Transport

Cl, SO_4 and Mg ions **penetration**

ETTRINGITE AND GYPSUM FORMATION

BRUCITE FORMATION

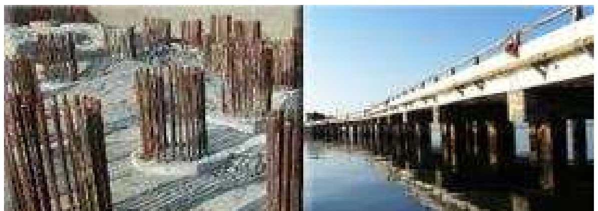
FRIEDEL'S SALT FORMATION

Ca and OH **leaching**

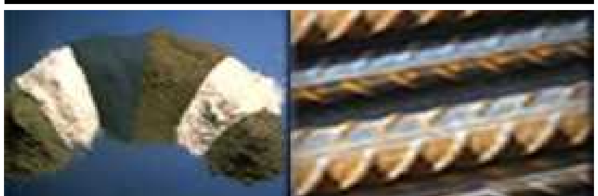
CALCIUM HYDROXIDE DISSOLUTION

C-S-H DECALCIFICATION

An Integrated Solution



LOCAL EXPOSURE CONDITIONS



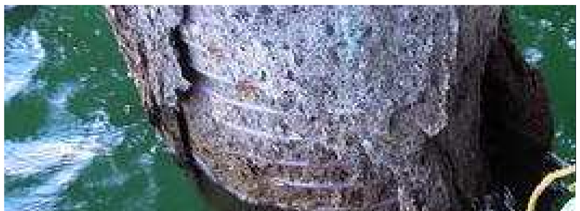
PROPERTIES OF MATERIALS

PROTECTION SOLUTIONS

SIMCO

STADIUM®

REGISTERED PROGRAM



CHEMICAL DEGRADATION

STEEL CORROSION

MOISTURE EMISSION

SIMCO

STADIUM® Approach

Existing Structure

1

Visual Inspection

Concrete Core Extraction

2

Concrete Characterization and Exposure Conditions Determination

3

Residual Service Life Analysis

4

Optimum Inspection and Maintenance Protocol

Identification of the Optimum Repair Scenario

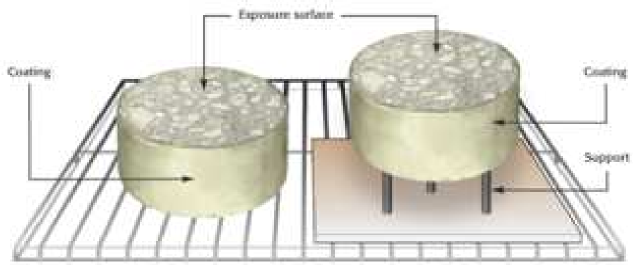
Structure's re-birth certificate

SIMCO

STADIUM® Lab

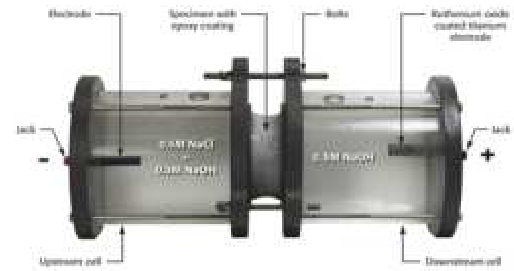
Input – Data Determination (IDC/MTC)

Moisture

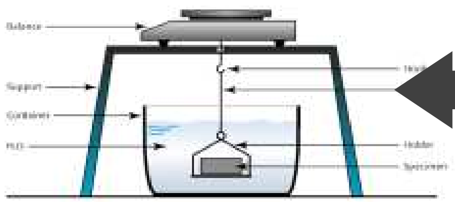


STADIUM® **MTC**

Chemical

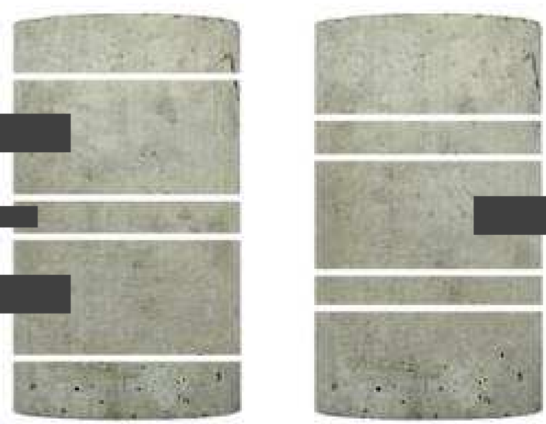


STADIUM® **IDC**



ASTM C642

Drying



Migration test

SIMCO

Case Studies

STADIUM® Approach

Parkway Bridges

NEW JERSEY TURNPIKE AUTHORITY, NJ

Parkway Bridges - NJTA

Southbound Structure:
- Year of construction: 1956
- Precast and cast-in-place concrete elements

Northbound Structure :
- Year of construction: 1973
- All elements under investigation were precast

Visual Inspection

Box Beams

Prestressed Piles

I-Beams

Pile Caps

Element Inventory

Element Rating

Exposure Condition Assessment

Northbound		Southbound	
Box beams	**Prestressed piles**	**I-beams**	**Pile caps**
Deicing salts	Airborne	Deicing salts (web)	Deicing salts
Airborne	Splash zone	Deicing salts (bottom portion)	Airborne
		Airborne	

Coring Program

Total number of cores: 56

31 cores from the northbound structure:
- 15 in the box beams
- 16 in the prestressed piles

25 cores from the southbound structure:
- 12 in the I-beams
- 13 in the pile caps

SIMCO

Characterization Test Results

Concrete Properties

	Box beams	I-beams	Pile caps	Prestressed piles
Volume of Permeable Voids (%)	14.2	12.3	12.0	12.7
Diffusion coefficient (E^{-11} m^2/s)	23.0	18.5	19.0	13.0
Water-binder ratio	0.40	0.40	0.40	0.40
Paste vol. (%)	28	32	28	29

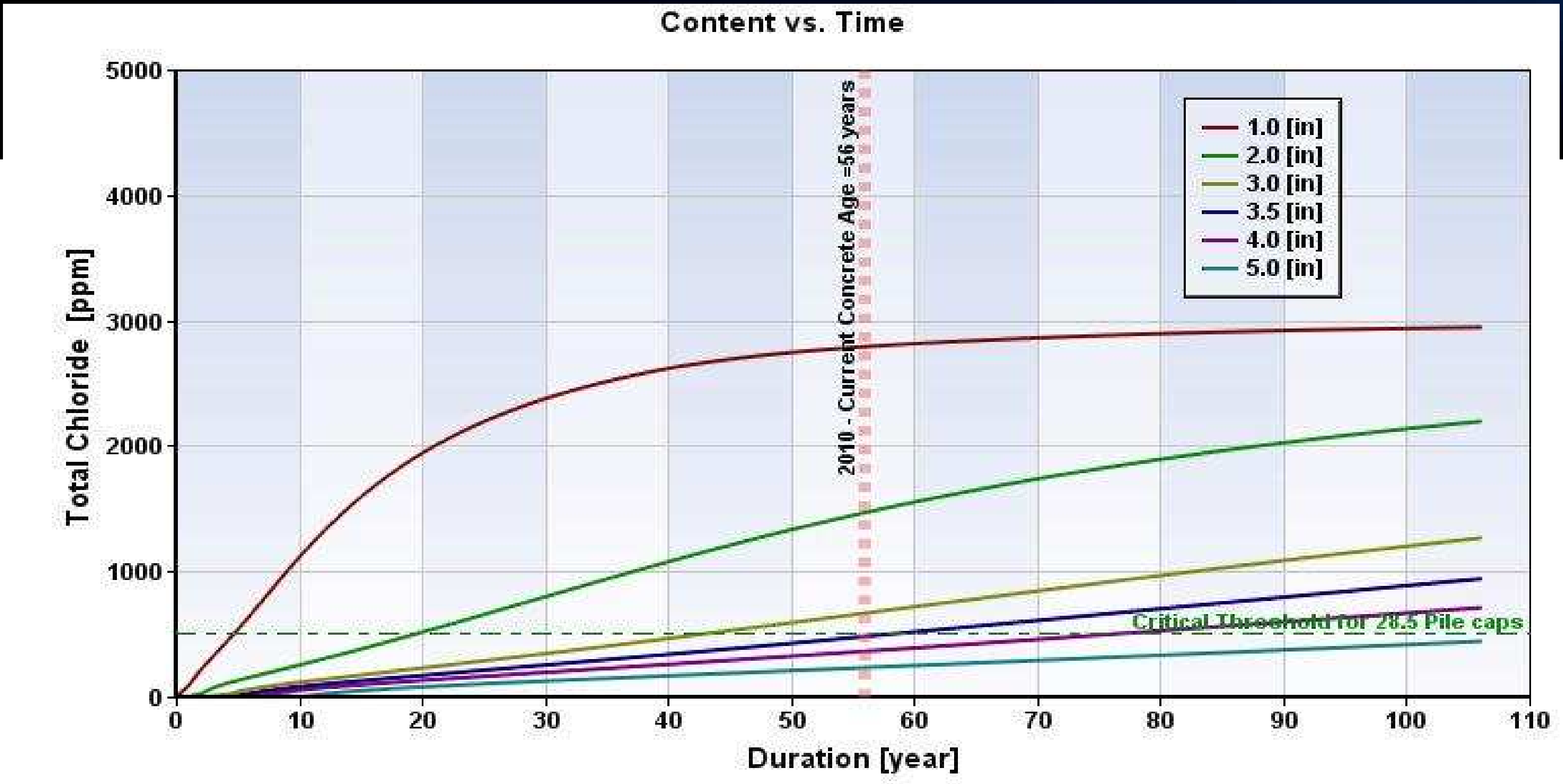
SIMCO

Numerical Simulation Program

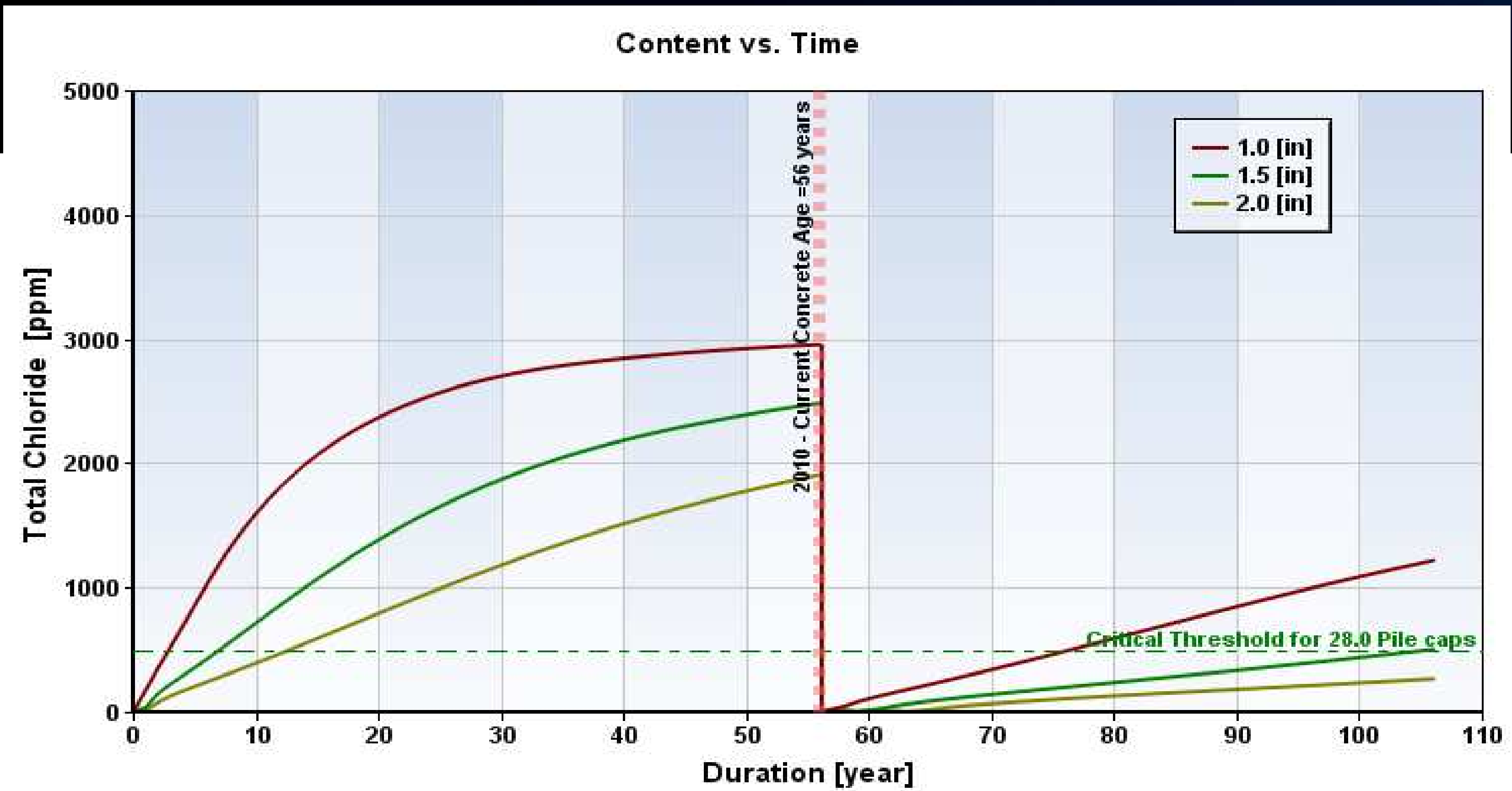
Box beams		I beams		Pile caps		Prestressed piles	
Deicing	Airborne	Deicing (web)	Deicing (bottom)	Deicing	Airborne	Airborne	Splash
No repair		No repair		No repair		No repair	
3 inch repair		2.0 inch repair	3.5 inch repair	2, 3, 6 inches repairs	Sealer every 10 years	Sealer every 10 years	Pile jacket
		Sealer every 10 years					1.5 inch repair with 0, 2 and 4 inch jacket

SIMCO

Residual Service Life   Pile Caps

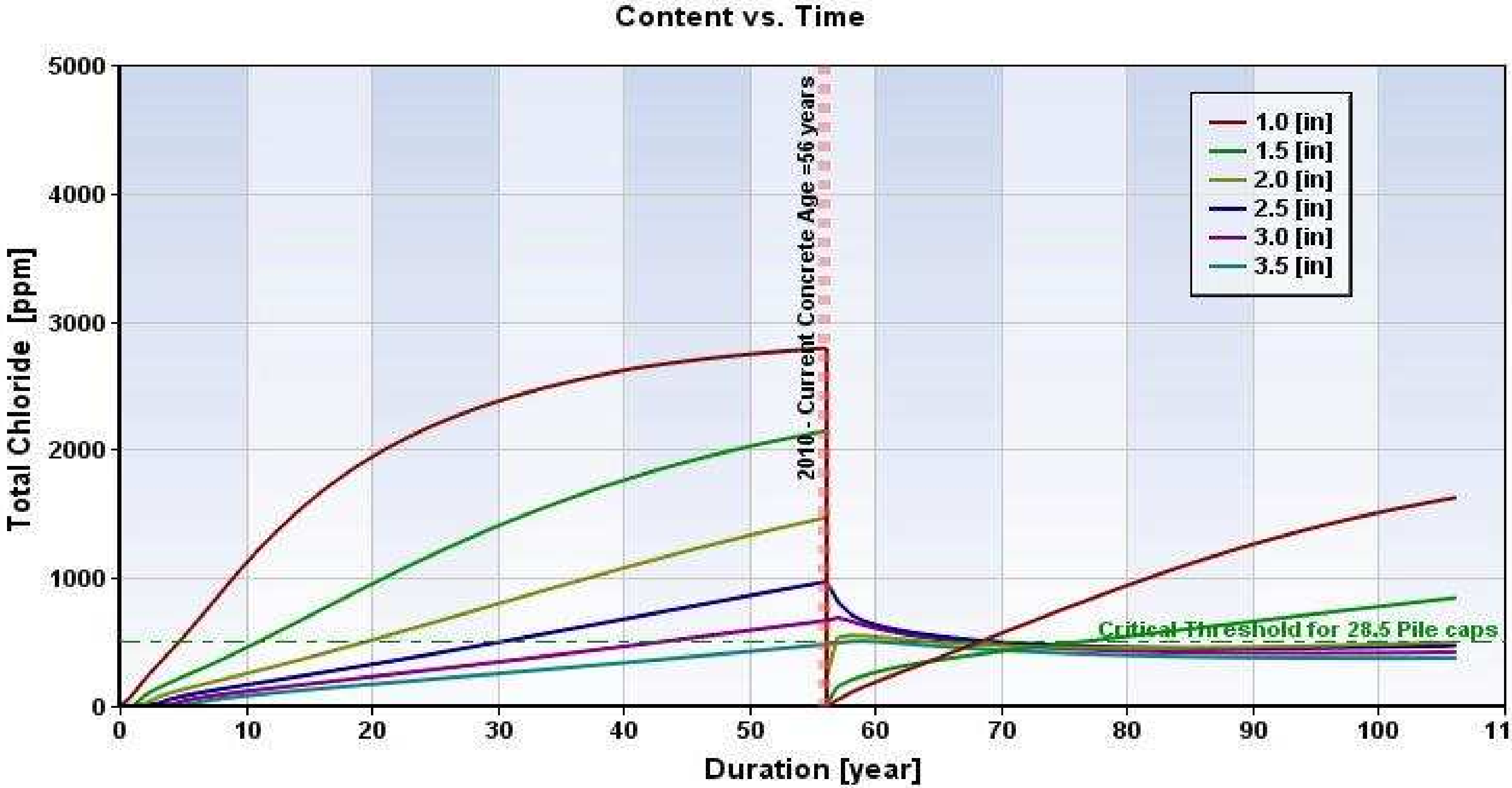


Pile Caps – Deicing – 6-inch Repair



Residual Service Life Analysis

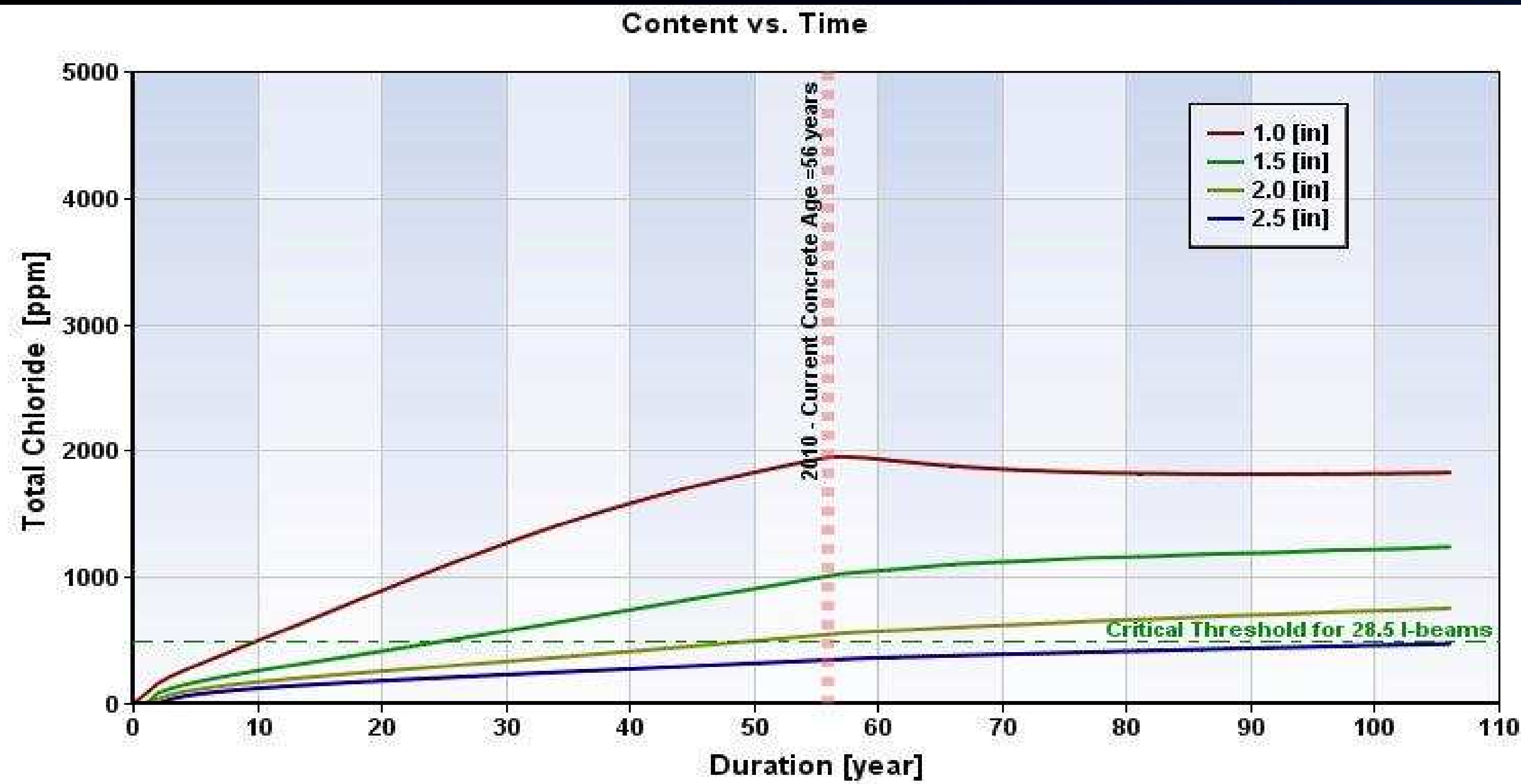
Pile Caps 2" repair



SIMCO

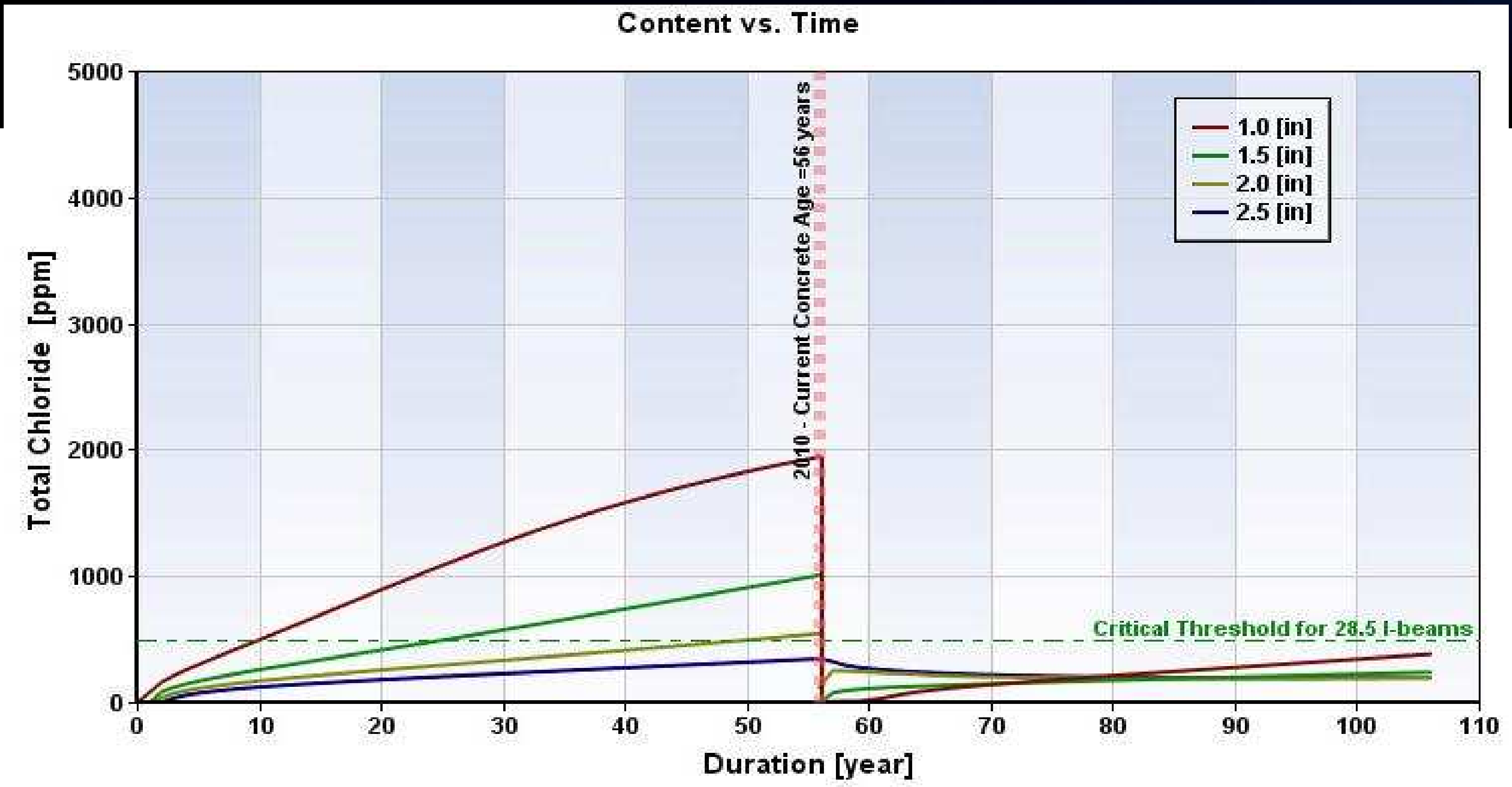
Residual Service Life

I-Beams (web) sealer every 10 years

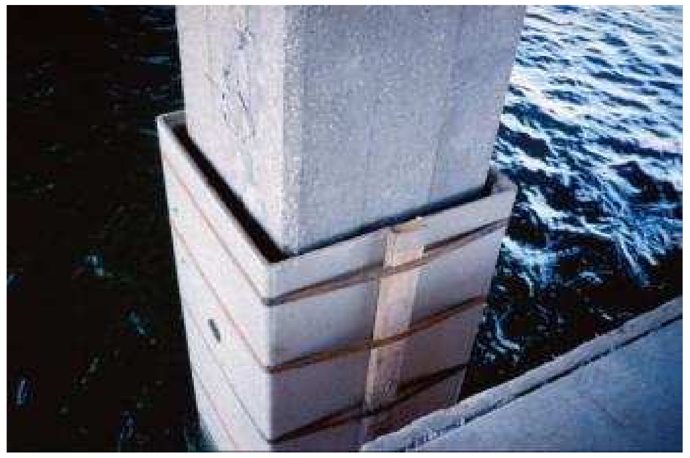


Residual Service Life

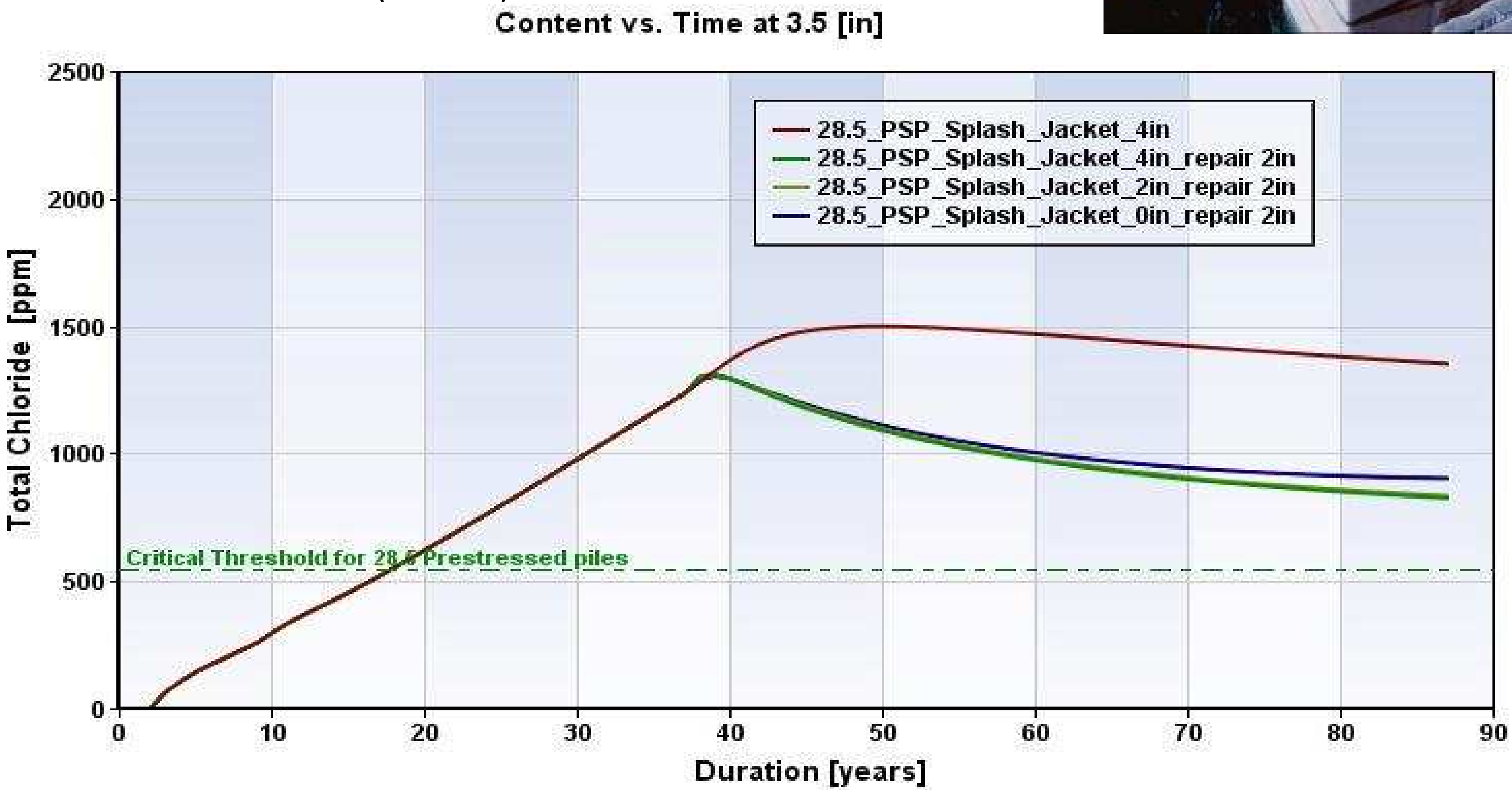
I-Beams (web) 2" Repair



Residual Service Life



Pre-stressed Piles (Jackets)



SIMCO

Thank you

Case Studies

Concrete Deterioration and Residual Service Life Prediction of a Deteriorated Concrete Overpass

Route 21 SB Viaduct | NEWARK NJ

SIMCO's - Scope of Work

1. Establish the viability of concrete repair and maintenance scenarios to extend the service life by 25 years
2. Investigation of the condition of the concrete elements (deck and beams)

RT. 21 Viaduct

New Jersey Experience with STADIUM®

- **Expansion joints**
- **Degradation**
- **Concrete piers**
- **Restrained bearings**

Rt. 21 Recommendations

Implementation of a repair and maintenance plan will increase the service life of the existing viaduct by an **additional 25 years**.

Summary

– Drainage system restoration and maintenance
– Concrete crack repair
– Bearing cleaning/replacement
– Joint replacement
– Sealing of exposed concrete surfaces
– Repair delaminated areas

SIMCO

Bottom Line

NJDOT Saved - $130 Million

PRELIMINARY SCENARIO

Full replacement $150 M

FINAL RECOMMENDATION

$20 M - 25 yrs extension

Route 21 Southbound Viaduct

“This analysis and the subsequent recommendations saved millions in repairs or a total replacement of the bridge, estimated at costing upwards of $100 million. [...]”

– *Brian Strizki, New Jersey’s State Transportation Engineer*

SIMCO

STADIUM® New/Existing Structures

- Materials selection
- Mix design optimization
- Concrete characterization
- Prediction of performance
- Life cycle cost analysis
- QA/QC

- Inspection
- Concrete characterization
- Damage analysis
- Residual service life determination
- Optimum maintenance plan & Repair scenario
- Life cycle cost analysis