Concrete Durability Enhancement - Corrosion Control

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Can we build timeless cities?

Working Life Considerations

- Functional
- Economic
- Technical

Degradation Mechanisms

Physical attack

- Salt crystallisation
- Freezing - thawing attack
- Abrasion, erosion and cavitation
- Thermal damage

Chemical attack

- Leaching
- Acid and base attack
- Alkali-silica reactions
- Delayed ettringite formation
- Sulfate attack
- Steel reinforcement corrosion

https://www.youtube.com/watch?v=kunTlcruqNo&t=14s

CORTEC CORPORATION

Environmentally Safe VpCI®/MCI® Technologies

EN 206-1 Design Methods

Limiting Value Method (Prescriptive)

Table F.1 — Recommended limiting values for composition and properties of concrete

	Exposure classes																	
	No risk of corrosion or attack	Carbonation-induced corrosion				Chloride-induced corrosion						Freeze/thaw attack				Aggressive chemical environments		
						Sea water			Chloride other than from sea water									
	X0	XC 1	XC 2	XC 3	XC 4	XS 1	XS 2	XS 3	XD 1	XD 2	XD 3	XF 1	XF 2	XF 3	XF 4	XA 1	XA 2	XA 3
Maximum w/c^{c}	–	0,65	0,60	0,55	0,50	0,50	0,45	0,45	0,55	0,55	0,45	0,55	0,55	0,50	0,45	0,55	0,50	0,45
Minimum strength class	C12/15	C20/25	C25/30	C30/37	C30/37	C30/37	C35/45	C35/45	C30/37	C30/37	C35/45	C30/37	C25/30	C30/37	C30/37	C30/37	C30/37	C35/45
Minimum cement content[c] (kg/m^3)	–	260	280	280	300	300	320	340	300	300	320	300	300	320	340	300	320	360
Minimum air content (%)	–	–	–	–	–	–	–	–	–	–	–	–	4,0[a]	4,0[a]	4,0[a]	–	–	–
Other requirements	–	–	–	–	–	–	–	–	–	–	–	Aggregate in accordance with EN 12620 with sufficient freeze/thaw resistance				–	Sulfate-resisting cement[b]	

[a] Where the concrete is not air entrained, the performance of concrete should be tested according to an appropriate test method in comparison with a concrete for which freeze/thaw resistance for the relevant exposure class is proven.

[b] Where sulfate in the environment leads to exposure classes XA2 and XA3, it is essential to use sulfate-resisting cement conforming to EN 197-1 or complementary national standards.

[c] Where the *k*-value concept is applied the maximum *w/c* ratio and the minimum cement content are modified in accordance with 5.2.5.2.

Performance-related Method

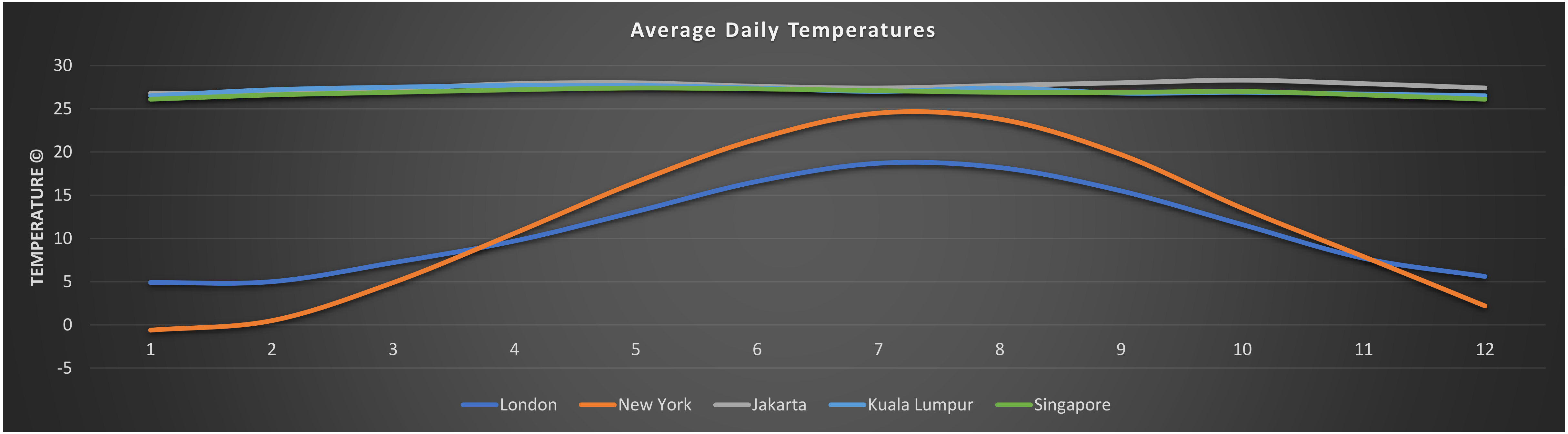
5.3.3 Performance-related methods

(1) The requirements related to exposure classes may be established by using performance-related methods for durability and may be specified in terms of performance-related parameters, e.g. scaling of concrete in a freeze/thaw test. The application of a performance based method depends on the provisions valid in the place of use of the concrete.

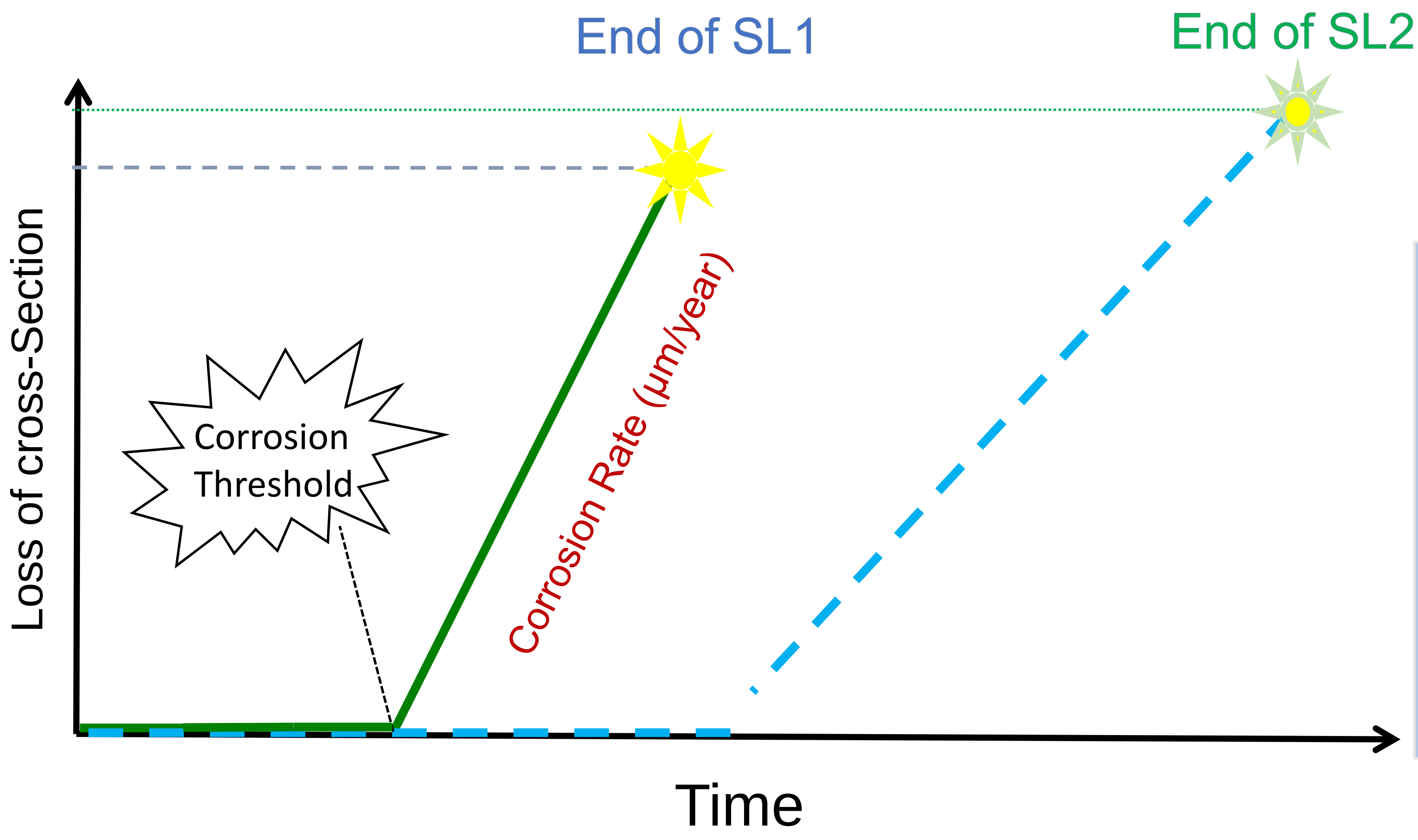
NOTE A suite of European performance-related test methods is being developed, e.g. CEN/TS 12390-9, CEN/TS 12390-10, CEN/TS 12390-11 and CEN/TR 15177 and the framework for the equivalent durability procedure has been published as CEN/TR 16563.

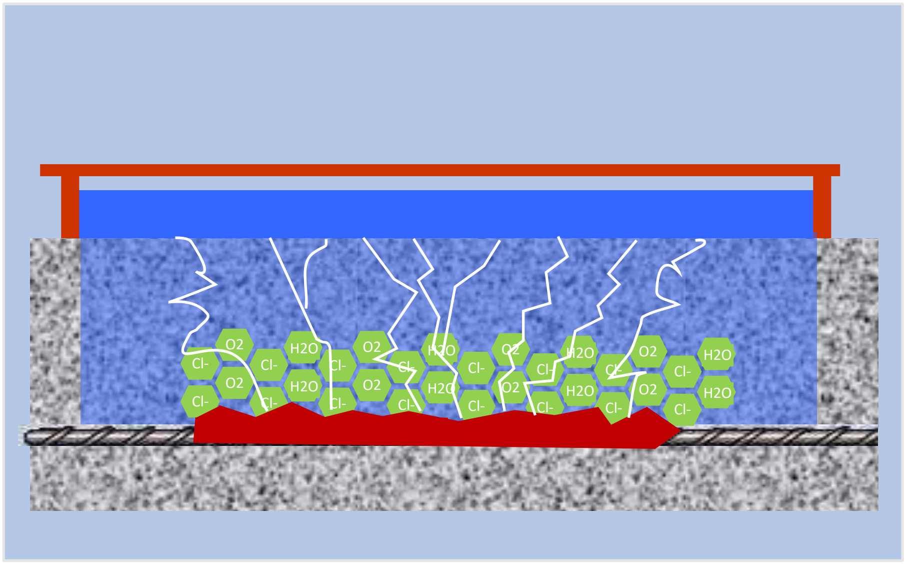
Temperature Vs Corrosion

Corrosion rate doubles of a metal doubles for every 10°C increase in temperature.
10 mpy at 30°C, expect 20 mpy at 40°C



Service Life Modelling





BS8500 Extended Service Life

BS 8500-1:2015+A2:2019

Incorporating Corrigenda No.1 and No. 2

BSI Standards Publication

Concrete – Complementary British Standard to BS EN 206

Part 1: Method of specifying and guidance for the specifier

Models to predict concrete requirements for long-life structures in chloride environments do not give identical predictions, and extrapolating performance from existing structures also has many practical problems. Consequently there is a degree of uncertainty with the recommendations for an intended working life of at least 100 years in the chloride (XD) and sea water (XS) environments. Reliance solely on cover and concrete quality might not be the most economic solution. In these situations, consideration may be given to using other techniques such as stainless steel or non-ferrous reinforcement, barriers, coatings and corrosion inhibitors, but these techniques also have their uncertainties. For guidance on these techniques see specialist literature, e.g. Concrete Society Technical Report 61 [6].

Technical Report 61 by CS

Concrete Society Technical Report No. 61

Enhancing reinforced concrete durability

Guidance on selecting measures for minimising the risk of corrosion of reinforcement in concrete

P.B. Bamforth

<u>Additional Protective Measures:</u>

- Corrosion Inhibitors
- Epoxy-coated reinforcement
- Galvanized steel
- Stainless steel
- Non-metallic reinforcement
- Cathodic prevention

ASTM C1582

Designation: C1582/C1582M – 11 (Reapproved 2017)[ε1]

Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete[1]

ε1 NOTE—Standard designations were corrected editorially in July 2017.

1. Scope*

1.1 This specification covers material for use as chloride-corrosion-inhibiting admixtures for concrete.

1.2 Results of the tests conducted to meet this specification are not to be used to rank the expected field performance of various chloride-corrosion-inhibiting admixtures.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

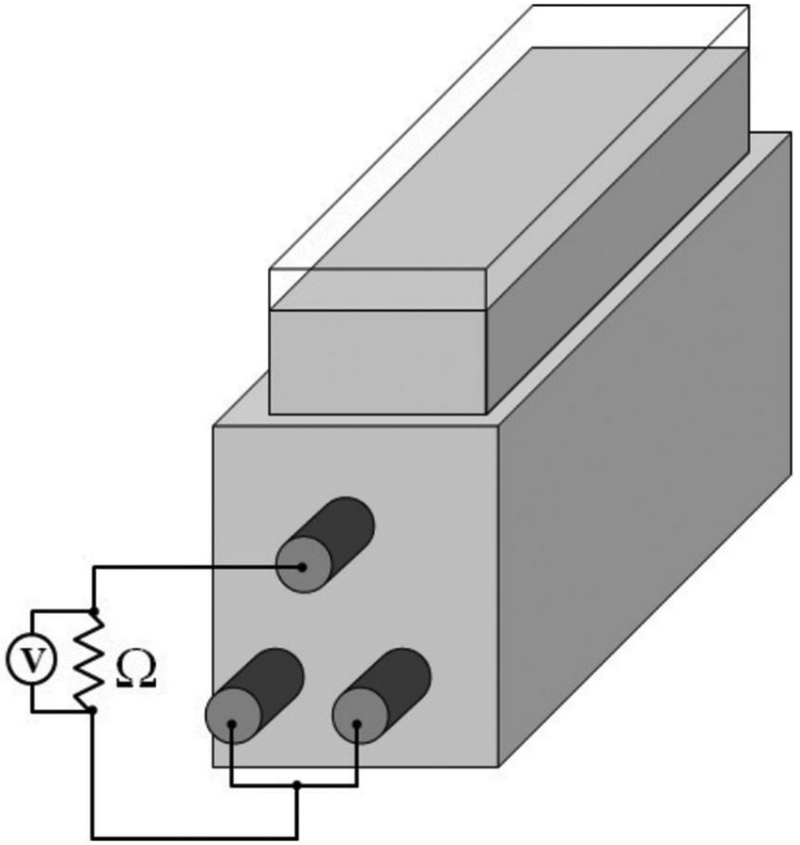
1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C78/C78M Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C125 Terminology Relating to Concrete and Concrete Aggregates
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C150/C150M Specification for Portland Cement
C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C260/C260M Specification for Air-Entraining Admixtures for Concrete
C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C494/C494M Specification for Chemical Admixtures for Concrete
C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C1152/C1152M Test Method for Acid-Soluble Chloride in Mortar and Concrete
G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[4]



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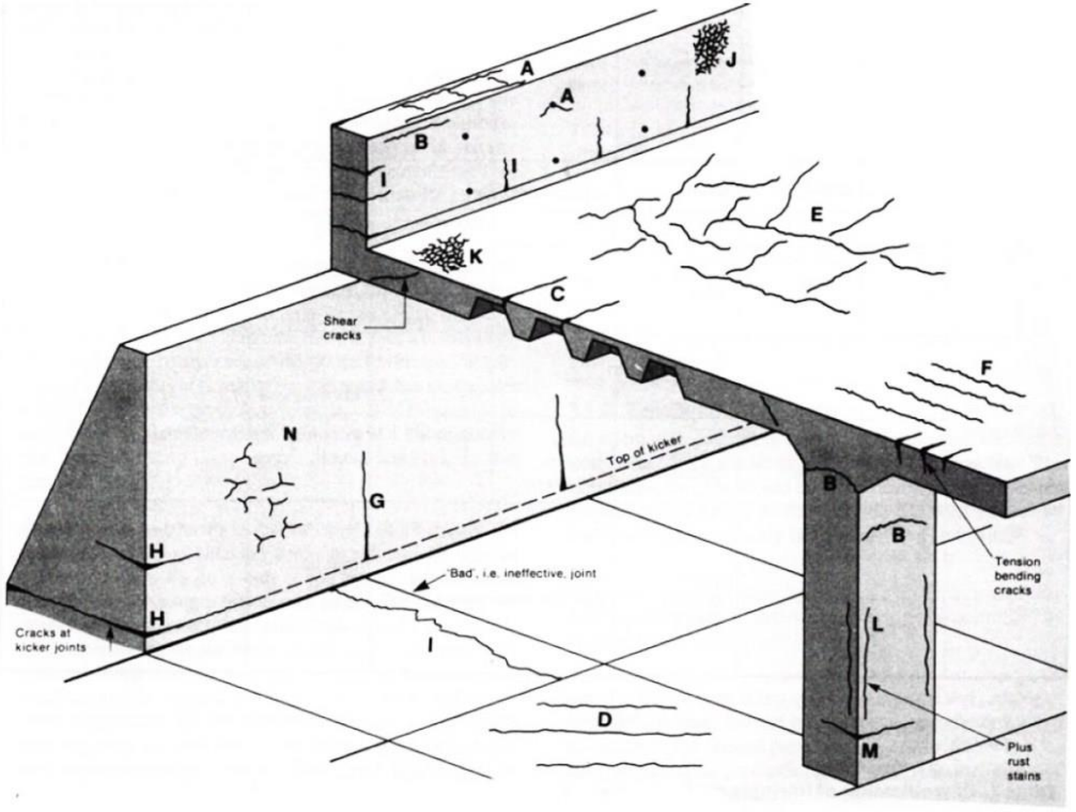
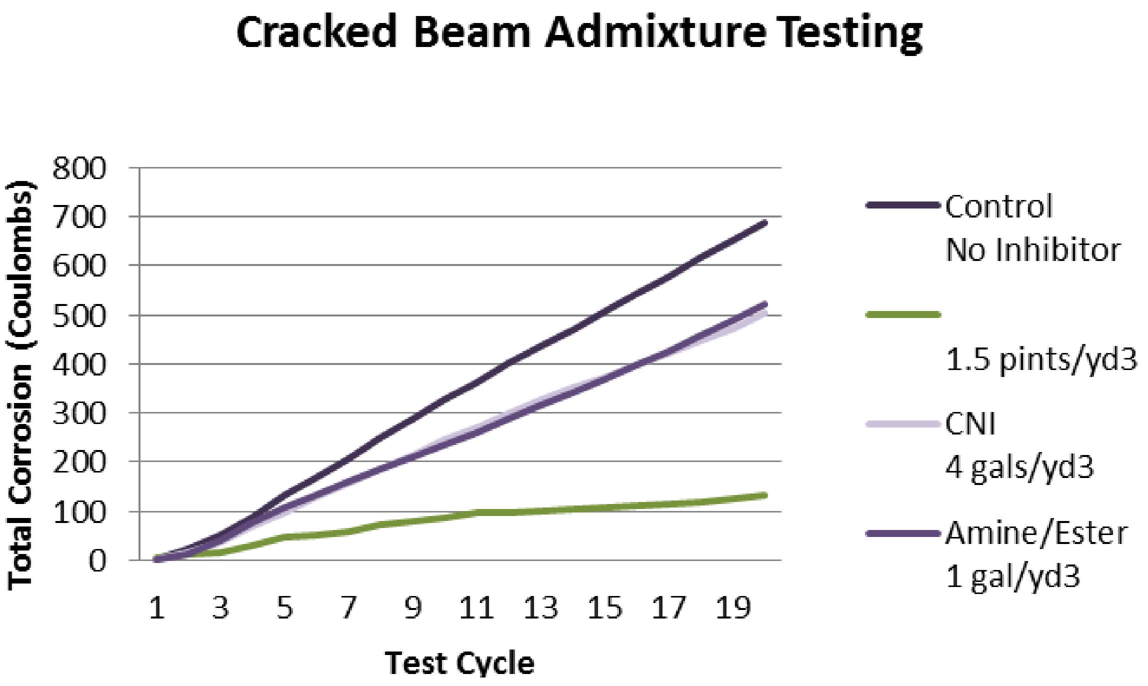
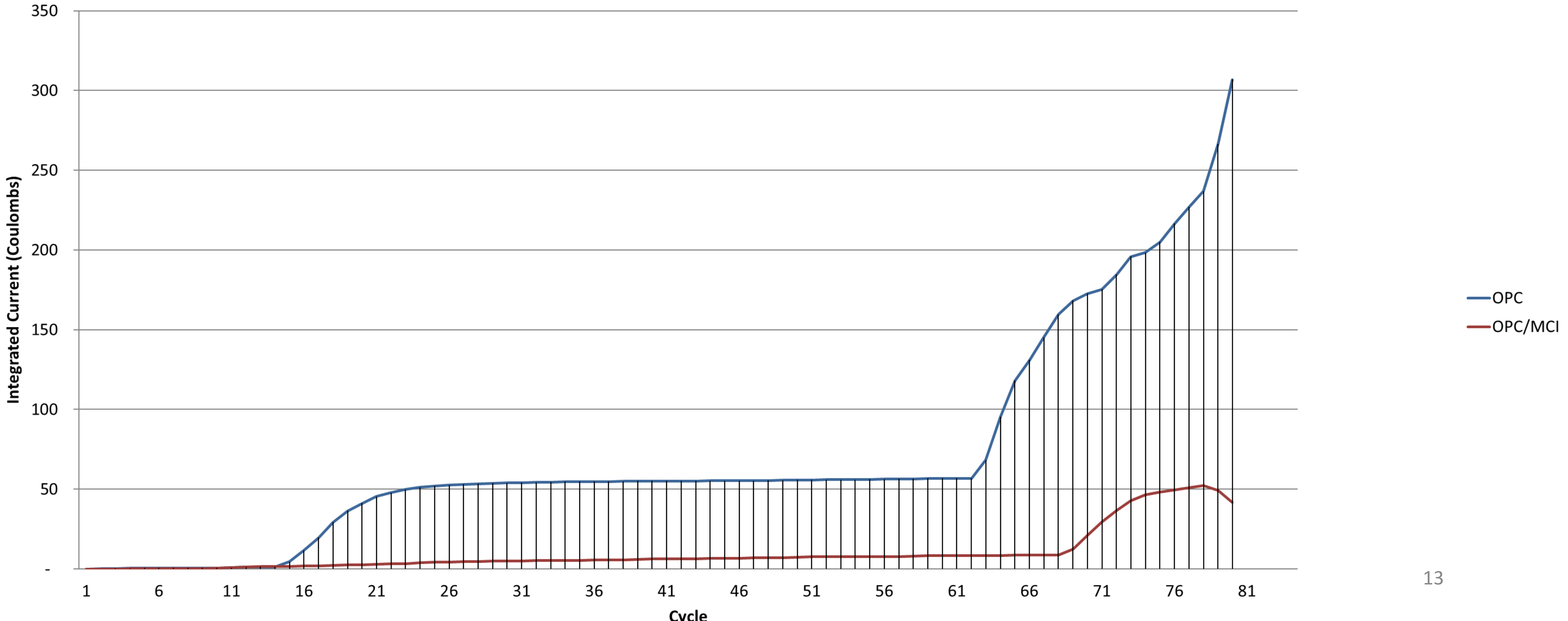
Concrete Crack Protection





10 Year Study – interim results



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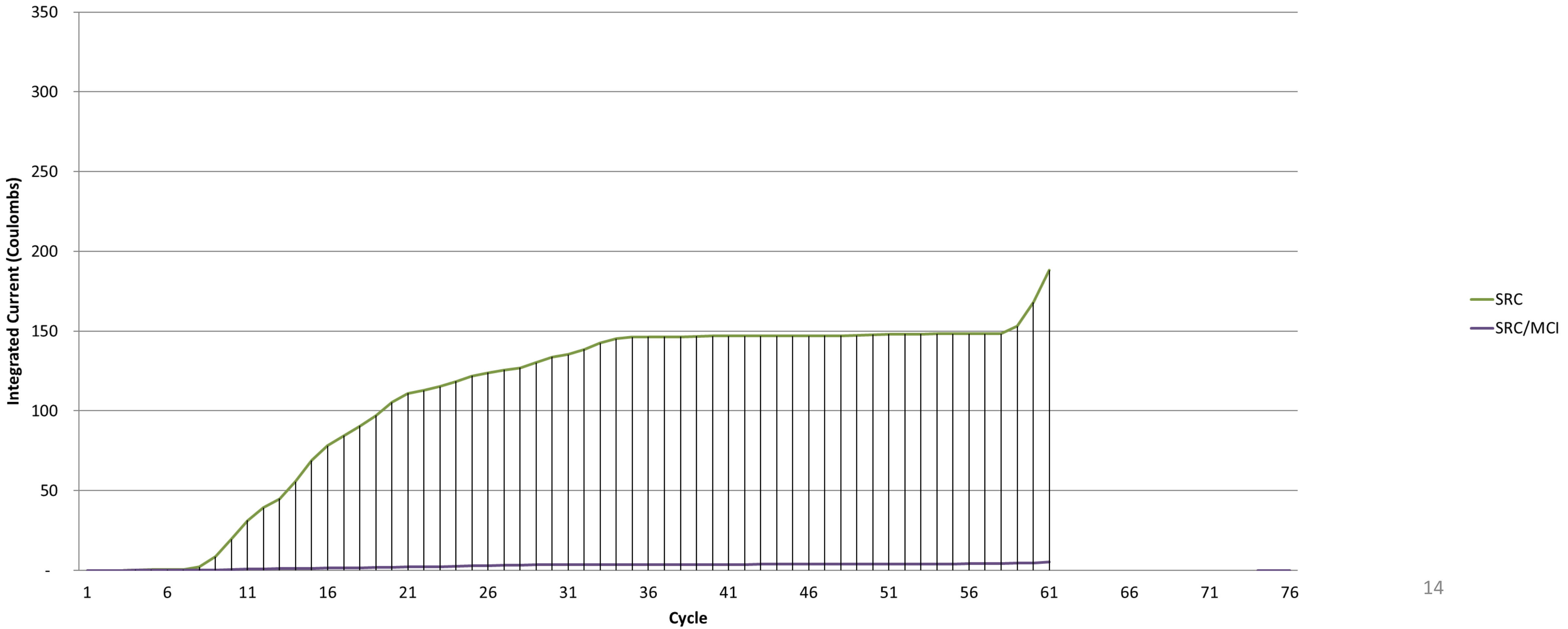
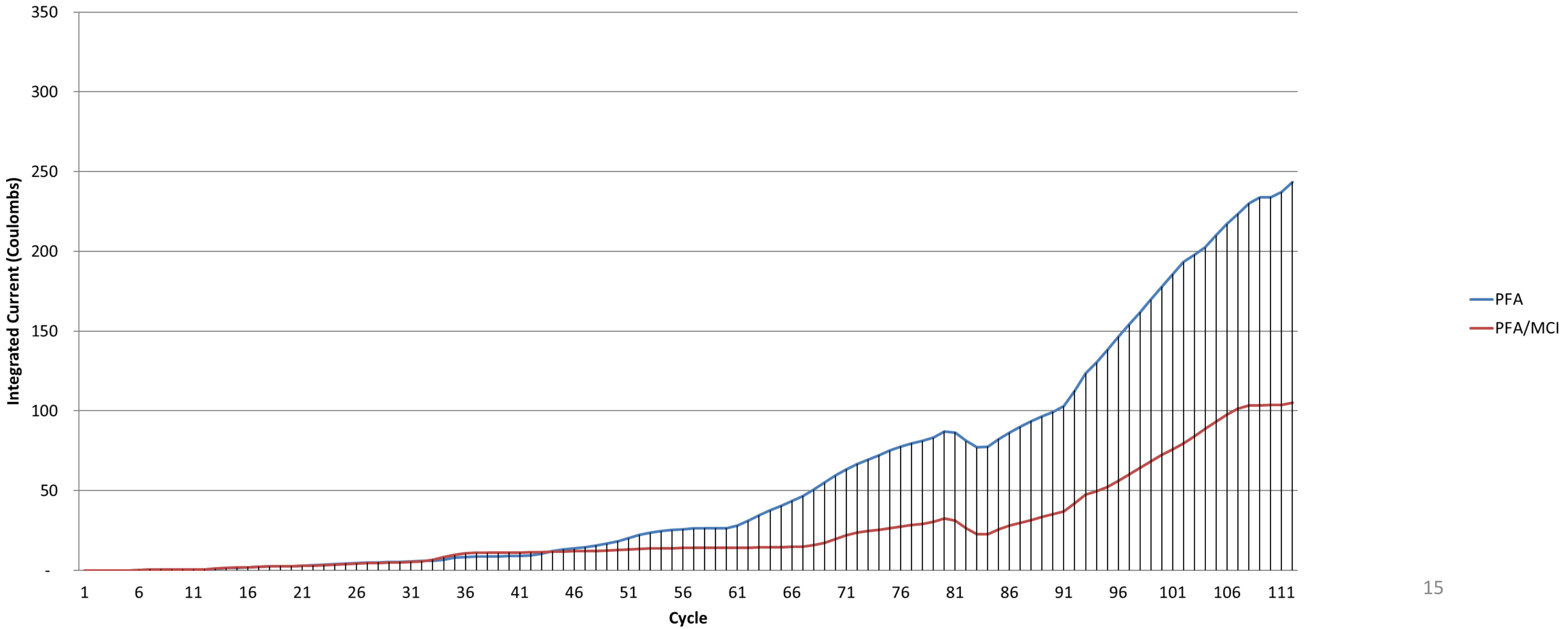
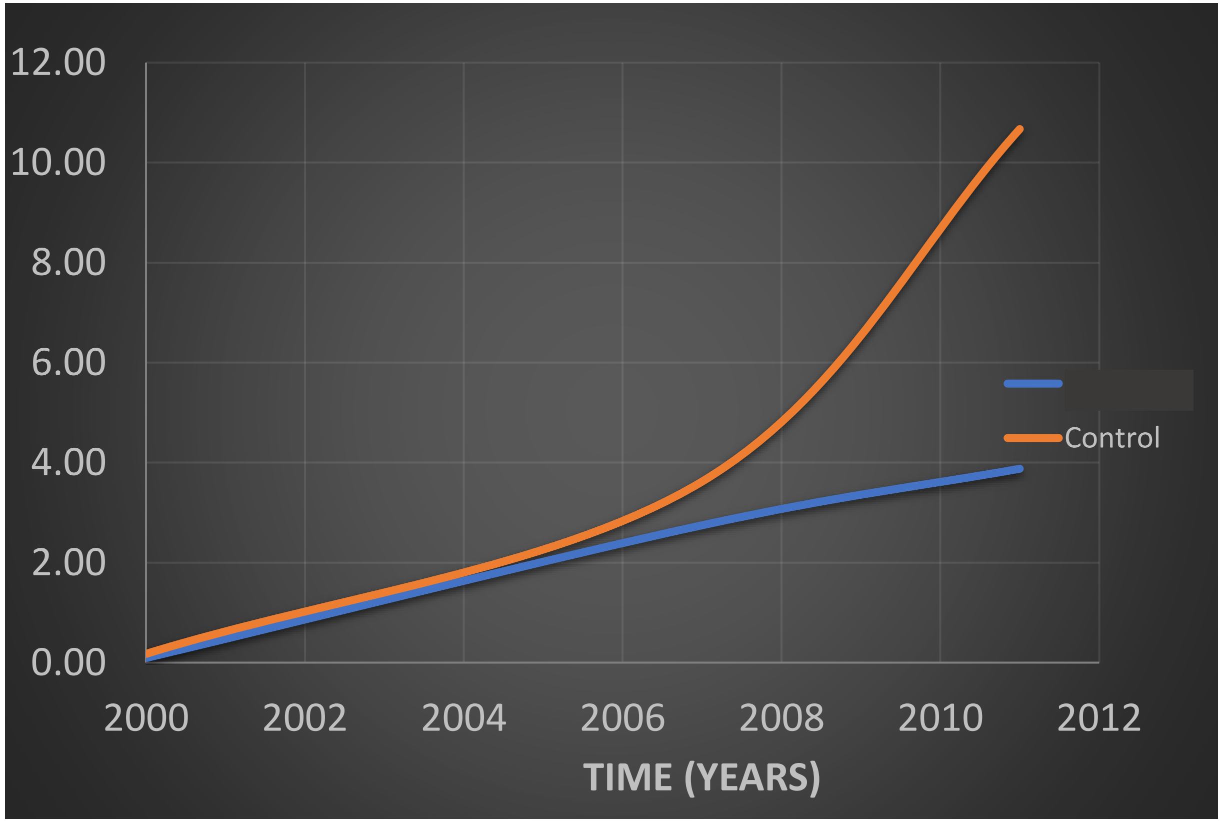


10 Year Study – interim results



Field Study

Time Vs Corrosion Rate



Can we build timeless cities?

We can by

- Performance-based durability design
- Adopting good concrete technology and practice
- Incorporate Additional Protective Measures