achieving sustainability by utilizing migratory corrosion inhibitor technology

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MIGRATING CORROSION INHIBITORS
FROM GREY TO GREEN

- Chlorides generated or from de-icing salts or marine environment penetrate existing cracks and diffuse through the concrete cover to the reinforcing steel, initiating corrosion.
- Corrosion products cause stresses and premature deterioration of structures

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FROM GREY TO GREEN

De-icing salt use

- Snow-ice related highway and business closures and accident represent a significant economic cost

Table 1: Road and bridge snow and ice control procedures in countries that participated in a 2002 European study of winter maintenance practices [3]

Country	Deicing Products Used	Metric Tons (1,000)	Deicing Period
Austria	$NaCl$, $CaCl_2$	NA	Nov. – March
Belgium	$NaCl$, $CaCl_2$	113	Oct. – April
Croatia	$NaCl$	NA	NA
Czech Republic	$NaCl$, $CaCl_2$, $MgCl_2$	215	Nov. – April
Denmark	$NaCl$	115	Oct. – April
Finland	$NaCl$	NA	Oct. – April
France	$NaCl$, $CaCl_2$	400 – 1,400	Nov. – March
Germany	$NaCl$, $CaCl_2$, $MgCl_2$	2,000	Nov. – March
Great Britain	$NaCl$, $CaCl_2$	2,200	
Hungary	$NaCl$, $CaCl_2$	NA	Nov. – March
Iceland	$NaCl$, $CaCl_2$	NA	Oct. – April
Ireland	$NaCl$	30-70	Nov. – April
Norway	$NaCl$	83	Oct. – April
Poland	No details	NA	NA
Romania	$NaCl$	108	Nov. – March
Slovenia	$NaCl$, $CaCl_2$, $MgCl_2$	NA	NA
Spain	$NaCl$, $CaCl_2$	80	Oct. – April
Sweden	$NaCl$	300	Oct. – April
Switzerland	$NaCl$, $CaCl_2$	NA	Oct. – April
The Netherlands	$NaCl$, $CaCl_2$	135	Oct. – April

NA – total tonnage data not available

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1.0 Objective

More than 1,234 kilometres of road bridges over 100 meters are spread across Europe

Most of the bridges built after 1945 was designed with a design life of 50 – 100 years.

The EU funded BRIME project in 2001 identified that highway bridges in three different European countries (France, Germany and the UK) present deficiencies at a rate of 39%, with the main cause being the corrosion of reinforcement.

The quality of the European bridges has been heavily questioned in the 2018, after the dramatic events of the Genova Bridge collapse in Italy.

It is noteworthy that the knowledge on the probabilistic occurrence of extreme natural events (e.g. earthquake, wind loads), material properties (especially reinforced concrete) and bridge design methods, were less developed when most European bridges were built.

As a consequence, the majority of EU countries must invest and address maintenance issues to ensure serviceability and safety.

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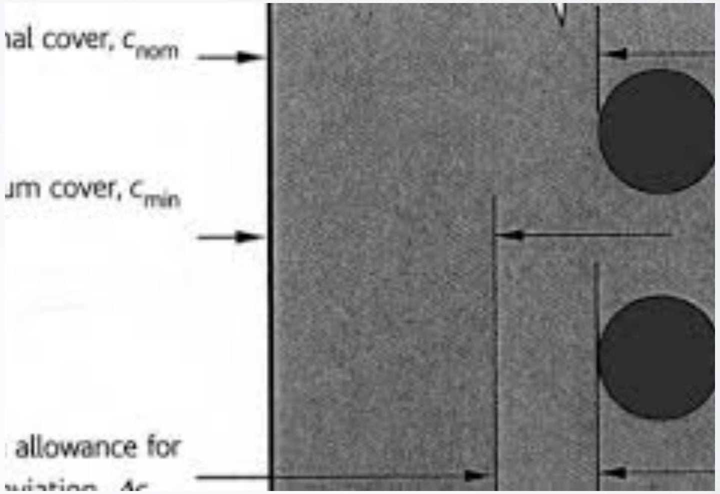
2.0 Corrosion of steel in reinforced concrete bridges

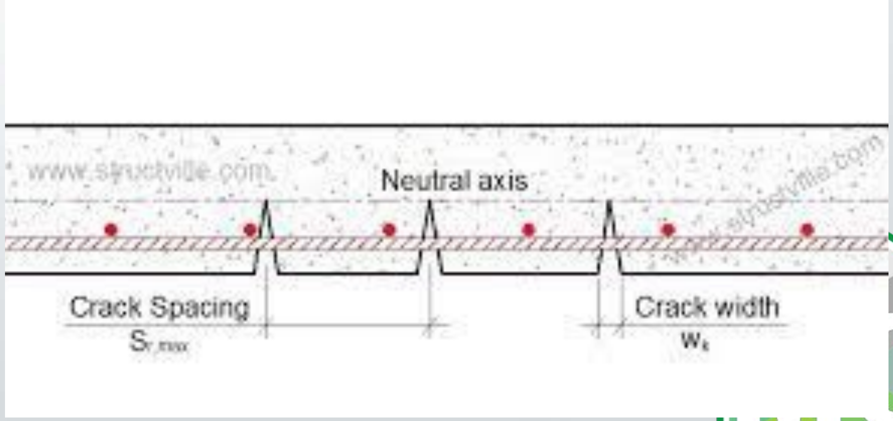
Selecting the appropriate corrosion mitigation approach is based on many factors:

- the amount and depth of contamination (chloride ingress or carbonation),
- amount of concrete cracking and concrete damage,
- severity and location of corrosion activity (localized or widespread),
- expected environmental exposure,
- use and service life of the structure, and
- the cost and design life of the corrosion protection system.

- Traditional approaches for enhancing the service life of bridges used in various codes and specifications such as Eurocodes or British Standards, are mainly in an indirect form, specifying the use of certain details or properties as:

    - cover thickness,
    - maximum crack width,
    - concrete compressive strength, etc.





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FROM GREY TO GREEN

Approaches to mitigating the corrosion:

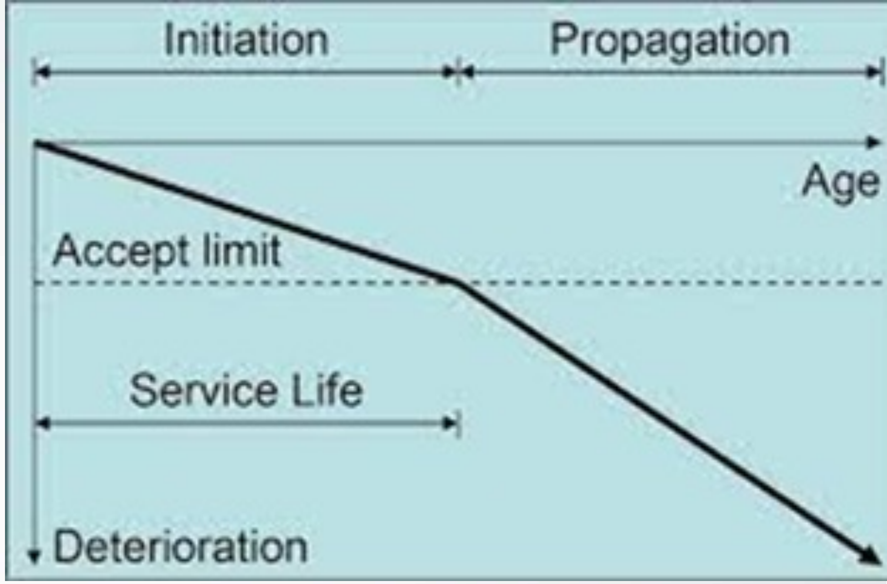
- To prevent or minimize chloride penetration by minimizing cracking using low permeability concretes, adequate concrete cover over the steel, membranes, sealers, or overlays.

- To prevent the steel from corroding or to minimize the rate of corrosion through means such as the use of corrosion-resistant reinforcement or cathodic protection or/and corrosion inhibitors.

- Depending on the specifics of a project, one or a combination of these approaches may be desirable.

- One of the missing elements for designing bridges for service life is “the framework”, that would approach the problem systematicly and provide a complete solution in a format that could ensure long lasting bridges.

- The steps within this framework should start at the design stage and should provide the owner with complete information to ensure the serviceability of the structure for a specified target service life



PELJEŠAC BRIDGE - INFLUENCE OF MIGRATORY CORROSION INHIBITORS ON SERVICE LIFE OF THE REINFORCED CONCRETE ELEMENTS EXPOSED TO THE MARINE ENVIRONMENT

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FROM GREY TO GREEN

Pelješac bridge, Croatia

Location: Highway Split - Ploče – Dubrovnik, Croatia

Investor/Client: HRVATSKE CESTE d.o.o., Zagreb, Croatia

Designer:

PONTING - PIPENBAHER CONSULTING ENGINEERS

SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET

Services: Conceptual / Preliminary / Final design

Navigation channel: 200 x 55 m

Length: 2404.0 m

Span arrangement:

72.0 + 96.0 + 118.0 + 203.5 + 5 x 285.0 + 203.5 + 118.0 + 96.0 + 72.0 = 2404.0 m

Total width: 23.60 m

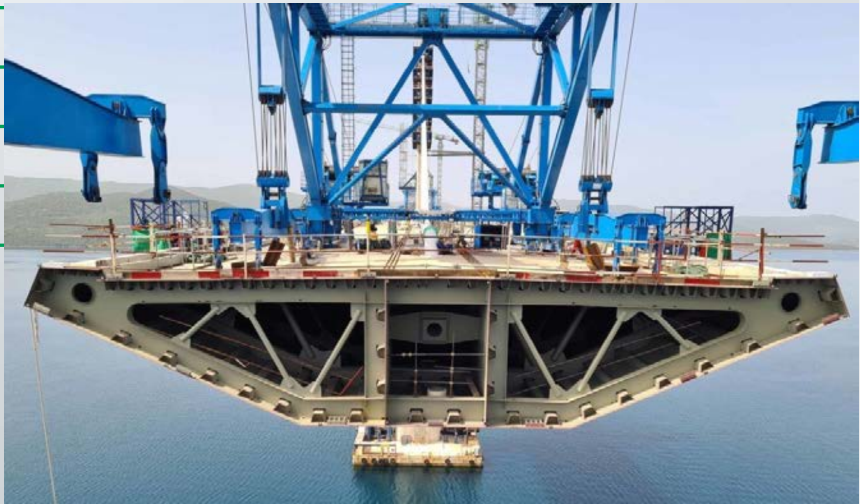
Total pylon height: 82.5 – 98.0 m

Type of foundations:

Deep on driven steel piles, D = 2.0 m, length up to 124 m

Superstructure: Steel orthotropic superstructure

Construction technology: Balanced cantilever method





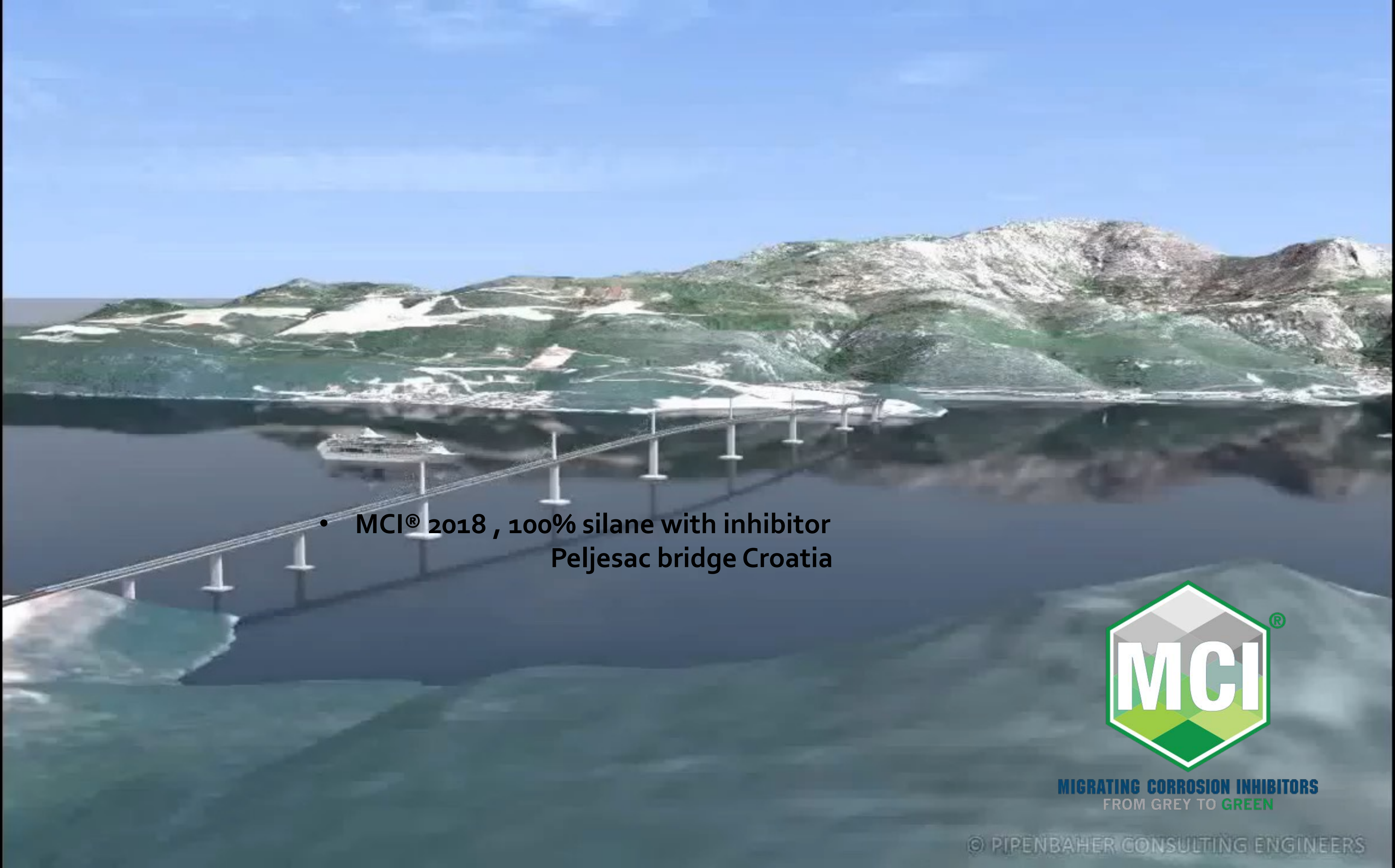

To Achieve 130 years lifetime in terms of durability

Additional AC Coatings, CP of steel piles, reinforcements and pile head

Concrete cover 65 – 85 mm, stainless steel reinforcement, and

Impregnation of all concrete surfaces with 100% silane with corrosion inhibitor

- **MCI® 2018 , 100% silane with inhibitor Peljesac bridge Croatia**



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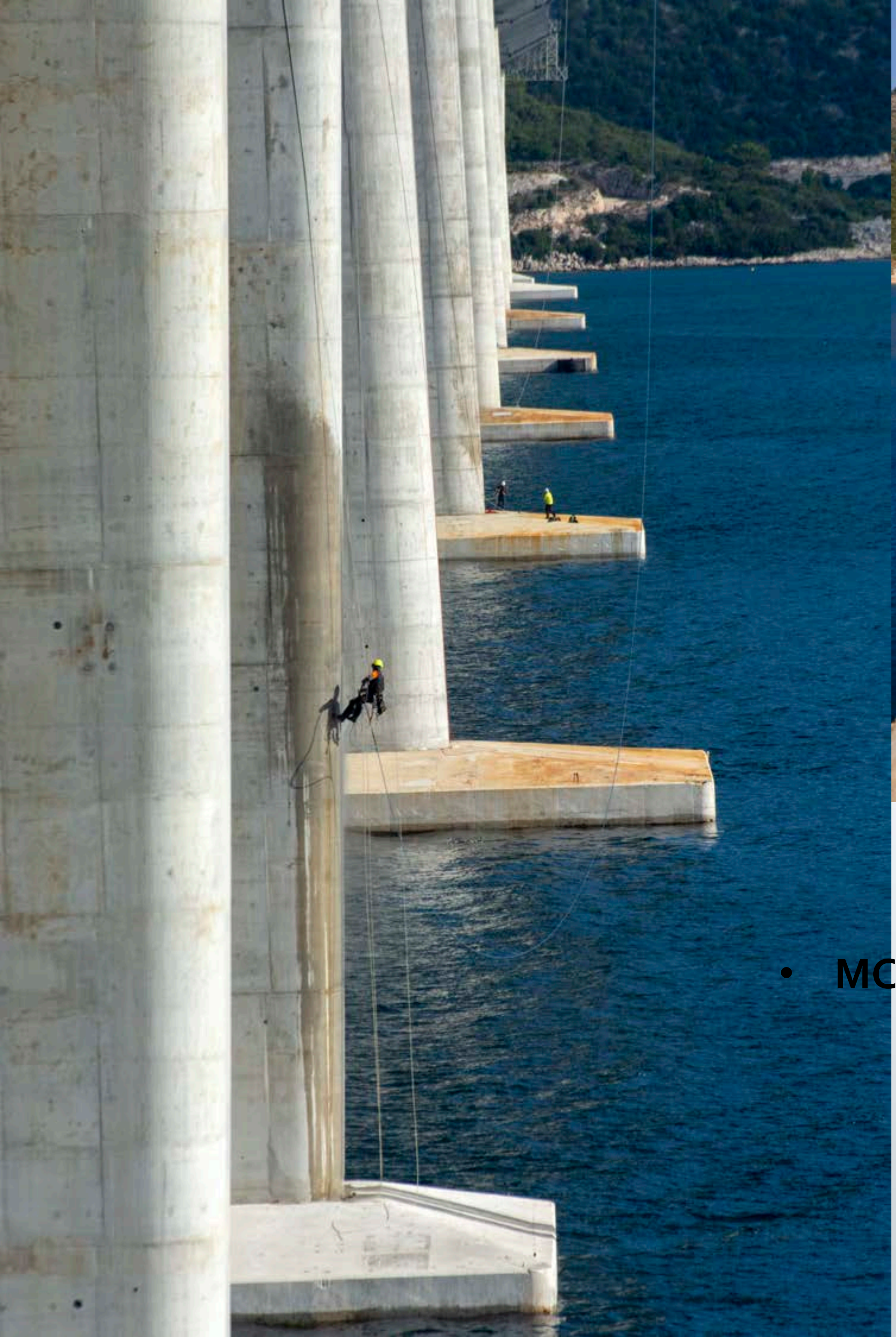

- MCI® 2018 , 100% silane with inhibitor

3.0 Influence of Inhibitors on Service Life of the Concrete Elements

- LCC analyses was done for estimating the lifetime of structure exposed to marine corrosion (Peljesac bridge in Croatia).

- Life - 365 service life prediction model for concrete structures was used to calculate LCC for four scenarios of concrete columns construction including:
  a) ordinary concrete (C40/50),
  b) ordinary concrete (C40/50) with sealer with CI,
  c) ordinary concrete (C40/50) with CI admixture.
  d) ordinary concrete (C40/50) with CI admixture and sealer with CI.

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Life 365

- Life assessment of the reinforced concrete elements is done for Peljesac bridge location by modeling in Life 365, in various scenarios, involving the use of migrating corrosion inhibitor technology, with a focus on the most common deterioration mechanisms:
  - chloride-induced steel corrosion

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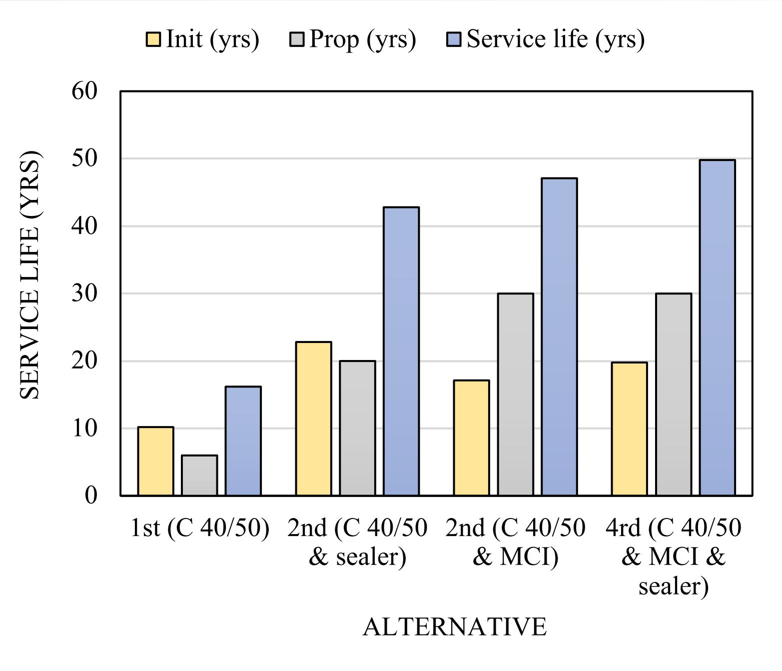
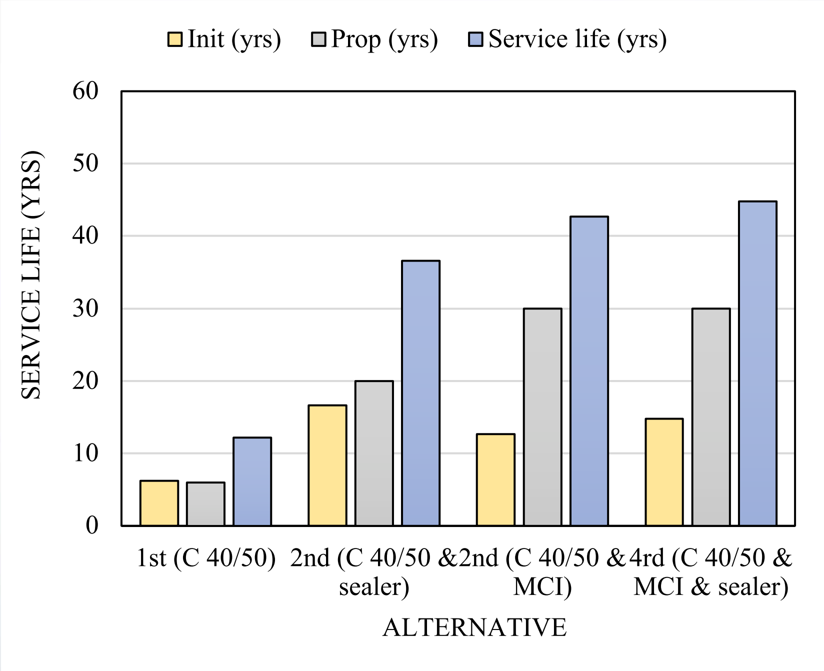
3.1 Prediction of service life for concrete columns exposed to:



a) marine spray zone



b) marine tidal zone

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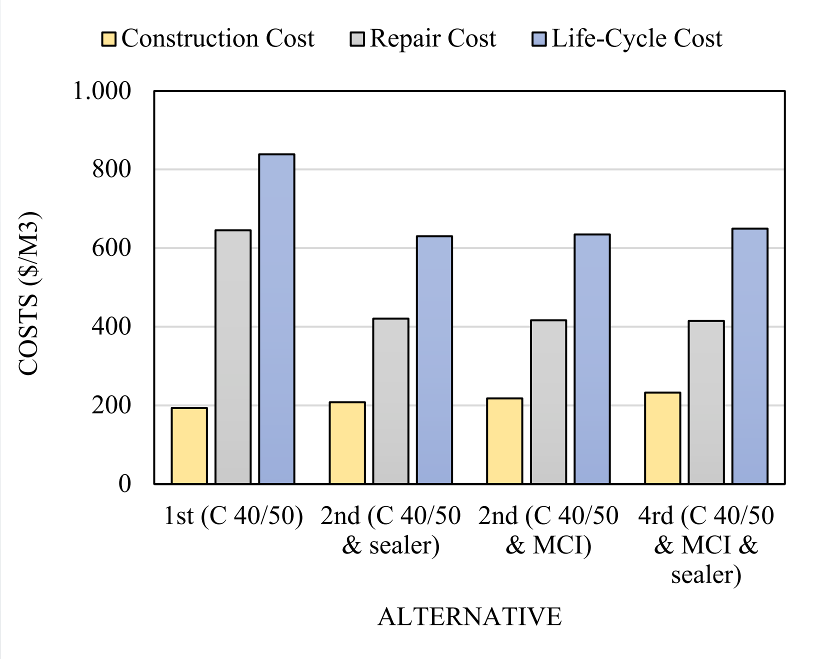
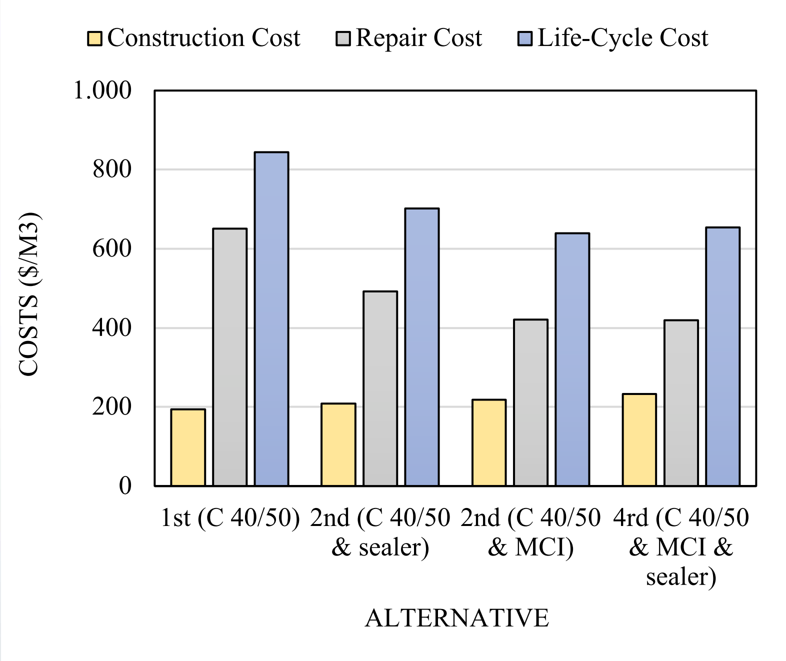
3.2 Life cycle costs for concrete columns exposed to:



a) marine spray zone



b) marine tidal zone

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4.0. EU Case Studies with use of CI

- There are many current cases of using organic corrosion inhibitor technology in projects around the Europe
- MCI where used for corrosion protection of PT concrete segments.

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Frederikssund

Bridge , Denmark

Client:

Rizzani de Eccher with its JV partners Besix and Acciona

Work Description:

Company is erecting the new Frederikssund Bridge. The project includes design & construction of an 8-km-long dual-carriageway highway, comprehensive of a bridge over the Roskilde Fjord, as well as several smaller civil structures.

MCI® 309
Product is used for PT protection.

MIGRATING CORROSION INHIBITORS
FROM GREY TO GREEN

Tagliamento, Italia

Bridge

Client:

Tiliaventum consortium (Rizzani de Eccher – Pizzarotti)

MCI® 309
is used for PT protection...

Work Description:

Company started erecting the viaduct over Tagliamento river. The project involves the enlargement to the A4 motorway to 3 lanes. The major structures include:

- a new bridge over the Tagliamento River consisting of two adjacent viaducts, each of which is the seat of a roadway.

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FROM GREY TO GREEN


Taro river, Italy

LNG Terminal, Russia – MCI-309

4.1 Krk bridge

The design solution for the repair and protection of this upper part of the structure was changed to only a chloride-impermeable permanently elastoplastic polymer coating, which is applied to a well-cleaned surface impregnated with organic penetrating corrosion inhibitor, OCI.

4.2. Maslenica bridge

Half cell potentials $Cu/CuSO_4$ (mV)						
(x,y)	1	2	3	4	5	6
1	-470	-425	-370	-375	-355	-375
2	-470	-405	-385	-355	-345	-350
3	-470	-465	-400	-370	-345	-350
4	-415	-415	-380	-360	-360	-335
5	-440	-395	-385	-365	-350	-350

OCI - rust primer was brushed on exposed rebar to passivate the metal from further corrosion, and OCI surface treatment was applied to the entire concrete structure to prevent any potential corrosion that was not apparent.

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5.0 STRATEGIES FOR ADDRESSING CORROSION

- The use of low permeability concrete,
- The use of increased concrete cover,
- The use of improved construction methods such as curing to minimize cracking,
- The use of corrosion-resistant reinforcement,
- The use of corrosion inhibitors to increase the corrosion initiation threshold,
- The use of membranes, coatings, and sealers, and
- The use of improved design details to keep elements dry and to prevent exposure to chlorides.

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MCI Solutions for the Construction Market

Admixtures

- MCI-2005/2005 NS
- MCI-2006 NS

Surface Treatments

- MCI-2020/2020 V/O
- MCI-2018
- MCI-2019
- MCI-2021

Specialty Products

- MCI-2020 Gel
- MCI-309
- MCI-2061
- MCI 2062

MIGRATING CORROSION INHIBITORS
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EU Regulations - EN 1504 (Surface treetements)

- Certification required for **concrete surface treatment products** compliance application covering repair area **System 2+**
  - MCI-2018
  - MCI-2019
  - MCI-2021
  - MCI-CorrVerter
  - MCI-Arch Coating

Applus+

CE

CERTIFICATE

ENAC

No. 0370-CPR-2642

CERTIFICATE OF CONFORMITY OF THE FACTORY PRODUCTION CONTROL

In compliance with Regulation 305/2011/EU of the European Parliament and of the Council of 9 March 2011 (the Construction Products Regulation or CPR), this certificate applies to the construction product:

PRODUCTS AND SYSTEMS FOR THE PROTECTION AND REPAIR OF CONCRETE STRUCTURES. DEFINITIONS, REQUIREMENTS, QUALITY CONTROL AND EVALUATION OF CONFORMITY:
- PART 2: SURFACE PROTECTION SYSTEMS FOR CONCRETE
- PART 7: REINFORCEMENT CORROSION PROTECTION

Produced by:

CORTEC CORPORATION
4119 WHITE BEAR PARKWAY
55110 ST. PAUL, NM (EE.UU.)

And produced at the manufacturing plant (s):

CHQ
4119 WHITE BEAR PARKWAY
55110 ST. PAUL, NM (EE.UU.)

This certificate attests that all provisions concerning the assessment and verification of constancy of performance described in Annex ZA of the standards

EN 1504-2:2004, EN 1504-7:2006

under system 2+ are applied and that **the factory production control fulfils all the prescribed requirements set out above.**

This certificate was first issued on 20th January 2017 and will remain valid as long as the test methods and/or factory production control requirements included in the harmonised standard, used to assess the performance of the declared characteristics, do not change, and the product, and the manufacturing conditions in the plant are not modified significantly.

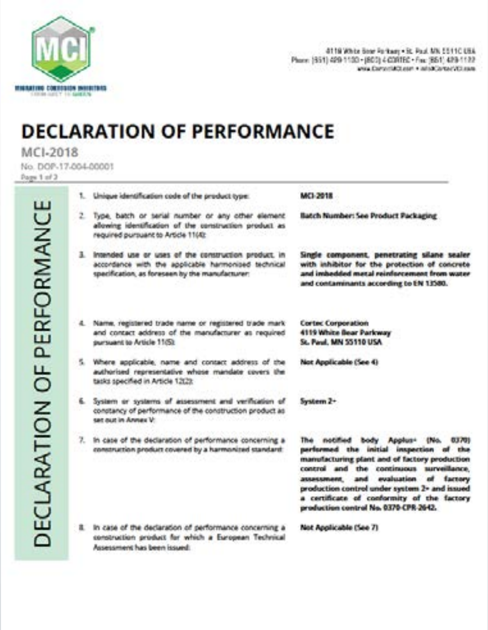
Expiration date of the certificate: 20th January 2018

Bellaterra, 20th January 2017

Applus+ LGAI Technological Center, S.A.
General Manager

Applus+ LGAI Technological Center, S.A.
Xavier Ruiz Peña
Product Conformity B.U., Managing Director

This document is not valid without its technical annex, whose number coincides with the number of certificate



MCI

4119 White Bear Parkway • St. Paul, MN 55110 USA

DECLARATION OF PERFORMANCE

MCI-2018

No. DOP-17-004-00001

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DECLARATION OF PERFORMANCE

1. Unique identification code of the product type:	**MCI-2018**
2. Type, batch or serial number or any other element allowing identification of the construction product as required pursuant to Article 11(4):	**Batch Number: See Product Packaging**
3. Intended use or uses of the construction product, in accordance with the applicable harmonised technical specification, as foreseen by the manufacturer:	**Single component, penetrating silane sealer with inhibitor for the protection of concrete and imbedded metal reinforcement from water and contaminants according to EN 13580.**
4. Name, registered trade name or registered trade mark and contact address of the manufacturer as required pursuant to Article 11(5):	**Cortec Corporation 4119 White Bear Parkway St. Paul, MN 55110 USA**
5. Where applicable, name and contact address of the authorised representative whose mandate covers the tasks specified in Article 12(2):	**Not Applicable (See 4)**
6. System or systems of assessment and verification of constancy of performance of the construction product as set out in Annex V:	**System 2+**
7. In case of the declaration of performance concerning a construction product covered by a harmonized standard:	**The notified body Applus+ (No. 0370) performed the initial inspection of the manufacturing plant and of factory production control and the continuous surveillance, assessment, and evaluation of factory production control under system 2+ and issued a certificate of conformity of the factory production control No. 0370-CPR-2642.**
8. In case of the declaration of performance concerning a construction product for which a European Technical Assessment has been issued:	**Not Applicable (See 7)**

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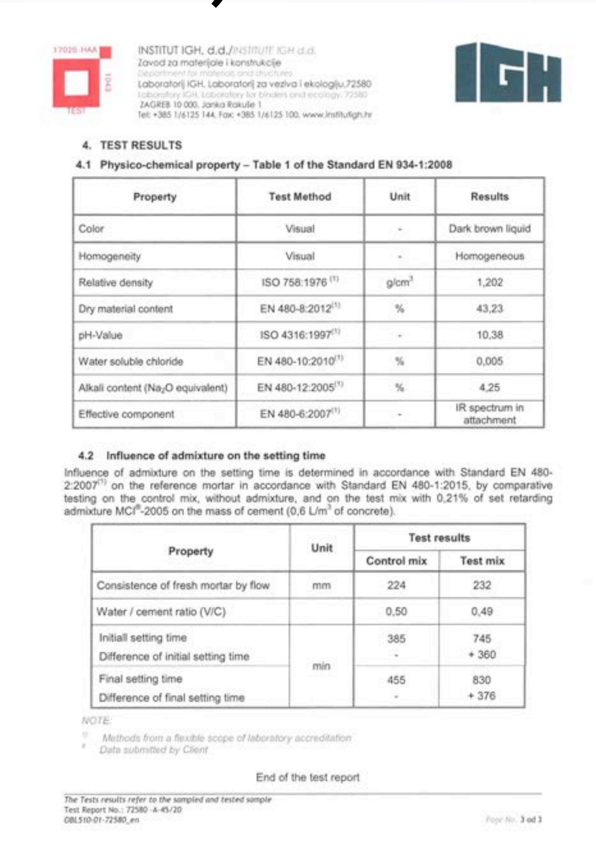
FROM GREY TO GREEN

Lack of EU Regulations - EN 934 (Admixtures)

- We certify to meet properties of specific CE/EN testing
- EN 934 – is the Harmonised European Standard – **Admixtures for concrete, mortar and grout**
  - **No test for Corrosion Inhibition**



17025-HAA
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TEST

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IGH

4. TEST RESULTS

4.1 Physico-chemical property – Table 1 of the Standard EN 934-1:2008

Property	Test Method	Unit	Results
Color	Visual	-	Dark brown liquid
Homogeneity	Visual	-	Homogeneous
Relative density	ISO 758:1976 (1)	g/cm^3	1,202
Dry material content	EN 480-8:2012(1)	%	43,23
pH-Value	ISO 4316:1997(1)	-	10,38
Water soluble chloride	EN 480-10:2010(1)	%	0,005
Alkali content (Na_2O equivalent)	EN 480-12:2005(1)	%	4,25
Effective component	EN 480-6:2007(1)	-	IR spectrum in attachment

4.2 Influence of admixture on the setting time

Influence of admixture on the setting time is determined in accordance with Standard EN 480-2:2007(1) on the reference mortar in accordance with Standard EN 480-1:2015, by comparative testing on the control mix, without admixture, and on the test mix with 0,21% of set retarding admixture MCI®-2005 on the mass of cement (0,6 L/m^3 of concrete).

Property	Unit	Test results	
		Control mix	Test mix
Consistence of fresh mortar by flow	mm	224	232
Water / cement ratio (V/C)		0,50	0,49
Initiall setting time Difference of initial setting time	min	385 -	745 + 360
Final setting time Difference of final setting time	min	455 -	830 + 376

NOTE:
(1) *Methods from a flexible scope of laboratory accreditation*
* *Data submitted by Client*

End of the test report

The Tests results refer to the sampled and tested sample
Test Report No.: 72580 -A-45/20
OBL510-01-72580_en
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MIGRATING CORROSION INHIBITORS
FROM GREY TO GREEN

Other Standards/References

- ASTM C494
- ASTM G109
- ASTM G180

- EN 934

- EN 206-1 Exposure Classifications
- EN 1504
- Concrete Society Special Reports (UK)
  - TR 18
  - TR 61

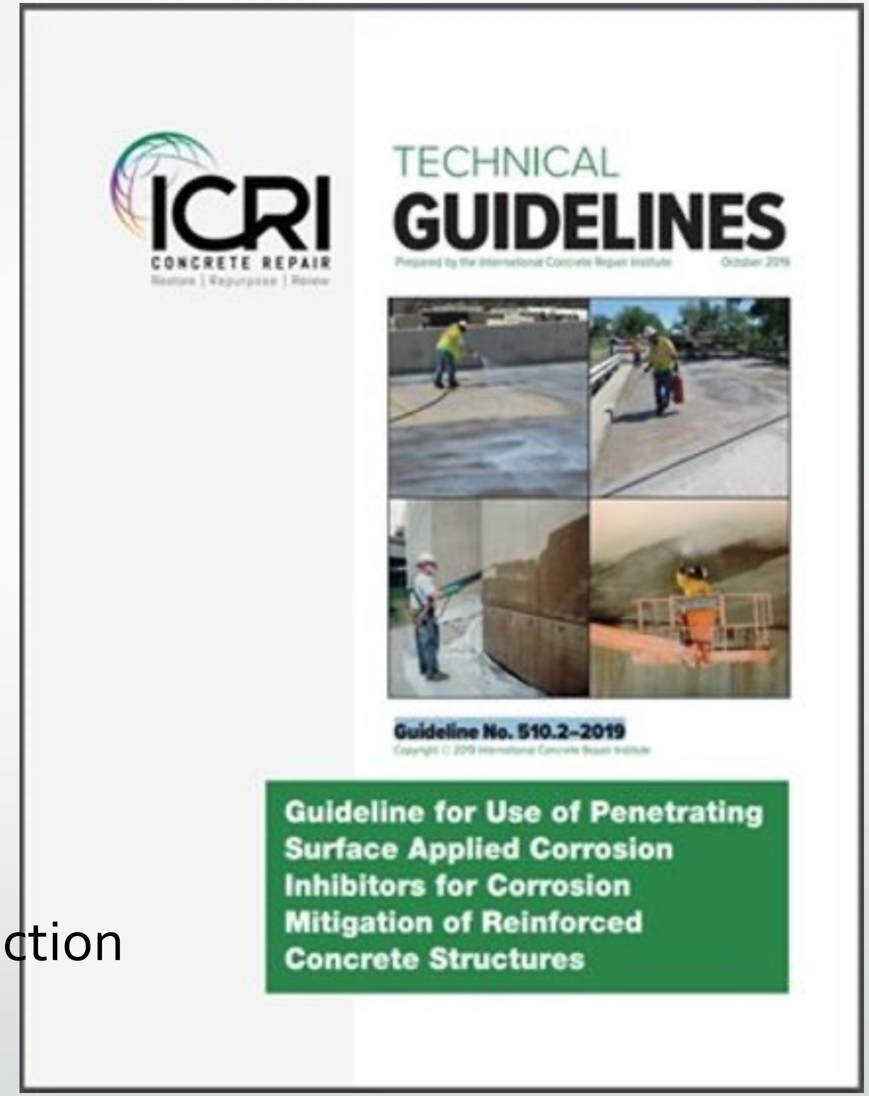
- MCI **Standard Test Methods Reference Chart**

Standard Tests for Cortec Products - corteclaboratories.com

MIGRATING CORROSION INHIBITORS
FROM GREY TO GREEN

ICRI & ACRP

- Guideline No. 510.2 - Use of Penetrating Surface Treatments for Corrosion Mitigation of Reinforced Concrete Structures
  - Published November 2019
  - Free PDF copy available to ICRI Members
- ACRP (European Association for Construction Repair, Reinforcement and Protection)
  - Preparing Guidelines for Repair of Maritime structures Corrosion Inhibitors/ CP



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FROM GREY TO GREEN

Conclusions

- Fundamental change is needed in approach in EU practice to achieve the goals of extended service life and a sustainable bridge infrastructure. Reaching these goals involves incorporating details in the design process necessary for extended service life.
- Previous studies have established the benefits of using migration corrosion inhibitors, the importance of good concrete, and the significance of the ingredients used to make the concrete.
- Concrete durability depends on many parameters and beside structural design, the attention should be directed also on the concrete mix design including corrosion protection, technology of the concrete production, building process and good-quality workmanship.
- Development of an Eurocodes, national codes, and concrete guidelines specification, with specific service life periods would be beneficial to bridge infrastructure sustainability in Europe.

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