REFURBISHMENT
TOTAL CORROSION MANAGEMENT TECHNOLOGIES

BUILDING TRUST

SIKA – YOUR PARTNER

When you have a reinforced concrete structure that is starting to deteriorate through corrosion, Sika is the ideal partner of choice. As the only manufacturer able to supply a fully comprehensive range of integrated products and systems for Total Corrosion Management, Sika can help you ensure that the right solution is selected for each specific project.

Whether your structure requires full electrochemical protection with the use of galvanic anodes or corrosion inhibitors, or you require coated or non-coated structures, Sika has the right system solutions. Through having the complete range of solutions, a fully compatible combination of materials and methods can be specified and applied to meet the needs of the owners, budgets and to provide durable long-term protection to the structures.

Everyone obviously prefers to work with a true expert, which is why Sika is the ideal partner and single source supplier of choice for owners, specifiers and contractors. Backed by decades of experience and state-of-the-art expertise, Sika provides the right guidance to ensure the success of your project - be it repair or protection to buildings, bridges or marine structures. Sika has developed an unrivalled knowledge and expertise of building refurbishment and concrete repairs - identifying the root cause of problems, which means time and money saved for you. Put your building trust in Sika, you can be confident of a successful working partnership and refurbishment projects that are fit for many years ahead.

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COST OF CORROSION

The cost of corrosion is now well documented by various different organizations including NACE in the USA and the World Corrosion Organization. It is estimated that a quarter of the world's annual steel production is destroyed by corrosion every year. This is equivalent to 150 million tons per year (equivalent to 5 tons/second). As a result the W.C.O. estimate the cost of corrosion as being between 3.1 to 3.5% of a nation's GDP annually (between € 1.3 and 1.4 trillion).

Year	% of GDP	Source
1950	2,1%	US study
1970	3,5%	UK study
1974	1,2%	Japan study
1975	4,5%	US study
1998	3.1%	US study
2013	3,1%	US study

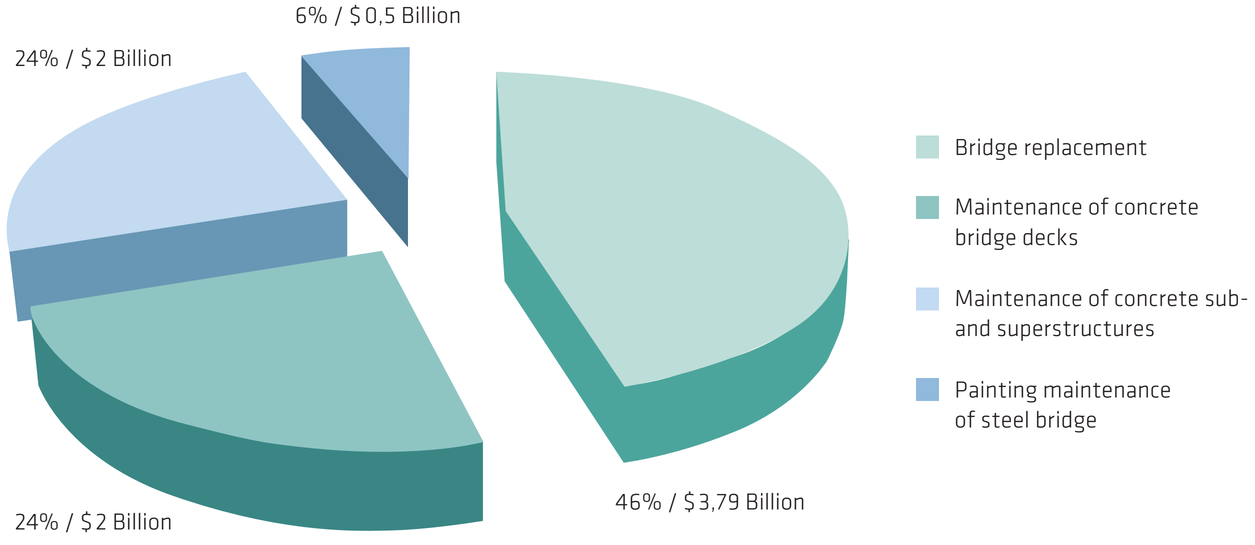
EVERY SECOND 5 TONS OF STEEL ARE DESTROYED BY CORROSION.

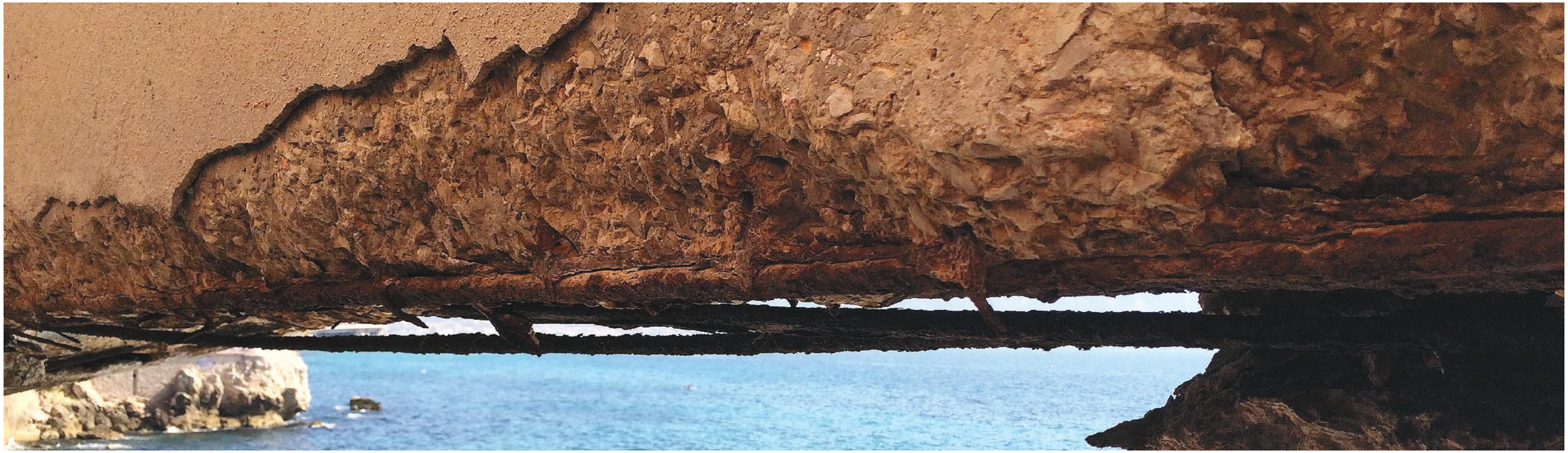
A study from COMACAC (Maroc) estimated the cost of corrosion at 5% of GNP and in France this is estimated to cost ~1 € per day per inhabitant of the country (~€ 23 x 103 Million per year)

Sources:
World Corrosion Organization, NACE, COMACAC, IMIST-CNRST©-2011-2015

In the USA, a NACE report in 2002 provided detailed information about these costs in different sectors such as infrastructures, drinking water and sewer systems etc. Highways and bridges alone cost a staggering $ 8,3 Billion per year

Corrosion Cost of Highway Bridges – Total: $ 8.29 Billion per year





IMPACTED AREAS

Bridges

Car Parks

Steel Framed Mansory Buildings

Concrete Buildings

Marine Structures

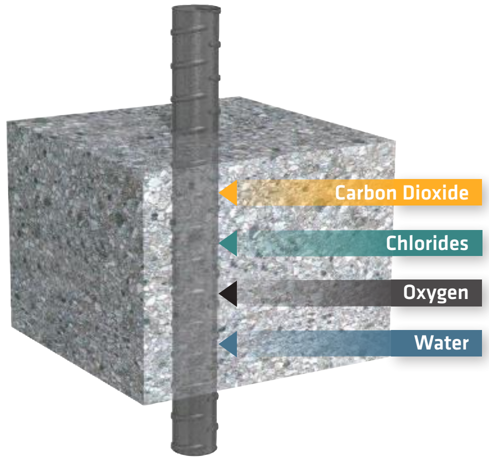
Silos

CORROSION IN REINFORCED CONCRETE STRUCTURES

AGGRESSIVE INFLUENCES ON REINFORCED CONCRETE

In reinforced concrete the steel is normally protected against corrosion by the passivating alkalinity of the cement matrix. Due to the ingress of aggressive environmental influences the steel can corrode. Three conditions must exist for reinforcing steel to corrode:

- The passivation of the steel must have been destroyed by chlorides or by carbonation
- The presence of moisture as an electrolyte
- The presence of oxygen

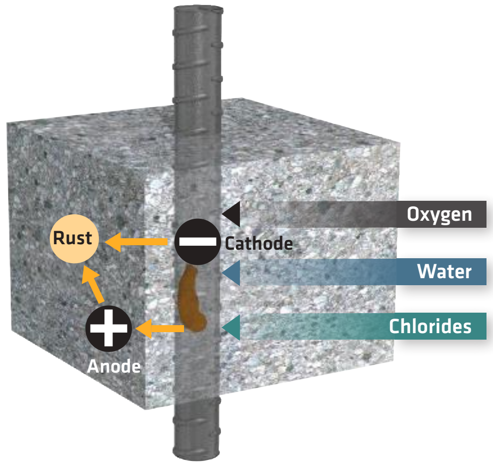


CARBONATION
Carbon dioxide ingress causes carbonation of the cement matrix progressively reducing the passivating alkaline protection of the steel reinforcement to a level where corrosion can occur.

CHLORIDE ATTACK
Chloride ions from deicing salts or marine exposure are carried into the concrete in solution in water. At the steel surface, even in alkaline concrete, they attack and break down the passivating layer and then accelerate the steel corrosion process.

THE EFFECT OF THE AGGRESSIVE INFLUENCES

CHLORIDES/CARBONATION
As soon as sufficient chloride ions (from deicing salts or marine exposure) or the carbonation front have reached the steel surface, the passive layer is destroyed and corrosion accelerates.



CONTACT WITH WATER (MOISTURE)
The original neutral iron will receive a negative charge as the positively loaded ions have the tendency to dissolve. The water film around the metal turns positive.

CONTACT WITH OXYGEN
The oxygen takes on the negative charge of the iron ions which have gone into solution. The result is iron hydroxide, the first stage of rust.

CORROSION INHIBITOR ADMIXTURE

Concrete is a marvelous building material, not least because in combination with reinforcing steel it exhibits tremendous load-bearing capacity. This combination of steel and concrete has the advantage that under normal conditions, the high pH value of concrete creates a passivating layer of iron hydroxides on the steel surface, which protects it from corrosion. However, steel can be compromised in its durability and performance by the presence of moisture and salt.


Damage to concrete structure due to insufficient concrete cover and low concrete quality.

Chlorides are displaced at the steel surface by Sika® FerroGard®, which forms a protective film that moves the corrosion potential and reduces the current densities to a very low level. Standard design and construction practice ensures that the corrosion of steel reinforcements is limited. This includes observing minimum concrete quality (w/c-ratio, cement content, minimum strength) and maintaining minimum concrete cover over the steel bars. However, in many cases, especially in environments with high levels of chlorides (de-icing salts, seawater or even contaminated concrete mix components), these basic protection procedures can prove insufficient.

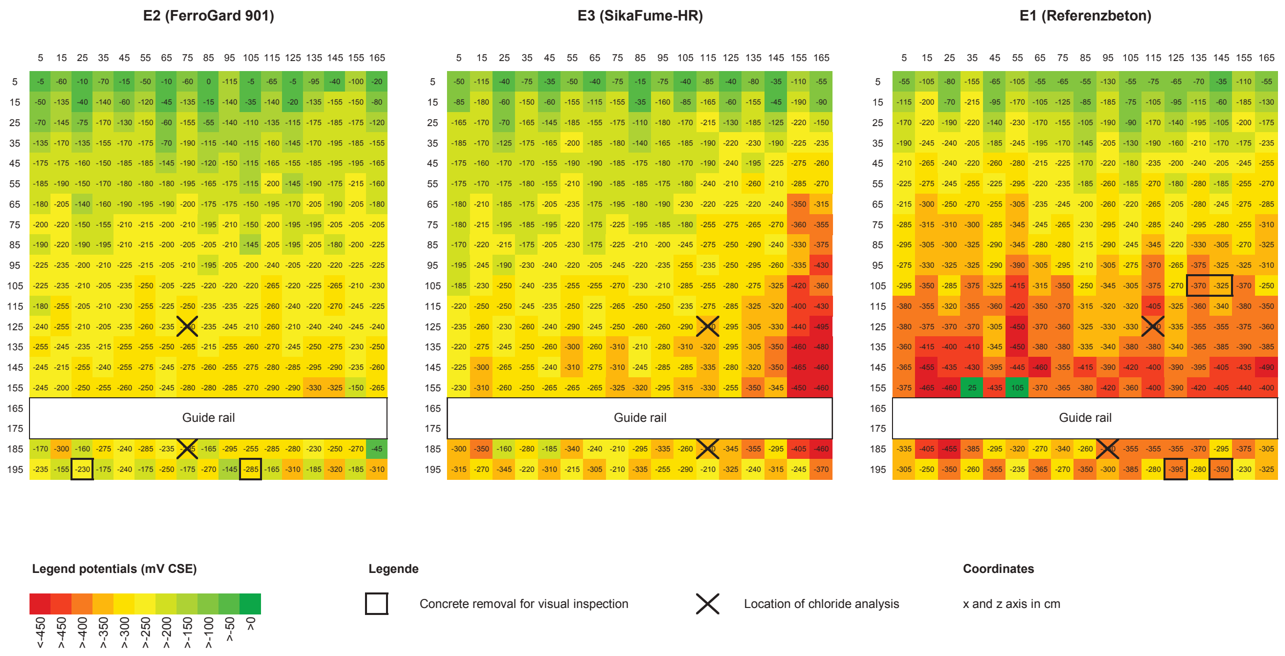
Concrete mix design advice and recommended measures:

Components	Description	Example formula	
Aggregates	Any quality aggregates possible	All aggregate sizes are possible	
Cement	Any cement meeting local standards	Target cement paste volume as low as possible for the respective placing method	
Powder additives	Fly ash, ground granulated blast furnace slag, silica fume, natural pozzolanes		
Water content	Fresh water and recycling water with requirements regarding fines content	w/c-ratio according to standards with regard to exposure class	< 0.46
Concrete admixtures	Supperplasticizer The dependent on placement and early strength requirements Corrosion inhibitor	Sika® ViscoCrete® SikaPLast® Sikament® Sika® FerroGard®-901 Sika® CNI	0.60 – 1.50% 10 – 12 kg/m³ 13 – 40 kg/m³
Installation requirements and curing	Curing compound Curing that starts as early as possible and is maintained for a sufficient period of time has significant influence on plastic and drying shrinkage	Careful installation and compaction. Subsequent curing to ensure high quality (compactness) of surfaces Sika® Antisol®	

In order to prevent corrosion or delay its start and thereby extend the life of a structure, four additional steps can be taken to protect reinforcing steel from corrosion:

- increase the concrete quality
- increase the concrete cover
- utilize corrosion inhibitors
- apply protective surface treatments / coatings

RESULTS: POTENTIAL MEASUREMENTS 2013



18+ YEARS OF FIELD EXPERIENCE – Sika® FerroGard®-901

Long-term, well documented field experience with organic corrosion-inhibiting admixtures for reinforced concrete is scarce. Sika contributes to closing this gap of knowledge by reporting on 18 years of field performance for a proprietary inhibitor formulation based on alkanolamines (Sika® FerroGard®-901). Sika launched the Sika® FerroGard® corrosion inhibitor in 1994. It was obvious that it would be rather difficult to convince owners and specifiers of the efficacy of a product that would show its performance most clearly in 20 years or even later. Therefore in order to ultimately show this long-term performance effect Sika started a long-term test in the Swiss mountains in 1995.

Reinforced concrete elements were exposed to chloride-bearing splash water on a road in the Swiss Alps. Periodically, the chloride profiles were measured and the specimens were monitored by galvanic current measurement, potential mapping, and electrical concrete resistance measurement. After 18 years, additional electrochemical measurements were taken on-site and selected zones of the reinforcement steel were visually inspected. Whilst in the untreated reference concrete, corrosion initiated after approx. 8 – 9 years at a cover depth of 15 mm (a concrete cover of only 15 mm had been chosen deliberately, in order to have meaningful results within a reasonable time frame), the reinforcing steel in the concrete with Sika® FerroGard® corrosion inhibitor was still essentially free from corrosion (at identical cover depths) after 18 years. Thus, under the realistic exposure conditions of this long-term field test, the corrosion inhibitor increased the time to initiation of chloride-induced reinforcing steel corrosion by a factor of approximately 2.

REPAIR MORTARS

When spalling occurs, defects are generally now repaired using quality controlled, pre-batched repair mortars.
In Europe, these repair materials should be in accordance with EN 1504-9 Principle 3 (CR) Concrete Restoration and comply with EN 1504-3.
Different application techniques can be used depending on the extent and location of the damage, including hand-placed, poured with formwork or machine spray applied (methods 3.1, 3.2 & 3.3 of EN 1504-9 respectively.

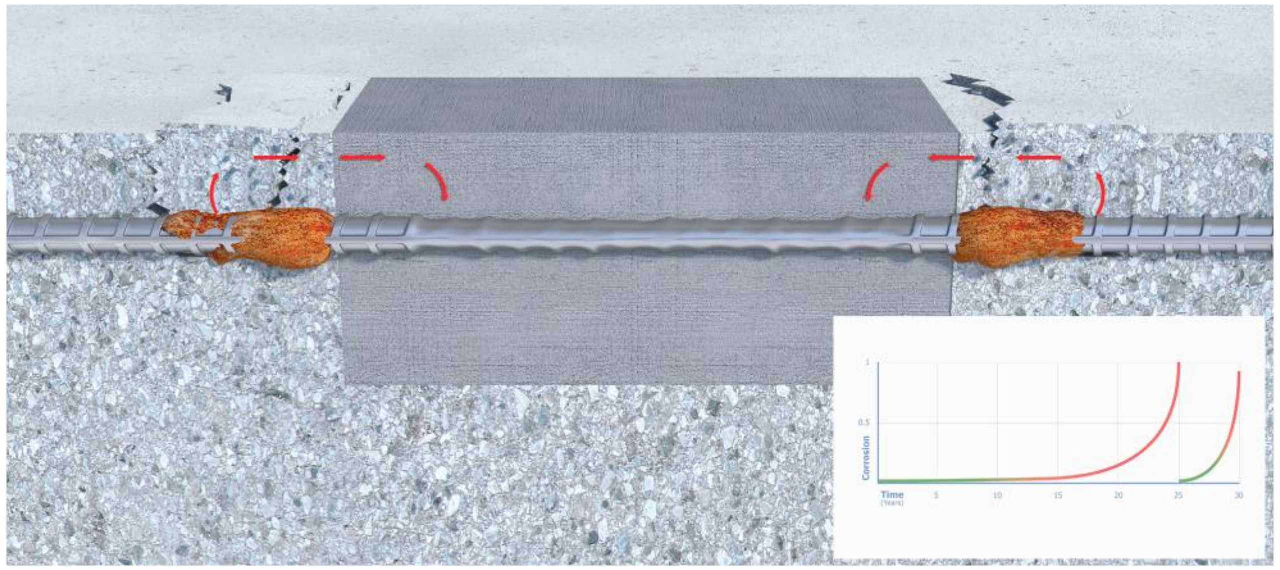

Damaged concrete structure


Sprayed mortar


Hand applied mortar


Repair work completed

INCIPIENT ANODE CORROSIONS



When repair mortars are used to re-profile areas which have spalled due to corrosion induced by chlorides, the previously anodic zone is turned cathodic due to the high alkalinity of the fresh mortar.
The previous cathodic zone is therefore now turned anodic and as chlorides and moisture are already present, if no other means of protection / prevention is provided, corrosion will be induced in the surrounding area of the repair at a fast rate. This phenomenon is known as incipient anode corrosion, or the 'halo effect'.
This is one of the major causes of premature failures of concrete repairs in chloride environments.
A paper presented at the CONREPNET conference in Cape Town, South Africa in 2008 showed that 50% of such repairs exhibit signs of failure within the first 5 years after the repair work was carried out.

MULTI-FUNCTIONAL CORROSION INHIBITORS

SIKA OFFERS A FULL RANGE OF SYSTEMS REQUIRED FOR THE TECHNICAL CORRECT REPAIR AND PRORECTION OF CONCRETE TO MEET EN 1504. From protection against ingress to control of anodic areas, the BS 11 principle allows engineers to specify the appropriate solution for any situation.

Sika® FerroGard®-903 Plus is:

- a unique blend of non toxic, organic corrosion inhibitor based on amino alcohol and salts of amino alcohol technology, designed for use as an impregnation on hardened reinforced concrete.
- a multifunctional inhibitor which controls the cathodic and anodic reactions. This dual action effect significantly retards both the onset and the rate of corrosion and increases the time to future maintenance. Sika® FerroGard®-903 Plus is normally applied as part of a corrosion management strategy.
- compatible and a component of all the Sika concrete repair and protection systems.

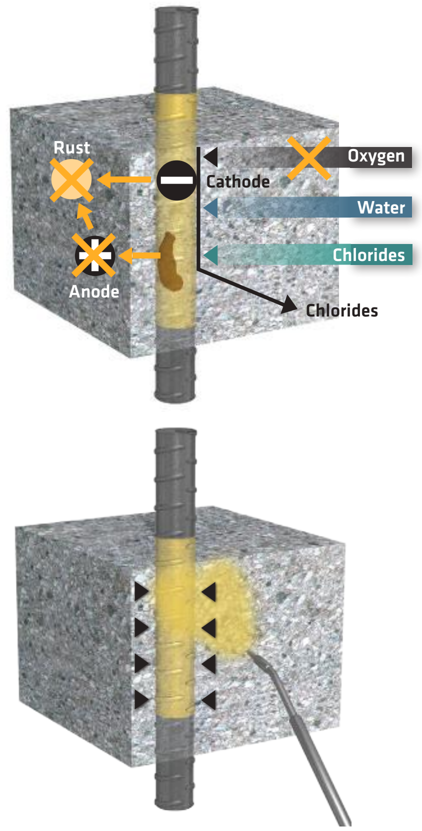
THE PERFORMANCE OF Sika® FerroGard®-903 Plus

PROTECTIVE LAYER
Sika® FerroGard®-903 Plus forms an adsorbed protective film on the reinforcement. The process of forming this protective film takes place even in carbonated concrete and even with the presence of chlorides in the concrete.

DELAY OF THE CORROSION PROCESS

- The dissolution of the iron in contact with water will be reduced thanks to this passivating protective film
- This film is also a barrier to the reduction of oxygen which will be prevented

APPLICATION
Sika® FerroGard®-903 Plus is applied as an impregnation by spray, roller or brush onto the surface of the concrete. The corrosion inhibitor penetrates into the concrete and protects the reinforcement by forming a protective film on the steel surface. Through this the onset of corrosion is delayed and the rate of corrosion reduced.

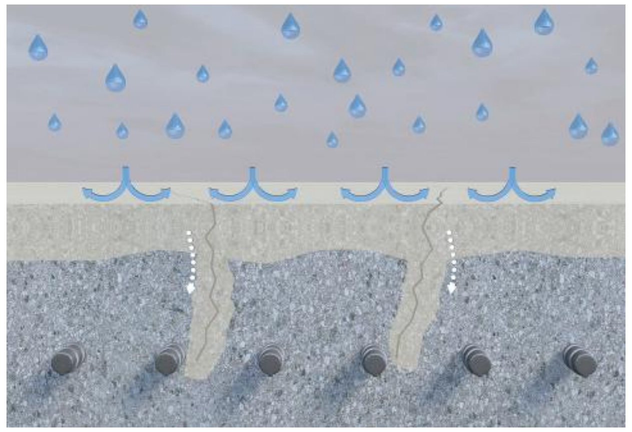


SILANE BASED HYDROPHOBIC IMPREGNATION

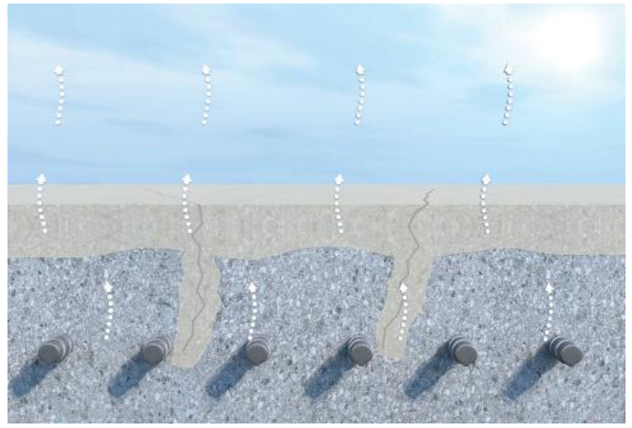
ONE OF THE METHODS RECOMMENDED BY EN 1504-9 to mitigate corrosion is to increase the resistivity of the concrete surrounding the reinforcing steel bars. If the moisture content falls below a certain level, even in chloride contaminated or carbonated concrete, corrosion is significantly reduced.

Hydrophobic impregnation treatments with silane based materials such as Sikagard®-705 L or Sikagard®-706 Thixo, will prevent further ingress of water into the treated concrete, whilst still allowing moisture in the concrete to escape as water vapor, thereby resulting in a dryer environment around the steel reinforcement.
Another important feature of these silane based products is their ability to block the ingress of other contaminants such as chlorides dissolved in water.
These products can penetrate deeply through the concrete surface making their protection effective even in the presence of cracks. Numerous independent tests and evaluations have been performed to confirm the above.

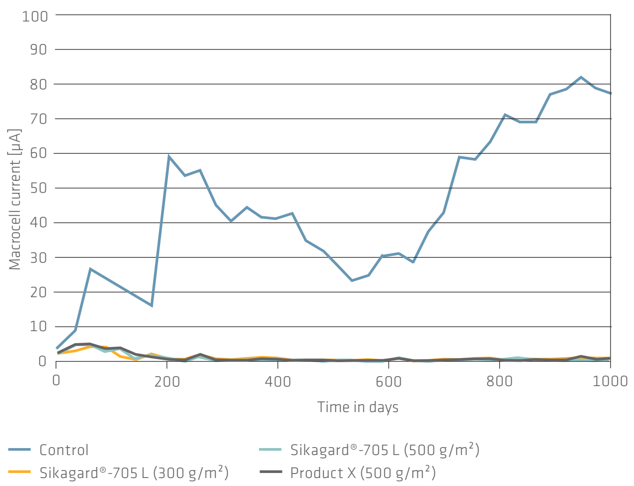
Wetting period
no water / low vapor absorption



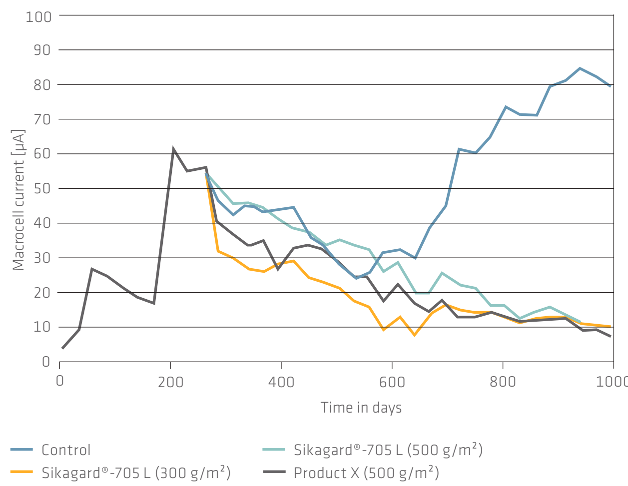
Drying period
high vapor evaporation



Average macrocell current
Silane applied **after** cracking and **before** corrosion initiation



Average macrocell current
Silane applied **after** cracking and **after** corrosion initiation



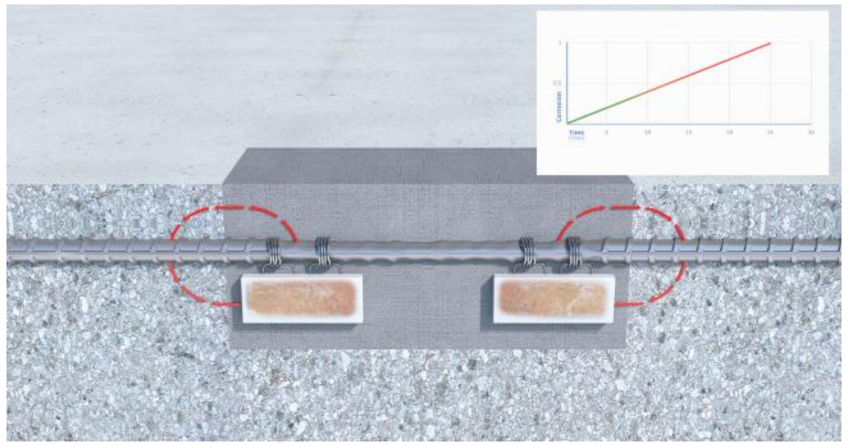
GALVANIC ANODES

TO CONTROL CORROSION IN SOUND BUT CONTAMINATED CONCRETE, galvanic anodes can be inserted into concrete that is not yet corroding.

As zinc and its alloys are less noble than iron and steel, they will corrode preferentially when moisture and contaminants are present near the steel reinforcing bars, thereby putting the steel in cathodic mode and hence preventing steel corrosion from developing.
Sika® FerroGard®- Patch CC anodes are placed directly in the reinforced concrete to be protected and work in galvanic mode. Sika® FerroGard® anodes are placed throughout large areas of reinforced concrete to provide protection and control corrosion. In many situations, these anodes can be an attractive alternative to impressed current cathode protection system.

TO PREVENT INCIPIENT ANODE CORROSION (also known as the 'halo' effect), galvanic anodes can be inserted in the periphery of the areas that are patch repaired.

When the galvanic anodes are placed around the repair areas and incipient anodes are triggered, the galvanic anodes will corrode in preference to the reinforcing steel; thus preventing premature failure of the repair and extending the life of the structure. Sika® FerroGard®-650, -655 or -670, or Sika® FerroGard® Reba are placed within the repair areas, whilst Sika® FerroGard® Patch anodes are inserted in the sound parent concrete around the periphery of the areas to be repaired. Hence by using Sika® FerroGard® Patch, a protective current is delivered directly to the steel outside of the patch repair and which is at greater risk of corrosion, as opposed to the cleaned steel within the repair zone.



For both incipient anode mitigation and corrosion control, Sika® FerroGard® anodes are available with different levels of zinc content, in order to cater for the required service-life extension of the structure.

PROTECTIVE COATINGS

DEPENDENT ON THE ROOT CAUSE(S) OF CORROSION (e.g. carbonation or chloride induced corrosion), protective coatings can be used as stand-alone system, or combined with surface applied corrosion inhibitors and/or hydrophobic impregnation to provide protection to concrete structures.

To allow the concrete to dry out, the protective coatings must allow the residual moisture in the structure to escape as water vapour.
For these applications 1-component water or solvent based protective coatings are generally used. However, in some situations it may be preferable to entrap the moisture, but prevent the future ingress of chlorides and other aggressive contaminants, plus to prevent oxygen migration as well. In these cases, impermeable high build epoxy resin based 2-component coatings are usually the preferred choice.

The Arenc silos in the port of Marseille in France, were refurbished in 2008 and the reinforced concrete facades were protected with a corrosion inhibitor and cement based protective coating (Sika® FerroGard®-903 and SikaTop® Seal-107 respectively).

The Saldahan jetty in South Africa is a typical reference for the use of a combined system to protect the reinforced concrete structure against future corrosion. For this complex and demanding project a surface applied corrosion inhibitor was applied, followed by a hydrophobic impregnation and then an elastic protective coating (Sika® Ferro-Gard®-903, Sikagard®-706 Thixo and Sikagard®-550 W Elastic respectively.

TOTAL CORROSION MANAGEMENT – SELECTION GUIDE

REPAIR MORTARS

	Application Parameters					Usage				
	Corrosion Protection	Increase Cover	Patch Repair	Pourable	Spray Repair	Bridges	Car Parks	Buildings	Tunnels	Marine Structures
SikaTop® Armatec® 110 EpoCem®	XXX	XXX	N/A	N/A	XXX	XXX	XX	X	XXX	XXX
Sika MonoTop®-910 N	XXX	N/A	N/A	N/A	XXX	XX	XX	XXX	X	X
Sika MonoTop®-412 NFG	XXXX	N/A	XXX	N/A	XXXX	XXX	XXX	XXX	XXX	XXX
Sika MonoTop®-732 N	XXXX	N/A	XXXX	N/A	XXX	XXX	XXX	XXX	XXX	XXX
Sika MonoTop®-352 NFG	XXXX	N/A	XXXX	N/A	XXX	XXXX	XXX	XXX	XXX	XXX
Sika MonoTop®-436 N	XXXX	N/A	XXXX	XXXX	N/A	XXXX	XXX	XXX	XXX	XXX
Sika MonoTop®-Gunite GP	XXXX	N/A	XXXX	N/A	XXXX	XXX	XXXX	XXX	XXX	XXX
Sika MonoTop®-612N	N/A	N/A	XXXX	N/A	N/A	N/A	N/A	N/A	N/A	N/A

PROTECTIVE COATINGS

	Aesthetic Parameters			Performance Parameters			Application Parameters			Usage				
	Color Retention*	UV Resistance*	Dirt pick up Resistance	Crack Bridging	Long Term Performance	Mechanical Cleaning Resistance	VOC	Hand Application	Machine Application	Bridges	Car Parks	Buildings	Tunnels	Marine Structures
Sikagard®-550 W Elastic	XXX	XXX	XX	XXX	XXX	–	XXXX	XXXX	XXXX	XXXX	XXX	XXXXX	–	XX
Sikagard®-680 S BetonColor	XXX	XXXX	XXX	–	XXXX	X	–	XXXX	XXXX	XXXX	XXXX	XX	X	XX
Sikagard®-720 EpoCem®	–	XXX	X	–	XX	–	XXX	XXX	XXX	XXX	XXX	–	XXX	XX

Legend: xxxx: Best performance xxx: Very suitable xx: Suitable x: can be considered for short to medium term – : Not suitable N/A: Not applicable
Note*: Strong dense shades have lower color retention and UV resistance than lighter pastel shades – refresher coats may be applied, but at reduced intervals, to maintain the aesthetics of the structure

TOTAL CORROSION MANAGEMENT – SELECTION GUIDE

HYDROPHOBIC IMPREGNATIONS

	Aspect		Performance Parameters					Application Parameters				Usage				
	Liquid	Thixotropic	Chloride Prevention	Penetration Behavior	Durability	Corrosion Protection	Freeze-thaw Resistance	VOC	Vertical	Overhead	Horizontal	Bridges	Car Parks	Buildings	Tunnels	Marine Structures
Sikagard®-705 L	✓	N/A	XXXX	XXXX	XXXX	XXXX	XXXX	XX	XX	XX	XXXX	XXXX	XXXX	XXX	XXXX	XXXX
Sikagard®-706 Thixo		✓	XXXX	XXXX	XXXX	XXXX	XXXX	XXX	XXXX	XXXX	X	XXXX	XXXX	XXXX	XXXX	XXXX
Sikagard®-700 S	✓	N/A	X	X	X	–	–	–	X	X	XXXX	X	X	X	X	X

CORROSION INHIBITORS AND GALVANIC ANODES

	Product Types			Performance Parameters			Application Parameters			Usage				
	Galvanic Anodes	Surface Applied Corrosion Inhibitor	Concrete Admixture Corrosion Inhibitor	Corrosion Prevention and Control	Corrosion Protection Chloride content % bwc <1%	Corrosion Protection Chloride content % bwc >1%	New Construction	Incipient Anodes Mitigation	Carbonation induced Corrosion	Bridges	Car parks	Buildings	Tunnels	Marine Structures
Sika® FerroGard® Anodes*	✓	N/A	– N/A	XXXX	XXXX	XXXX	XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Sika® FerroGard®-903 Plus	N/A	✓	–	XX	XX	–	N/A	XX	XXXX	X	X	XXX	X	X
Sika® FerroGard®-901	N/A	N/A	✓	XXXX	–	N/A	XXXX	–	–	XXXX	N/A	N/A	N/A	XX

Legend: xxxx: Best performance xxx: Very suitable xx: Suitable x: can be considered for short to medium term – : Not suitable – : Not suitable N/A: Not applicable
Note*: Depending on the types of anodes used, refer to specific brochures.

EVERYDAY, EVERYWHERE

SIKA IS ON YOUR PROJECT SITE

YOU CAN RELY ON our experienced construction experts available in every phase of the construction process for valuable advice: from the initial consultation phase, through the project planning phase, the detailed design phase, application on site and finishing with quality control, completion and final handover.

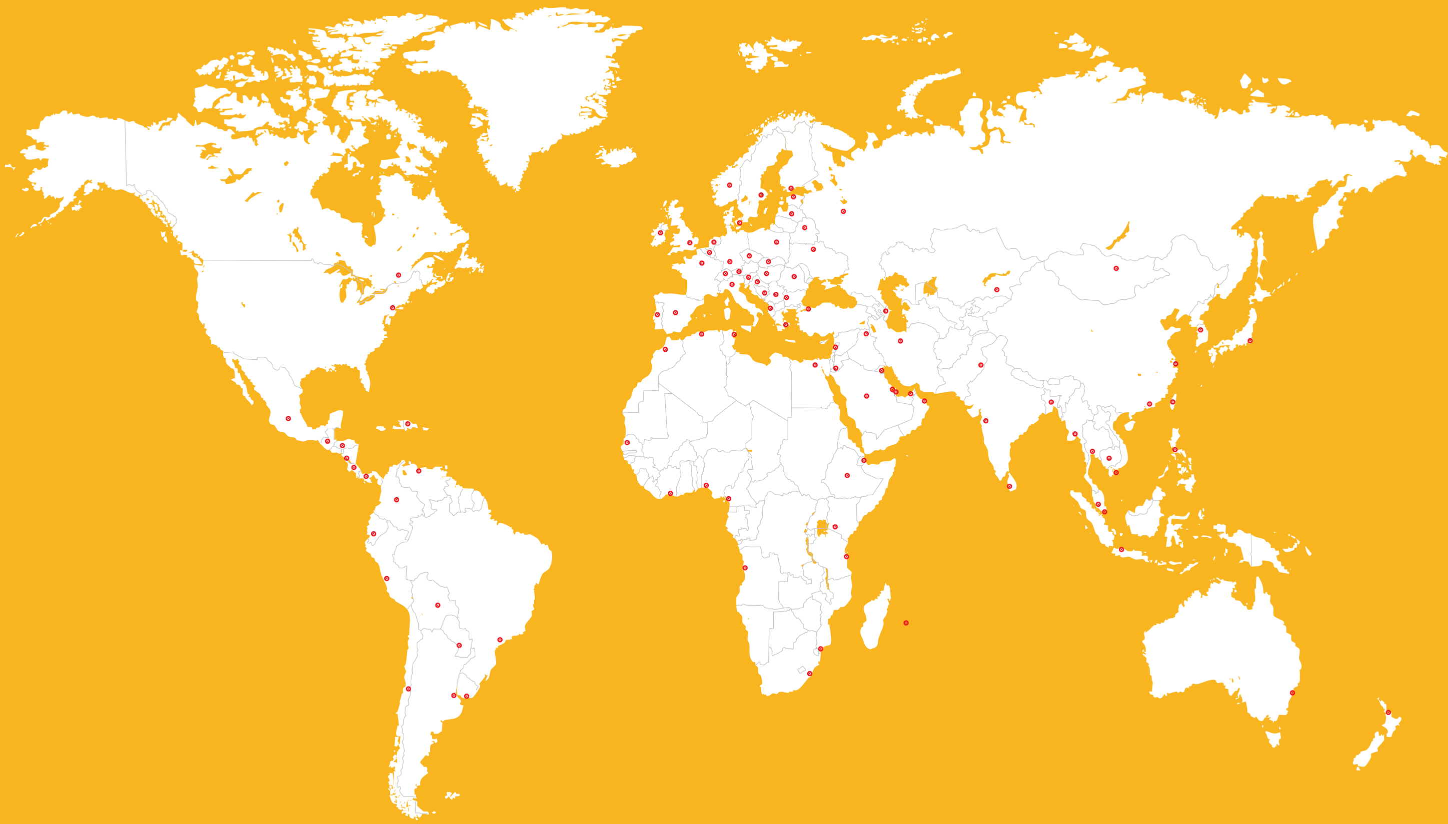
Our knowhow in projects is based on more than 100 years of onsite experiences, which enables us to provide recommendations and long-lasting solutions for any project you have, no matter how large or small. Such projects include:

CIVIL ARCHITECTURE
- Residential buildings
- Educational buildings
- Office buildings
- Transportation buildings
- Cultural buildings
- Sports facilities
- Commercial buildings
- Healthcare facilities
- Communication facilities
- Judiciary buildings
- Landscape architecture
- Mixed-use highrise buildings
- Other domestic buildings / structures

INDUSTRIAL FACILITIES
- Research / lab / test buildings
- Industrial buildings
- Other industrial structures

INFRASTRUCTURE
- Water infrastructure
- Transportation infrastructure
- Power plants
- Mining
- Other infrastructure

GLOBAL BUT LOCAL PARTNERSHIPS



WE ARE SIKA
Sika is a specialty chemicals company with a leading position in the development and production of systems and products for bonding, sealing, damping, reinforcing and protecting in the building sector and the motor vehicle industry. Sika's product lines feature concrete admixtures, mortars, sealants and adhesives, structural strengthening systems, flooring as well as roofing and waterproofing systems.

HEAD OFFICE
55 Elizabeth Street
Wetherill Park, NSW 2164
P: (02) 9725 1145
F: (02) 9725 2605

VICTORIA
33 Fiveways Boulevard
Keysborough, VIC 3173
P: (03) 9797 0600
F: (03) 9797 0666

NEW SOUTH WALES
122 Newton Road
Wetherill Park, NSW 2164
P: (02) 9725 1700
F: (02) 9756 5001

SOUTH AUSTRALIA
28 Kenworth Road
Gepps Cross, SA 5094
P: (08) 8162 9055
F: (08) 8162 9009

QUEENSLAND
30 Parker Court
Pinkenba, QLD 4008
P: (07) 3633 9222
F: (07) 3633 9200

SOUTH AUSTRALIA
1-2/28 Maxwell Road
Para Hills West, SA 5096
P: (08) 8349 4955
F: (08) 8349 7061

QUEENSLAND
70 Platinum Street
Crestmead, QLD 4132
P: (07) 3489 3000
F: (07) 3489 3099

WESTERN AUSTRALIA
61 Bushland Ridge
Bibra Lake, WA 6163
P: (08) 9395 5300
F: (08) 9395 5399

sika.com.au
1300 22 33 48

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