# Cathodic Protection in Concrete: Activated Titanium anodes specifications.

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# Presentation Outlook

1. Concrete CP System components

2. Anode Systems General Requirements

3. Activated Titanium Anode Systems for Atmospherically Exposed Concrete

4. Installation procedures for Activated Titanium Anode Systems

# CP System Components (EN 12696)

- Anode System intended to distribute the CP current to the surfaces of the embedded steel to be protected

- ICCP systems:

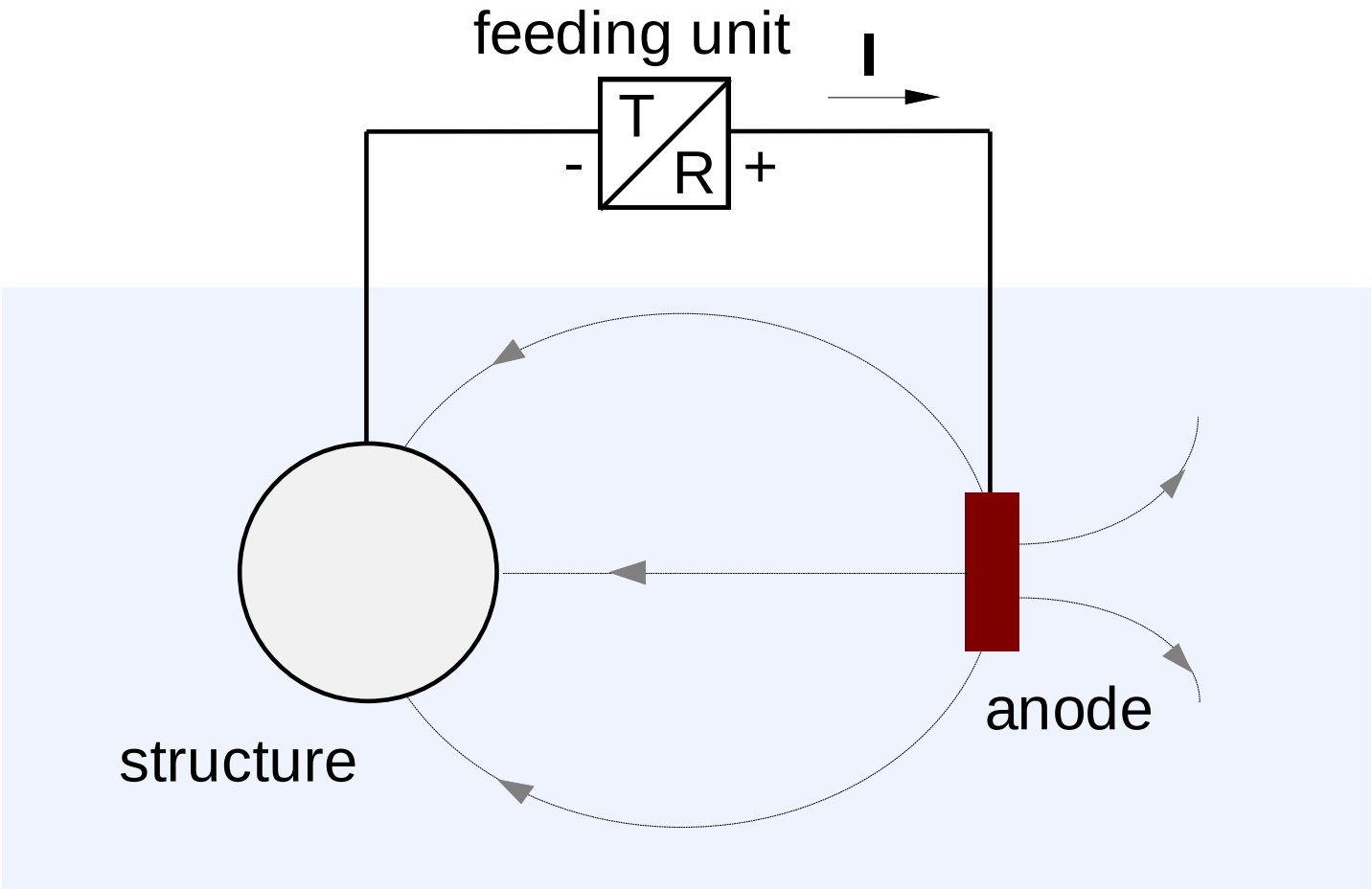
  - d.c. power supply

  - **positive** d.c. cables between power supply and **anodes**

  - negative d.c. cables between the d.c. power and the steel

- Monitoring system ( reference electrodes and other sensors)

# CP System Components (EN 12696)
# Impressed Current



# Anode Systems General Requirements

- The anode system shall be **capable of supplying the performance** required by the cathodic protection design. (Protection Current, Current Distribution, Max Ohmic Drop)

- The anode system's calculated or anticipated life shall be **sufficient for the design life** incorporated in to the design, with, where necessary, planned maintenance or replacement of the anode system or parts of the system at periods designated in the design

# Anode Systems General Requirements

For anodes in direct contact with concrete

the anode **current density** shall conform to the design and shall **not exceed such values** resulting in a performance reduction of either:

a) the concrete at the anode/concrete interface;

b) the anode

E.g.: Typical long term Activated Titanium anode current density: 110mA/m2

# Anode Systems for Atmospherically Exposed Concrete

A variety of anode systems have been developed, tested and demonstrated in long-term field applications to be used embedded in concrete or applied to concrete primarily (but not exclusively) in the CP of steel in atmospherically exposed concrete. The anode is **in contact with the highly alkaline concrete pore water**. In operation the anodic electrochemical reactions at the **anode/concrete interface are oxidising, producing acidity**

# Anode Systems for Atmospherically Exposed Concrete

2 categories of anodes in the standard EN12696:

Anode systems which **have been in use for a minimum of 5 years** with **extensive, generally succesful track records:**

Conductive Coating Anode Systems

**Activated Titanium Anode Systems**

New anode materials needs performance demonstrated by lab testing, trials and/or past projects: galvanic anodes, conductive asphalt overlays

# Activated Titanium Anode Systems

- These anodes are used as impressed current anodes.
- Activated Ti mesh was introduced in Italy and USA in 1985.
- Anode system has a substrate of Grade 1 ASTM B265 Titanium and an electrocatalytic coating containing oxides of Pt group metals such as iridium or ruthenium along with oxides of titanium, zirconium or tantalum.

# Activated Titanium Anode Systems

- These anodes are frequently described as MMO/Ti anodes ( Mixed Metal Oxide coated Titanium ) or DSA®. Trademarks: ELGARD® and LIDA®

- The life of the coating is determined by its composition and the amount of coating deposited on the substrate “coating loading”. Coatings are proprietary and patent protected. NACE TM 0294 – 2007.

# Activated Titanium Anode Systems

**Current density:** Limited to a long-term maximum of 110 mA/m$^2$

(Current density at the effective surface contact area between the anode and the concrete).Limiting factor is acid attack of the surrounding concrete (browning, softening generated by ARP). Current densities up to 220 mA/m$^2$ may be permitted (Short-term limit). Discrete anodes have been designed for operation at anode/mortar current densities up to 800 mA/m$^2$ **but not continuously.**

# Activated Titanium Anode Systems

**Lifetime**: from 50 years to 120 years. Other components of the CP system requires planned maintenance to reach the same life.

NACE TM 0294 – 2007 or equivalent to demonstrate compliance.

**Application technique:** embedded into new concrete structures or applied to existing structures. The titanium substrate may be in the form of an expanded mesh, a strip (solid or ribbon mesh), tubes.

**Minimum Anode/reinforcement steel distance:** 15mm to grant proper current distribution and avoid accidental shortcircuits.

# Activated Titanium Anode Systems

## Existing structures

- Surface mounted activated titanium mesh and grid anodes require cementitious overlays and the surface preparation, pre-treatment, design and application of the cementitious overlay is critical to the total performance of the system (disbondment of the overlay)
- Mesh ribbon cast into slots cut into cover concrete or discrete tubular anodes cast into mortar in drilled holes
- Strips in joints in historical buildings (masonry clad steel-framed buildings)

# Activated Titanium Anode Systems

## New structures

- Grid system with ribbon mesh anode + Titanium CD bar applied before casting concrete. Non-metallic fixings to facilitate installation on to exposed reinforcement prior to concrete placement

## Current distribution

- Titanium connectors shall be spot welded to the mesh or grid to distribute current to all component parts of the anode

# Activated Titanium Anode Systems

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# Activated Titanium Anode Systems NACE Standard TM 0294-2007

**" Testing of Embeddable Impressed Current Anodes for Use in Cathodic Protection of Atmospherically Exposed Steel – Reinforced Concrete"**

**Accelerated testing** of anodes for use in concrete to provide an indication of anode's ability to perform satisfactorily for a specific number of years. Testing **cannot be run in concrete** because high current levels result in premature failure of the concrete.

# NACE Standard TM 0294-2007

## 3 aqueuous solutions:

30 g/L of sodium chloride in distilled or deionized water

simulation of piers in SWT – Chlorine evolution

$2\ Cl^- - 2\ e^- \longrightarrow Cl_2$ (chlorine)

40 g/L of sodium hydroxide in distilled or deionized water- simulation of high pH – fresh overlays – Oxygen evolution

$2H_2O - 4\ e^- \longrightarrow O_2 + 4H^+$

Simulated pore water in sand ( tolerate cured concrete): by mass

0.20% $Ca(OH)_2$ 3.20% KCl 1.00% KOH 2.45% NaOH 93.15% distilled or deionized water.

# NACE Standard TM 0294-2007

## Test Requirements:

a) Minimum Charge Density: 38500 Ah/$m^2$ of actual surface area

Equivalent to:

40 years of operation at 110 mA/$m^2$

40*365*24*0.11 = 38544 Ah/m

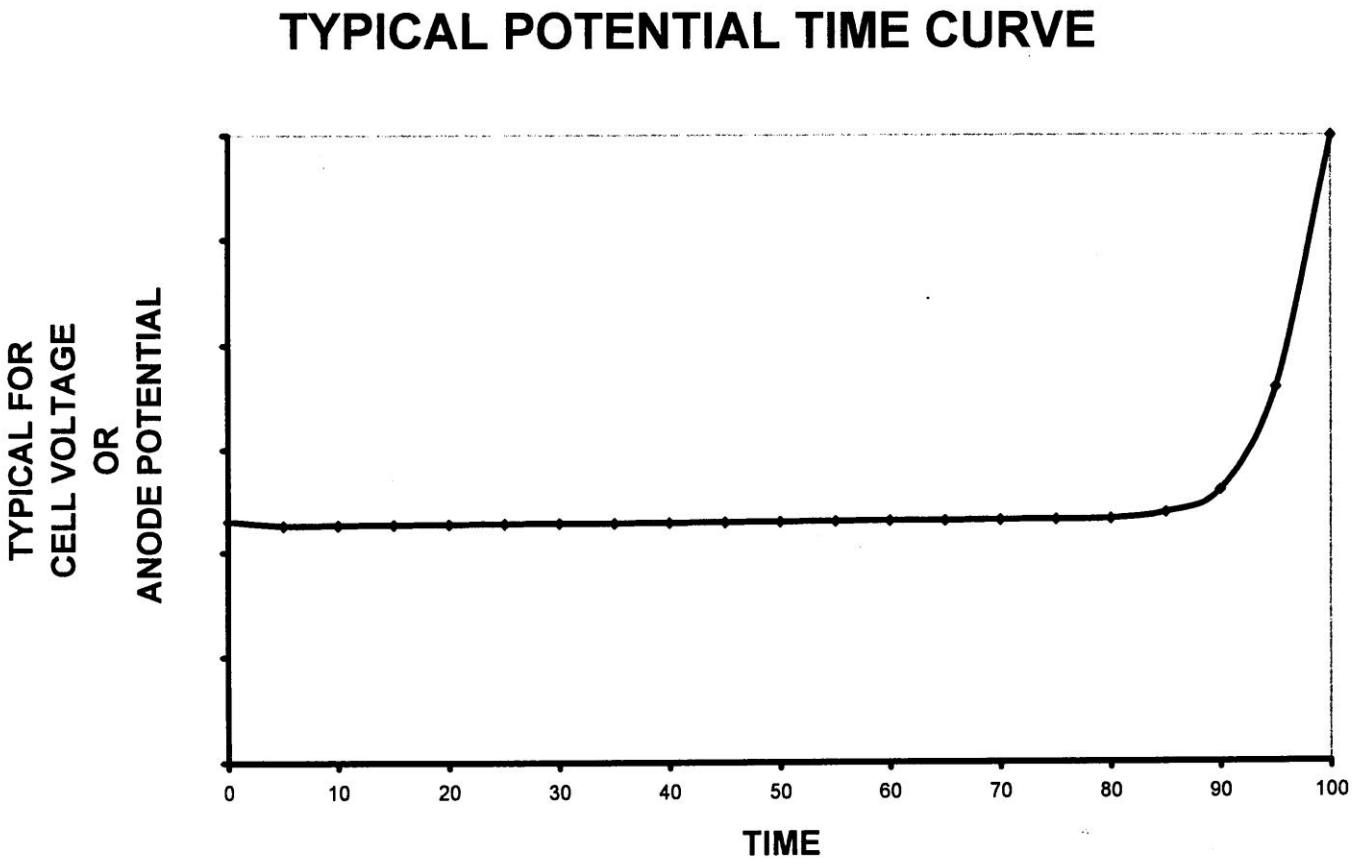
**Minimum period: 180 days**

Test may be extended to meet required Charge density. We submitted our anodes to 3 consecutive lifetests equivalent to 120 yrs.

# NACE Standard TM 0294-2007

Failure of the anode:

rapid escalation in both cell voltage and anode potential.



# Installation MMO Titanium Anodes Existing structures

**Electrical continuity check:** of steel reinforcement to avoid corrosion induced by interference. Minimum 2 locations per 100 $m^2$ . Contact cleaned to bright steel.

•d.c. reverse polarity resistance measurement technique or d.c. potential difference measurement technique.

a) Measurement between two point of the reinforcement **R< 1 Ohm**

b) Unstable readings, more than 0.5 Ohms in 15 s = discontinuity

# Installation MMO Titanium Anodes Existing structures

Potential measurement by locating a reference electrode in a fixed location measuring potential by doing the electrical connection in different point of the reinforcement grid.

**SAME POTENTIAL:** Stable, less than 1mV.

**If discontinuous steel shall be located as defined previously it shall be bonded to the continuous section reinforcement.**

# Installation MMO Titanium Anodes Existing structures

**Mechanically damaged concrete** remotion:

**Chloride contaminated concrete can remain**.

Spalled and delaminated concrete as well as cracks of width > 0.5mm shall be removed by excavation by either chipping hammers or high pressure water blasting to the depth of the reinforcing layer only.

**Surface cleaning:** The surface shall be grit blasted to remove all dust and contaminants leaving visually clean surface. After Inspection: additional reinforcement if needed, concrete reprofiling, wetting and coating.

# Installation MMO Titanium Anodes Existing structures

**Anode installation:** MMO Titanium mesh anode in rolls with a cementitious overlay (next slide).

•Anode mesh panels shall be placed according to design drawings interconnected with a CD system.

• CD on the concrete surface and anode mesh placed on top. Titanium CD bar (e.g.: 1x15mm or 0,5x10mm) is spot welded to the mesh at every mesh strand crossing.

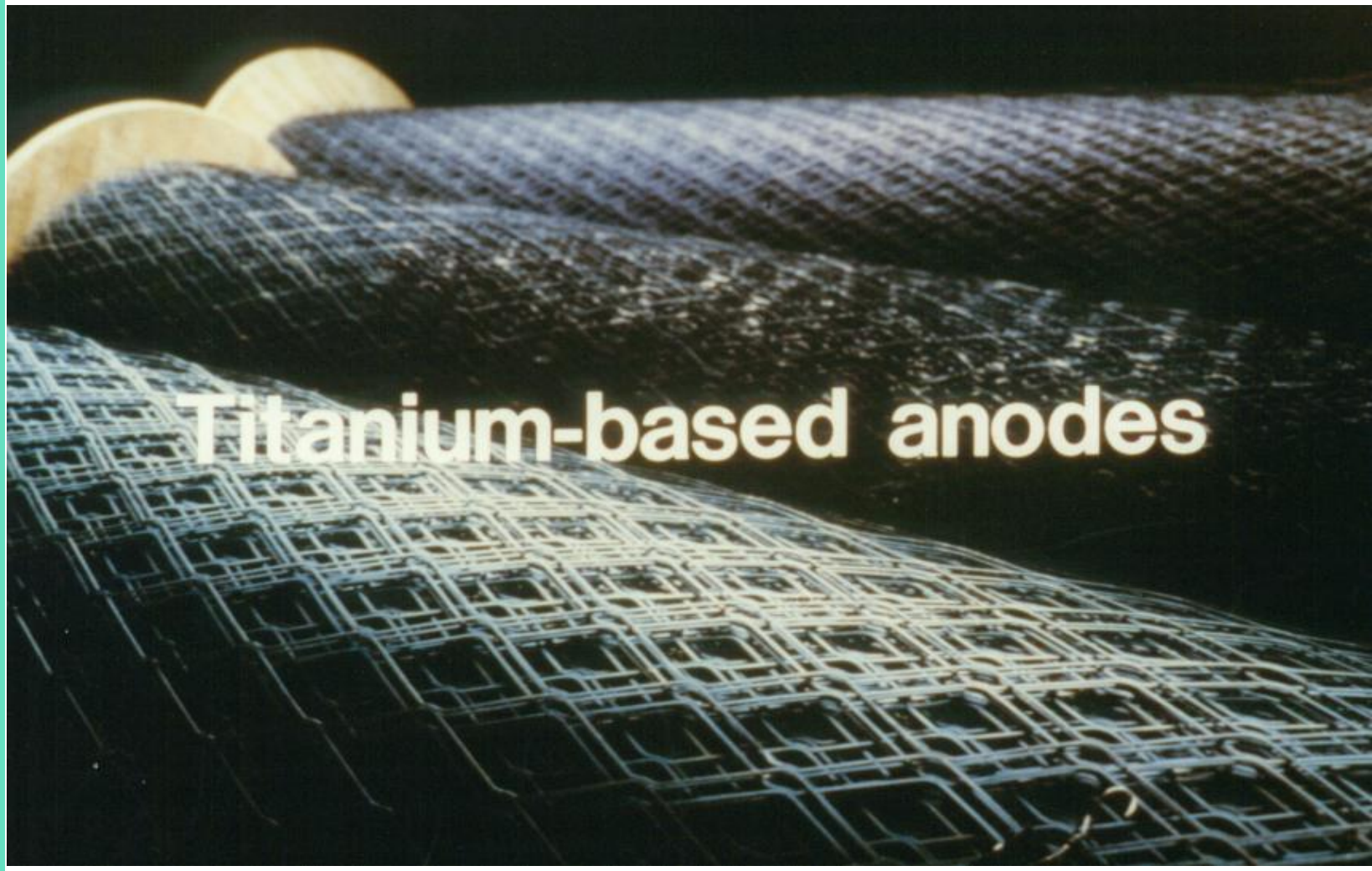
# Installation MMO Titanium Anodes Existing structures

## Anode installation:

- Max distance between adjacent anode mesh panels shall be 100mm.

- Mesh panels shall be securely fastened to the concrete surface using the anode manufacturer's approved non-metallic fasteners to ensure a tensioned installation which will not be displaced during overlay placement.

# Installation MMO Titanium Anodes Existing structures



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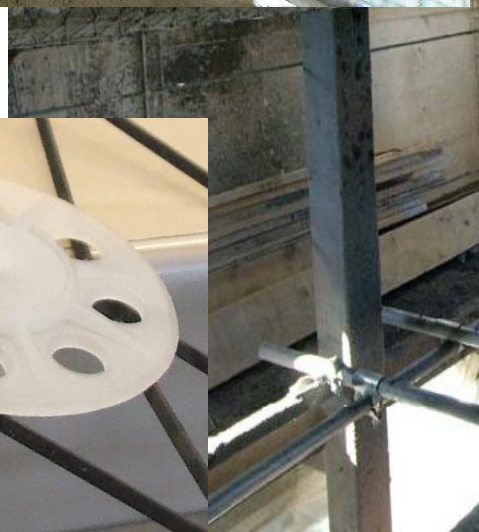

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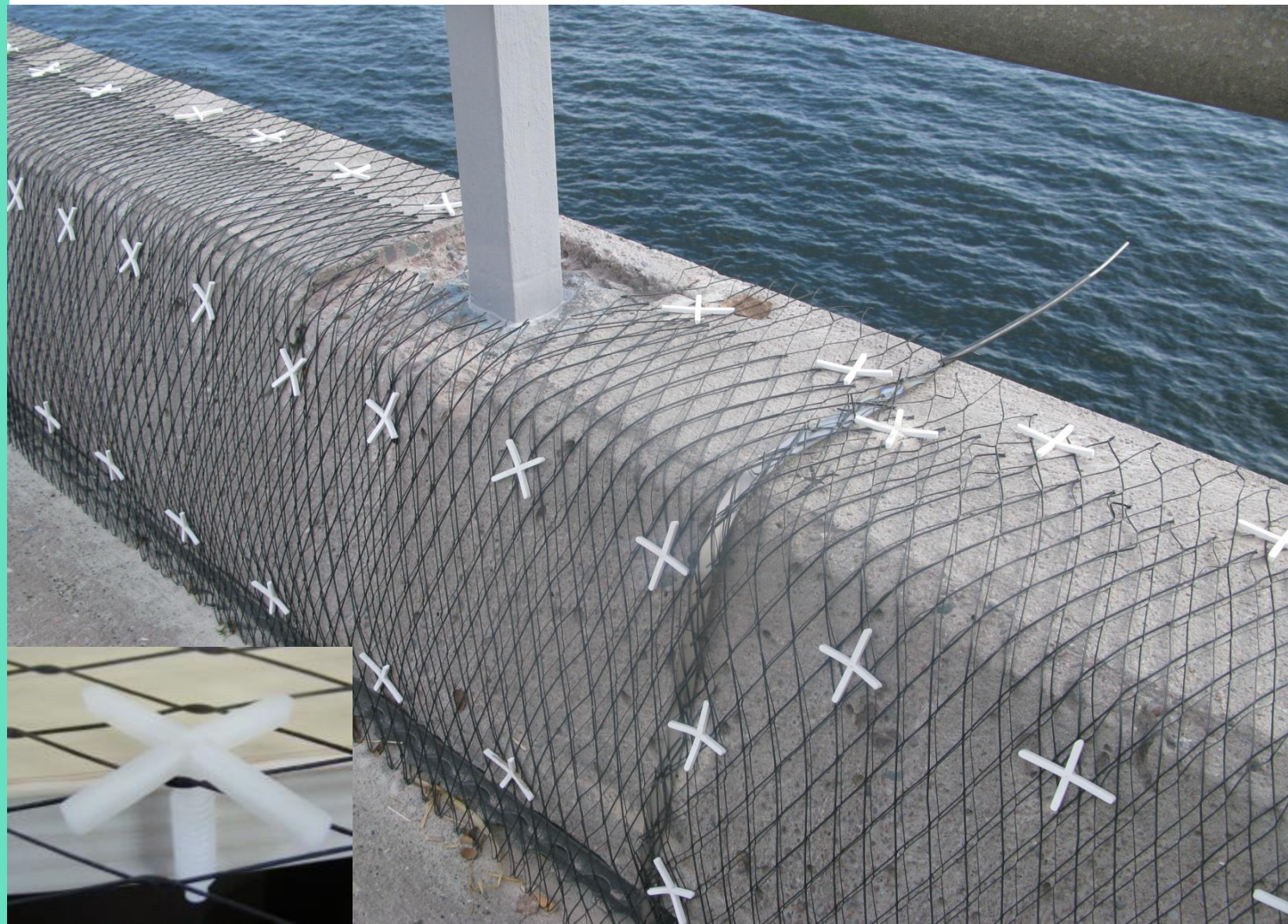

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**Positive connections:** Pre-stripped copper core of the positive cable shall be compression crimped to a 100mm long length of 3mm diameter Ti rod. The assembly encapsulated with a suitable, mecanically strong adhesive lined heat shrinked tube, which extends 50 mm either side of the crimp center.

•Metallurgical welding connection ( min of 3 welds) between Ti CD bar and Ti rod.

# Installation MMO Titanium Anodes Existing structures

**Anode overlay:** shall extend over the whole area covered by cathodic protection anodes to provide physical protection and a ionic current path between the anode material and the rebar.

MAX resistivity: 50000 Ohm-cm after 28 days of curing with potable water (shading vs. direct sunlight).

Complete Adhesion w/o delamination for 50 yrs.

# Installation MMO Titanium Anodes Existing structures

- **Horizontal deck surfaces:** poured concrete mix free from polymeric additives. Pre-wetting with potable water for 24 hours prior to application; shading or polythene sheeting may be adopted for T> 30°C. 20 min MAX between mixing and application of the overlay material. Applied in a single layer of nominal thickness as shown on the drawings.

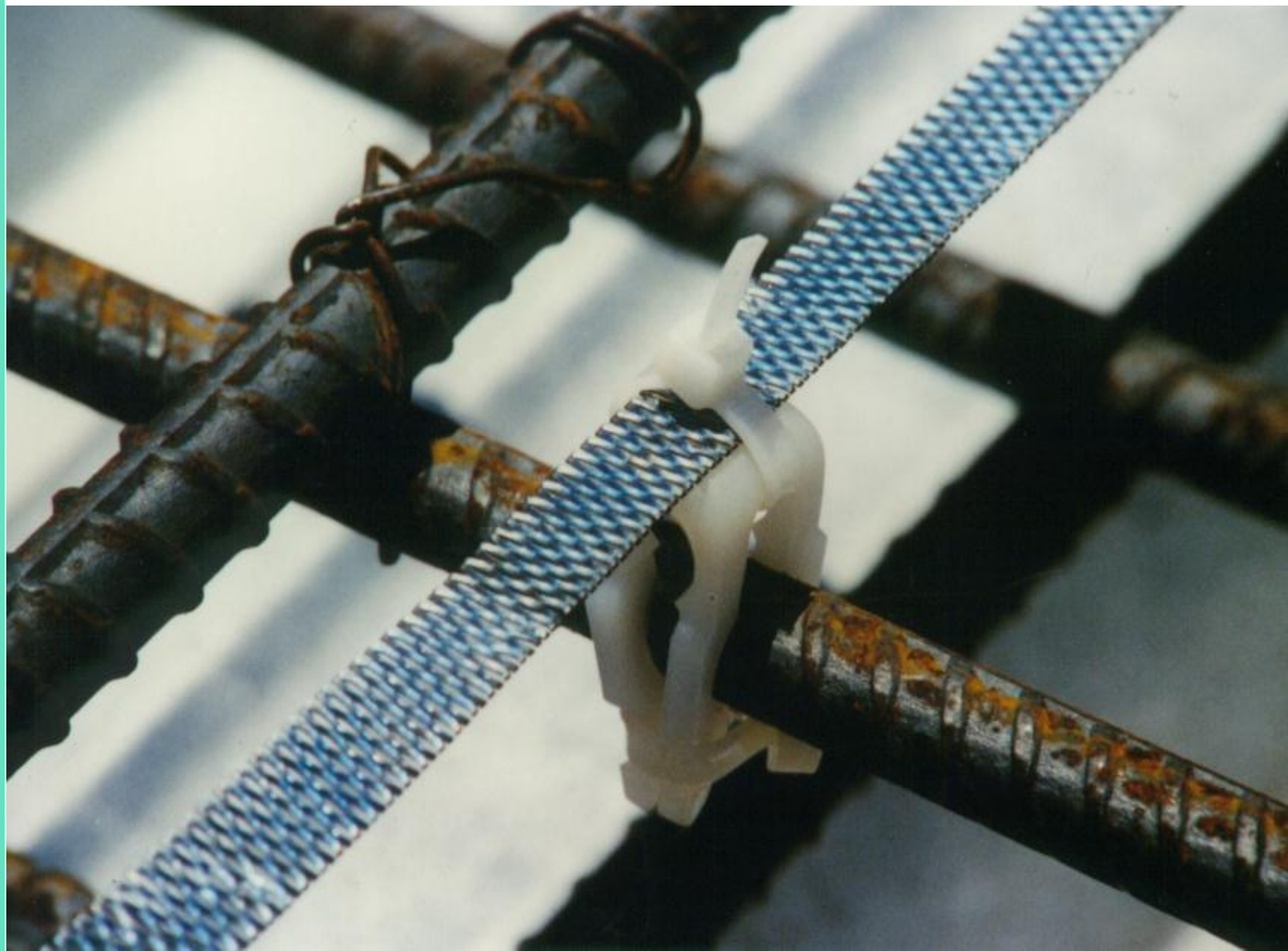
- **Vertical and overhead surfaces:** sprayed concrete applications such as shotcrete or gunite or proprietary pre-packaged material as specified.

# Installation MMO Titanium Anodes Cprev of new structures

- **Electrical continuity check:** Before installation it's mandatory to check electrical continuity of steel reinforcement that has to behave as an homogeneous cathode. Minimum 2 locations per 100 $m^2$.

- **Anode installation:** MMO Titanium ribbon mesh anode in rolls with Titanium CD bar. Spacing between the anode and reinforcing steel in structure shall be a minimum of 10mm to avoid shortcircuit up to 15mm to have proper protection current distribution.

# Installation MMO Titanium Anodes Cprev of new structures



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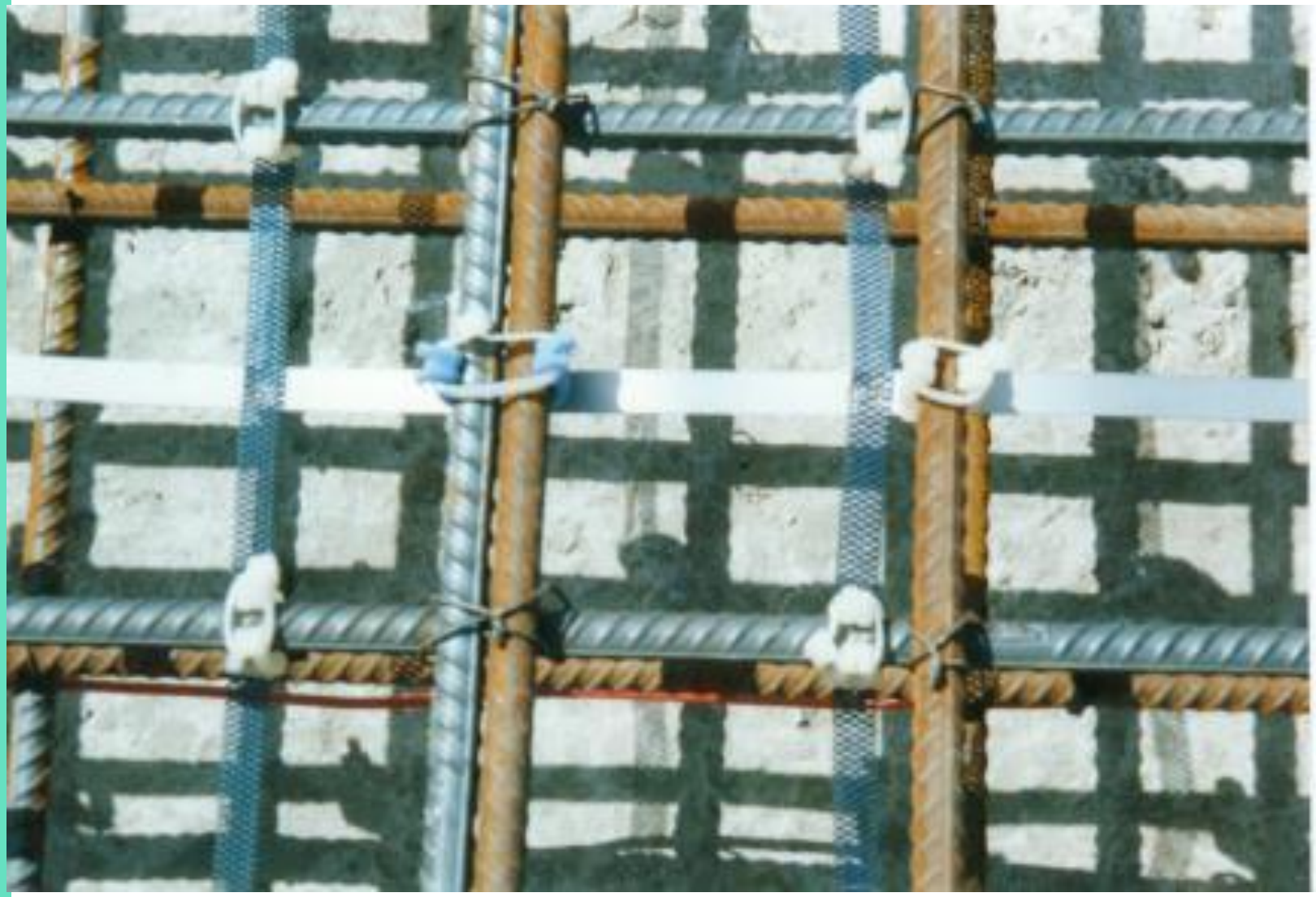

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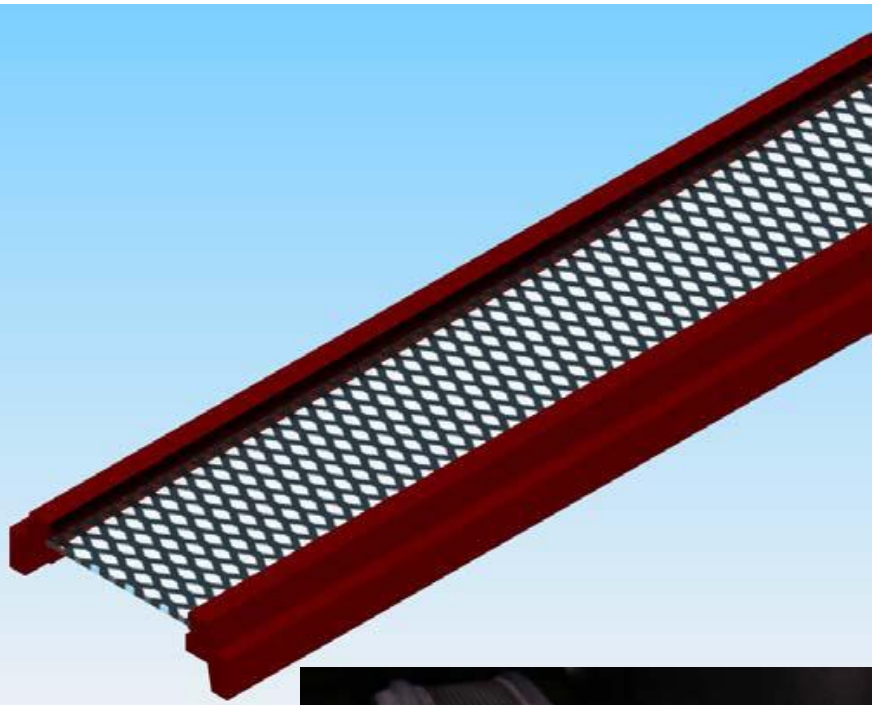

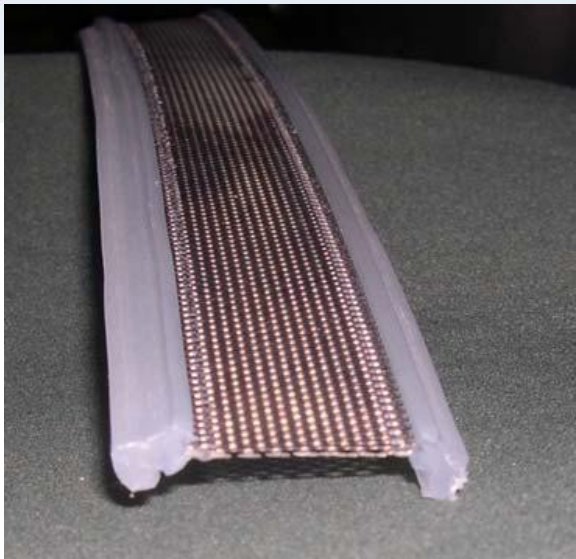

# Installation MMO Titanium Anodes Cprev of new structures

- The anode shall be securely attached to the reinforcing steel using plastic rebar clips and plastic cable ties, so that the construction activity associated with the concrete pour does not cause the anode to shift or come in contact with any part of the structural steel assembly.
- Ensure that no part of the anode or connection system comes into contact with reinforcement during installation and that the system is sufficiently rigid to ensure that the placement of the concrete does not cause any movement of the anode system.

# Installation MMO Titanium Anodes Cprev of new structures

- i.e.: anode clips with adequate tensioning, continuous cementitious spacer, continuous plastic spacer, continuous plastic spacer assembled to the mesh ribbon anode.
- All anode to conductor bar connections shall be metallurgical bonds (titanium spot welding).The titanium rods shall be fixed to the the conductor bar with Titanium spot welding.
- Supervision during concrete pouring is strictly required.

# MANY THANKS FOR YOUR TIME !

**If you need more details write to:**

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