

White Paper on Cathodic Corrosion Protection in Reinforced Concrete



Key Take-Aways:

- **How it Works:** CCP electrochemically transforms the metal surface of steel rebar into the cathode of an electrochemical cell, inhibiting the oxidation process, effectively preventing corrosion without the need to remove contaminated concrete.
- **Main Advantages:**
 - Prolongs the lifespan of concrete structures.
 - Cost-effective, especially in scenarios requiring extensive concrete removal
 - Reduces CO2 emissions by minimizing the need for demolition and reconstruction.
- **Challenges**
 - Knowledge gap in the construction industry regarding CCP adoption
 - Professionals may find it challenging to grasp the electrochemical principles of CCP.

Introduction

Cathodic Corrosion Protection (CCP) represents a pivotal innovation in modern construction maintenance. This white paper, based on a podcast “Concretely” discussion with Daniel Oberhänsli, CEO of Suicorr AG and a CCP expert, explores the multifaceted aspects of CCP. The white paper discusses the CCP's mechanisms, applications, and prospects, providing invaluable insights for the construction industry.

Background on Cathodic Corrosion Protection

I. The Fundamentals of CCP

In a typical concrete environment with high pH levels (around 11-12), steel reinforcement naturally forms a passive film that guards against corrosion. In the early 20th century, it was widely believed that steel rebar remained perfectly protected inside concrete. However, over time, environmental factors like chloride ingress (from de-icing salts or seawater) and carbonatization can compromise this protection, leading to accelerated corrosion. CCP addresses this issue by electrochemically transforming the metal surface into the cathode of an electrochemical cell, inhibiting the oxidation process in steel rebar. Unlike conventional repair methods, CCP does not require removing contaminated concrete, and its success can be ensured through a monitoring system.

II. Historical Context and Modern Importance

CCP, originally used in the 19th century for ship hulls and pipelines, has gained increasing relevance in the concrete industry. It is a key solution for extending the lifespan of structures like bridges and tunnels while preserving historical monuments.

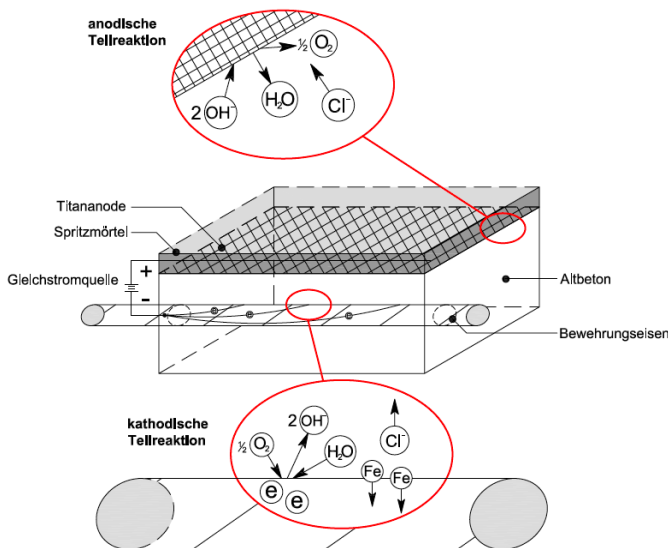


Abb. 1: Schema of Cathodic Corrosion Protection in Reinforced Concrete. Source: suicorr AG



Abb. 2: Application of a titanium grid anode (to be covered by mortar). Source: suicorr AG

The Role of CCP in Modern Construction

CCP systems apply a small electric current to steel rebar, neutralizing the natural electrochemical process that causes corrosion. This approach not only extends the lifespan of structures but also plays a crucial role in contemporary construction and refurbishment projects.

In More Detail

For Cathodic Corrosion Protection in reinforced concrete, an external anode made of materials like titanium, carbon, or conductive coatings is installed near the surface. A controlled electrical current (an exceptionally low voltage of around 3 volts, equivalent to a remote-control battery's 9 volts) is then applied to this anode, which flows to the rebars, reversing the electrochemical reactions causing corrosion. The concrete, or more precisely, the pore solution between the anode and the rebars, acts as the electrolyte (current transmitter). This process effectively transforms the rebars into the cathode of the electrochemical cell, protecting them against corrosion. The current distribution is carefully regulated to ensure uniform protection, particularly in areas most susceptible to corrosion. This technique is essential for halting and preventing the corrosion of steel within concrete, thereby extending the structure's lifespan.

Advantages of Cathodic Corrosion Protection

I. Increasing Lifespan of Structures

The successful application of CCP in Tessin, Switzerland, 35 years ago demonstrates its effectiveness. The treated structure remains corrosion-free, highlighting CCP's significant role in enhancing the durability of concrete infrastructures.

II. Cost-Effectiveness and Efficiency

CCP often outperforms traditional methods in terms of economic efficiency, particularly in scenarios requiring extensive concrete removal due to deep chloride penetration. For example, CCP in car park refurbishments often requires less concrete removal and reprofiling, resulting in lower overall costs and reduced disruption.

III. Environmental Benefits

By reducing the need for extensive concrete demolition and reconstruction, CCP contributes to lower CO2 emissions. This reduction is especially impactful considering the substantial carbon footprint of cement production. Additionally, the decreased concrete waste and material usage align CCP with sustainable construction practices, reflecting a growing environmental consciousness in the industry.

Case Studies and Applications

I. Tessin, Switzerland: A Benchmark for Longevity

In Tessin, Switzerland, a bridge column and thrust bearing heavily contaminated with chloride were treated with CCP. As one of the first concrete applications of CCP in Europe, this structure has remained free from corrosion for 35 years. This longevity, with no signs of concrete spalling or rust and no need for further maintenance, highlights the long-term effectiveness and reliability of CCP.

II. The Gotthard Road Tunnel: Preventive Application

While more than 90% of CCP applications are refurbishment projects, its application in the ongoing construction of the Gotthard Road tunnel exemplifies its preventive potential in critical infrastructure, highlighting CCP's versatility.

III. Car Parks: A Classic Application

CCP is particularly beneficial in car parks, where chloride ingress is common due to road salt. Traditional repairs might require closing the floor below for safety reasons during extensive concrete removal. CCP's minimal concrete removal needs often allow for faster, more environmentally friendly repairs.

IV. Historical Monuments, Tunnels, and More

The application of CCP extends to a variety of structures, each with unique environmental and structural challenges, underlining the method's adaptability and broad applicability.

Challenges and Future Directions

I. Adoption and Implementation Hurdles

The primary challenge in CCP adoption lies in the knowledge gap within the construction industry. Dr. Oberhänsli notes that many professionals are more accustomed to traditional methods and may find it challenging to grasp the electrochemical principles of CCP. This gap hinders broader implementation and acceptance of CCP technologies.

II. Potential for Future Research and Development

CCP presents significant opportunities for research and development, especially in the context of new materials like CO₂-reduced cements and advanced composites. Understanding how these materials interact with CCP systems is crucial for advancing CCP applications in modern construction.

Future Trends and Emerging Technologies in CCP

I. Integration with Smart Technologies

The incorporation of IoT and AI in CCP systems promises more precise monitoring and efficient corrosion protection. This technological integration can lead to enhanced performance and predictive maintenance capabilities.

II. Eco-Friendly and Sustainable Practices

The shift towards sustainable construction practices is influencing CCP development, driving innovation towards environmentally compatible materials and methods. This trend aligns with the global movement to reduce carbon emissions and promote ecological sustainability in construction projects.

Recommendations and Best Practices

I. Training and Education

Bridging the knowledge gap is essential for wider CCP adoption. Comprehensive training programs and educational resources are needed to acquaint construction professionals with the principles, benefits, and practical applications of CCP.

II. Collaborative Research and Development

Collaboration between construction companies, material scientists, and corrosion experts is key to advancing CCP technologies. Joint initiatives can foster innovation and facilitate the adoption of CCP in diverse construction projects.

Conclusion

Cathodic corrosion protection represents a significant leap forward in extending the lifespan and durability of concrete structures. The insights from Dr. Oberhänsli in the "Concretely" podcast provide a valuable understanding of the complexities and potential of CCP. As the construction industry continues to evolve, embracing CCP and its advancements will be key to building safer, more sustainable, and longer-lasting infrastructures.

The future of CCP lies in overcoming the current challenges through education and collaboration. By doing so, the construction industry can unlock the full potential of this vital technology, ensuring that our structures stand the test of time, just as the ancient Pantheon has.

Further CCP References

- Car Park Binelli, Adliswil CH: 3420 m²
- Tunnel West Fraport, Frankfurt DE: 950 m²
- Indoor Swimming Pool, Kleinhüningen CH: 101 m² (Abb. 4)
- Bridge Goldswilviadukt, Interlaken CH: 960 m²
- Car Park Sihlcity, Zürich CH: 18576 m² (Abb. 3)



Abb. 3: CCP at Car Park Sihlcity



Abb. 4: CCP at Swimming Pool, Kleinhüningen