# Cathodic Protection against corrosion of rebar in concrete

## Corrosion of rebar in concrete

Concrete on its own is strong under pressure, but can be weak under tension, therefore rebar is used to give the concrete more tensile strength. Healthy concrete has not been degraded by carbonation or chloride-intrusion of internal or external influences. Healthy concrete is alkaline and provides protection for the rebar. By intrusion of chlorides of internal or external sources, like for instance additives for faster curing of concrete, sea wind or salt used for winter control operations, the acidity of the concrete can change and the layer of protection disappears. Without this protective layer and in contact with the elements, water and air, corrosion can occur on the rebar and compromise the strength of the concrete structure.

Tell-tale signs of corrosion of rebar in concrete:

- Brownish drops or pits in concrete
- Red brown or dark stains on concrete
- Cracks in concrete
- Crumbled pieces of concrete
- Visible rebar, often corroded or partially decayed

## Corrosion of rebar

The corrosion of steel rebar, the strengthening in concrete, is an electrochemical process. Electrodes are exchanged between rebar, water and oxygen. The energy for this circuit is derived from the rebar. The origin of iron is iron ore, a natural form of oxidized iron. A high amount of energy is used in blast furnaces to turn iron ore into iron, this energy is stored in the metal and the metal wants to be transformed back to its original form, therefore it needs to transfer its energy. The circuit runs partially through the rebar and partially through pore water in the concrete. Where (positive) current leaves the rebar, so-called anode places, corrosion takes effect: iron dissolves and rebar is affected. Where the circuit enters the rebar, so-called cathode places, oxygen reacts with water creating hydroxide, an innocent by-product. Draining the “steel-concrete-battery” leads to corrosion causing problems in concrete because of the expansion of the steel material and increasing pressure on the concrete.

## Why Cathodic Protection of concrete?

Carbonation of concrete is associated with the corrosion of steel reinforcement, Cathodic Protection therefore focusses mainly on stopping the corrosion of rebar. Concrete is durable, has a high compressive strength and a low tensile strength. Iron has a high tensile strength, while unprotected, iron will oxidize. Combining these two materials offers a good synergetic effect: iron compensates for the tensile forces that the concrete will be under when subjected to flexural stresses and the high alkalinity of the concrete provides the rebar with a protective layer eliminating the process of rust. When by internal or external influences or intrusion of salts the acidity of concrete is compromised and therefore does not provide sufficient protection for the rebar, the steel will oxidize, expand and push away the concrete. In addition the rebar will fail in its purpose to compensate the tensile forces. Cathodic Protection takes control in the electrochemical corrosion process of the rebar.

## Cathodic Protection of concrete

Concrete is a very solid building material with high flexibility in application. Healthy concrete can survive a long time with little maintenance. Internal and external influences can afflict the concrete in such a way that the synergy between concrete and rebar gets disrupted an carbonation can occur. Cathodic Protection can be deployed preventively on locations known for their aggressive environment, this is known as cathodic prevention. When carbonation has already taken place or when salts has invaded the concrete, Cathodic Protection can be applied as part of the repair to make sure the quality remains guaranteed.

## Cathodic Protection of rebar

Oxidizing rebar is the cause of carbonation. The rebar in reinforced concrete is normally protected against corrosion because of the concretes alkalinity. By ways of carbonation or chloride intrusion this natural protection of the rebar by concrete expires. The rebar will be subject to rust. Rust (iron oxide) has a bigger volume than steel and therefore expands. The oxidized rebar can put strain of the concrete and push it away, hence compromising the structural integrity and safety of the concrete structure. Cathodic Protection can be implemented to give electrochemical protection against corrosion to the rebar. Preventive or afterwards so, despite carbonation or chloride intrusion in concrete, the rebar will not oxidize and the structural integrity is guaranteed.

## Cathodic Protection in repairing carbonation

Cathodic Protection is indispensable in most instances for sustainable solutions against corrosion of rebar. By implementing a Cathodic Protection System based on Galvanic anodes (GCP) or Impressed Current (ICCP) it is able to slow down the process of corrosion or stop it completely. In traditional concrete repair loose concrete is removed and replaced with new mortar. It is quite possible that in the remaining concrete, surrounding the repair, chloride is also present. By this presence the process of corrosion can continue. Cathodic Protection offers an electrochemical protection against corrosion of rebar, even if it is in carbonated or chloride affected concrete. Therefore Cathodic Protection is indispensable in most instances of repairing corroded rebar and afflicted concrete.

## Two ways of Cathodic Protection

Cathodic Protection of rebar in concrete can be applied in two different ways: Galvanic (GCP) or through Impressed Current (ICCP).

### Galvanic Cathodic Protection (GCP)

Galvanic Cathodic Protection uses anodes made from lesser base material than the rebar. When connected to each other the anode will oxidize instead of the rebar, therefore the term *sacrificial anode* is used for anodes making use of this principal, the anode sacrifices itself for rebar.

### Impressed Current Cathodic Protection (ICCP)

Cathodic Protection based on Impressed Current makes use of the *electro*-part of the electrochemical corrosion process. By placing anodes in or on the concrete and connecting an direct current power source between the anode and rebar in the concrete a potential difference has been created. Ions will be transferred through the concrete and the rebar is forced into a cathodic position, hence halting the corrosion.

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