

### 4.3 CORROSION MECHANISM

Corrosion of steel reinforcement occurs by an electrochemical process which involves exchanges of electrons similar to that which occurs in a battery. The important part of the mechanism is the separation of negatively charged areas of metal or „anodes“ where corrosion occurs and positively charged areas or „cathodes“ where a harmless charge balancing reaction occurs.

At the anode the iron dissolves and then reacts to form the solid corrosion product, rust. The rust is formed at the metal/oxide interface, forcing previously formed oxide away from the steel and compressing the concrete, causing it to spall.

So in other words for corrosion to occur four basic elements are required: Anode – Site where corrosion occurs and current flows from

Cathode – Site where no corrosion occurs and current flows to.

Electrolyte – A medium capable of conducting electric current by ionic current flow (i.e. Soil, Water or Concrete)

Metallic path – connection between the anode and cathode, which allows current return and completes the circuit.

Reinforcing steel in concrete normally does not corrode because of the formation of a passive oxide film on the surface of the steel due to the initial corrosion reaction.

The process of hydration of cement in freshly placed concrete develops a high alkalinity, which in the presence of oxygen stabilizes the film on the surface of embedded steel, ensuring continued protection while the alkalinity is retained.

Normally, concrete exhibits a pH above 12 because of the presence of calcium hydroxide, potassium hydroxide – the term pH is a measure of the alkalinity or acidity, ranging from highly alkaline at 14 to highly acidic at zero, with neutrality at 7. Although the precise nature of this passive film is unknown, it isolates the steel from the environment and slows further corrosion as long as the film is intact. However, there are

two major situations in which corrosion of reinforcing steel can occur.

These include:

1. Carbonation,
2. Chloride contamination

### **Deterioration through Carbonation**

Carbonation is a process in which carbon dioxide from the atmosphere diffuses through the porous concrete and neutralizes the alkalinity of concrete.

$\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$  Carbon dioxide, which is present in air in proportions of around 0.3 percent by volume, dissolves in water to form a mildly acidic solution. Unlike other acids that may chemically attack and etch the surface of the concrete, this acid forms within the pores of the concrete itself where the carbon dioxide dissolves in any moisture present. Here it reacts with the alkaline calcium hydroxide forming insoluble calcium carbonate.

The pH value then drops from 12.5 to about 8.5. The carbonation process moves as a front through the concrete, with a pH drop across the front. When it reaches the reinforcing steel, the passive layer decays when the pH value drops below 10.5. The steel is then exposed to moisture and oxygen and is susceptible to corrosion.

Concrete inside the building frequently carbonates totally without any sign of deterioration as the concrete dries out, leaving the steel exposed to air but not moisture. Problems are seen externally where concrete is exposed to the elements and in certain situations internally, such as kitchens and bathrooms, where the concrete is susceptible to condensation or water-leakage.

### **Deterioration due to Chloride**

Salt causes corrosion by a different mechanism. When salt is dissolved in water sodium chloride forms a versatile, highly corrosive solution of sodium ions ( $\text{Na}^+$ ) and chloride ions ( $\text{Cl}^-$ ). Salt is used for de-icing roads and its presence in sea water is a major problem for reinforced concrete structures. The very mobile chloride ions disperse through concrete pores in solution and where they come into contact with the reinforcing steel they attack the passive layer. Steel oxidizes in the presence of air and water to form

rust which has a volume of up to 10 times that of the steel consumed.

As concrete has a low tensile strength it will crack when as little as a tenth of a millimeter of steel has been consumed. Horizontal cracks form, causing corners to „SPALL“ and surfaces to „delaminate“ as the reinforcement's concrete cover becomes detached and falls away in sheets. The consequence can be seen on the underside of road bridges and many buildings and structures beside the sea.

ACI recommends the following chloride limits in concrete for new construction, expressed as a percent by weight of cement:

Pre-stressed concrete 0.08%

Reinforced concrete in wet conditions 0.10% Reinforced concrete in dry conditions 0.20%

But in existing structures 0.026% is enough to breakdown the Passive Layer.

### **Factors Influencing corrosion of Reinforcement**

Various factors initiate and sustain the process of corrosion in R.C. structures. They are broadly divided into two groups:

General Influencing factors

General accelerating factors

#### **General Influencing factors**

The following are the factors that generally influence corrosion of reinforcement in R.C. structures.

pH Value Moisture Oxygen Carbonation Chlorides

Ambient temperature Severity of exposure Quality of concrete

Cover to the reinforcement Initial curing condition

Formation of cracks

#### **General Accelerating factors**

The following are the factors which accelerate the process of corrosion in R.C. structures Chlorides

Sulphates Chlorine Electrical Charges Methane Acids