

***Module 2: The Eight Forms of Corrosion: Uniform attack; galvanic corrosion; crevice corrosion; pitting corrosion; intergranular corrosion; selective leaching; erosion corrosion; stress corrosion cracking including hydrogen embrittlement.***

***The 8 forms of corrosion common in industries are:***

- 1. General (Uniform) attack:** This is the most common form of corrosion. It occurs when a chemical or electrochemical attack occurs over a large area in a uniform manner. This is often referred to as a general wall loss or thinning. Uniform attack is the greatest destruction of metal on a tonnage basis. It can be prevented by using: proper materials, including coatings, inhibitors or cathodic protection.
- 2. Crevice corrosion:** Is also known as Two-Metal Corrosion. A potential difference usually exists between two dissimilar metals when they are immersed in a corrosive or conductive solution. If these metals are placed in contact (or otherwise electrically connected), this potential difference produces electron flow between them. This occurs through the electrochemical cell. It requires electron flow, and is characterized by the presence of an anode (negative), cathode (positive) and an electrolyte. Most corrosion occurs at the anode, although some corrosion will occur at the cathode. Depending on the cell configuration, the corrosion may be localized or uniform. Crevice corrosion is a highly localized attack occurring in a crevice or an otherwise shielded area when a material is exposed to a stagnant corrosive media. Common locations for crevice corrosion are:
  - a. Crevices(such as under bolt or rivet heads)
  - b. Gasket surfaces
  - c. Holes
  - d. Lap joints
  - e. Surface deposits

It is sometimes called deposit or gasket corrosion.

**3. Galvanic corrosion:** is an electrochemical process in which one metal corrodes preferentially to another when both metals are in electrical contact in the presence of an electrolyte.

**4. Pitting corrosion:** Is a form of extremely localized attack that results in holes in the metal. A highly localized corrosion attack that results in holes is referred to as pitting. Pits may be isolated or localized and of virtually any configuration. They occur at defects or imperfections in a protective or passive film. It is a form of corrosion difficult to predict by laboratory test.

**5. Intergranular corrosion;** is a common form of attack on alloys but occurs rarely in pure metals. The attack is usually caused by impurities at the grain boundaries, enrichment of one of the alloying elements or depletion of one of these elements in the grain-boundary areas. All materials, with the exception of amorphous materials (such as plastic), are composed of grains and grain boundaries. Intergranular corrosion occurs when the grain boundaries are attacked in preference to the material matrix. The only difference between this and uniform corrosion is that the grains remain undamaged. Metallographic examination is usually the only way to identify this corrosion mechanism.

**6. Selective leaching:** It is also known as dealloying: This is the removal of one element from a solid alloy by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification). Most materials are made up of a combination of several elements. Dealloying occurs when one of the elements is removed from the metal matrix, leaving an altered residual structure. It is commonly identifiable by a color change or a drastic change in mechanical strength.

**7. Erosion corrosion;** is used to describe the increased rate of attack caused by a combination of erosion and corrosion. If a fluid stream contains suspended particles, or where there is high velocity or turbulence, erosion will tend to remove the products of corrosion and any protective film and the rate of attack will be markedly increased. For example: plastics inserts are used to prevent erosion–corrosion at the inlet to heat-exchanger tubes.

**8. Stress corrosion cracking including hydrogen embrittlement;** Stress corrosion cracking refers to cracking caused by the simultaneous presence of tensile stress and a specific corrosive medium. Many investigators have classified all cracking failures occurring in corrosive medium as stress corrosion cracking, including hydrogen embrittlement. However, these two types of cracking failures respond differently to environmental variables. To illustrate, cathodic

protection is an effective method for preventing stress-corrosion cracking whereas it rapidly accelerates hydrogen–embrittlement effects. Hence, the importance of considering stress-corrosion cracking and hydrogen embrittlement as separate phenomena is obvious.

**Environmental corrosion cracking is also known as *Stress corrosion cracking including hydrogen embrittlement*;**

**i. Stress Corrosion Cracking:** occurs when a material is exposed to a corrosive media while a force (stress) or pressure is applied. The material usually remains undamaged with the exception of cracks that grow through the material matrix. These cracks are usually very fine, visible only under microscopic conditions, but often network through the material, ultimately causing failure.

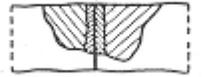
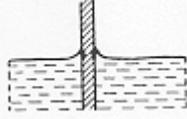
**ii. Hydrogen-Induced Cracking (HIC) and Sulfide Stress Cracking (SSC)**

Hydrogen-induced cracking results from the combined action of a tensile stress and hydrogen in the metal. It results in the brittle failure of otherwise ductile materials when exposed to an environment where hydrogen can enter the metal. Sulfide stress cracking is a type of HIC in which sulfide is the primary poison for the hydrogen evolution. SSC of medium-strength steels has been a continuing source of trouble in oil fields.

**iii. Liquid Metal Embrittlement (LME):** This is defined as the decrease in strength or ductility of a metal or alloy as a result of contact with a liquid metal. Unlike fracture by SSC, cracking begins immediately upon the application of stress if the liquid metal has wetted the solid material.

**Biological Corrosion:** In itself, biological corrosion is not a mechanism but a cause. The presence of microorganisms can lead to any of the above mechanisms occurring. Corrosion caused by microorganisms is usually indistinguishable from other sources; it is often determined by sampling the process condition for evidence of microbiological activity.

List of the various types of corrosion.

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|---|--|---|
|  <p><b>Uniform corrosion</b><br/>The reaction starts at the surface and proceeds uniformly.</p>  |  <p><b>Localized corrosion (pitting corrosion)</b><br/>The basis metal is eaten away and perforated in places in the manner of holes, the rest of the surface being affected only slightly or not at all.</p> |  <p><b>Wide Pitting corrosion</b><br/>The corrosion causes localized scarring.</p>   |
|  <p><b>Intergranular corrosion</b><br/>Imperceptible or barely perceptible from outside, since the corrosion proceeds at the grain boundaries.</p> |  <p><b>Transgranular corrosion</b><br/>The grain boundary material is retained, since the corrosion proceeds preferentially within the grain.</p>   |  <p><b>Galvanic corrosion</b><br/>Increased corrosion in crevices or cracks or at contact surfaces between two metal articles.</p> |
|  <p><b>Selective corrosion</b><br/>Corrosive attack on structural constituents</p>   |  <p><b>Exfoliation corrosion</b><br/>Occurs in deformed articles. Corrosion follows "fiber orientation"</p>   |  <p><b>Interfacial corrosion</b><br/>Frequently observed at water-air interfaces</p>   |

## Corrosion Causes and Treatment in Plumbing

Corrosion of home plumbing and fixtures has been estimated to cost the public hundreds of millions of dollars per year. Lead and cadmium, both toxic metals, occur in tap water almost solely due to corrosion. Three other metals, usually found in high concentrations due to corrosion of piping systems are copper, iron, and zinc. Copper causes blue staining and imparts a metallic bitter taste. Iron corrosion causes reddish or brown water and also imparts a metallic taste. Zinc corrosion does not usually discolor the water, but can also cause a metallic taste. All waters are corrosive to some degree, and water's corrosive character depends on its physical and chemical

constituents. The type of material the water comes in contact with also affects the "corrosivity". For instance, water that may corrode iron pipe may not be as corrosive to copper pipe.

In our area, the most common causes of corrosion of plumbing systems on municipally treated water are from "electrolysis" or electrically induced corrosion. This is often due to improper grounding of electrical systems to water pipes, or by the creation of **"galvanic corrosion cells" in home systems due to the dual use of iron and copper piping** in the same system. This "electrically-induced" corrosion is aggravated by waters high in total dissolved solids, making the water more conductive.

On private water systems, the most common cause of corrosion is from low pH (less than 7.0) waters. Often these waters are of high quality and are low in buffering calcium minerals, but are high in dissolved carbon-dioxide gas, which can cause the low pH or acidity. Treatment is accomplished by neutralizing the water with the use of an automatic neutralizer. These water filter tanks are filled with a blend of calcium and magnesium carbonates made from naturally occurring minerals, which dissolve into the water, making it less corrosive. Other methods commonly used are pH adjustment by injecting soda ash or a sodium hydroxide solution into the water upstream of a holding or retention tank.

### **Concrete Spalling in Buildings**

Nowadays; it's hard not to notice the prevalence of reinforced concrete as a structural material in constructions; majorly in buildings. From the humble foundation slab for a domestic dwelling to the column members used in cityscape skylines, you will not find a building without some form of concrete. With reinforced concrete and indeed all structural materials, it is important to be able to identify and rectify any material defects that may affect the structural integrity of the building.

#### ***How does spalling happens?***

Concrete spalling or 'concrete cancer' as it is known colloquially, is an extremely common yet potentially dangerous issue that arises within reinforced concrete. The basic definition of 'concrete cancer' terms and how it can compromise the structure includes issues such as:-

Water Ingress - Water entering the concrete element due to cracking in the concrete or break down of a waterproof membrane;

Chloride Contamination – In aggressive high chloride environments, chloride ions diffuse through the concrete causing de-passivation (reduction in alkalinity) in the protecting concrete and set up a more acidic zone, leading to accelerated corrosion. This occurs in an exposed salt laden surf environment or where Magnesite topping has been used;

Concrete Cover - A lack of concrete cover from the exposed surface to the reinforcement due to bad design or poor building practices;

Carbonation – This occurs due to the ingress of carbon dioxide from the atmosphere into the concrete reacting with the cement and lowering the concentration of hydroxide ions, (OH<sup>-</sup>). This reduces the pH value, creating a less alkaline environment and destroying the passivation “film” around the steel reinforcement, leading to increased corrosion potential.

Reinforcement Corrosion - Water penetration through the concrete in the presence of oxygen will corrode (rust) the steel reinforcing bars. The steel reinforcement bar can then expand up to four (4) times as the parent metal is “eaten away”;

**Concrete Spalling** - The corrosion expansion of the reinforcement bar induces high localised stresses on the encasing concrete, causing significant cracking and de-bonding of the steel reinforcement. A loss of structural integrity and capacity results.

### ***Why is Concrete Spalling bad?***

Concrete surrounding the steel reinforcement cracks at the surface and de-bonds due to the expansion of the reinforcing bar. The first signs are localised cracks in the concrete at the surface in the line over the steel reinforcing bar.

Cracking and spalling concrete become dislocated and create a serious safety risk hazard, as loose concrete may fall onto passers-by and property below.

If unattended, the steel corrosion will escalate and spread relatively quickly through the full cross section and length of the reinforcement bars, comprising the building’s structural integrity.

**How can you tell whether your building’s concrete is spalling? There are numerous tell-tale signs that should indicate to the wary property owner if their property is being affected.**

Is your property near a coastal environment?

It is likely that the prolonged exposure to airborne salts will accelerate the rate of concrete spalling to your structure.

Is it in existence for over a decade?

Early 60's and 1970s' Magnesite (expanded woodchip), chloride-ion rich topping, were used extensively in the 1960's and 1970's as an acoustic levelling compound over concrete floors. Construction during these times also used a more porous concrete and generally had inadequate concrete covers to the reinforcement. The reinforcement corrosion occurs when chlorides are liberated from the magnesite topping by moisture and then migrate into the concrete. The moisture source can be water ingress from a balcony, a window, an external cavity wall or flow from an internal wet area such as a bathroom, laundry or even kitchen. We have also evidence that the carpet at an entry door, where an occupant brushes their shoes can provide a sufficient water source. The observation of a lifting or crumbling under a carpet or vinyl may be pointing to a prolonged time of concealed concrete cancer.

Cracking and spalling concrete and rust staining to exposed concrete slab soffits or edges?

Most likely concrete spalling has already begun. A simple test is to scratch or tap a coin over the affected area: if the sound heard is a hollow 'drummy' sound, then most likely the concrete has already been affected and there is rusting reinforcement.

Concrete Spalling (How to Repair)?

We at Partridge understand the causes and insidious nature of concrete spalling and the risk that it poses to your overall structure. Unfortunately concrete spalling will only get worse the longer it is not dealt with. A 'do nothing' approach is not a cost-effective option with concrete spalling if left long enough, and compromising the overall structural integrity of the building.

**When concrete cancer is observed it is likely the concrete is already damaged and the reinforcement rusting.**

The **most critical issue is** to identify the cause of the spalling. At Partridge we know that the rectification of the spalled concrete is only half of the issue and our experienced remedial team take the time with each individual situation to identify and rectify the cause of the concrete spalling as well as the repair.

Corrosive engineers can ensure a cost effective solution concrete spalling issue by addressing questions such as, “Is simple repair adequate? .

Can the structure be remediated before considering costly demolition? Can the water source be isolated so there is no further concrete cancer?

Is replacement of members a more cost effective option than repair?”