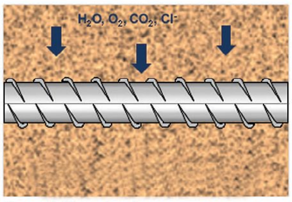
AN ADDED INSURANCE AGAINST CORROSION

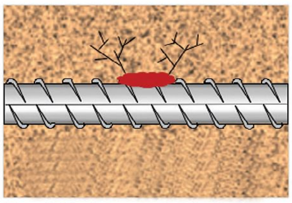
accessibility restrictions and are typically costly and disruptive to implement. At worst, complete replacement of the structure may be required well before its full design life has been reached, if structural integrity has been sufficiently compromised.

Reinforcement corrosion is now considered to be the leading cause of premature concrete failure in the world today and needs to be adequately addressed for structures situated in highly corrosive environments.

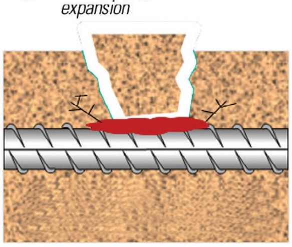
Reinforcement Corrosion: Cause and Effect



Stage 1: Corrodant ingress



Stage 2: Crack propagation due to rust expansion



Stage 3: Concrete spalling after extensive cracking

Bare steel reinforcement relies entirely on protection provided by the surrounding concrete. Most obviously, the concrete cover serves as a physical barrier separating the reinforcement from the external environment. Also, because the cement constituent in concrete is highly alkaline, a natural chemical reaction takes place at the steel surface to form a thin impervious film which resists corrosion. The steel surface is said to be 'passivated' by this reaction and the passive film will remain intact as long as the surrounding concrete retains a high alkalinity.

However, in reality, concrete is rarely impermeable, allowing ingress of atmospheric corrodants (moisture, oxygen, carbon dioxide). Because carbon dioxide reduces the alkalinity of the concrete, a process known as 'carbonation', the steel surface can depassivate, rendering it susceptible to corrosion. A more dire situation exists in the presence of chloride salts which applies to structures in contact with seawater or along coastlines where airborne chloride concentrations are high. It is well recognized that chloride salts can permeate concrete and will depassivate the steel even if the alkalinity of the surrounding concrete remains high. In this circumstance extensive and rapid corrosion can take place due to the extreme corrosivity of chloride salts.

Steel corrosion (rusting) causes the reinforcement to delaminate from the concrete, weakening the structure. Furthermore, because rust has a volume up to 10 times that of the steel consumed, significant tensile stresses are generated in the adjacent concrete. Since concrete is strong in compression but relatively weak in tension these expansionary stresses cause cracks that can eventually extend to the concrete surface. Besides further weakening the structure, the cracks cause corrosion to accelerate by providing a ready conduit for further unimpeded entry of corrodants. Eventually this self-perpetuating process leads to severe concrete spalling which then fully exposes the reinforcement to the external corrosive environment.

Nowadays, with greater recognition of this problem, concrete practices and technologies have been adopted to better manage the risk. For example, greater attention is given to the importance of reducing concrete permeability through optimal water/cement ratios, appropriate compaction and curing conditions, together with the use of concrete impregnation methods or membrane-type concrete coatings. Likewise, the importance of appropriate reinforcement placement to ensure adequate depth of concrete cover is well recognized. Nevertheless, despite precautionary measures and best practice, technical perfection may be difficult to achieve and practical experience over the years has convincingly demonstrated that concrete structures can still remain vulnerable to reinforcement corrosion particularly in more aggressive environments.

Protecting reinforcement by galvanizing

Galvanizing is the process of applying a metallurgically bonded zinc coating to steel by immersion in molten zinc and is used extensively throughout the world for corrosion protection. The coating's excellent corrosion protection derives from both the low natural corrosion rate of zinc coupled with its ability to extend protection to adjacent exposed steel areas should they be present, an effect known as cathodic protection. The coating also exhibits strong adhesion to the underlying steel surface due to its unique metallurgical bond which, together with the inherent toughness of a metallic coating, provides superior resistance to mechanical damage.

The combination of these features results in a very durable coating, enabling concrete structures to be more tolerant of variabilities in concrete quality and reinforcement placement. Besides this, use of galvanized reinforcement is uniquely advantageous for the following reasons:

- it offers better resistance to chloride salt attack and is unaffected by concrete carbonation
- zinc's cathodic protection inhibits corrosion at any minor coating discontinuity and also prevents 'undercutting' of the coating, confining any corrosion risk solely to the local area of exposed steel.
- any zinc corrosion products that may form over time are benign. As there is no accompanying volume change, unlike with steel corrosion, there is no adverse impact on the surrounding concrete. On the contrary, research shows that any corrosion products simply diffuse into the adjacent concrete, helping to fill microporosity which inhibits further ingress of corrodants.

Ultimately, the purpose of galvanized reinforcement is to provide a safeguard against unexpected corrosion leading to premature deterioration of the structure. This extra protection generally adds minimal cost to a construction project budget, and should be viewed in the context of insurance against the risk of costly cycles of concrete repair and remediation or worse still, replacement of a prematurely failed structure.

Deterioration of the bare steel reinforcement in a coastal balcony