Dulux PROTECTIVE COATINGS

Concrete Floors – Concrete Spalling

Spalling is the deterioration of steel reinforced concrete, and is characterised by the appearance of cracks and red rust. In severe cases, concrete sections completely break away from the reinforcing steel bar (known as “rebar”), exposing the rebar to the elements.

The challenge with spalling is the problem is not obvious initially, and as the problem advances, the treatment becomes increasingly difficult and costly to rectify.

Causes of concrete spalling

Carbonation and incipient anode formation[1], which are two unrelated mechanisms, are two examples of what can cause concrete spalling.

1. Carbonation of Concrete

Mild steel rapidly corrodes in the presence of moisture, oxygen and ions (ie salts). If, however, mild steel is embedded in fresh concrete, the high alkalinity of the concrete passivates the surface of the steel, providing an excellent barrier to oxidation.

Concrete can be quite porous and readily absorbs moisture (H_2O), carbon dioxide (CO_2), and many other acidic chemicals in the air and in rainwater. These acidic chemicals neutralise the calcium hydroxide, ($Ca(OH)_2$) in cement.

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$

This neutralisation process is known as “carbonation” of the concrete, and the point at which alkalinity of the concrete drops below a pH of 9 is called the “carbonation front.” The carbonation front begins at the surface of the concrete and steadily moves towards the rebar.

When the carbonation front reaches the rebar, the alkalinity at the rebar drops, and uncoated rebar loses its only protection against corrosion. That is, when the carbonation front reaches the rebar reinforcement, the protective layer of concrete depassivates and corrosion initiates.

When the embedded steel rebar corrodes, the corrosion products take up eight (8) times the volume of the original steel. This expansion within the concrete exerts a far greater force than the concrete’s flexural strength will allow, resulting in cracks and spalling of the concrete around the affected steel. The cracks expose the steel to further corrosion leading to more concrete breakdown.

Whilst the oxidation-reduction reactions between iron metal, oxygen and water can get somewhat complicated, the simplistic equation below shows the oxidation process producing a very large and complex molecule of greater volume than the original iron metal.

$$\underset{\text{Iron}}{4Fe} + \underset{\text{Oxygen}}{3O_2} + \underset{\text{Water}}{nH_2O} \rightarrow \underset{\text{Hydrated Iron Oxide (Rust)}}{2Fe_2O_3{\cdot}nH_2O}$$

1. Guide to Concrete Repair and Protection”, a joint publication of ACRA, CSIRO and Standards Australia.

2. Incipient Anode Formation

Incipient anode formation, also known as ring anode formation or halo effect, can occur when the natural cathodic protection that occurs in concrete is disrupted during patch repairs following rectification of concrete spalling. That is, when a concrete repair is completed, the new fresh concrete has a higher pH than the surrounding concrete, making the local rebar cathodic to the surrounding rebar, which now becomes the anode and location where red rust and spalling can occur if the corrosion elements are still present. It is therefore very important to fully follow the manufacturer's repair instructions to avoid this occurrence.

Reinforcing concrete with steel

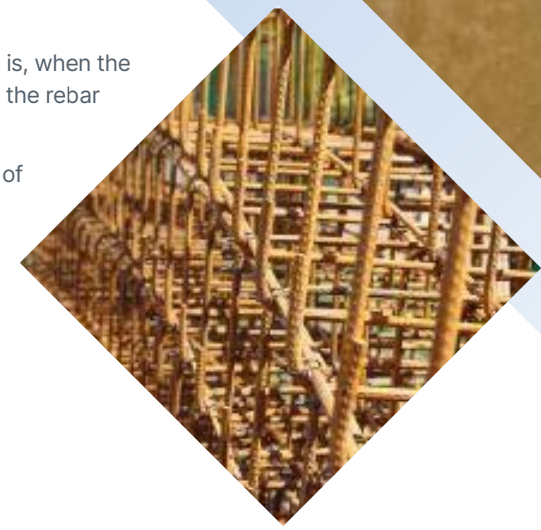
There are several reasons for reinforcing concrete with steel:

- Concrete has very high compressive strength, but very poor flexural strength. Therefore, concrete will has the potential to crack with the slightest flexural pressure exerted by normal stresses such as thermal changes or ground movement (such as earth tremors, foundation settling or soil volume changes due to seasonal moisture level fluctuations). The design of rebar reinforcement (placement, size, volume of rebar etc.) is critical in providing the best outcome for a building or structure to withstand such pressures.
- Concrete and steel are fully compatible with each other as they have the same approximate coefficients of expansion, that is, they expand and contract with changes in temperature at the same rates. Using a reinforcing material of differing thermal expansion and contraction rates would result in stress fractures.
- Steel rebar can be quickly fabricated to accommodate a wide range of architectural designs.
- Steel rebar is readily available and cost-effective.

What Contributes to Concrete Spalling

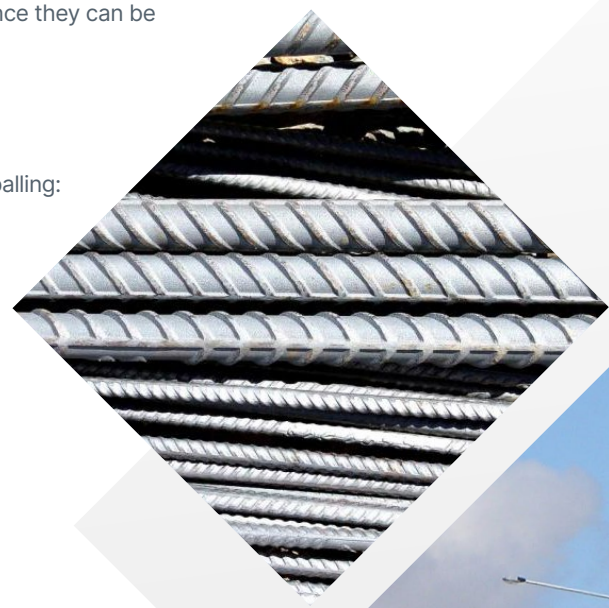
Issues that can contribute to concrete spalling are:

- Faulty concrete specification or design
- Incorrect placement of rebar and/or mesh, resulting in inadequate concrete cover. That is, when the rebar is placed too close to the surface of the concrete, the carbonation front will reach the rebar sooner, resulting in quicker concrete spalling.
- Poor site supervision during pouring, when the rebar is pushed too close to the surface of the concrete, as noted above, the closer the rebar is to the surface, the faster spalling can occur.
- Lack of a protective "anti-carbonation" surface coating to prevent ingress of acidic chemicals.
- Improper concrete repairs.



Rust Staining

Rust staining is not always a sign of spalling. Small steel bits such as tie wires and chairs legs are often embedded near the surface of concrete, as they are close to the surface these steel bits can corrode leaving rust stains that can bleed through most applied finishes. As these steel pieces do not impact the integrity of the structure, this is purely an aesthetic concern. If concerned with the appearance they can be gauged out and the gouged filled with a cementitious repair mortar.



Prevention of Spalling

There are several measures that can be adopted to reduce and prevent concrete spalling:

1. Specify a minimum concrete cover according to the exposure classification of the structure as per Australian Standard AS3600 “Concrete structures”.
2. Arrange adequate site supervision to ensure that specified concrete coverage is achieved or exceeded.
3. Ensure that good concrete curing techniques are followed to achieve the maximum concrete design strength.
4. Specify and ensure the use of a certified and effective anti-carbonation and chloride ion resistant coating system.
5. Fully follow manufacturer’s concrete patch repair instructions.

Using Protective Coatings to Prevent Spalling

Protective coatings that are anti-carbonation and chloride ion resistant are key to protecting buildings from concrete spalling by blocking carbon dioxide, chloride ions, and moisture from entering the concrete. Such coatings can prevent both the carbonation of the concrete and the formation of incipient anodes on the surface of the reinforcing steel.

Dulux Protective Coatings Anti Carbonation Options

Dulux Weathermax HBR, when applied at 100 microns over Dulux Durebild STE at 125 microns, not only offers exceptional anticarbonation and chloride ion resistance, but also provides resistance to defacement by graffiti. This offers a total protection system for all public areas and is the reason many VicRoads projects are now protected by the Durebild STE – Weathermax HBR coating system. Additional Dulux Protective Coatings systems have been tested and approved for anti-carbonation properties and are available upon request. Please contact your local Protective Coatings Representative for more information.

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