# Technical Advice Note 8

Carbonation is a naturally occurring process in cement chemistry and is not detrimental as long as the concrete is not required to protect embedded steel reinforcement from corrosion. In fact, it may even improve the durability of unreinforced concrete.

In normal good quality steel reinforced concrete the reinforcing steel is protected from corrosion by the alkalinity of the concrete. Steel embedded in concrete should have a PH value of 9 or more. Tricalcium Silicate and Dicalcium Silicate in the cement react with water during mixing and setting (see Technical Advice Note 2 The Hydration Process) to form Calcium Hydroxide $(Ca(OH)_2)$ giving the concrete its high alkalinity pH value 12+ and forming the passivating layer around the reinforcement bars within the concrete.

Over time Carbon Dioxide (CO_2) and other environmental gases in the atmosphere combine with moisture and can penetrate the concrete surface through micro pores, blow holes, cracks etc. The Carbon Dioxide reacts with the Calcium Hydroxide forming Calcium Carbonate $(CaCO_3)$ which is of less alkalinity, effectively reducing the alkalinity of the concrete to pH 8 or 9 allowing corrosion of the Reinforcement.

Carbon Dioxide dissolved in moisture also forms Carbonic Acid (H_2CO_3) which is a weak electrolyte and assists in the formation of Hydrated Iron Oxide $(Fe_2O_3H_2O)$ (rust).

The speed of which carbonation penetrates is dependant on the quality of the concrete, depth of cover, type of cement, initial water cement ratio, extent of any honeycombing, cracking and exposed environment and relative humidity.
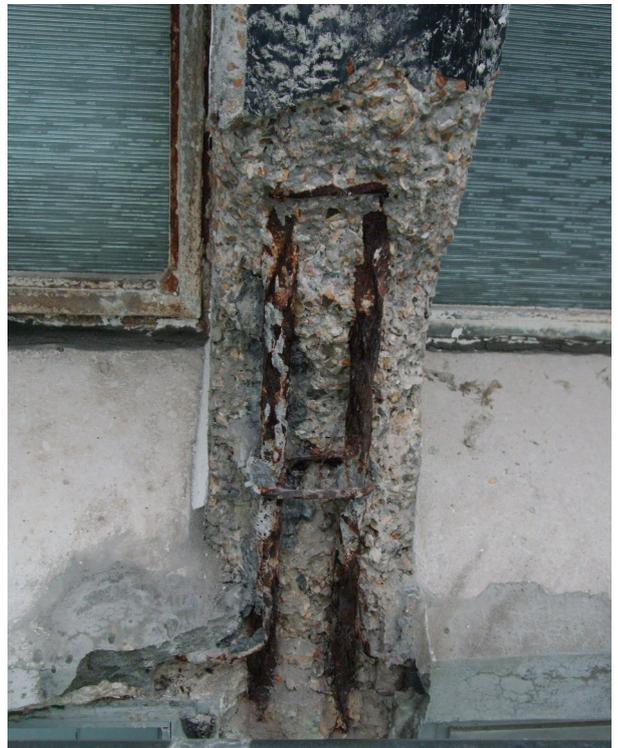
The rust will form Hydrated Iron Oxide (rust) which increases the volume of the steel by up to 10 times its original diameter.

It is these massive expansive forces which cause the concrete around it to crack and spall.

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Carbonation starts on the surface and slowly penetrates into the concrete. The rate of penetration slows down the deeper the penetration. The penetration depth is approximately proportional to the square root of the length of time exposed.

This means we can measure the rate of carbonation by using the following formulae.

The mathematical representation is: $t = (d/k)^2$

Where   t = time for carbonation

d = concrete cover depth

k = the permeability

Permeability Values Versus Concrete Grade	
Concrete Grade	Permeability
15	17
20	10
25	6
30	5
35	4
40	3.5

Carbonation Depth Testing:

Carbonation depth testing entails a Phenolphthalein solution being sprayed onto on a freshly fractured face of the concrete.

There are four main methods of testing.

- Where concrete is already damaged (spalled/cracked surface) carefully break away a small area of concrete 25-50mm² using lump hammer and chisel, brush or blow out the area to remove dust, lightly spray exposed rough surface with phenolphthalein indicator solution. Measure from the surface to the purple discolouration and record.

- Where surface appears sound, drill two holes (20mm) in close proximity to each other, carefully break out the concrete between holes, brush or blow out any dust in the area, lightly spray phenolphthalein indicator solution onto the broken concrete. Measure from the surface to the purple discolouration and record.

- Core drill and extract core samples. Split the cores vertically, brush or blow out any dust in the area, lightly spray phenolphthalein indicator solution onto the broken concrete. Measure from the surface to the purple discolouration and record.

- Laboratory Petrographic Testing can be carried out, this is much more accurate than any of the site testing , however it is very expensive and time can be lost awaiting results. The method entails having core samples taken to the laboratory and using microscopy - either optical microscopy using thin-sections, or scanning electron microscopy using polished sections .