BRIDGE OVER HAWKESBURY RIVER

AT WINDSOR

EFFECTS OF CARBONATION ON CONCRETE AND REINFORCEMENT

Carbonation in the Reinforced Concrete Superstructure

The reinforced concrete superstructure (deck and beams) of the existing bridge at Windsor exhibits some so called "concrete cancer". This is as a result of carbonation of the concrete, causing a loss of the corrosion protection around the reinforcement that is provided by the strong alkaline environment of the concrete. (See Figs. 2,3 & 4). It will be observed that it is mainly the outer beams that have significant spalling, because of a poor drainage detail that can be readily corrected.

Carbonation is the reaction of carbon dioxide in the air with the calcium hydroxide in the cement paste. This reaction produces calcium carbonate and lowers the alkalinity from a pH of around 13 a pH of around 9. At this value the protective oxide layer surrounding the reinforcing steel breaks down and corrosion becomes possible.

The reaction of carbon dioxide and calcium hydroxide only occurs in solution and so in very dry concrete carbonation will be very slow. In saturated concrete the moisture presents a barrier to the penetration of carbon dioxide and again carbonation will be slow. The most favourable condition for the carbonation reaction is when there is sufficient moisture for the reaction but not enough to act as a barrier. In most reinforced concrete structures made with good quality concrete, carbonation will take many years to reach the location of the reinforcement (See Figure 1).

Stage 1	Stage 2	Stage 3
Crossection through concrete and reinforcement	Concrete attacked by carbonation	Passive layer around reinforcement compromised

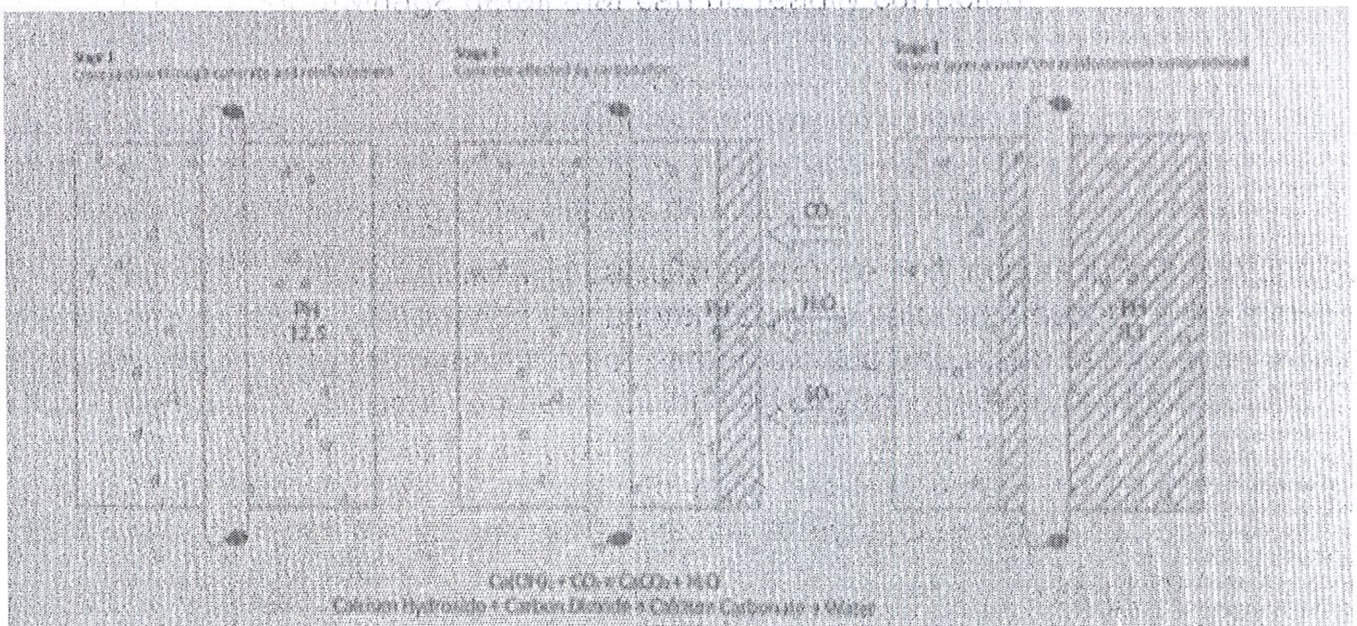

Figure 1: The carbonation of concrete

Carbonation depth is assessed using a solution of phenolphthalein indicator that appears pink in contact with alkaline concrete with pH values in excess of 9 and colourless at lower levels of pH. The test is most commonly carried out by spraying the indicator on freshly exposed surfaces of concrete broken from the structure or on split cores. Alternatively, the powder from drill holes can be sprayed or allowed to fall on indicator-impregnated paper.

Appropriate Level of Protection

Measures for improving the resistance of the concrete to carbonation and approaches to modelling carbonation rates are available, depending on the severity of the environment (coastal or inland), the quality of the concrete, the cover to the reinforcement and the effectiveness of the repair.

Selecting the appropriate level of corrosion protection is based on many factors such as the level of carbonation, amount of concrete damage, location of corrosion activity (localized or widespread), the cost and design life of the corrosion protection system, and the expected service life of the structure. The following levels of protection can be used as a guide to decide the most effective strategy.

In our experience, reinforcement corrosion and consequent spalling of concrete usually occurs in bridges in marine environments, such as Bridges over Cooks River carrying General Holmes Drive as it enters Botany Bay at Kyeemagh, over the entrance to Lake Macquarie at Swansea or Missingham Bridge over the mouth of the Richmond River at Ballina. Causes for this effect are mainly as a result of chlorides in the seawater and also carbonation.

In all cases effective repairs have been made using conventional repair methods consisting of:

a) undertake hammer test to establish all loose areas of concrete;

b) hack off loose concrete from around the exposed steel bars;

c) grit blast to remove corrosion and other deposits from the exposed steel reinforcement including hidden faces, to the back of the steel bars, and to intersections of bars;

d) apply a proprietary bar primer to the surface of the reinforcement. This could either be alkali based or encapsulating, such as epoxy resin or sacrificial, normally zinc-rich paints;

e) moisten and patch repair areas of concrete using a cementitious material and sand, and a polymer dispersion agent.

In addition, for serious cases of deterioration caused by carbonation, electro-voltaic solutions are employed to reinstate the alkalinity of the concrete. This very expensive procedure is considered not warranted for the bridge at Windsor.

Protecting concrete in the future

A long term solution to inhibit further carbonation would be to restrict the entry of carbon dioxide by applying a coating to the concrete that will act as a protective barrier. The coating should prevent the ingress of liquid water, but allow water vapour to pass through. There are various products on the market specifically designed for this purpose.

The necessary surface preparation has to be undertaken, which will usually consist of cleaning the surface back to a sound finish. The coating treatment should then be checked for its compatibility with the concrete, and the number of coats and total thickness required also determined.

Such coatings also provide the opportunity to give a facelift to the building, and these systems usually carry a guarantee with a recoating required at given intervals.

Recommendation

Our recommendation is to undertake the normal repair procedure based on the method outlined above followed by the application of a barrier coating. In our experience, such a procedure should result in an extension of life for a long period.

FIG. 2 TYPICAL VIEW OF UNDERSIDE OF DECK. NOTE SOUND INTERNAL BEAMS BUT SPALLING ON UPSTREAM EDGE BEAM

FIG 3. POOR DECK DRAINAGE DETAIL CONTRIBUTING TO EXTRA MOISTURE TO ENABLE CARBONATION OF CONCRETE

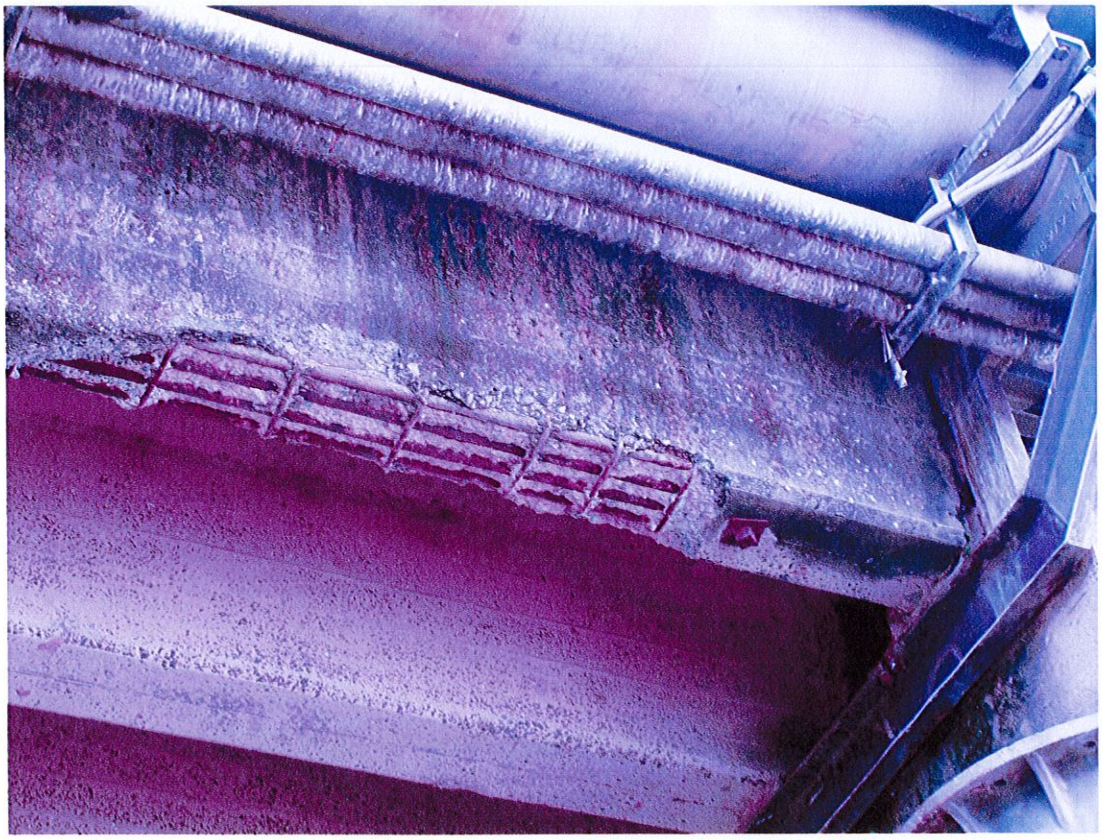

FIG 4. SPALLING ON DOWNSTREAM EDGE BEAM