Australian Parliament House

Predicted life 100 years and will be exceeded because of Hot Dip Galvanized Steel Reinforcement in Concrete

Australia's Parliament House is an iconic structure located in Canberra, ACT. Construction began in 1981 and was completed in 1988. The building was designed to meet a life of 200 years and the architects Mitchell, Giurgola & Thorpe Architects, ACT specified galvanized steel reinforcement to ensure the project was completed with a high level of quality control.

The year 2006 is 18 years after completion and around 24 years after the first concrete was poured. The Department of Parliamentary Services commissioned a study into the precast facades at Parliament House. The condition assessment was undertaken due to the departments observation of weathering, staining and the like on the buildings stone and concrete facades. The first assessments were conducted in 2004 and involved eleven coring samples* of 20mm diameter taken from several pre-cast walls of the Parliament House buildings. These samples were taken from the precast elements of the building as these are exposed to the elements and utilized galvanized reinforced steel for durability. This sampling technique is a relatively simple process where a core of concrete is taken from the wall using a special hole saw and the chloride content and levels of carbonation are measured.

Parliament House is located in Canberra, which has a relatively benign environment being inland and away from the coastal and industrial environments. The typical maximum winter temperatures are around 15°C at 80% humidity and the summer temperatures are typically 25°C at 60% humidity (at 3 pm). Canberra rarely gets hot with only 4 days a year exceeding 35°C but is known for being cold with more than 100 days a year at minimum temperature at or below 2.2°C.

The rate at which the corrosion of steel reinforcement in concrete occurs is related to: the coating thickness of the cement (cover over the reinforcement); the quality of the cement mix; and the environmental conditions at the surfaces [2-4]. Normally steel in concrete does not rust because the concrete is alkaline and the steel becomes passivated at these pH levels. However, after a period of time concrete changes its alkalinity by absorbing water from the air which tends to carry dissolved carbon dioxide and ultimately this reacts to form carbonates in the concrete. The problem

* Ten samples revealed consistent results with one sample providing an outlier results which warrants further investigations into the basis for localized degradation.

is that concrete is porous to water, and this water transfers the carbon dioxide into the concrete and away from the surface and the reactions are generally slow to occur and the result is a depth of carbonation. When the atmospheric conditions have a low relative humidity such as 60%RH, then there is significantly lower quantity of moisture in the air to facilitate this transfer compared to conditions at 80%RH. Concrete exposed to 60%RH only will have more than a 50% increase in durability when compared to an exposure of 80%RH, in the absence of chloride contamination [1].

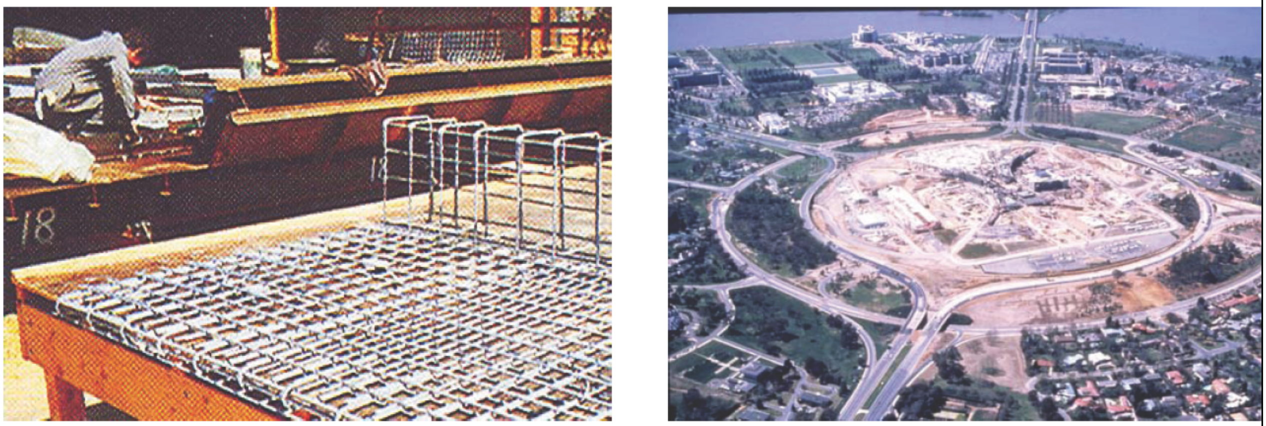

Figure 2: Parliament house during construction

This carbonation is not a uniform process so some concrete walls in a building may suffer greater at the bottom where they are likely to be damp compared to the top of the wall where the wind and often full exposure to the sun keeps the wall dry by evaporation. The surface finish also has an effect where a rough finish such as an acid wash finish has a higher surface area and slightly easier penetration of water compared to a smooth finished precast panel. The acids used to create the rough finish may also contribute to the chloride concentrations in the outer layers of the concrete panels.

If the location is near the coast then chlorides can also be driven onto the concrete surface by the wind and driven by the moisture into the concrete section. The steel reinforcement exposed to the chlorides results in corrosion of the steel since the passivation is lost. The critical concentration is 0.060% chloride (mass/mass) in the concrete. Obviously the environment and the level of pollution are very important, as is the type of concrete and coverage of the reinforcement steel. The chloride concentration in the cored concrete samples was measured to be in the range of 0.002% to 0.016%, which is well below the critical concentration.

The rate at which concrete degrades has been extensively investigated and modelled but is typically described by a simple equation based on Ficks 1st law [1-2].

$$x = C\sqrt{t}$$

x = depth of carbonation at time t (m)
t = time (s)
C = constant dependent on concrete quality / environment

The variables in the C value are affected by the environmental conditions (temperature and humidity), the quality of the concrete and finish, porosity of the material, time of curing [4]. It is important to remember that every wall of a building has a different orientation to the sun and exposure to the wind, and has different humidity with the bottom typically having a higher humidity than the drier top of a wall. This accounts for often significant variations in carbonation results on a single wall.

Galvanized Reinforcement Bar – a sound decision

There is a direct relationship between the amount of cement covering the 25mm diameter reinforcement steel and the time for the carbonation to occur at the reinforcement steel and start the corrosion process. From the eleven measurements of the coverage of the cement over the reinforcement steel, the measurement was found to be ~40mm at the Senate building and ~31mm at the House of Representatives Parliament Building [5].

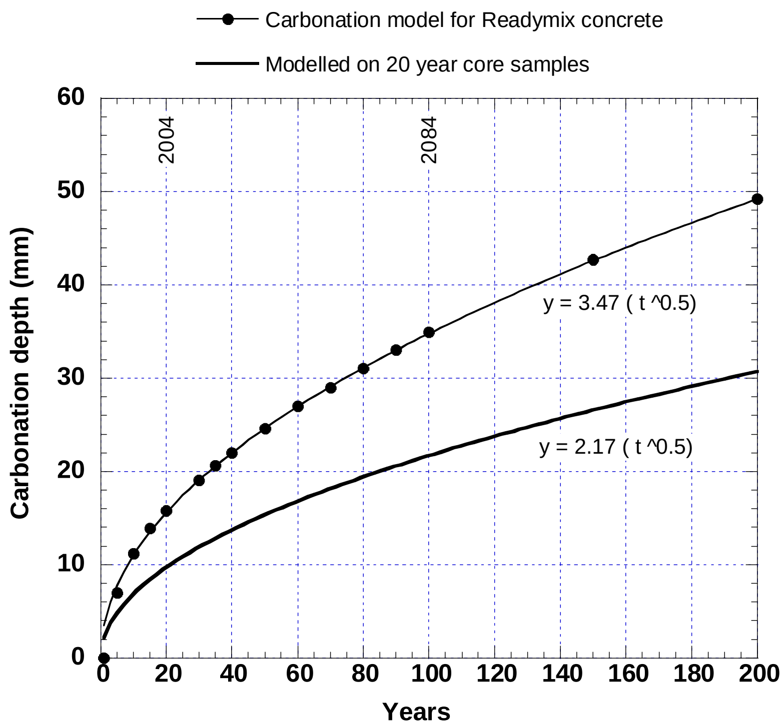

Figure 3: Carbonation rates for the Australian Parliament House concrete [5]

The coring of the concrete results indicated the depth of accumulated carbonation rate to be in the range of 5 to 10mm for the 20 years. This level is significantly lower than the original carbonation model. Based on the single sample after 20 years, the predicted carbonation rate has been plotted in Figure 3 and the difference in the expected durability is significant.

From the graph and measuring the concrete cover, the onset of corrosion is expected at ~130 years (40mm cover) for the Senate building and ~80 years (31mm cover) for the HOR Parliament

Building. The use of hot dipped galvanized (HDG) reinforcement steel with a 600g/m^2 (~85µm) coating will provide an addition period of corrosion protection ranging for 50 to 70 years in the absence of chlorides [6-7]. This increase occurs because zinc coated steel performs significantly better when the surrounding cement becomes carbonated. The zinc in the HDG coating reacts and forms a stable zinc carbonate ($ZnCO_3$) layer which passivate the zinc and significantly reduced the corrosion rate. Basically, as the concrete becomes carbonated the conditions become ideal for zinc and less favourable for plain uncoated steel [7]. Hot dipped galvanized steel reinforcement therefore presents an ideal solution to combat carbonation and significantly extend the durability of a building. On this basis the onset of corrosion of the reinforced steel is expected at ~200 years (40mm cover) for the Senate building and ~150 years (31mm cover) for the HOR Parliament Building.

There is also a latent period between the onset of corrosion and the formation of cracks in the outer surface of the concrete. Given the expected low chloride concentrations in the concrete, this delay is very dependent up the climatic conditions but at an average of 80%RH the expected period is 55 to 65 years [1]. On this basis the onset of visible cracking of the concrete from the corrosion of the reinforced steel is expected at ~255 years (40mm cover) for the Senate building and ~205 years (31mm cover) for the HOR Parliament Building.

Measured Results

The measured carbonation rates from the majority of the samples are ~37% below the expected modelled rate and this could be related to the fact that the last 5-6 years in Canberra have been in drought and the average humidity may have been lower than 80%RH. In addition the quality of the concrete may have been better than originally expected with a recorded higher strength of 39MPa compared to specification [8]. The fact is, as noted in the graph, the Senate Building and the House of Representatives at the Australian Parliament will be durable for more than 200 years, due to the choice of cement, the environment and the use of HDG steel reinforcement.

References

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