Hot Dip Galvanized Case Study No. 4
Hot dip galvanized Reinforcement in Concrete

The Application

Hot dip galvanized reinforcement for additional corrosion protection of reinforced concrete structures. The use of hot dip galvanized reinforcement is not a replacement for good quality concrete, but as additional corrosion control, which is estimated to extend the service life of concrete structures by between 3 and 4 times. The quality of concrete is subject to many variables, not least being practical site conditions, installation and placement supervision, compaction of the concrete; cement water ratio, curing, depth of concrete cover over and ultimately environmental conditions.

Environmental Conditions

The environmental conditions are described as severe marine, (class C5 in terms of ISO 9223), subjected to sea spray, chloride attack, carbonation, and quality of the concrete, i.e. durability (oxygen permeability and sorptivity).

The Site

This case study is the result of a detailed investigation of a pedestrian bridge situated along the foreshore of Algoa bay. The stairway was rebuilt in 1980 using galvanized reinforcement due to spalling concrete.

The site an old pedestrian bridge (No B776) that was demolished in April 2005

Hot dip galvanized reinforcement was used in the sea side (left hand side) approach stairway that was re-built 25 years earlier than the demolishment date

The surf was 50 meters to the left of the photograph

Sample concrete cores were extracted from the sea facing side, top slab and landside of the structure. These samples were sent to an independent concrete diagnostic & durability laboratory with instructions to establish the ingress of chlorides, carbonation and quality of the concrete.

Depth of concrete cover over the reinforcement confirmed as 45 to 60 mm. Samples of hot dip galvanized reinforcement was retrieved for examination.

Findings

Chloride concentrations (% as mass of cement) at a depth of 45 to 60 mm ranged between 0.15 & 0.65% on side facing inland, and 0.27 & 1.26% on the sea facing side. At a depth of 30 to 45 mm the chloride concentrations ranged between 0.19 and 2.6%. Chloride levels at a depth of 15 to 30 mm rose to between 0.49 to 8.8% of cement mass.
Accepting that the typical limit is 0.1% chloride for uncoated reinforcement, it should be totally unacceptable to use plain reinforcing without additional corrosion protection in this environment.

Carbonation was found to be more severe on the landside of the structure, with penetration depths of 18 to 22 mm.

Concrete durability index testing results of oxygen permeability was as follows:- 1 sample “very good”, 1 sample “good”, 4 were “poor” and 1 “very poor”. Sorptivity of 2 samples were excellent, 2 good and 2 were poor.

2 Core Samples
from the side facing inland

Carbonation penetration 18 to 22 mm, chloride level at 45 to 60 mm 0.15% to 0.65% of concrete mass

2 Core Samples
from the sea facing side

Carbonation penetration 5 to 23 mm, chloride levels at 45 to 60 mm 0.27% to 1.26% of concrete mass

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depths and increased chloride levels, the hot dip galvanized coating was continuing to protect the reinforcing bars.

In certain isolated cases where the corrosive conditions had penetrated to the steel, due to very limited cover, the zinc had been sacrificed and some attack was evident on the carbon steel.

Isolated red rust was found, usually associated with minimum concrete cover and/or mechanical damage to the concrete cover

The condition of exposed hot dip galvanized reinforcement found during the demolition of the 40 year old bridge was, with isolated exceptions, found to be exceptional condition

Typically 98% of that inspected was similar to that shown in the photograph

Condition of the reinforcement

Micrographs from sample reinforcement bars were developed and are shown in figures 1 & 2. The depths of cover of these samples were selected at 45mm and 60mm respectively.

The outer appearance of the bar section demonstrated a dull grey colouration with no significant zinc layer degradation.

A transverse cross section through the bar revealed a 'normal' galvanized zinc and inter-metallic layers, clearly delineated in Figures 1 and 2. The galvanized coating thickness was between 240 and 260µm.

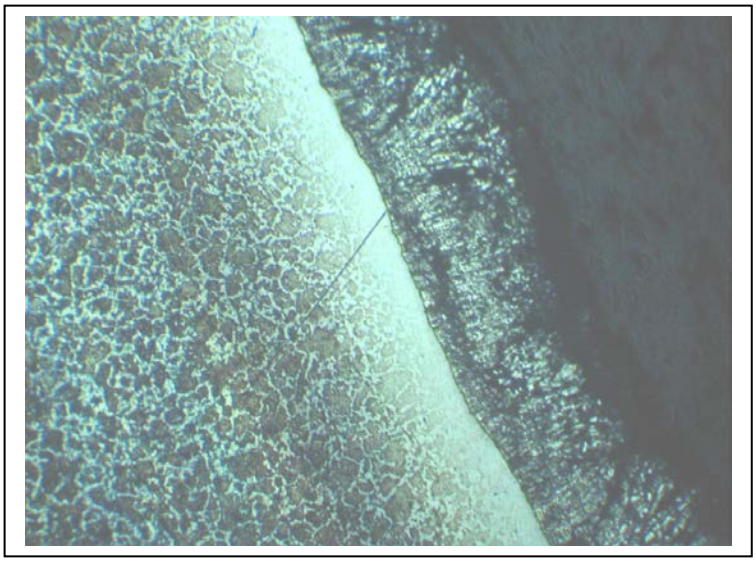

Figure 1

Hot dip galvanized coating on the reinforcement bar Coating thickness of 70 to 90µm

(magnification100X)

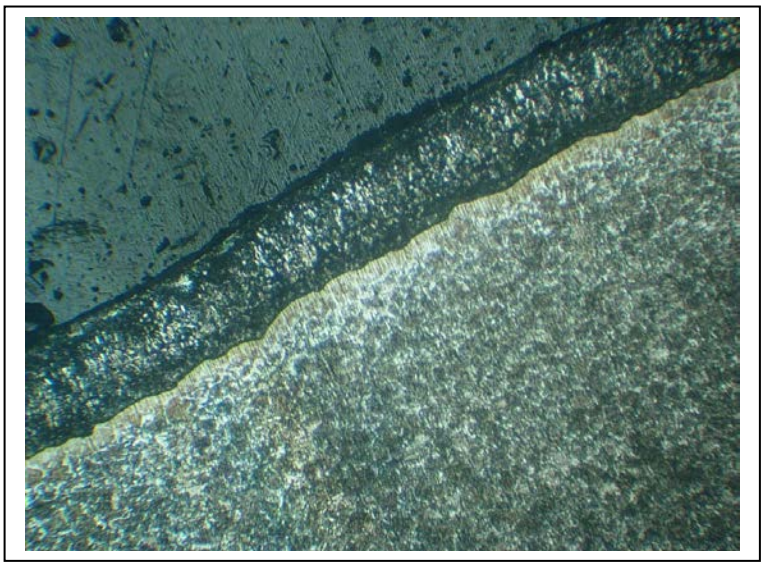

Figure 2

Hot dip galvanized reinforcement at a depth of cover measured in a range from 45 to 50 mm

All test samples were recovered from the demolished bridge

Conclusion

Examination of the stairway hot dip galvanized reinforcing, after 25 years in service in a severe marine environment, revealed conclusive evidence that the zinc coating was providing excellent corrosion control of the carbon steel reinforcement.

While other forms and methods of reinforcement protection are available, it can be shown that hot dip galvanizing of reinforcing is a preventative process that must be applied as part of the construction process. It is a system of “prevention is far better than cure”

Economics and extra costs are best described in terms of a quotation taken from **“Corrosion of Steel in Concrete”** by Bertolini, Elsener, Pedeferri and Polder.

“The cost of adequate corrosion prevention carried out during the stages of design and execution are minimal compared to the savings they make possible during the service life and even more so, compared to the cost of rehabilitation, which might be required at later dates.

The so-called De Sitter’s “law of five” can be stated as follows:

One dollar (R13-00) spent in getting the structure designed and built correctly is as effective as spending $5 (R65-00) when the structure has been constructed but corrosion has yet to start, $25 (R325-00) when corrosion has started at some points, $125 (R1625-00) when corrosion has become widespread”.

Exchange rate as at October 2015