HOT DIP GALVANIZERS ASSOCIATION SOUTHERN AFRICA

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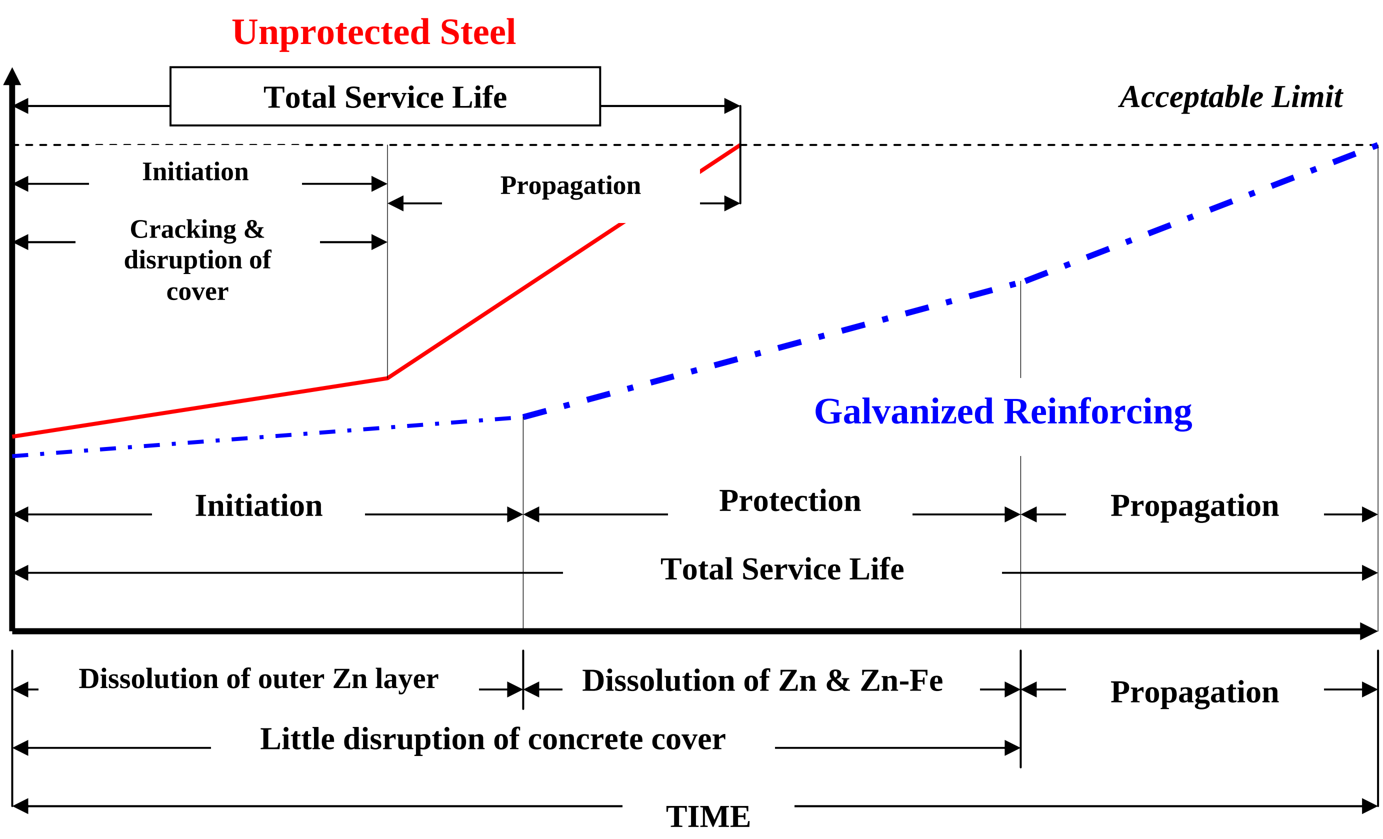
Hot Dip Galvanized Case Study No. 4 *(Revision)*

Hot Dip Galvanized Reinforcement in Concrete

The Application

Hot dip galvanized reinforcement for additional corrosion protection for reinforced concrete structures. The use of hot dip galvanized reinforcement is not a replacement for good quality concrete, but as an added corrosion protection, 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 the reinforcement and ultimately the environmental conditions.



Corrosion Damage

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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 the 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 site of the 40-year-old pedestrian bridge (No B776) that was demolished in April 2005. It was established that hot dip galvanized reinforcement was used in the approach stairway, which was on the sea facing side, indicated on the left of the photograph, with the sea some 50 meters further left. This stairway was part of a refurbishment of the seriously corroding structure in 1985.

From information received the hot dip galvanized reinforcing in the refurbished stairway (1985) had been in service for 20years

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. The depth of reinforcement cover was confirmed as being 45 to 60 mm and a sample of hot dip galvanized bar was retrieved for examination.

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Our *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 rise to between 0.49 to 8.8 as a % 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
Taken on the side facing inland. Carbonation penetration 18 to 22 mm, chloride level at 45 to 60 mm 0.15% to 0.65% as mass of cement.

2 Core Samples
Taken on the sea facing side. Carbonation penetration 5 to 23 mm, chloride levels at 45 to 60 mm 0.27% to 1.26% as mass of cement.

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Notwithstanding the findings at the 45 to 60 mm depth of cover, numerous reinforcing bars were found at depths of 15 to 45mm. Even at the reduced concrete cover 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 of the carbon steel.

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

Condition of exposed hot dip galvanized reinforcement found during the demolition of the 20 year old approach stairway. With isolated exceptions, the hot dip galvanized reinforcing shown, in this photograph, is typical of 98% of that inspected.

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This photograph shows two uncoated reinforcing bars that were used in the stairway without being hot dip galvanizing. The corrosive attack is clearly evident, while the hot dip galvanized bars located alongside are performing with complete satisfaction.

Condition of the reinforcement

Reinforcement was taken from the structure for micrograph analysis to establish the amount of zinc coating that was retained after 20 years in service. The depth of cover of the two 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 in terms of white rust formation.

A transverse cross section through the bar revealed a 'normal' galvanized zinc skin with the constituent sub-layers clearly delineated (Figures 1 and 2). The galvanized skin thickness was 240-260µm.

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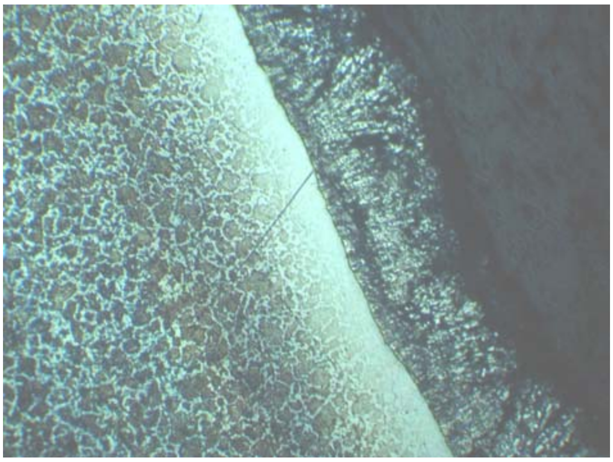

Figure 1.
Galvanized layer (70 to 90µm) on the reinforcement bar (100X).

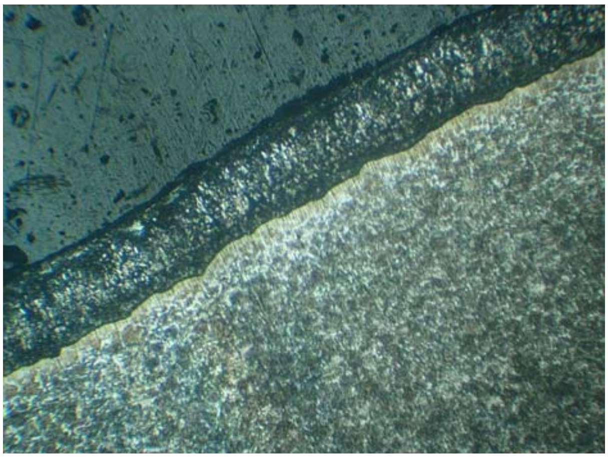

Figure 2.
Galvanized layer on the reinforcement bar 45 to 50 mm cover. (100X)

Test samples were extracted from the demolished bridge.

Conclusion

Examination of the hot dip galvanized reinforcing, after 20-years in service, revealed conclusive evidence that the zinc coating was providing excellent corrosion protection to the steel reinforcement.

While other forms 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" The economics are best described in the following extract from a recent publication "Corrosion of Steel in Concrete" by Bertolini, Elsener, Pedeferri and Polder.

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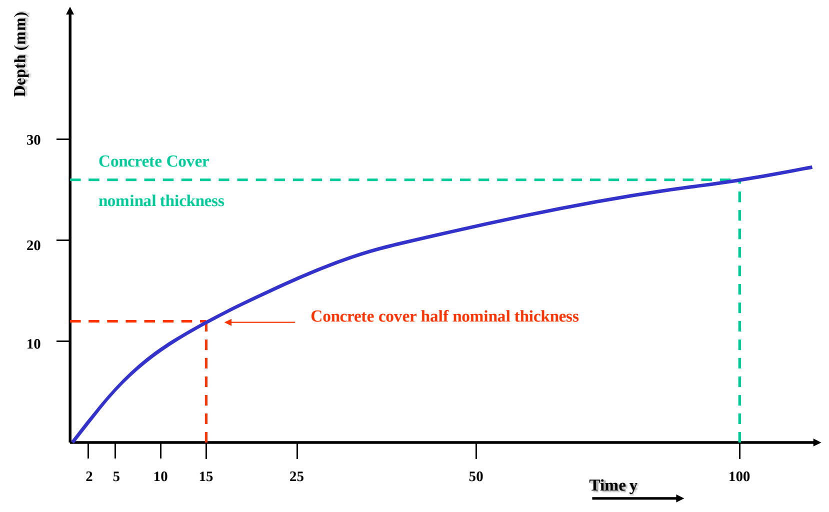
"The cost of adequate prevention carried out during the stages of design and execution are minimal compared to the savings they make possible during the service life and even more so, compared to the cost of rehabilitation, which might be required at later dates. The so-called De Sitter's "law of five" can be stated as follows: one dollar (R6-00) spent in getting the structure designed and built correctly is as effective as spending $5 (R30-00) when the structure has been constructed but corrosion has yet to start, $25 (R150-00) when corrosion has started at some points, $125 (R750) when corrosion has become widespread".



Reduction of initiation time of corrosion due to local reduction in concrete cover

This diagram illustrates the importance of concrete cover. The concrete cover represents a form of "barrier protection" through which the corrosive elements must pass before attack on the reinforcement can commence.

Hot Dip Galvanizers Association Southern Africa

Technical Marketing & Support
to
Consultants, ends users and our members

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