Asia Pacific Edition HOT DIP GALVANIZED STEEL







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HOT DIP GALVANIZED REINFORCING Steel for concrete structures



AN ADDED INSURANCE AGAINST CORROSION

In coastal or chemical environments, or where extra durability and security is required, the practice of hot dip galvanizing steel reinforcement in concrete is now a well-proven safeguard against corrosion.

The maxim that "prevention is better than cure" finds no greater example than the use of hot dip galvanized reinforcement with a history of usage extending over 50 years.

Despite the increased usage of steel, concrete remains the most widely used construction material in the world today. Whilst it is universally understood that exposed steel structures are vulnerable to corrosion, less well appreciated is that steel reinforcement in concrete is also similarly susceptible under certain conditions and that this can have serious consequences. The fact that reinforcement is embedded within the concrete and is therefore hidden from view renders the corrosion problem all the more insidious. Often by the time the first tell-tale signs such as cracking or rust staining at the concrete surface become visible, corrosion is in all likelihood already well advanced. Concrete remediation or use of corrosion mitigation systems to halt further destructive deterioration can often be rendered difficult, if not impossible, by

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AN ADDED INSURANCE AGAINST CORROSION

accessibility restrictions and are typically costly and disruptive to implement. At worst, complete replacement of the structure may be required well before its full design life has been reached, if structural integrity has been sufficiently compromised.

Reinforcement corrosion is now considered to be the leading cause of premature concrete failure in the world today and needs to be adequately addressed for structures situated in highly corrosive environments.

Reinforcement Corrosion: Cause and Effect



Stage 1: Corrodant ingress



Stage 2: Crack propagation due to rust expansion



Stage 3: Concrete spalling after extensive cracking

Bare steel reinforcement relies entirely on protection provided by the surrounding concrete. Most obviously, the concrete cover serves as a physical barrier separating the reinforcement from the external environment. Also, because the cement constituent in concrete is highly alkaline, a natural chemical reaction takes place at the steel surface to form a thin impervious film which resists corrosion. The steel surface is said to be 'passivated' by this reaction and the passive film will remain intact as long as the surrounding concrete retains a high alkalinity.

However, in reality, concrete is rarely impermeable, allowing ingress of atmospheric corrodants (moisture, oxygen, carbon dioxide). Because carbon dioxide reduces the alkalinity of the concrete, a process known as 'carbonation', the steel surface can depassivate, rendering it susceptible to corrosion. A more dire situation exists in the presence of chloride salts which applies to structures in contact

with seawater or along coastlines where airborne chloride concentrations are high. It is well recognized that chloride salts can permeate concrete and will depassivate the steel even if the alkalinity of the surrounding concrete remains high. In this circumstance extensive and rapid corrosion can take place due to the extreme corrosivity of chloride salts.

Steel corrosion (rusting) causes the reinforcement to delaminate from the concrete, weakening the structure. Furthermore, because rust has a volume up to 10 times that of the steel consumed, significant tensile stresses are generated in the adjacent concrete. Since concrete is strong in compression but relatively weak in tension these expansionary stresses cause cracks that can eventually extend to the concrete surface. Besides further weakening the structure, the cracks cause corrosion to accelerate by providing a ready conduit for further unimpeded entry of corrodants. Eventually this self-perpetuating process leads to severe concrete spalling which then fully exposes the reinforcement to the external corrosive environment.

Nowadays, with greater recognition of this problem, concrete practices and technologies have been adopted to better manage the risk. For example, greater attention is given to the importance of reducing concrete permeability through optimal water/cement ratios, appropriate compaction and curing conditions, together with the use of concrete impregnation

methods or membrane-type concrete coatings. Likewise, the importance of appropriate reinforcement placement to ensure adequate depth of concrete cover is well recognized. Nevertheless, despite precautionary measures and best practice, technical perfection may be difficult to achieve and practical experience over the years has convincingly demonstrated that concrete structures can still remain vulnerable to reinforcement corrosion particularly in more aggressive environments.

Protecting reinforcement by galvanizing

Galvanizing is the process of applying a metallurgically bonded zinc coating to steel by immersion in molten zinc and is used extensively throughout the world for corrosion protection. The coating's excellent corrosion protection derives from both the low natural corrosion rate of zinc coupled with its ability to extend protection to adjacent exposed steel areas should they be present, an effect known as cathodic protection. The coating also exhibits strong adhesion to the underlying steel surface due to its unique metallurgical bond which, together with the inherent toughness of a metallic coating, provides superior resistance to mechanical damage.

The combination of these features results in a very durable coating, enabling concrete structures to be more tolerant of variabilities in concrete quality and reinforcement placement. Besides this, use of galvanized reinforcement is uniquely advantageous for the following reasons:

- it offers better resistance to chloride salt attack and is unaffected by concrete carbonation
- zinc's cathodic protection inhibits corrosion at any minor coating discontinuity and also prevents 'undercutting' of the coating, confining any corrosion risk solely to the local area of exposed steel.
- any zinc corrosion products that may form over time are benign. As there
 is no accompanying volume change, unlike with steel corrosion, there is
 no adverse impact on the surrounding concrete. On the contrary, research
 shows that any corrosion products simply diffuse into the adjacent
 concrete, helping to fill microporosity which inhibits further ingress of
 corrodants.

Ultimately, the purpose of galvanized reinforcement is to provide a safeguard against unexpected corrosion leading to premature deterioration of the structure. This extra protection generally adds minimal cost to a construction project budget, and should be viewed in the context of insurance against the risk of costly cycles of concrete repair and remediation or worse still, replacement of a prematurely failed structure.



Deterioration of the bare steel reinforcement in a coastal balcony

Performance of Galvanized Reinforcement Concrete

Since galvanized reinforcement was first used in the 1950's its performance has been extensively studied and documented. These studies range from fundamental scientific research to in-situ surveys of existing concrete structures, some in service for 30-40 years. These surveys have been very thorough, even to the point of periodic extraction of sample cores from structures for detailed examination. The references later cited under "Further Information" should be consulted for in-depth information on performance evaluations.

Key measures of performance are serviceability and durability. Serviceability relates to the reinforcement's ability to fulfil its intended function of imparting strength to the structure over its service life. Relevant factors here are that galvanizing has been proven to have no adverse effect on reinforcement's inherent strength nor on the bond strength with concrete. In fact, the evidence shows bond strength can be significantly higher with galvanized reinforcement. In regard to durability, galvanized reinforcement appreciably extends the service life of the concrete structure by delaying the time for corrosion initiation by a factor of 4-5 times that of unprotected reinforcement under similar conditions.



Galvanized Reinforced Wave-wall - Port Phillip Bay

Galvanized Reinforcement Applications

Particular circumstances where the galvanizing of reinforcement is likely to be a cost effective engineering decision include:

- marine or coastal structures
- high risk structures in corrosive environments
- immersed or buried structures subject to groundwater effects or chloride presence (reclaimed land)
- containment structures subject to prolonged contact with water or structures subject to extended periods of wetness
- high visibility architectural facades and lightweight precast panels for buildings. For these types of applications the avoidance of unsightly staining caused by rust "weeping" from corroding reinforcement is a major concern.

The benefits of galvanized reinforcement are globally recognized and many examples exist around the world where it has been successfully used in a variety of applications. Examples include:

- seawalls, jetties, pontoons and offshore structures
- coastal bridges and roads (crash barriers, paving)
- building construction, especially in coastal areas (exterior cladding, balconies, balustrades, external staircases, porches, foundations)
- industrial sites such as chemical plants, water and sewerage treatment plants
- cooling towers
- tunnel structures both underground and submerged
- critical support structures (columns, beams, poles).

Some examples of prominent structures utilizing galvanized reinforcement are featured in this article.



Galvanized Reinforced Sea-wall - Sydney Harbour

Some FAQ's

0. Does galvanized reinforcement need to be handled differently to ordinary bare steel reinforcement during the concreting process? **A.** No.

Q. Can I use galvanized reinforcement in conjunction with bare steel reinforcement?

A. Yes. In fact, it may only be considered necessary to use galvanized steel in the more critical locations of a structure where there is a higher risk of corrosion or where the consequences of corrosion could have particularly serious consequences.

Q. Do compliance standards exist for galvanized reinforcement?

A. Yes. In Australia and New Zealand galvanizing of reinforcement falls under the AS/NZS Standard 4680:2006 "Hot–dip galvanized (zinc) coatings on fabricated ferrous articles". In other countries (eg. USA and some European countries) a product-specific standard exists.

Q. How does galvanized compare to (fusion bonded) epoxy coated reinforcement?

A. Galvanized compares very favourably. Being soft, epoxy coatings are easily prone to damage, requiring extreme care be taken at all stages of storage and installation, since corrosion at even minor areas of damage will progressively spread beneath the surrounding coating. In contrast, no special precautions are necessary for handling galvanized reinforcement due to its excellent damage resistance. Even if localized damage occurs zinc's cathodic protection will prevent corrosion from spreading. A further important distinction is that studies of reinforcement's bond strength to concrete has shown this to be generally lower for epoxy coated, and certainly more variable, than galvanized. Significantly, in view of its superior performance, some infrastructural authorities responsible for marine structures (in the USA) have now opted to use galvanized in preference to epoxy coated reinforcement.

Further information on galvanized reinforcement Please refer to the following websites and other sources of valuable, practical information:

- Websites: www.galvanizedrebar.com and www.gaa.com.au
- International contact address for queries: galvrebar@iza.com
- Publications:
- Galvanized Steel Reinforcement in Concrete, Yeomans SR (see box below)
 List Dip Calvanized Reinforcing Steel
- Hot Dip Galvanized Reinforcing Steel -A Concrete Investment.

GALVANIZED STEEL REINFORCEMENT IN CONCRETE

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- Brings together a world-wide body of knowledge into a concise and authoritative text dealing with the characteristics and use of galvanized reinforcement in concrete construction
- Provides the most up-to-date and comprehensive collection of technical information and data presently available
- Contributions from expert authors from across the world, representing both academia and industry: SR Yeomans, RN Swamy, AA Sagues, TJ Langill, B Dugan, C Andrade, C Alonso, ND Allan, O Kayali and JP Broomfield
- Topics include: Overview of use; Design for durability; Corrosion in concrete; Zinc materials; Electrochemical aspects; Laboratory and field performance; The Bermuda experience; Bond and structural performance; A Consultant's perspective
- ILZRO Sponsored Project (ZE 429)

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